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Diversity, distribution and abundance of insect pests associated with western Himalayan oaks (*Quercus* spp) in Himachal Pradesh

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ABSTRACT

Oak forests are a vital component of the western Himalayan ecosystem, providing essential services such as soil and water conservation, biodiversity support and livelihood sustenance. These forests are increasingly threatened by insect pests, biotic pressures and climate change. The present study assessed the diversity, abundance and seasonal dynamics of insect pests in oak forests of Himachal Pradesh, western Himalaya. Surveys were conducted at 25 oak-dominated sites across six districts during pre-monsoon, monsoon and post-monsoon seasons from October 2019 to March 2022. A total of 107 insect pest species belonging to 38 families and seven orders were recorded. Lepidoptera was the most dominant order in terms of abundance and richness, followed by Coleoptera and Hemiptera. Pest abundance peaked during the monsoon season, though diversity and evenness varied among sites, with Chamba and Kinnaur showing higher diversity despite lower abundance. Lepidopteran defoliators caused the most severe damage, while borers and sap-sucking insects affected multiple plant parts. The results indicate increasing pest pressure on Himalayan oak forests, emphasizing the need for regular monitoring and integration of pest management strategies into forest conservation programmes.

Keywords: Oak forests; Insect pests; Lepidoptera; Biodiversity; Seasonal variation; Western Himalaya; Forest health; Climate change

INTRODUCTION

Oaks occupy a vital place in the Himalayan region due to their major role in soil and water conservation, support of rural livelihoods, maintenance of biodiversity and provision of multiple ecosystem services (Bhatt et al 2015). Insects, though often overlooked, play a crucial ecological role in sustaining life on earth and represent the most abundant animal group in forest ecosystems. Forests worldwide host thousands of insect species associated with oaks, many of which depend on them for food and shelter (Metcalf and Flint 1962).

Among these, only a limited number of insect groups significantly affect oak resources. These include leaf-feeding insects such as defoliators, skeletonizers and leaf miners; various borers attacking bark, phloem, wood, roots, twigs, shoots and acorns; sap-sucking insects and species that cause indirect damage by acting as disease vectors. Early documentation in the Indian Forest Records by Beeson and Bhatia (1939) reported rich insect diversity on Himalayan oaks, including 41 species associated with *Quercus leucotrichophora*, 23 species on *Q floribunda* and several species on *Q semecarpifolia*.

Kharsu oak (*Q semecarpifolia*) forests have shown a marked decline across the Himalayan region, largely due to overexploitation for fodder, fuelwood and grazing (Shrestha 2003). Forest stands often display a dominance of mature trees but lack seedlings and saplings, indicating poor regeneration. This condition may result from insect pest outbreaks or prolonged human-induced biotic pressures, both of which negatively influence natural regeneration processes (Bhuyan et al 2003). Supporting this view, Ramola and Singh (2022) reported a strong relationship between cerambyciid borer infestation and human-mediated disturbances contributing to the mortality of Kharsu oak trees in the Garhwal Himalaya.

In Himachal Pradesh, Verma et al (1979) described an outbreak of the Indian gypsy moth, *Lymantria obfuscata* on oaks. In 1976, the insect defoliated *Q floribunda* and *Q leucotrichophora* across a broad area in Haripurdhar forest in Rajgarh forest division, Himachal Pradesh. In Himachal Pradesh, butterflies and moths (1,250 spp) form the most dominant group. They are followed by Coleoptera (1,100 spp), Diptera (720 spp), Hymenoptera (470 spp) and Hemiptera (368 spp). These five orders together constitute 89.6 per cent of Himachal entomofauna (Singh and Banyal 2013). Additionally, oaks help mountain springs refuel (Valdia 1998). Oak forests are experiencing a loss as a result of rising disturbance and biotic interaction and in the western Himalaya, *Arundinaria falcata* Nees and *Lantana camara* are encroaching on these stands (Rawat et al 1994).

