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Seasonal abundance of *Anomala lineatopennis* from mid and high hills of Himachal Pradesh

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Abstract
The seasonal dynamics of *Anomala lineatopennis* were investigated across the mid and high hills of Himachal Pradesh to elucidate population trends and emergence patterns relative to altitudinal gradients. This study aimed to determine abundance fluctuations and peak activity periods to inform pest surveillance protocols amidst varying climatic influences. Sampling conducted from March to September 2023, utilizing a combination of light traps and manual collection methods, revealed a significant unimodal distribution of beetle populations driven by location-specific environmental factors. Peak abundance was recorded in May at mid-hill locations, with counts reaching 491 beetles at Seobag and 375 at Palampur, followed by a marked decline to 39 and 36 beetles, respectively, by July. Conversely, the high-hill region of Janjeheli exhibited a distinct temporal delay, with peak activity occurring in July with 351 beetles, underscoring the critical impact of altitude on life cycle synchronization. These findings identify *A. lineatopennis* as a significant pest in temperate agro-ecosystems, particularly within fruit orchards, where emergence patterns necessitate targeted monitoring. The established temporal variation provides a scientific basis for optimizing integrated pest management strategies, allowing for precise, timely interventions that align with peak pest pressure to effectively reduce crop damage.

Keywords: *Anomala lineatopennis*, seasonal abundance, Himachal Pradesh, mid hills, high hills, emergence patterns

Introduction

Scarabaeoidea is among the largest Coleopteran superfamilies, comprising nearly 31,000 species, of which 27,800 belong to the family Scarabaeidae (Jameson & Ratcliffe, 2001). The family consists of 13 subfamilies, with Melolonthinae and Rutelinae being the most diverse and widely distributed. Their adults typically emerge during May-June and are commonly known as May beetles, June beetles, or cockchafers due to their seasonal appearance and foliage-feeding habits. Within this group, *Anomala* Samouelle, 1819 is recognized as the largest and most species-rich genus in the animal kingdom (Jameson et al., 2003; Sarkar et al., 2017) [13, 22], comprising roughly 1,000 species worldwide. It belongs to the family Scarabaeidae and the subfamily Rutelinae (Machatschke, 1972) [15]. Globally, this subfamily includes about 200 genera and 4,100 species, commonly referred to as shining leaf beetles (Machatschke, 1972) [15].

The *Aomala* beetle larvae inhabit the soil and are commonly referred to as white grubs, feeding on roots, compost, and decaying organic matter (Gardner, 1935) [10]. In the north-western Himalaya, a total of 116 scarabaeid species have been documented, the majority of which (82 species) fall under the subfamilies Melolonthinae and Rutelinae. Notably, 19 of these species belong to the genus *Anomala* alone (Mehta et al., 2010) [16]. More than 2,000 species of white grubs are reported from the Indian subcontinent, of which over 40 species inflict serious damage on a wide variety of crops (Veeresh et al., 1991) [26].

White grubs are major pests affecting a wide range of crops, including sugarcane, groundnut, chillies, potato, maize, wheat, barley, jowar, bajra, sesame, sunflower, cotton, tobacco, soybean, brinjal, cucurbits, and bhendi, as well as turf, meadows, lawns, and forest trees (Fujiie & Yokoyama, 1996) [9]. White grub damage on potato in India was first reported from Himachal Pradesh by Sharma and Bhalla (1964) [23], who identified *Brahmina coriacea* and *Lachnosterna (Holotrichia) longipennis* as the major species attacking multiple crops including potato. Subsequent studies recorded 5.7-26.5% damage to potato tubers and ginger rhizomes (Misra, 1992) [20], while damage in endemic mid-hill regions often exceeds 50% (Chandel, 1992) [4]. In the Shimla hills, tuber losses due to *B. coriacea* reached 62% (Thakur et al., 2008) [25], and overall potato damage in hilly areas ranges from 8.5 to 75% (Chandel et al., 2015) [6].

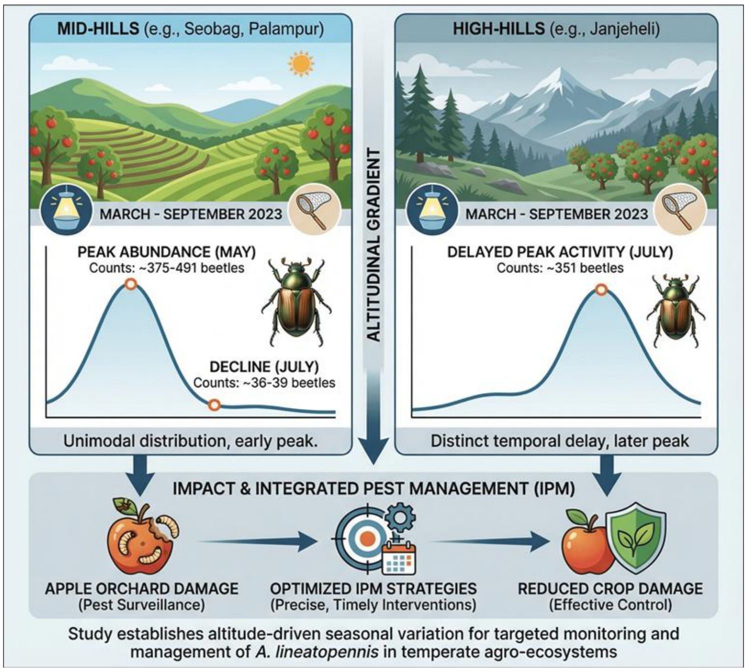

Fig 1: Seasonal dynamics of *Anomala lineatopennis* in Himachal Pradesh: Altitudinal influence & management implications

