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Diversity and occurrence of defoliators and stem borers associated with *Eucalyptus camaldulensis*, *Dalbergia sissoo*, and *Vachellia nilotica* in Chichawatni Plantation, Punjab, Pakistan

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Abstract

Insect pest outbreaks pose a significant threat to productivity and sustainability of plantation forests in Pakistan, particularly in the context of the country's severe forest deficit. Current study provides the first comprehensive assessment of defoliator and stem borer complexes associated with three cornerstone plantation species, Eucalyptus, Shisham and Babul in the Chichawatni irrigated plantation of Punjab, Pakistan. A systematic survey employing stratified random sampling was conducted over a complete annual cycle. Insect collection were made using visual observation, hand-picking and beating sheet methods for defoliators, while stem borers were detected through symptom-based examination of exit holes, frass, gum exudation and bark dissection. A total of 3158 individual pest from 26 species were recorded, with the defoliators constituting 59.9% and stem borers 40.1% of the assemblage. Babul hosted the highest pest load and exhibited most severe defoliation along with the poorest tree health score. Shisham predominantly affected by stem borers while Eucalyptus showed more balanced pest complex with significant pressure from both *Chrysophtharata bimaculata* and *Phoacantha semipunctata.* Statistical analysis revealed strong positive correlation between pest abundance and defoliation and strong negative correlation between defoliation and tree health. One way ANOVA showed significant difference in defoliation among species. Current study identifies key pest species requiring prioritized management and establishes baseline data for monitoring pest population dynamics in Chichawatni plantation. The findings support development of species-specific integrated pest management strategies, with critical implication for sustaining plantation productivity in one of Pakistan's largest man-made forest.

1 Introduction

Pakistan is one of the most forest-deficient countries of the world (Khan *et al*., 2024). Just 4.8% of total land area of Pakistan is forest cover, which is very less than the recommended 25% for a country's economic and ecologic stability (Najeeb *et al*., 2023). Because of this scarcity, intense pressure is faced by existing forest resources (Abid and Aziz, 2025). In the heartland of Pakistan's agriculture and industry, Punjab province, this deficit is acute (Shahzad *et al*., 2024). To meet the demands of fuel wood, timber and fodder, Punjab Forest Department (PFD) invested in large-scale plantation projects

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(Rafiq *et al*., 2024). Forestry sector contributes approximately PKR 130 billion in GDP of Pakistan (Maqbool). Among these, Chichawatni plantation, present in District Sahiwal, stands as ecological and historical landmar. It is established in British colonial era in the early 20th century. It is one of the largest irrigated plantations in Pakistan of approximately 10,000 hectares (Najeeb *et al*., 2023). This plantation served as a multi-functional ecosystem and a vital source of wood and no-wood forest products for local and national economies (Waheed *et al*., 2024).

This plantation is a mixture of indigenous and exotic species. Three genera have emerges as cornerstones of this and also for many other plantations across the Punjab: Eucaluptus (*E. camadulensis*), Shisham (*Dalbergia sissoo*) and Babul (*Acasia nilotica*) (Waheed *et al*., 2024). Each species plays a very important and distinct role. *Eucaluptus camadulensis* (River Red Gum), introduced from Australia (Syukri and Singh, 2024). It is widely cultivated due to its fast growth, adaptability to waterlogged and saline conditions and also for production of straight pole. It is a principal source of pulpwood and plywood (Avisar et al., 2025). *Dalbergia sissoo* (Shisham) is a native hardwood, its wood is very durable, used in high-value furniture and it is a termite-resistant timber. This species also plays important ecological roles like nitrogen fixation and enhances soil fertility (Marko, 2021). *Acacia nilotica* (Kikar/ Babul) is a drought resistant species. It provides Charcoal, fodder for livestock, hard timber and high quality fuel wood (Devi *et al*., 2023). Despite their resilience, this plantation faces an escalating threat: insect pest outbreak. Two functional guilds of insect pose most direct and severe damage: defoliators and stem borers (Roychoudhury, 2025). Defoliators are the insects of order Lepidoptera (butterflies, moths) and Coleoptera (beetles) that causes the plants to shed their leaves. These insects feed on leaves and young shoots. Due to this they deplete energy reserves and reduce the growth of plants. Severe defoliation leads to crown loss, dieback and ultimately death of tree, especially when trees are under other stressors like drought (Schafellner and Möller, 2022).