Bhasin et al (1961) were the first to provide a comprehensive account of lepidopteran diversity associated with Ban oak *Q leucotrichophora* (Fagaceae), reporting 35 species feeding on this tree, which is widely distributed in the moist temperate forest zone from the western to the central Himalaya. Subsequent studies expanded this knowledge, with detailed investigations on the life cycle of the Indian gypsy moth *L obfuscata* Walker on *Q leucotrichophora* conducted by Verma et al (1979) and Thakur et al (2015) in Himachal Pradesh. In addition, two more lepidopteran species were later recorded on this oak in the Kumaon region of Uttarakhand (Smetacek and Smetacek 2011).

Earlier, Beeson (1941) had documented *Antheraea roylei* Moore (Saturniidae) feeding on *Q leucotrichophora* along with seven other lepidopteran species, which were subsequently included in the compilation by Bhasin et al (1961). Altogether, 39 lepidopteran species belonging to 16 families are presently known to feed on *Q leucotrichophora* in the Himalayan region of India and no additional records have been reported so far.

Beyond oak ecosystems, recent studies have highlighted serious pest issues in other Himalayan tree species. Kumar and Negi (2018) reported severe infestation of *Dioryctria abietella* (Lepidoptera: Pyralidae) on Chilgoza pine cones, with damage levels sometimes reaching 100 per cent. The same study recorded *Plodia interpunctella* (Lepidoptera: Pyralidae) for the first time as a borer infesting stored Chilgoza seeds. Similarly, juniper berries and seeds were found to be heavily damaged by a single borer species, *Homaloxestis cholopis* (Lepidoptera: Lecithoceridae), which was documented as a new pest both in natural habitats and under storage conditions.

In the broader context, projected global warming is expected to favour insect pest population growth, increase the frequency of outbreaks and enable the geographic expansion of many pest species. These changes are likely to intensify economic losses and pose serious threats to forest health and food security. Consequently, the current and future challenges posed by phytophagous insect pests are expected to be further aggravated under changing climatic conditions (Andrew et al 2013, Thackeray et al 2016).

Despite scattered reports, comprehensive data on pest diversity in western Himalayan oaks is limited. Hence, the present study was conducted to assess the diversity and abundance of insect pest species in western Himalayan oak forests in order to determine the richness of the forest insect pests.

MATERIAL and METHODS

Study sites were selected in oak-dominated forests located within the moist and dry temperate forest zones of the western Himalaya. In total, 25 sites across six districts of Himachal Pradesh were surveyed to assess insect pest infestation on five oak species (Table 1, Fig 1). Field sampling was conducted during the pre-monsoon, monsoon and post-monsoon seasons from October 2019 to March 2022, following an appropriate and systematic sampling design. As most insect pests associated with oaks are commonly found on foliage, leaf-based surveys formed the primary method of collection. Accordingly, sweeping, handpicking and direct visual observations on standing trees were employed as the most effective techniques for documenting insect pests infesting oak species.

Insects were collected and site details were recorded along with the life history of pests in the laboratory and in the field. Study on effect of pest incidences was carried out by assessing and monitoring the different affected plant parts. Life cycles and complete biology of the insect pests were also studied. Measures of diversity were calculated, namely Shannon's diversity index (Hs) and Margalef's richness

Table 1. Details of survey study sites of oak covered in different districts of Himachal Pradesh

District	Sites	Altitudinal range (m amsl)	Species	Time of survey
Shimla	Taradevi, Kharapatthar, Kot, Narkanda, Ghanahatti	1,638-2,800	*Q floribunda*, *Q oblongata*, *Q glauca*, *Q semecarpifolia*	March-November
Kullu	Jalori Jot, Gulaba, Brundhar	1,951-3,120	*Q floribunda*, *Q semecarpifolia*, *Q oblongata*	April-October
Chamba	Langera, Salooni, Satrundi, Kihar, Tissa	1,780-3,552	*Q floribunda*, *Q semecarpifolia*, *Q oblongata*	April- October
Mandi	Bandli, Thunag, Chail Chowk, Jhungi	1,278-1,980	*Q floribunda*, *Q semecarpifolia*, *Q oblongata*, *Q glauca*	March-November
Solan	Chail, Janedghat, Shilli	1,290-2,250	*Q oblongata*, *Q glauca*	March- November
Kinnaur	Shongthong, Reckong Peo, Urni, Tapri, Meru	1,842-2,671	*Q ilex*	April- October