White grubs are among the most successful beetle groups, with most species occurring in subtropical and tropical regions (Carpaneto, 2008) [2]. They are generally crepuscular or nocturnal and are strongly attracted to artificial lights (Sushil et al., 2011; Chandel et al., 2021) [24, 7]. These beetles form a distinct and specialized lineage, easily recognized by their lamellate antennae, while their larvae commonly referred to as white grubs primarily inhabit grassland soils, feeding on the roots of diverse plant species (Misra & Chandel, 2003) [19].

Anomala lineatopennis Blanchard (Coleoptera: Scarabaeidae) is an important species of the genus *Anomala*, reported from Himachal Pradesh, Uttarakhand, West Bengal, and Kathmandu. In the north-western Himalaya, it is a major pest of pome and stone fruits and various agroforestry trees. The species is common in the mid and high-hill regions of Himachal Pradesh, including Chamba, Kullu, Shimla, and Sirmaur. As an early-emerging scarabaeid, coinciding with full foliage and fruit development on temperate fruit trees, *A. lineatopennis* acts as a serious defoliator of these crops (Ali, 2001; Gupta et al., 1977; Chandel et al., 2010; Chandra, 2005; Kumar et al., 2007; Chadha, 2001; Chandel et al., 2021; Mishra et al., 1998) [7, 11, 5, 8, 14, 3, 7, 18].

In *A. lineatopennis*, the third instar lasts 202-223 days, with overwintering occurring deep in the soil inside hard earthen cells. As temperatures rise, the hibernating grubs resume activity, and pupation occurs in April (Mishra, 2001) [17]. Adults have been reported feeding on apple, peach, and apricot (Musthak Ali, 2001) [21]. In north western himalayan regions like Himachal Pradesh, Uttarakhand etc., the species completes its life cycle in approximately 320 days (Mishra, 2001) [17].

Given the economic significance and wide distribution of *Anomala lineatopennis* in the north-western Himalayan fruit-growing belts, understanding its population dynamics is crucial for timely and effective pest management. Despite being a major defoliator of temperate fruits and a common species in the mid- and high-hill regions of Himachal Pradesh, comprehensive information on its seasonal abundance, activity peaks, and altitudinal patterns remains limited. Since the species exhibits early emergence, prolonged larval development, and region-specific life-cycle duration, precise knowledge of its seasonal occurrence is essential for predicting outbreak periods and optimizing control interventions. Therefore, the present study investigates the seasonal abundance of *A. lineatopennis* across mid and high hills of Himachal Pradesh, aiming to generate location-specific insights that can support improved monitoring, forecasting, and integrated management strategies for this important scarabaeid pest.

Materials and Methods

Study Area Description

The study was conducted across multiple locations in the mid and high hills of Himachal Pradesh, specifically Seobag, Palampur, Sunder Nagar, Janjeheli, Salooni, Bajaura, Chailchowk, and Solan. These sites were selected to represent varying ecological conditions, with elevations ranging from 600 to 2500 meters above sea level. The chosen areas are characterized by diverse climatic ranges conducive to the cultivation of temperate fruits, notably apple, peach, pear and plum which serves as a key host plant for *Anomala lineatopennis*.

Sample Collection

Adult beetles were sampled using a combination of standard light traps and manual collection methods to enhance capture efficiency. Light traps equipped with ultraviolet incandescent bulbs were deployed in open fields adjacent to fruit orchards where adult activity was anticipated. Each trap was positioned at a height of 1.5 meters above the ground and operated nightly over a continuous period from March to September to capture beetles attracted to the light source. Concurrently, manual collection was performed during nocturnal hours, Sampling commenced in March 2023, capturing both initial emergence and peak abundance periods.

Taxonomic Identification

Captured specimens were preserved in 70% ethanol and subsequently identified to the species level using taxonomic keys given by Arrow (1917), focusing particularly on the male genitalia

Observation Period & Seasonal Categorization

The observation period was systematically segmented into three distinct seasons: pre-monsoon (March to May), monsoon (June to August), and post-monsoon (September). Seasonal categorization was based on emerging patterns of beetle activity aligned with climatic shifts, particularly temperature and humidity, which influence phenological processes.

Data Recording

Data collection involved recording the total number of adult *A. lineatopennis* captured per sampling event, aggregating counts weekly to assess population trends.

