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Seasonal Abundance of *Anomala Varicolor* from Himachal Pradesh

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Abstract
The study investigates the seasonal abundance of Anomala varicolor in Himachal Pradesh, aiming to understand its population dynamics in relation to climatic factors and agricultural practices; sampling was conducted from March to August across ten ecological sites in Palampur, Hamirpur, Sirmaur, Solan, and Chamba, utilizing light traps and hand collection techniques to gather data on beetle counts, revealing that populations exhibited a pronounced unimodal distribution peaking in May with maximum counts of 896 individuals at UNA, 803 at Hamirpur, and a general decline in activity through June and July, with significant drops of approximately 60-80% from peak values, culminating in dormancy by August, indicating critical implications for pest management strategies that emphasize aligning control measures with the ecological and climatic patterns influencing beetle populations, thereby advancing our understanding of the interplay between pest dynamics and environmental conditions within these agricultural landscapes

Keywords: *Anomala varicolor*, Himachal Pradesh, pest management, population dynamics, seasonal abundance, white grubs

Introduction
Globally, 389,487 beetle species belong to 176 families (Zhang, 2013). In these, More than 36,000 species of scarab beetles have been reported worldwide (Schoolmeesters, 2024) [1], with over 2,000 species documented from India (Harish *et al*., 2023) [2]. The North-Western Himalayan region, particularly the states of Himachal Pradesh, Uttarakhand etc. constitutes an important centre of white grub diversity, owing to its pronounced altitudinal variation, heterogeneous soil profiles, and distinct microclimatic regimes (Mishra *et al*., 2024) [3]. Nevertheless, comprehensive investigations on the species diversity, geographical distribution, and population dynamics of scarabs in this region remain scarce.

Scarab beetles perform contrasting ecological roles in both agricultural and forest ecosystems. Several species contribute beneficially to ecosystem functioning, including enhanced nutrient turnover during the larval (grub) stage (Sreedevi *et al*., 2022; Niero *et al*., 2025) [6, 5] and pollination in the adult stage (Paschapur *et al*., 2022) [4]. However, despite these positive contributions, scarab beetles are also regarded as predominant leaf-chafing insects, and their larvae constitute some of the most destructive soil-dwelling pests. Scarab beetles are collectively classified as "Pleurosticts" for their feeding on living tissues, though their feeding behaviours are markedly diverse. (Chandel *et al*., 2021) [7].

The scarabaeids are one of the most successful groups of beetles with the majority of species occur in subtropical and tropical regions (Carpaneto, 2008) [8]. Most species exhibit crepuscular or nocturnal activity patterns and are strongly attracted to artificial light sources (Sushil *et al*., 2011; Chandel *et al*., 2021) [11, 7]. They represent a distinct and highly specialized group of beetles, readily identifiable by their lamellate antennae. The larvae, commonly known as white grubs, predominantly inhabit grassland ecosystems, where they feed on the roots of various plant species (Misra & Chandel, 2003) [3].

These beetles belongs to the superfamily Scaraboidea and family Scarabaeidae. This family is prominent within the order Coleoptera and is identified by beetles with sheathed wings, preferring tropical and subtropical regions with adequate rainfall and vegetation (Kritika &

Jaimala, 2017) [11]. Scarabs belongs to different sub families such as Aphodiinae, Dynastinae, Melolonthinae, Rutelinae, and Scarabaeinae. However, beetles of the Rutelinae subfamily are destructive pests known for their glossy bodies and vivid coloring, primarily consuming floral parts (Chandra, 2000; Jackson & Klein, 2006; Chandra & Gupta, 2012; Chandra & Gupta, 2013) [12, 13, 14, 15]. Rutelinae contains about 200 genera and 4,100 species globally, with 38 genera from India (Machatschke, 1972; Hongsuwong *et al*., 2020; Ratcliffe *et al*., 2018) [16, 17, 18].