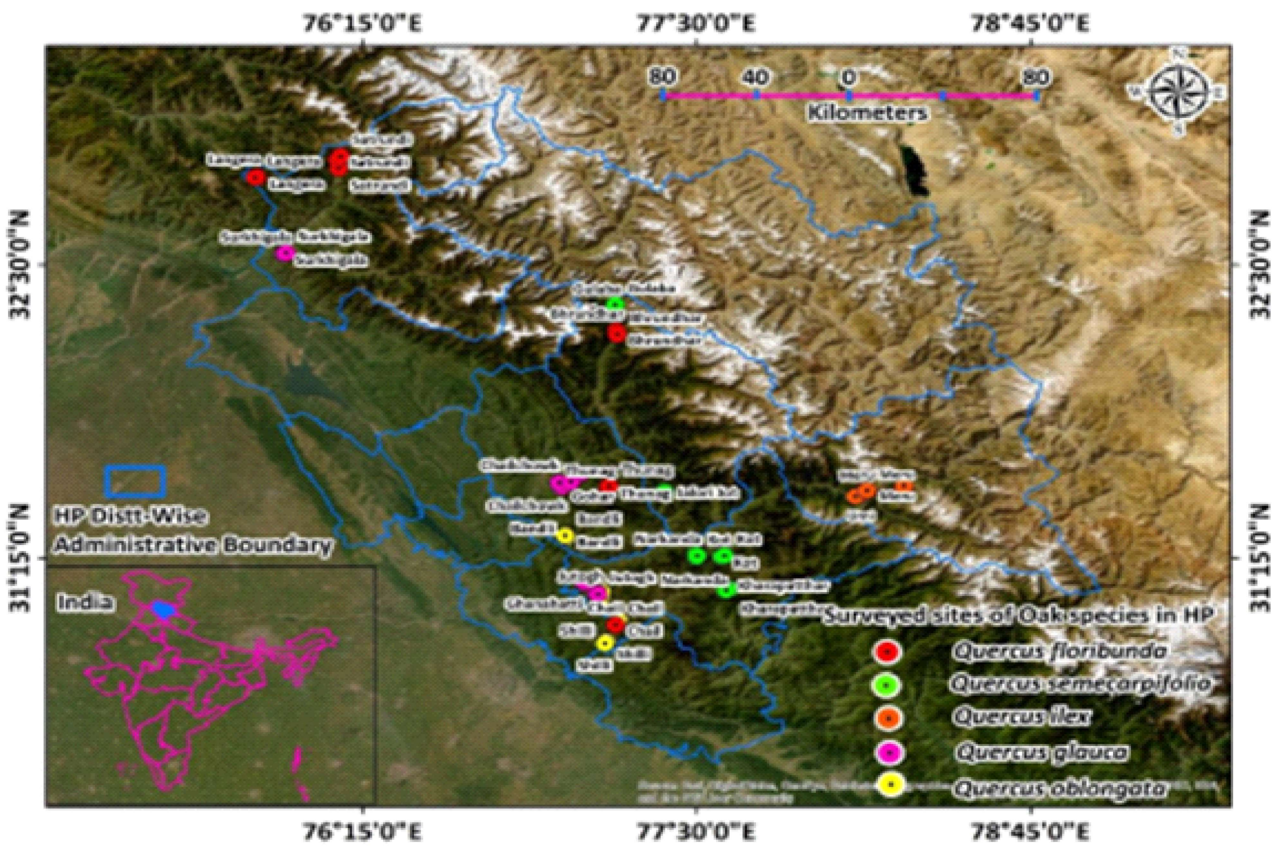

Fig 1. GIS map of study sites surveyed for insect pests of oak in Himachal Pradesh