Table 1: Seasonal abundance of *Anomala lineatopennis* recorded at different locations in Himachal Pradesh

Location	March	April	May	June	July	August	September
Palampur	0	45	375	350	36	7	1
Solan	0	21	231	360	215	72	10
Salooni	0	14	175	236	180	61	31
Bajaura	0	70	300	270	15	0	0
Seobag	0	39	491	376	39	17	0
Janjeheli	0	7	142	250	351	210	94
Chailchowk	0	19	215	321	178	56	2
Sunder Nagar	0	78	330	292	21	0	0

This table presents the total counts of *Anomala lineatopennis* collected across eight locations between March and September. Peak abundance across most locations occurred primarily during May and June, indicated by shaded columns and superscript notation (^).

Results

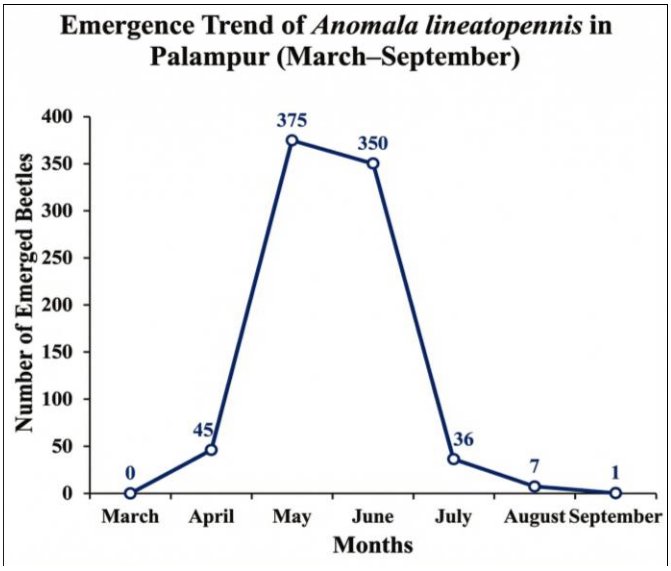

Fig 2: Seasonal emergence pattern of *Anomala lineatopennis* observed at Palampur during March-September

The seasonal abundance of *Anomala lineatopennis* monitored in Palampur exhibited a distinct unimodal emergence pattern during the observation period from March to September. Adult activity was absent in March (0 beetles), with initial emergence commencing in April (45 beetles) before escalating sharply to record the highest population abundance of 375 beetles in May. This peak activity persisted through June with 350 beetles, likely triggered by optimal soil moisture and temperature conditions associated with pre-monsoon and early monsoon precipitation which typically facilitates adult emergence from the soil. Following this active period, the population witnessed a precipitous decline in July (36 beetles) and continued to taper significantly in August (7 beetles), eventually reaching the lowest recorded abundance of 1 beetle in September, a trend presumably attributed to the completion of the adult mating phase, host plant phenological changes, and natural senescence.

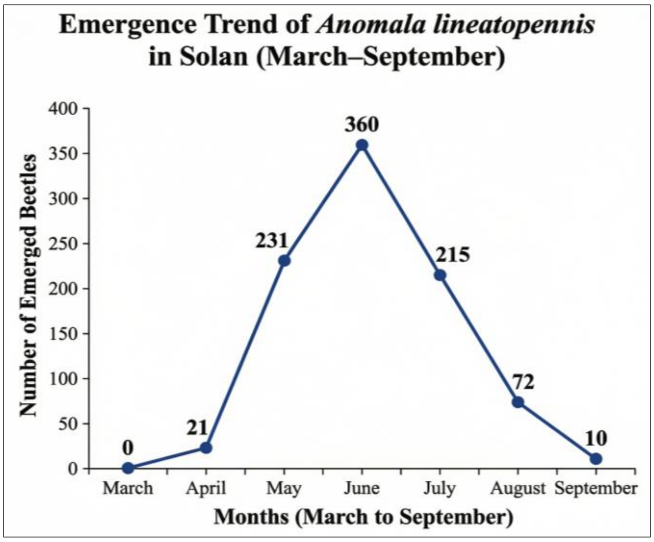

Fig 3: Seasonal emergence pattern of *Anomala lineatopennis* observed at solan during March-September

The seasonal emergence dynamics of *Anomala lineatopennis* monitored in Solan revealed a characteristic unimodal distribution pattern spanning the observation period from March to September. While the population remained dormant in March (0 beetles), initial adult emergence was recorded in April (21 beetles), followed by a sharp exponential increase in May (231 beetles). The population abundance reached its zenith in June with a maximum recovery of 360 beetles, a phenomenon likely synchronized with the onset of monsoon precipitation and elevated humidity which favor adult emergence from pupal chambers in the soil. Post-peak activity demonstrated a steady biological decline, with beetle counts reducing to 215 in July and 72 in August, before tapering to a minimum of 10 beetles by September, indicative of the natural cessation of the adult reproductive phase and subsequent mortality.