Stem bores are the insects mostly from order coleptera (Buprestidae, Cerambycidae) and Lepidoptera (Sessiidae, cossidae), whose larvae tunnel into the tree trunk and branches and creates intricate galleries within sapwood. This physical damage disrupts the vascular system and impairs the transportation of water and nutrients. Plants become structurally week and show the symptoms of decline and succumb. In addition to this, borer galleries serve as entry point for pathogens like bacteria, fungi and viruses (Remadevi, 2022). Eucalyptus plantation becomes a hotspot for insect pest in Pakistan (Rehman et al., 2024). Most notorious defoliator is the Eucalyptus Leaf Beetle. Both larvae and adults of this beetle skeletonize the leaves and leads to severe defoliation. In India, outbreak of this pest caused upto 70-80% defoliation, which leads to significant growth losses. Globally, most devastating stem borers are Eucalyptus Longhorned Borer and Eucalyptus Gall Wasp. Borer larvae tunnel under the bark while wasp induces galls on leaf midribs, petioles and stem which causes stunted growth and dieback (Barbosa et al., 2023).

Larvae of Shisham borer, bore into the main stem and branches, their feeding galleries often girdling the tree. Shot hole borer beetle along with introducing fungi, create small hole and tunnels. In Punjab, Pakistan, surveys have linked severe dieback directly to heavy borer infestation, with mortality rates in affected plantations reaching 30-40% over a few years. The loss of a single mature Shisham tree represents a significant financial blow, given the high value for its timber (Roychoudhury, 2025). Babul faces a persistent threat from defoliators, most significant 'Babul defoliator'. Larvae of this moth web together leaves and twigs and girdling young shoots and branches. Babul stem borer is a major menace. Its grubs feed on root-collar region and underground roots, particularly damaging form of attack as it remains undetected until the tree shows wilting and dieback symptoms. This borer is frequently reported as key pest of *Acacia nilotica* in plantations of Pakistan and India. Outbreaks are often cyclical and linked to climatic conditions, with warm, dry periods favoring population surges (Bhatnagar & Verma, 2025). Despite the evident severity of the problem, critical knowledge gaps hinder effective management in Chichawatni plantation and similar ecosystems. There is lack of systematic, long term data on pest species composition, seasonal incidence and their population dynamics in Chichawatni plantation's micro-climate and silvicultural conditions.

This research paper aims to provide a comprehensive, scientifically rigorous assessment of defoliator and stem borer complexes threatening Eucalyptus, Shisham and Babul plantations of Chichawatni, Punjab, Pakistan by conducting a systematic survey to identify and document species composition of pest.

2. Materials and Methods:

A robust methodological framework was employed to conduct a comprehensive assessment of defoliators and stem borers which are associated with Eucalyptus, Shisham and Babul within the Chichawatni plantation. Current study was designed to be field-based and diagnostic, integrating ecological surveying techniques, insect collection and preservation protocols and statistical analysis.

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2.1 Geographic location of study area:

The study was conducted in the Chichawatni plantation, one of the largest man-made irrigated forest plantations in Pakistan. It is located in Sahiwal District of Punjab. Geographical coordinates of study zone are $30^0$32'N, $72^0$41'E.

2.2 Climatic and Ecological zone:

This plantation falls within the Semi-arid subtropical zone characterized by three major seasons: Summer, monsoon and winter season. Annual rainfall is approximately 200-400 mm. This climatic region significantly influences insect pest life cycle, with peak activity typically observed during the warm, humid months in which temperature of this region often exceeding 40 ^{0}C.