index (Hm) (Hammer et al 2001). The methodology for identification, taxonomy and diversity analysis of insect pests adopted by Kumar and Thakur (2011), Kumar et al (2008), Kumar and Thakur (2009), Kumar (2016), Kumar et al (2016), Thakur et al (2013), Srivastava et al (2006) was followed during the study.

RESULTS

A total of 107 insects species from 38 families and seven orders were collected and identified after conducting extensive surveys to all oak inhabiting sites in different seasons of the year. The orders, Lepidoptera (45.38%) and Coleoptera (33.38%) were found to be most abundant, followed by Hemiptera (10.82%), Hymenoptera (4.04), Dermaptera (2.22%), Diptera (2.12%) and Thysanoptera (2.02) (Table 2, Fig 2). Insect abundance varied between monsoon and non-monsoon periods across all six sites in Himachal Pradesh (Table 3, Figs 3, 4). The sites showed the same patterns for abundance: Shimla had the largest number of insects (94) and Kinnaur was found to have the smallest number (21). Monsoons, therefore, appeared to be the most important time of year for insect abundance in this area. It is interesting to note that total abundance at any site did not necessarily equate to the highest diversity. For example, Chamba recorded the second highest total number of insects (42), however, it also recorded the highest diversity of insects (H' = 1.40) and the community composition of Chamba was the most even (J' = 0.78). On the other hand, Kinnaur recorded the least number of insects

Table 2. Abundance and richness of insect pests of oak in surveyed areas of Himachal Pradesh

Order	Number of species	Number of individuals	Number of families	Relative abundance (%)	Margalef richness index
Lepidoptera	56	449	14	45.38	9.00
Coleoptera	37	330	12	33.38	6.21
Hemiptera	6	107	6	10.82	1.07
Dermaptera	3	22	2	2.22	0.65
Hymenoptera	3	40	2	4.04	0.54
Diptera	1	21	1	2.12	0.00
Thysanoptera	1	20	1	2.02	0.00
Total	107	989	38		