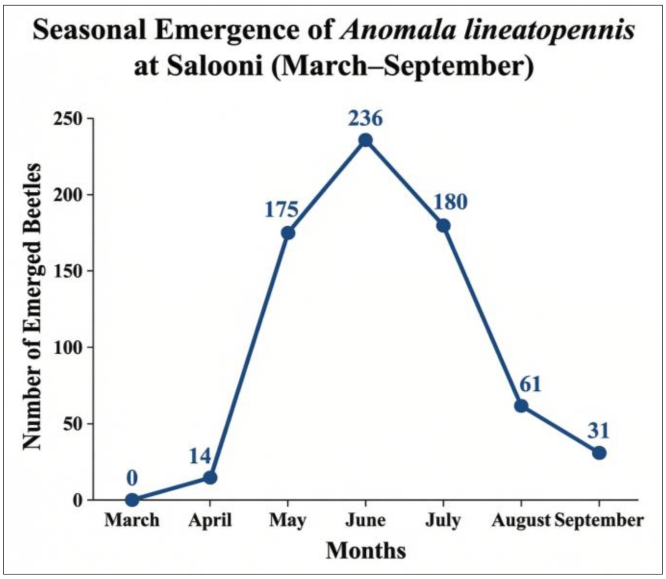

Fig 4: Emergence fluctuation of *Anomala lineatopennis* at Salooni from March to September

The seasonal emergence pattern of *Anomala lineatopennis* recorded at Salooni exhibited a defined unimodal trend characterized by a distinct active period following initial dormancy. While no adult activity was observed during March (0 beetles), the onset of emergence commenced in April with 14 beetles, followed by a substantial population surge in May (175 beetles). The population density reached its peak in June with a maximum emergence of 236 beetles, a temporal fluctuation likely driven by the onset of monsoon precipitation and the resultant favorable edaphic moisture conditions essential for adult eclosion. Following this zenith, the abundance showed a gradual decline to 180 beetles in July, accelerating to a sharper reduction in August (61 beetles) and tapering to 31 beetles in September, a downward trajectory attributed to natural adult senescence and the conclusion of the reproductive phase.

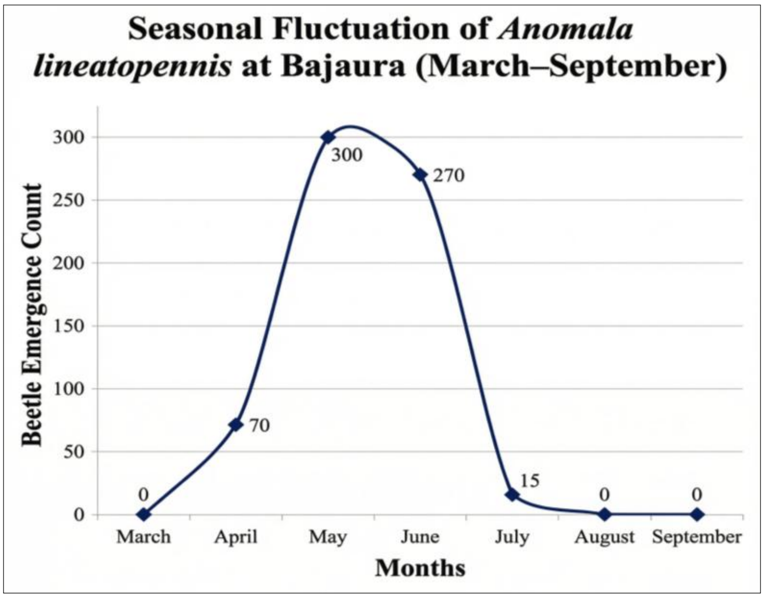

Fig 5: Emergence trend of *Anomala lineatopennis* at Bajaura from March to September

The seasonal population fluctuations of *Anomala lineatopennis* recorded at Bajaura demonstrated a highly concentrated, unimodal activity period characterized by a rapid surge and subsequent cessation of adult activity. While the population remained non-existent during March (0 beetles), emergence initiated abruptly in April (70 beetles) and escalated to reach a distinct peak abundance of 300 beetles in May. High population levels were sustained through June (270 beetles), a phenomenon likely facilitated by optimal thermal conditions and soil moisture essential for adult emergence, before undergoing a precipitous decline to 15 beetles in July. The adult population completely disappeared by August and remained absent through September (0 beetles), suggesting a synchronized completion of the biological life cycle, mating cessation, and natural mortality following the active reproductive phase.

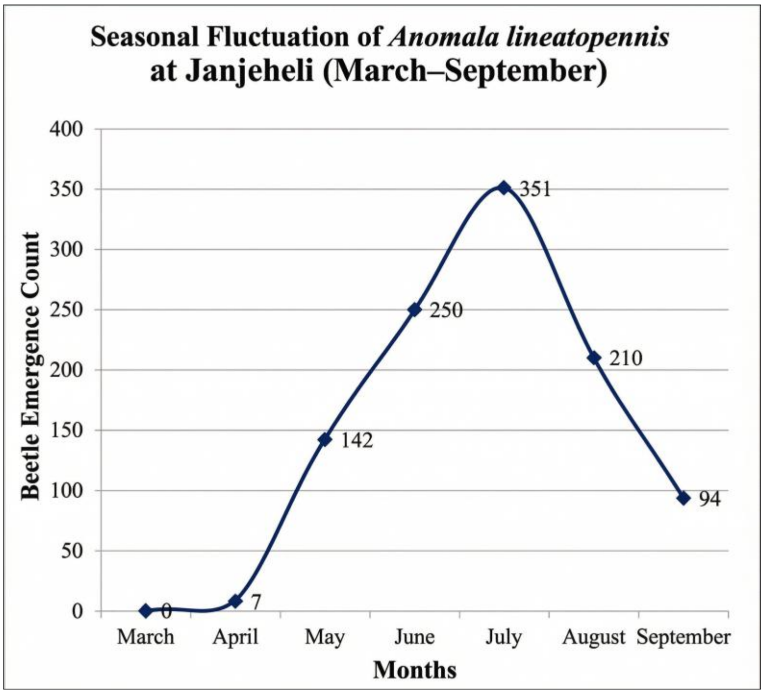

Fig 6: Emergence trend of *Anomala lineatopennis* at Janjeheli from March to September