2.3 Edaphic and Hydrological features:

Most critical feature of this plantation is Canal-based irrigation system, which is fed from nearby Upper Chenab Canal. Its soil is predominantly alluvial and loamy.

2.4 Forest structure and composition:

The plantation is a mixed stand, though with blocks of monoculture. Ecucalyptus, Shisham and Babul are the focal species in various patterns along with other secondary species. Tree ages vary, providing a gradient from young saplings to mature trees, which was considered in the sampling design. A pilot survey was conducted over a two week period to assess the distribution of target tree species. To ensure the data was represented and captured variability within plantation, Stratified random sampling design was adopted. A map of plantation was obtained from Forest department, and all areas dominated by each target species were identified. Using a random number generator, coordinate pairs were selected to place the center of each sample plot. This eliminated selection bias and ensured every individual tree within a stratum had an equal probability of being included. Circular plots with a radius of 10 meters were established. Circular plots are efficient for minimizing edge effect and are logistically simpler to survey in a forest setting. A total of 30 sample plots were established with 10 plots per tree species. This replication provided robust data for statistical comparison among the species. Within each plot, all individuals of the target species with a Diameter at Breast Height >5cm were tagged and included in the survey. A minimum distance of 50 meters was maintained between plot centers to ensure spatial independence and avoid pseudo-replication. Survey was conducted monthly over a period of one complete annual cycle to account for seasonal variations in insect pest populations. Each plot was visited once per month.

2.5 Survey for defoliators:

Defoliators were assessed by using two complementary techniques: 1. Visual observation and hand-picking: All visible foliar damage was inspected. Larvae, pupae and adults found on leaves and twigs were carefully collected using soft forceps and placed into labeled ventilated plastic vials. 2. Beating sheet sampling: This standardized method was used to collect cryptic and small arthropods. A white cloth beating sheet was spread under a selected branch. The branch was struck sharply three times with a padded pole. Dislodged insects fell onto the sheet and were immediately collected using aspirators or forceps. Per plot, this was repeated on five randomly selected branches of the target species, at varying heights (low, mid-canopy where possible).

2.6 Survey for Stem borers:

Stem borers were detected using a symptom-based approach, as adults are often elusive. Each tree with a plot was meticulously examined for the external symptoms: Exit/entry hole, Frass, Gum exudation/Oozing sap, Sawdust extrusions and signs like swellings, crack or galleries visible on the bark surface. For a subset of infested trees, careful dissection was performed. Survey timing was stratified to account for diel activity patterns of insect pest. Diurnal insects were surveyed during daylight hours (08:00-16:00). Nocturnal insects were sampled during night time (19:00-23:00) using light sheets and headlamps while Crepuscular species was targeted during dawn (5:30-7:30) and dusk (17:30-19:30).

2.7 Damage and tree health assessment parameters:

For every individual tree of the target species within a plot, quantitative and qualitative parameters like Infestation incidence, defoliator severity, stem borer intensity and tree health status were recorded on a standardized data sheet.

2.8 Specimen preservation:

Immediately after collection, specimens were euthanized using Ethyl acetate killing jars. Soft-bodied larvae were first placed in hot water for 1-2 minutes to fix proteins and prevent shrinkage, before transferring to preservative. All specimens were stored in 70% Ethanol in sealed plastic vials. Each vial was labeled with a unique code detailing plot number, tree species, date, collection method and collector's name. This concentration of ethanol is optimal for preserving morphology without excessive brittleness. A field notebook and digital spreadsheet were maintained concurrently, linking the vial code to the full set of ecological data recorded for that tree/plot. Specimens were stored into major orders under a stereomicroscope. Identification was carried out using standard taxonomic keys.

2.9 **Statistical analysis**

All data were analyzed by using SPSS (Statistical Package for Social Sciences) and means were compared using ANOVA.