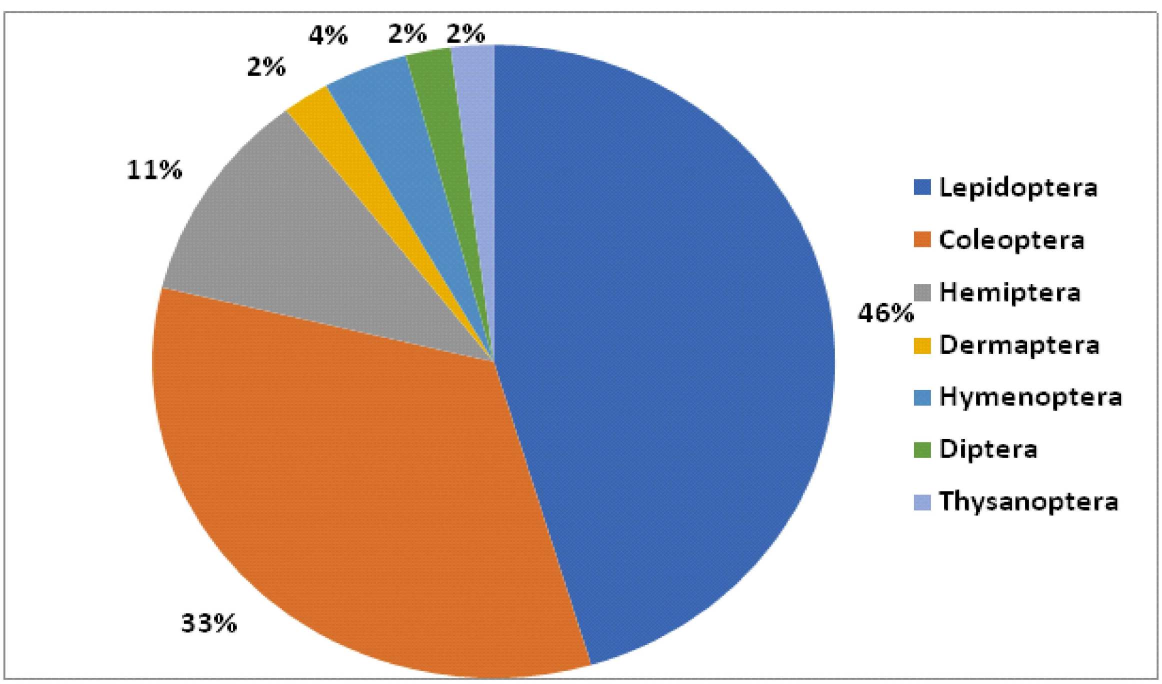

Fig 2. Relative abundance of orders of insect pests in oak forests recorded in surveyed areas

Table 3. Seasonal diversity of insect pests of oak in surveyed areas

Site	Number of insects			Total number of insects	H-index	Evenness
	Pre-monsoon	Monsoon	Post-monsoon			
Shimla	19	51	24	94	0.84	0.52
Kullu	13	36	14	63	1.25	0.64
Chamba	4	29	9	42	1.40	0.78
Mandi	8	27	12	47	1.19	0.66
Solan	4	23	6	33	0.81	0.58
Kinnaur	4	12	5	21	1.30	0.80