The seasonal population dynamics of *Anomala lineatopennis* observed at Janjeheli displayed a progressive unimodal trend characterized by a delayed peak in abundance relative to the early season. Adult activity was non-existent in March (0 beetles) and remained negligible in April (7 beetles), before intensifying significantly in the subsequent months with counts rising to 142 in May and 250 in June. The population density culminated in July with a maximum emergence of 351 beetles, a peak likely synchronized with the sufficient accumulation of thermal units and optimal soil humidity required for pupal eclosion in this specific agro-ecological zone. Following this zenith, the abundance exhibited a consistent decline to 210 beetles in August and 94 beetles in September, reflecting the natural progression of adult senescence and the gradual cessation of reproductive activity towards the end of the season.

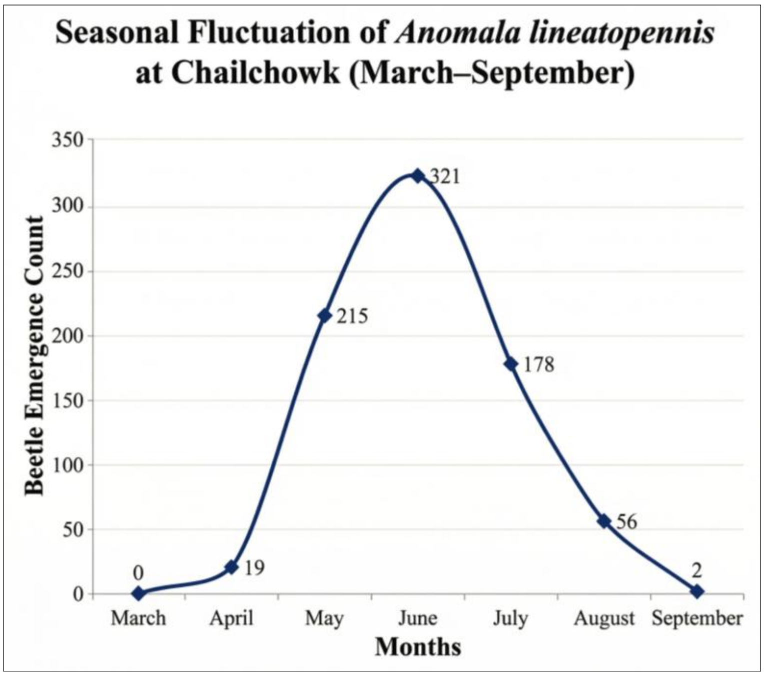

Fig 7: Emergence trend of *Anomala lineatopennis* at chailchowk from March to September

The seasonal population dynamics of *Anomala lineatopennis* recorded at Chailchowk exhibited a distinct unimodal distribution pattern marked by a rapid escalation and subsequent decline in adult activity. While the population remained dormant throughout March (0 beetles), the initiation of emergence was observed in April with a count of 19 beetles, which surged significantly to 215 beetles by May. The population abundance culminated in June with a peak emergence of 321 beetles, a zenith likely synchronized with favorable edaphic conditions, particularly soil moisture and temperature regimes that facilitate mass eclosion. Following this maximum activity, the population followed a steady downward trajectory, reducing to 178 beetles in July and further contracting to 56 beetles in August, before tapering to a negligible abundance of 2 beetles in September, a decline indicative of the natural completion of the adult biological cycle and senescence post-mating.

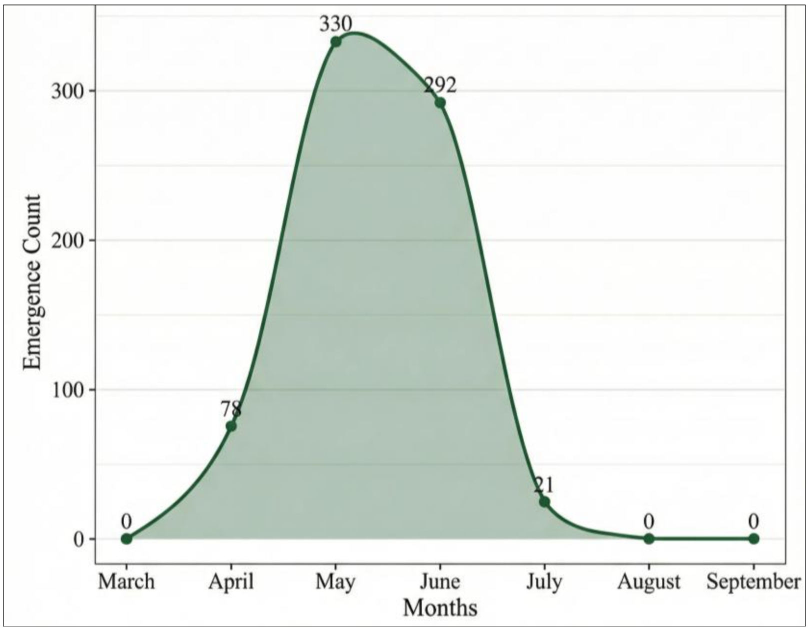

Fig 8: Seasonal Emergence of *Anomala lineatopennis* at Sundernagar from March to September