Anomala Samouelle, 1819 is one of the most diverse and dominant genera (Murthy, 2020; Pathania *et al*., 2015; Kumar *et al*., 2019) [22, 23, 24] within the subfamily Rutilinae under Anomalini tribe, with nearly 1,000 species described globally, including about 100 species in the New World and around 800 in the Old World. Several species of this genus are known agricultural pests and have become invasive beyond their native ranges. Due to its considerable size and diversity, *Anomala* has been subjected to taxonomic neglect and is increasingly considered a paraphyletic group (Jameson *et al*., 2009) [19]. Adult food availability is a major environmental factor influencing beetle behaviour and plays a key role in determining the distribution of both adults and larvae (Veeresh, 1978) [20]. The abundance and distribution of white grubs are regulated by the species present, their preferred host plants, and the location of these hosts relative to the emergence site (Veeresh, 1988) [21]. The knowledge of Scarabaeidae from the North-Western Himalayan biogeographic zone of India is largely derived from the work of several researchers (Arrow, 1910; Arrow, 1917; Arrow, 1931; Mikšič, 1976; Mikšič, 1977; Mikšič, 1982; Mikšič, 1987; Biswas & Chatterjee, 1985; Endrödi, 1985; Young, 1989; Sabatinelli, 1993; Biswas & Ghosh, Chatterjee & Biswas, Chatterjee & Biswas, Chatterjee, Chatterjee, Zidek & Pokorny, Mittal & Jain, Ahrens & Fabrizi, 2016; Bhattacharyya *et al*., Mozhui & Ao, Sreedevi *et al*., 2022) [25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 6] leads to understand white grubs constitute an important pest complex, causing damage to potato, vegetables, ginger, fruit and forest trees, their nurseries, maize, and rice. As a result, considerable emphasis has been placed on managing white grub infestations in this region.

Materials and Methods

Study Area Description

The study, Palampur, Hamirpur, Sirmaur, Solan, and Chamba. These regions span an elevational gradient ranging from approximately 400 to 2200 meters above sea level, presenting diverse climatic conditions characterized by a temperate climate with distinct seasonal variations. Sampling was primarily executed within agricultural ecosystems dominated by host plants such as maize (*Zea mays*) and wheat (*Triticum aestivum*), along with associated vegetation.

Sampling Design

To estimate the seasonal abundance of *Anomala varicolor*, sampling was performed using a combination of light traps and hand collection techniques.

1. **Frequency and Duration:** The survey was conducted on a fortnightly basis from March to August of the study year.
2. **Site Selection:** A total of 10 sampling sites were selected to represent different ecological zones across the surveyed districts.
3. **Layout:** Each sampling site was established following a randomized block design to minimize bias and ensure representative data collection across the variable topography.

Identification of Specimens

Collected specimens were transported to the laboratory for processing. Identification of *Anomala varicolor* was confirmed using the illustrated key by Ahrens (2007) [36], which provides essential taxonomic information for the identification of phytophagous scarabs of Nepal. Identifications were further validated by expert taxonomists where necessary to ensure accuracy. For long-term storage and morphological study, specimens were preserved in 70% ethanol or pinned according to standard entomological curation methods.

Data Recording

Beetle abundance and count data were systematically recorded for each sampling site during every survey interval. Concurrently, meteorological data specifically temperature, relative humidity (RH), and rainfall were recorded to evaluate the influence of abiotic factors on population dynamics

Results

The data in table 1, revealed distinct temporal and spatial patterns in the measured values across nine locations from March to September. All locations showed zero values in March, indicating the complete absence of activity during this initial period. The onset of activity was observed in April, with values ranging from 7 in Janjeheli to 97 in UNA, establishing the beginning of the active period.

May represented the peak activity period across all locations, with the highest values recorded throughout the entire study period. UNA exhibited the maximum value of 896, followed closely by Hamirpur at 803 and Sirmour at 801. Palampur recorded 750, while Bajaura showed 742, indicating relatively high activity levels in these locations. Solan demonstrated moderate activity at 623, whereas Seobag recorded 423 and Chamba showed 140. Janjeheli displayed the lowest peak value of 51, representing less than 6% of the maximum observed value.

June showed a substantial decline from May levels across all locations, with values decreasing by approximately 60-80% in most cases. UNA maintained the highest value at 345, followed by Sirmour at 320 and Hamirpur at 301. Bajaura recorded 284, while Palampur showed 279. The remaining locations demonstrated considerably lower values, with Seobag at 210, Solan at 170, Chamba at 70, and Janjeheli at 26.