3. Results:

Species composition and abundance of insect pest:

A total of 26 pest species were recorded across the three tree species in the Chichawatni plantation, belonging to two functional guilds: defoliators and stem borers. The species were distributed across the orders Lepidoptera and Coleoptera, with representatives from multiple families. Species composition is described in table 1.

Table 1: Species composition

Tree	Pest	Order	Family	Species	Number of Pupae	Number of Larvae	Number of Adult	Total Number
Eucalyptus	Defoliators	Lepidoptera	Lasiocampidae	*Streblote siva*	8	21	58	87
			Eupterotidae	*Eupterote mollifera*	56	48	20	124
			Geometridae	*Thyrinteina leucocerae*	62	33	108	203
		Coleoptera	Chrysomelidae	*Chrysophtharata bimaculata*	36	197	82	315
				Altica sp.	18	9	29	56
	Stem borer	Lepidoptera	Hepialidae	*Sahadrassus malabaricus*	7	9	7	23
			Metarbelidae	*Indarbela quadrinotata*	19	31	28	78
		Coleoptera	Cerambycidae	*Phoracantha semipunctata*	21	53	68	142
				Phorocantha recurva	13	11	43	67
				Batocera rufomaculata	7	3	8	18
			Bostrichidae	*Sinoxylon anale*	11	13	17	41
Shisham	Defoliators	Lepidoptera	Erebidae	*Plecoptera reflexa*	19	5	22	46
				Achaea janata	19	73	67	189
			Pieridae	*Eurema blanda*	13	11	21	45
			Lycaenidae	*Bindahara phocides*	1	8	13	28
	Stem borer	Lepidoptera	Cossidae	*Zeuzera offeae*	17	21	24	62
			Metarbelidae	*Indarbela tetraonis*	27	23	17	67
		Coleoptera	Cerambycidae	*Aphate ganga*	37	69	42	148
				Aristobia approximator	73	95	63	231
			Bostrichidae	*Sinoxylon sudanicum*	12	9	13	34

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			Curculionidae	*Xyleberus perforans*	6	4	9	19
Babul	Defoliators	Lepidoptera	Metarbelidae	*Indarbela quadrinotata*	161	211	126	498
				Indarbela tetraonis	51	34	49	134
			Gelechiidae	*Anarsia sp.*	18	11	38	67
		Coleoptera	Chrysomelidae	*Mimastra sp.*	32	15	42	89
	Stem borer	Lepidoptera	Cossidae	*Cossus sp.*	3	4	20	27
		Coleoptera	Cerambycidae	*Celosterna scabrator*	47	31	78	156
				Xystrocera globosa	25	21	26	72
				Aeolesthes holosericea	5	7	19	31
			Bostrichidae	*Sinoxylon crissum*	19	7	18	44

Total pest abundance per tree species:

The highest total pest count was recorded on Babul (1136 individuals), followed by Eucalyptus (1153 individuals) and Shisham (869 individuals). Babul was predominantly infested by defoliators, especially *Indarbela quadrinotata* (498 individuals). Eucalyptus showed high defoliator loads from *Chrysophtharata bimaculata* (315) and *Thyrinteina leucocerae* (203). Shisham was most affected by the stem borer *Aristobia approximator* (231) and defoliator *Achaea janata* (189). Pest abundance is described in table 2 while most prevalent symptoms associated with pest guild were presented in Table 3. The composition of dominant pests varied considerably among tree species (Figure 1).

Table 2: Pest abundance on target species

Tree species	Defoliator count	Stemborer count	Total pest count
Eucalyptus	785	368	1153
Shisham	308	561	869
Babul	788	348	1136

Table 3: Most prevalent symptoms associated with pest guilds

Symptom type	Defoliator (%)	Stem borer (%)	Combined (%)
Leaf skeletinoizing	65.2		65.2
Frass extrusion	12.4	88.8	50.3
Gum exudation	8.7	75.4	41.5
Gall formation	5.3	35.3	45.7
Bark cracking	0	31.3	15.7

The identification of key pest species revealed distinct damage profiles for each tree species (Table 4). Damage severity was classified based on established thresholds: very high, Medium and Low. Corresponding management priorities were assigned, with Babul requiring Critical intervention while Shisham and Babul requires high priority.