The seasonal emergence profile of *Anomala lineatopennis* monitored at Sundernagar displayed a highly condensed unimodal pattern characterized by an early seasonal peak and a precipitous post-monsoon decline. While the population remained dormant in March (0 beetles), a substantial onset of emergence was recorded in April with 78 beetles. The population density escalated rapidly to reach its zenith in May with a maximum count of 330 beetles, followed closely by a high abundance in June (292 beetles), indicating a concentrated period of adult activity likely favored by optimal early-season thermal and moisture regimes. However, the population witnessed a drastic reduction in July, falling sharply to just 21 beetles. By August, adult activity had completely ceased (0 beetles) and remained absent through September, suggesting a swift completion of the reproductive phase and natural mortality earlier in the season compared to other surveyed location

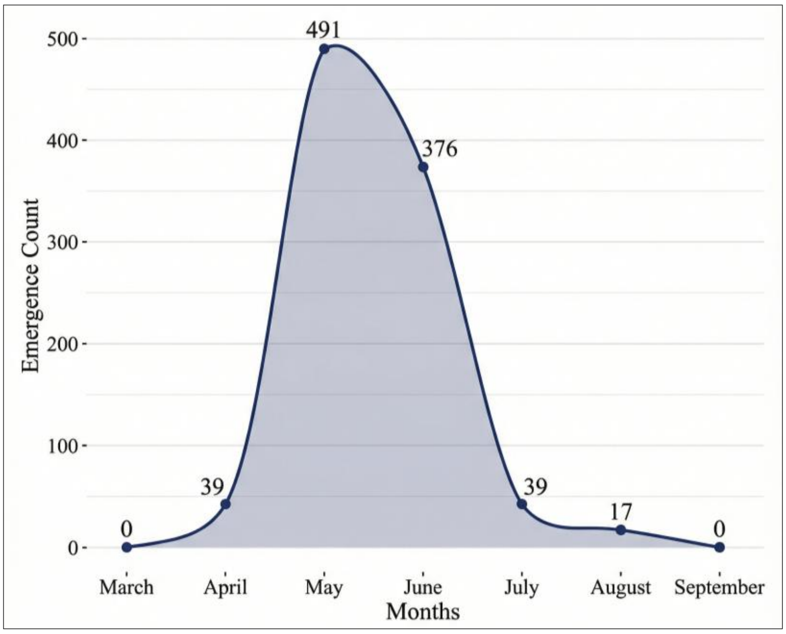

Fig 9: Seasonal Emergence of *Anomala lineatopennis* at Seobag from March to September

The seasonal emergence dynamics of *Anomala lineatopennis* recorded at Seobag exhibited a highly pronounced unimodal distribution characterized by an explosive early-season surge and a sharp post-peak decline. While the population remained dormant throughout March (0 beetles), the onset of adult activity was recorded in April with the emergence of 39 beetles. The population density escalated dramatically to reach a pronounced zenith in May with a maximum count of 491 beetles, followed by a sustained high abundance in June (376 beetles), a period of intense activity likely driven by optimal thermal accumulation and favorable soil moisture conditions. However, the population witnessed a precipitous reduction in July, plummeting to 39 beetles, and further tapered to 17 beetles in August. By September, adult activity had completely ceased (0 beetles), indicating a synchronized conclusion of the biological cycle and natural senescence following the reproductive phase.