July exhibited further reductions in activity, with values dropping to single or double digits in most locations. UNA recorded the highest July value at 60, while Seobag showed 64. The remaining locations displayed values between 1 and 56, with Solan recording the minimum value of 1. August demonstrated minimal activity across most locations, with only UNA, Hamirpur, and Sirmour showing residual values of 3, 2, and 1 respectively, while all other locations returned to zero.

September marked the complete cessation of activity across all locations, with zero values recorded universally, mirroring the initial March conditions. The overall pattern indicated a concentrated activity period spanning April through July, with May representing the absolute peak and a progressive decline thereafter until complete termination by September.

Table 1: Monthly Abundance of Anomala varicolor Across Nine Study Locations (March-September)

	March	April	May	June	July	August	September
Palampur	0	67	750	279	47	0	0
UNA	4	97	896	345	60	3	0
Hamirpur	0	73	803	301	56	2	0
Sirmour	2	75	801	320	51	1	0
Solan	0	50	623	170	1	0	0
Chamba	0	14	140	70	12	0	0
Bajaura	0	75	742	284	43	0	0
Seobag	0	24	423	210	64	0	0
Janjeheli	0	07	51	26	14	00	0

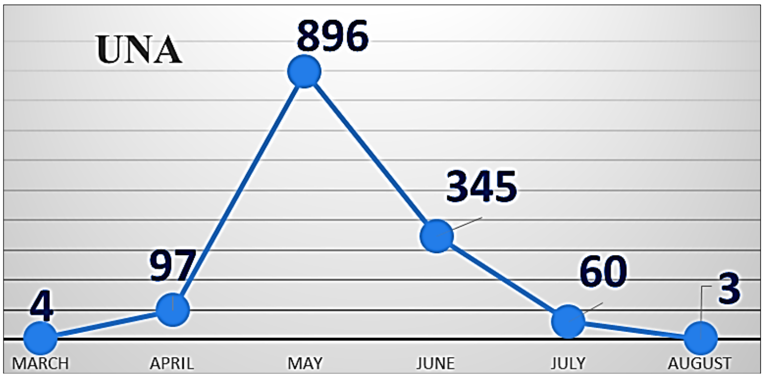

Fig 1: Seasonal Incidence of Anomala varicolor from UNA

The temporal analysis of the UNA dataset spanning from March to August reveals a distinct, non-linear distribution characterized by a pronounced bell-shaped curve with extreme variance. Initial observations in March established a minimal baseline value of 4, which was followed by a moderate increase to 97 in April, signaling the onset of a rapid upward trajectory.

The trend culminated in a significant statistical peak in May, reaching a maximum value of 896, which represents the zenith of the observed period and indicates a concentrated surge in activity. Following this inflection point, the data exhibited a sharp deceleration, contracting to 345 in June and further diminishing to 60 in July. The observation period concluded in August with a value of 3, marking a complete return to the negligible levels recorded at the commencement of the study.

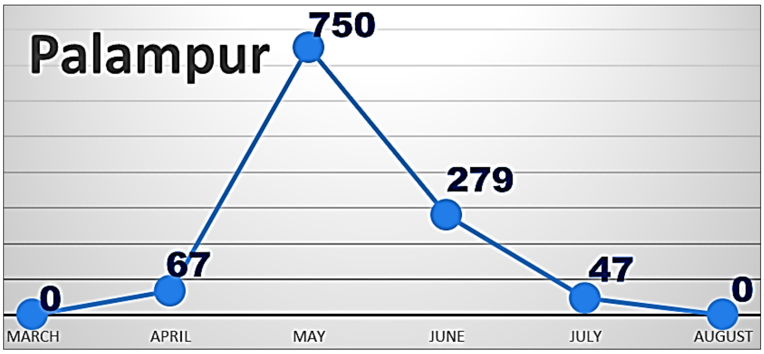

Fig 2: Seasonal incidence of Anomala varicolor from Palampur

Palampur Dataset Trend Analysis

The longitudinal analysis of the Palampur region indicates a volatile trend characterized by a sharp central peak bordered by periods of inactivity. Commencing with a null value in March, the dataset recorded a slight initial increase to 67 in April, preceding a precipitous rise to the maximum observed frequency of 750 in May. Following this apex, the metrics demonstrated a rapid decline, falling to 279 in June and 47 in July, before ultimately returning to the baseline value of 0 in August, suggesting a highly seasonal or event-driven phenomenon confined strictly to the mid-period months.