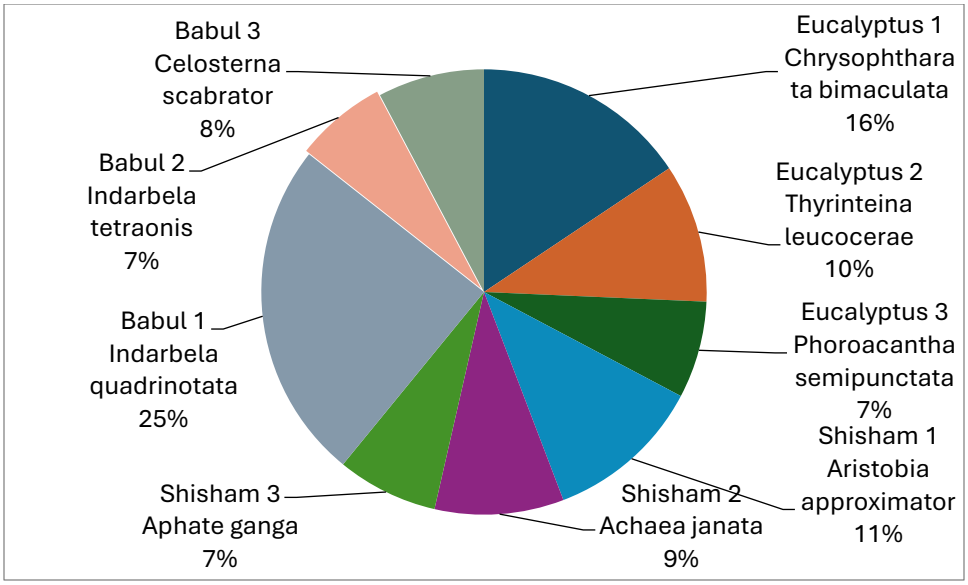


Fig 1: Top three pest per species

Table 4: Key pest species identification and damage assessment

Tree species	Key defoliator	Damage severity	Key stem borer	Damage severity	Management priority
Eucalyptus	*C. bimaculata*	High (315 count, 65% defoliation)	*P. semipunctata*	Medium (142 count, 7 galleries)	High
Shisham	*A. janata*	Medium (189 count, 40% defoliation)	*A.approximator*	High (231 count, 12 galleries/tree)	Very high
Babul	*I. quadrinotata*	Very high (498 count, 75% defoliation)	*C. scabrator*	Medium (156 count, 6 galleries/tree)	Critical

The concentration of pest pressure was remarkably high, with the top three species accounting for 57.2-70.4% of total pests on each tree species (Table 5). This oligodominance pattern suggests that targeted management of these key species could substantially reduce overall pest pressure. On Babul trees, *Indarbela quadrinotata* alone represented nearly half of all pests recorded, indicating an exceptionally high degree of host-specific infestation.

Table 5: Dominant pest species by tree host

Rank	Ecucalyptus	Count (% of host total)	Shisham	Count (% of host total)	Babul	Count (% of host total)
1	*C. bimaculata*	315(27.3%)	*A. approximator*	231(26.6%)	*I. quadrinotata*	498 (44.5%)
2	*T. leucocerae*	203 (17.6%)	*A. janata*	189 (21.7%)	*C. scabrator*	156 (13.9 %)
3	*P. semipunctata*	142 (12.3 %)	*A. ganga*	148 (17.0%)	*I. tetraonis*	134 (12.0%)
Top 3 Total		660 (57.2%)		568 (65.30%)		788 (70.4%)

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One way ANOVA revealed significant difference in pest damage among the three tree species (Table 6). Defoliation percentage varied significantly, with Babul showing the highest mean defoliation, followed by Ecucalyptus and Shisham.