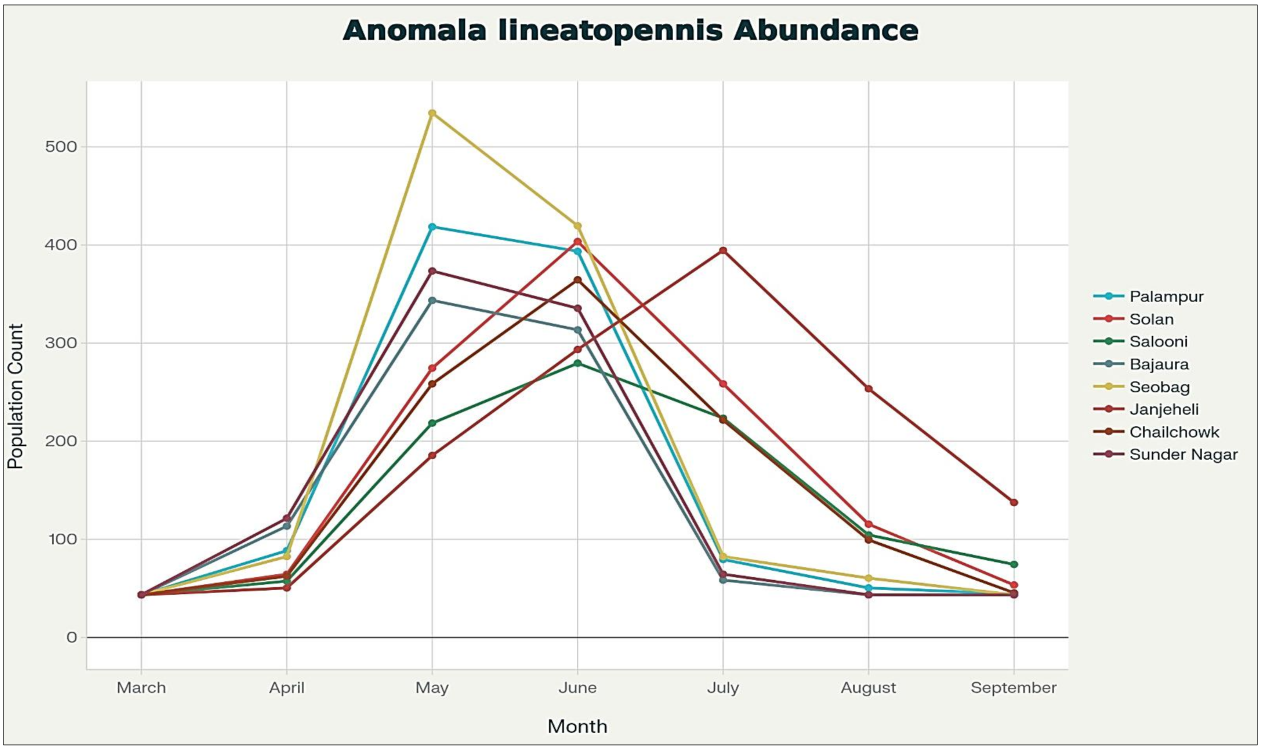

Fig 10: Comapritive Seasonal abundance of *Anomala lineatopennis* across locations

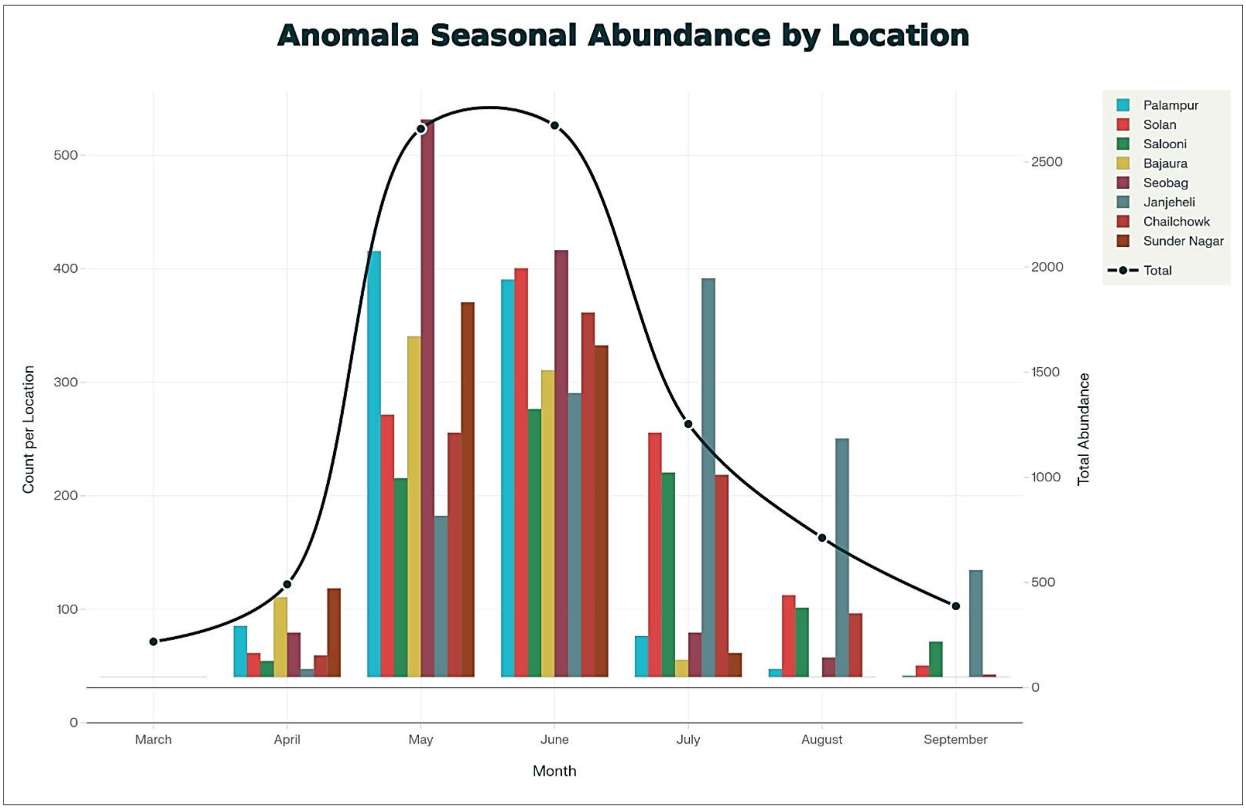

Fig 11: Comapritive Seasonal abundance of *Anomala lineatopennis* across locations