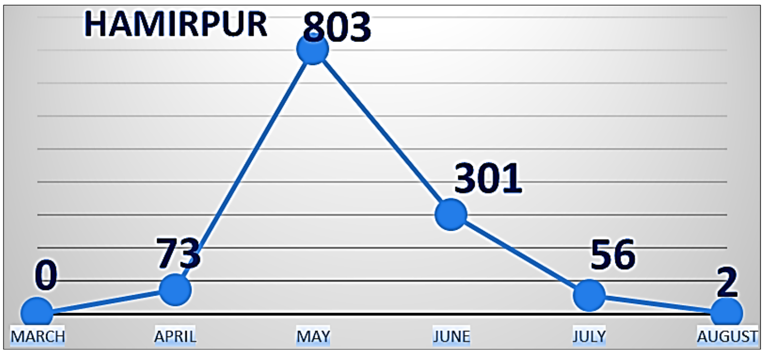

Fig 3: Seasonal incidence of *Anomala varicolor* from Hamirpur

The temporal analysis of *Anomala varicolor* adult emergence in Hamirpur reveals a distinct unimodal flight pattern over the observed six-month period. Following a period of dormancy in March where no activity was recorded, the onset of adult emergence was initiated in April with 73 individuals. This was immediately followed by a rapid, synchronous population surge, reaching a significant peak density of 803 individuals in May. Post-peak, the population exhibited a sharp decline, tapering to 301 individuals in June and 56 in July, before reaching near-cessation of flight activity by August, where only 2 individuals were recorded.

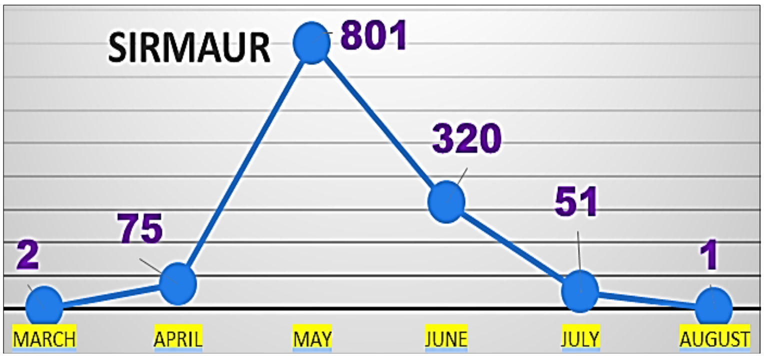

Fig 4: Seasonal incidence of *Anomala varicolor* from Sirmaur

"In the Sirmaur region, the seasonal phenology of *Anomala varicolor* exhibited a sharply defined unimodal distribution, commencing with negligible activity in March (2 individuals) before escalating to 75 individuals by April. This demographic trajectory culminated in a pronounced population maximum of 801 individuals during May, indicative of peak emergence synchrony within the region. Subsequently, the population abundance underwent a substantial stepwise decline, subsiding to 320 individuals in June and 51 in July, ultimately resolving to a solitary recording (1 individual) by August, signaling the termination of the active flight period."