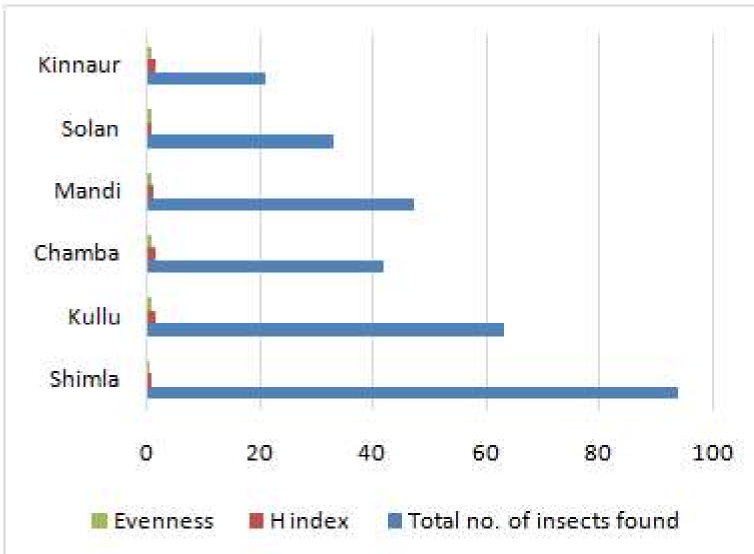

Fig 3. Diversity and evenness of insect pests in study area

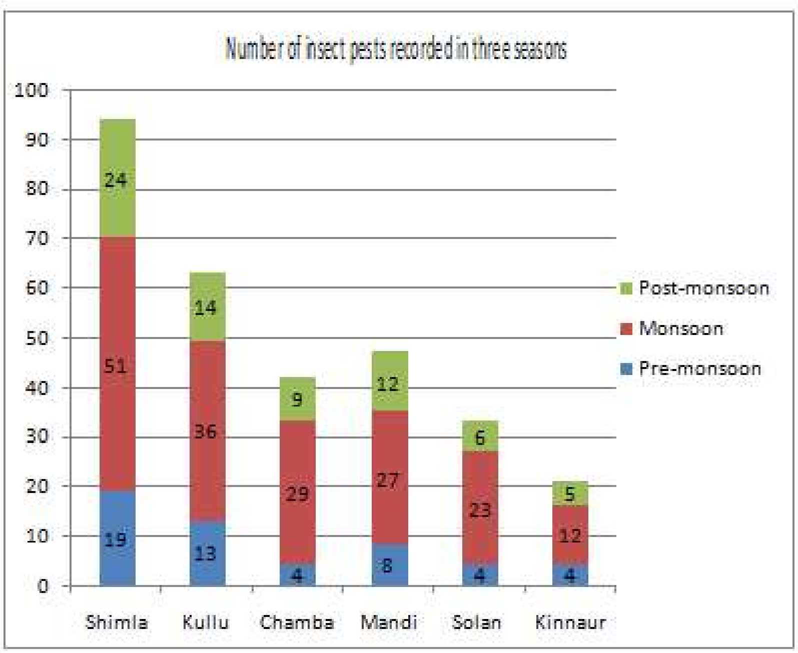

Fig 4. Seasonality pattern of the insect pests in oak forests in the study area

(21), however, it also recorded some of the highest diversity of insects (H' = 1.30) as well as the most even community structure (J' = 0.80). This indicates that although the abundance may vary greatly, there are differences in diversity and distribution between sites. Both Kullu (63, H' = 1.25, J' = 0.64) and Mandi (47, H' = 1.19, J' = 0.66) fell somewhere in the middle, suggesting that both areas had fairly diverse communities of insects. However, the communities did appear to be slightly uneven. As can be seen from the data for Shimla and Solan, both areas had very little diversity of insects (Shimla: 94, H' = 0.84, J' = 0.52; Solan: 33, H' = 0.81, J' = 0.58). These two areas, therefore, represented two extremes for diversity and evenness within the five areas sampled. These extreme values suggest that in both Shimla and Solan there appeared to be a dominant species or group of species that made up the majority of the total number of insects. Thus monsoon appears to drive abundance throughout the area; however, there were great differences in how evenly species distributed themselves among the different sites.

This study also showed that the richness of insects in the order Lepidoptera was the highest (Margalef index = 9.00) compared to other insect orders (Table 2). The Lepidoptera order included a diverse range of pests, primarily moths, which significantly impacted oak species such as *Q oblongata*.

The abundance of insect pests in the study areas can cause tree death or decline. Roots, seedlings, young saplings, tender stems and leaves are subject to injury by insect pests. These insect pests constitute defoliators, piercing or sucking insects, borers, scale insects and gall forming insects. Lepidopteran defoliators, among the numerous insect species that feed on oak, significantly harm the tree.

DISCUSSION

Among all the insect pests recorded during the study, most of the damage was caused by the defoliators. The most prominent defoliators which affect broadleaved trees of western Himalaya were *Heterocrasa expansalis*, *L obfuscata, L concolor, L mathura, Dasychira* sp and *Euproctis* sp. In India, the *L obfuscata* Walker, also known as the Indian gypsy moth, is a major pest that affects over 200 species of broad-leaved trees, including the oak (*Quercus* spp), willow (*Salix* spp), poplar (*Populus* spp) (Dharmadhikari et al 1985, Rishi and Shah 1985). According to Beeson (1941), it was the main pest of apple trees and Ban oaks in Kotgarh, Shimla, Himachal Pradesh.

In earlier research, it was listed as one of the most damaging pests of fruit and forest plantations, such as apple, walnut, willows and poplars in Kashmir (Dar et al 1977, Sheikh 1975, Masoodi et al 1990, Kumar et al 2007). There have also been reports of *L obfuscata* infestations on apple, willow and other plantations in India (Pruthi and Batra 1960, Singh and Singh 1986).

There was recorded extensive oak tree defoliation in Sirmour district of Himachal Pradesh (Singh et al 2007). Around 15,500 species belonging to 104 families under three sub-orders have been identified only from India, among which, Coleoptera is one of the most varied orders of class Insecta (Sengupta and Pal 1998). Additionally, a study on the species diversity of insects in the southern forest-steppe zone of the Chelyabinsk region found that the order Coleoptera had the greatest number of species seen (Makarova et al 2022). Oak forests face compounded threats from biotic pressure and climate change; pest monitoring must be integrated into forest management.