Table 6: One-way ANOVA results for comparison

Parameters	Source	Sum of squares	df	Mean square	F-Value	P-value
Total pest	Between species	7245.2	2	3622.6	0.402	0.673
	Within species	243294.8	27	9010.9		
	Total	250540	29			
Defoliation (%)	Between species	1284.6	2	642.3	3.125	0.061
	Within species	5548.4	27	205.5		
	Total	6833	29			
Health score	Between species	3.267	2	1.634	2.897	0.072
	Within species	15.233	27	0.564		
	Total	18.5	29			

The correlation between stem borer galleries and tree health was moderate but significant, suggesting that internal stem damage contributes to overall decline, though to a lesser extent than defoliation. The non-significant correlation between total pest count and galleries indicate that defoliator and stem borer populations operated independently rather than synergistically (Table 7).

Table 7: Correlation matrix among pest and damage variables

Variable	Total pest	Defoliation %	Galleries count	Health score
Total pests	1	-	-	-
Defoliation %	0.172	1	-	-
Galleries Count	0.158	0.145	1	-
Health score	-0.634	-0.798	-0.428	1

4. Discussion:

The sustainability of plantation forestry in semi-arid regions is intrinsically linked to the effective management of insect pests; a challenge magnified in nations like Pakistan where forest covers is critically low. This study provides a detailed assessment of the defoliator and stem borer complexes in the economically vital Chichawatni plantation, revealing a pest assemblage characterized by pronounced host specificity. The extreme oligodominance observed, where a few species account for the majority of pest load on each tree host, aligns with ecological principles of simplified ecosystems. In monoculture plantation, reduced biodiversity often leads to pest outbreaks due to absence of natural regulatory meachanisms (Josephrajkumar et al., 2022).

The dominance of *I. quadrinotata* on Babul corresponds findings from other regions where Indarbela species are recongnized as major defoliators of *A. nilotica* in dryland plantations (Bharuo, 2021). This species' success is facilitated by

its larval behavior of constructing protective silken webbing, which creates favorable microhabitat and offers refuge from natural enemies (Bhaurao, 2021)

While, stem borer dominated pest profile of Shisham follows patterns observed in other high-value hardwoods. The prevalence of A. approximator correlates with reports of Cerambycid borers causing significant moratlity in Dalbergia sissoo plantations across South Asia, particularly under conditions of environmental stress. Eucalyptus, as an exotic species system, showed a more generalized pest profile, consistent with observations that introduced tree species often face novel pest complexes that differ from those in their native regions (Paine *et al.*, 2011)

Strong correlation between defoliation and declining tree health has particular significance in semi-arid environments. Research has shown that defoliation in water-limited systems can trigger physiological stress beyond simple biomass, disrupting water relations. This is especially relevant in irrigated plantations like Chchawatni, where trees may experience periodic water stress despite the canal system. Stem borer damage adds chronic stress in various systems worldwide. The temporal stratification of pest activity observed which reflects their adaptive strategies (Welch & Harwood, 2014). Effective monitoring and intervention must align with target species' activity peaks-a principal well-established in agriculture and forest entomology. Silvicultural practices must be combined with biological and chemical controls as needed- an approach consistent with modern integrated pest management principles in plantation forestry

5. Conclusion:

The Chichawatni plantation faces a clear and present threat from specialized insect pests, but this threat is now quantified and defined. The path forward lies in moving from blanket approaches to precision management. By focusing interventions on the key pest species identified for each tree host and by employing a mix of cultural, biological and carefully targeted chemical controls informed by regular monitoring, the productivity and ecological value of this historic plantation can be preserved. In doing so, this work contributes not only protection of a single forest but to the development of a science based model for sustainable plantation management in Pakistan and similar semi-arid regions globally.

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