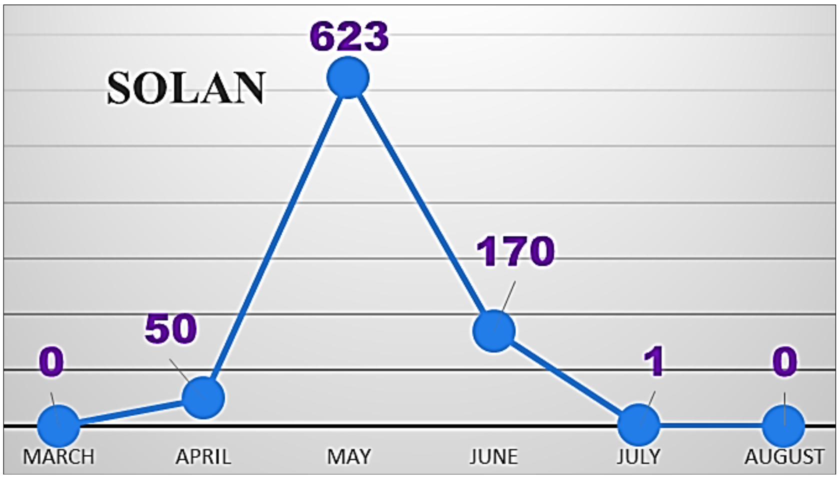

Fig 5: Seasonal incidence of *Anomala varicolor* from Solan

"In the Solan region, *Anomala varicolor* displayed a concise period of adult activity, characterized by an absence of emergence in March and an initial recording of 50 individuals in April, which rapidly escalated to a singular, dominant peak of 623 individuals in May. This surge was immediately succeeded by a precipitous decline to 170 individuals in June, with the population effectively collapsing to negligible levels (1 individual) in July and returning to zero by August."

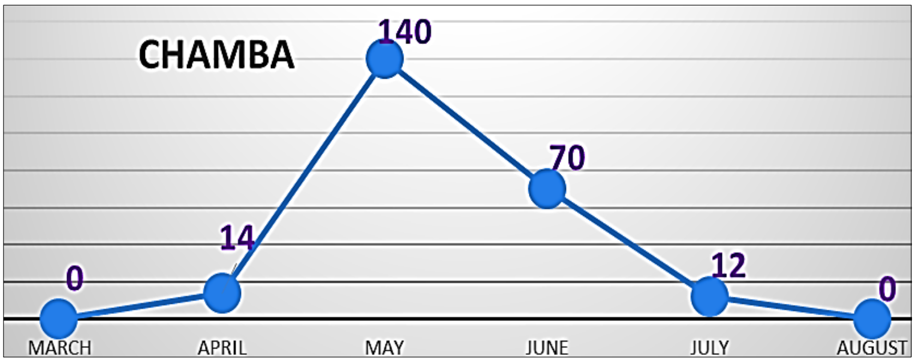

Fig 6: Seasonal incidence of *Anomala varicolor* from chamba

"In the Chamba region, the temporal profile of *Anomala varicolor* emergence was characterized by a comparatively subdued population density. Following a dormant phase in March, adult activity initiated with a modest emergence of 14 individuals in April, rising to a maximum abundance of 140 individuals in May. This peak was succeeded by a progressive decline, with populations halving to 70 in June and further diminishing to 12 in July, before reaching complete cessation of flight activity by August.

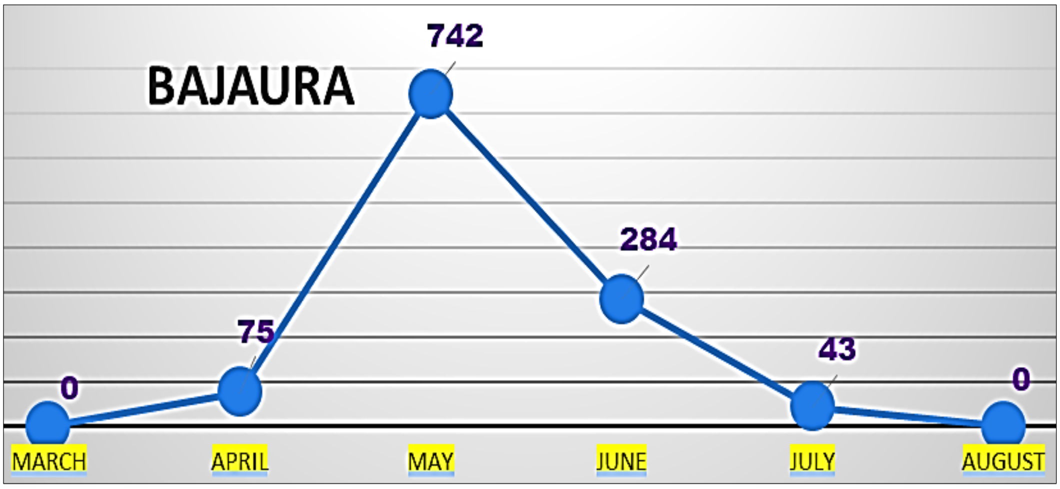

Fig 7: Seasonal incidence of *Anomala varicolor* from Bajaura

"In the Bajaura region, the seasonal phenology of *Anomala varicolor* followed a clearly defined unimodal trajectory, initiating from a baseline of zero in March to 75 individuals in April, before undergoing a rapid proliferation to reach a zenith of 742 individuals in May. This peak abundance was succeeded by a steady population recession, with recorded numbers falling to 284 in June and 43 in July, ultimately returning to complete dormancy by August."