Defoliators and their impact

Climate change is major cause of changes in pest occurrence, movement and viability. A pest or disease's usual range may increase due to a change in the climate, disrupting native plant groups and increasing losses (Rosenzweig et al 2001). One of the primary variables influencing the growth and development of insect pests is temperature. (Bale et al 2002, Patterson et al 1999). High summer temperatures would favour growth of temperate zone insects leading to faster development and additional generations per year (Bale et al 2002, Porter et al 1991). High summer temperatures would encourage the proliferation of temperate zone insects, resulting in more generations per year and rapid development (Porter et al 1991).

Drought stress affects plant physiology, causing some plants to become more susceptible to pests and pathogens, especially when combined with higher temperatures, which can suppress plant defense responses (Rosenzweig et al 2001). The study indicated that there was variation in the abundance, richness and diversity of insect pests of oak in different seasons and the number of lepidopteran defoliators was very large. They reduce leaf area and sap production. Defoliation decreases carbohydrate production which leads to nutrient shortage, growth loss and a consequent reduction in wood production (Kozlowski 1963, 1969) and if not controlled in time, they can also cause tree death and decline.

Borers and acorn pests

Insects, especially weevils, cause geographically extensive and quite varying damage to the acorns of many species of oak (Korstian 1927, Kautz and Liming 1939, Downs and McQuilkin 1944, Reid and Goodrum 1957, Burns et al 1954, Chellman 1954, Brezner 1960, Crocker and Morgan 1983, Oliver and Chapin 1984). The oak forests of the Himalaya are of great importance, being used as firewood and in checking soil erosion. Their regeneration is very poor at present (Ralhan et al 1982). The acorns are mainly infested by weevils, *Dicvunognuthus nebulosus* (Kalia 1988), *Curculio glandium* (Joshi 1988) and *C sikkimensis* (Bora 1989). In present study, *C glandium* (acorn borer) was found affecting the trees of Ban oak (*Q oblongata*) and Moru oak (*Q floribunda*) to a greater extent. Some lepidopteran borer species were also recorded infesting the oak trees.

Sap suckers and indirect damage

Oak trees can be affected by a variety of aphid, coccid and insect species. They typically deplete host resources, which affects the health of their host trees. Additionally, indirect consequences like lower photosynthesis brought on by the growth of sooty molds and early leaf fall may further deplete resources (Salle and Battisti 2016). In present study, 10 species of sap suckers were recorded in the oak forests which consisted members of the order Hemiptera, Dermaptera, Thysanoptera and some species of Coleoptera.

Climate change implications

Oak forests face compounded threats from biotic pressure and climate change; pest monitoring must be integrated into forest management.

CONCLUSION

The present study provides a comprehensive assessment of insect pest diversity and abundance in oak forests of the western Himalaya, revealing a rich assemblage of pest species with marked spatial and seasonal variation. Lepidopteran insects, particularly defoliators, were the most dominant and damaging group, underscoring their critical role in influencing oak health and forest dynamics. While monsoon conditions promoted higher insect abundance across all sites, diversity and evenness varied considerably, indicating that pest pressure is shaped not only by climate but also by local ecological conditions. The combined effects of defoliation, borer infestation and sap-sucking insects pose a serious threat to oak regeneration, especially in forests already stressed by anthropogenic disturbances. In the context of projected climate change, which is expected to enhance pest survival, reproduction and geographic spread, these challenges are likely to intensify further. The study emphasizes the urgent need for long-term monitoring of insect pest populations and the incorporation of pest management strategies into forest conservation and management plans. Protecting oak forests from escalating biotic stress is essential for maintaining ecosystem stability, biodiversity and the vital ecological services these forests provide in the Himalayan region.

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