Comparative Seasonal Abundance of *Anomala lineatopennis* Across Locations

The cumulative seasonal dynamics of *Anomala lineatopennis* across the distinct agro-ecological zones revealed a robust, unimodal population trend characterized by significant spatial heterogeneity in emergence timing. Adult activity initiated at low levels during March and April, signaling the onset of the active season across the region. The aggregate population density surged dramatically to reach a zenith in May and June, driven largely by explosive emergence events in Seobag, Palampur, and Sunder Nagar. The total abundance curve indicates that these two months represent the optimal temporal window for adult beetle activity, likely synchronized with regional pre-monsoon showers and rising temperatures.

A distinct phenological divergence was observed in Janjeheli, which exhibited a delayed activity pattern compared to the other locations. While populations in lower/mid-hill areas (such as Bajaura, Seobag, and Chailchowk) peaked early in May and underwent a precipitous decline by July, the Janjeheli population continued to rise, reaching its maximum abundance in July. This delay extended the overall presence of the species in the region. Consequently, while most locations showed near-total senescence by August and September, the persistence of populations in Janjeheli and Salooni maintained noticeable abundance levels late into the season.

Discussion

In this study, we elucidate clear patterns in the seasonal emergence and abundance of *Anomala lineatopennis* across varying elevations in Himachal Pradesh. Our findings indicate that beetles emerged substantially earlier at lower elevations compared to mid and high elevations, with significant peak populations recorded at Seobag. This peak aligns closely with the presence and phenology of fruit orchards, which serve as vital host plants for this species.

Emergence Timing across Elevations

The month-to-month analysis reveals significant differences in emergence timing between the sites. Emergence dates confirmed this elevation-based trend; for instance, *A. lineatopennis* commenced emergence in April at lower altitudes, showing a mean emergence of 39 beetles at Seobag compared to 21 in Solan, and 0 in March for all sites. Beetle counts at lower elevations surged to 491 in May, tapering off to 39 by July. In contrast, higher elevations such as Janjeheli only peaked in July (351 beetles) after an initial emergence delay.

This temporal disparity underscores the impacts of temperature and other climatic variables on beetle life cycles. Previous studies, including those by Mehta et al. (2010) [16] and Chandel et al. (2021) [7], confirm that such patterns of delayed emergence in higher terrains are consistent with broader ecological trends observed in temperate insect populations. The climatic conditions governing these patterns are linked to temperature gradients, with analyses indicating a strong relationship between elevation, temperature, and humidity. Persistent high humidity and soil moisture during late April and early May facilitate synchronized adult emergence, essential for maximizing reproductive success.

Seobag Peak Population and Host Plant Dynamics

The remarkable peak population in Seobag can be significantly attributed to the lush presence of apple orchards in the vicinity. These orchards serve not only as feeding grounds but also correlate with the phenological phases necessary for successful mating and development. As other authors have suggested, the phenology of *A. lineatopennis* closely follows that of its host plants. The data indicate that beetle populations follow orchards' flowering and fruiting cycles, a relationship that enhances the availability of resources during crucial life stages.

Management strategies in Seobag, especially concerning apple orchards, are particularly relevant. Orchards commonly exhibit different management practices which can directly affect beetle populations. For instance, pesticide applications near fruiting periods must be carefully timed to mitigate risks to beetle populations while maintaining target pests.

Ecological Mechanisms and Alternative Explanations

Exploring the ecological mechanisms, factors like synchronized emergence and microclimate variations within orchard environments cannot be overlooked. Temperature-driven development, as elucidated by several studies (e.g., Ali, 2001; Gupta et al., 1977) [1, 11], reveals that *A. lineatopennis* larvae require specific thermal cues before emerging. Additionally, passive dispersal facilitated by wind patterns during their active periods also warrants consideration.

Potential alternative explanations include sampling bias due to unequal trap efficiencies across elevations and potential impacts of orchard pesticide use, raising doubts about the completeness of our data. Year-to-year climatic variation could also influence population dynamics, particularly with changes in precipitation or temperature that disrupt established emergence patterns.

Summary and Conclusion

The study regarding the seasonal abundance of *Anomala lineatopennis* in the mid and high hills of Himachal Pradesh underscores significant variations in beetle populations dictated by elevation and climatic conditions. Findings reveal a general surge in adult activity during May and June, a period where increased soil moisture and warmer temperatures facilitate emergence from pupae. However, altitude plays a specific role, as lower sites like Seobag and Bajaura see early peaks, whereas higher areas like Janjeheli experience delayed activity until July. This data highlights a strong synchronization between the beetle's life cycle and the growth stages of fruit orchards, which serve as their primary host plants. Understanding these temporal and spatial dynamics is crucial for growers to time their pest management interventions effectively. By aligning control strategies with these specific peak periods, agricultural productivity in the region can be significantly enhanced and better protected against infestation.

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