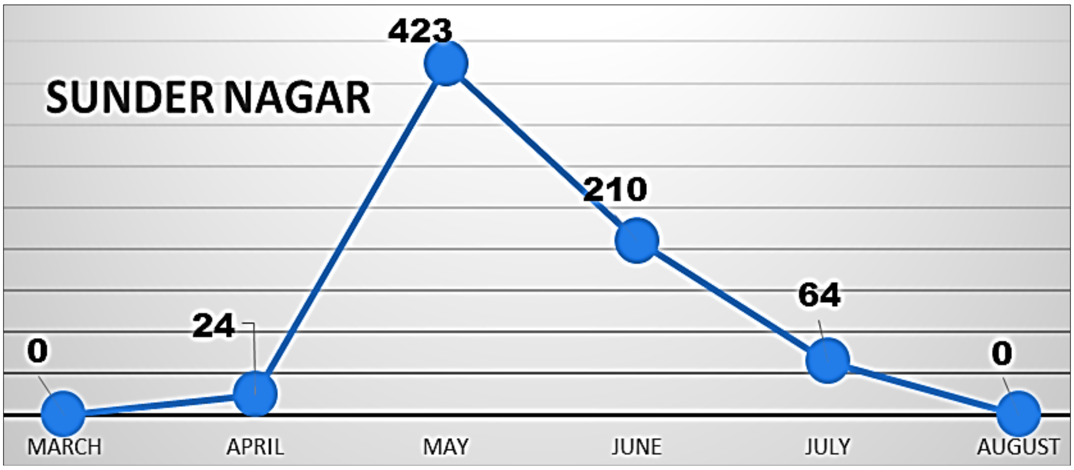

Fig 8: Seasonal incidence of *Anomala varicolor* from Sunder Nagar

In the Sunder Nagar region, the temporal dynamics of *Anomala varicolor* emergence adhered to a clear unimodal distribution. Following a period of complete dormancy in March, adult flight activity commenced at a low intensity in April with 24 individuals recorded. This initial phase was succeeded by a sharp escalation in population density, reaching a peak of 423 individuals in May. Post-peak, the population exhibited a progressive decline, tapering to 210 individuals in June and 64 in July, before flight activity completely ceased by August

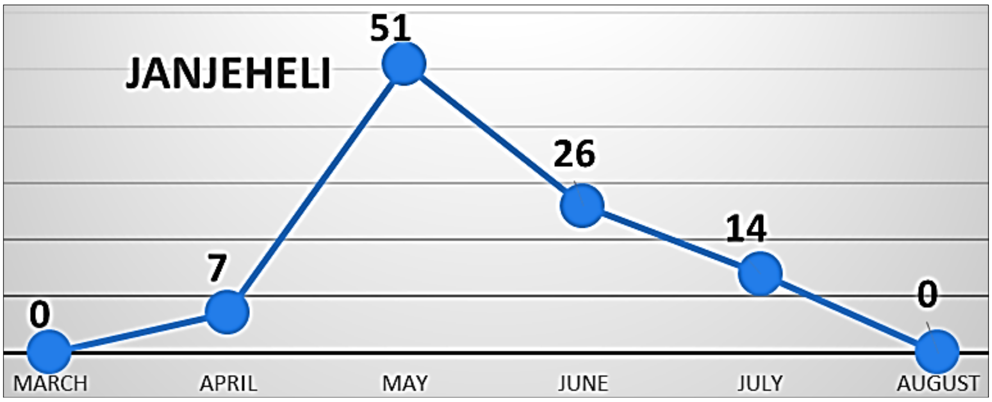

Fig 9: Seasonal incidence of *Anomala varicolor* from Janjeheli

In the Janjeheli region, the emergence profile of *Anomala varicolor* was notably suppressed, characterized by the lowest population density among all surveyed districts. Following a dormant phase in March, adult activity initiated with a negligible onset of 7 individuals in April. The population climax occurred in May but was restricted to a modest peak of only 51 individuals. This low-intensity wave subsided gradually, recording 26 individuals in June and 14 in July, before concluding with a total cessation of flight activity by August.

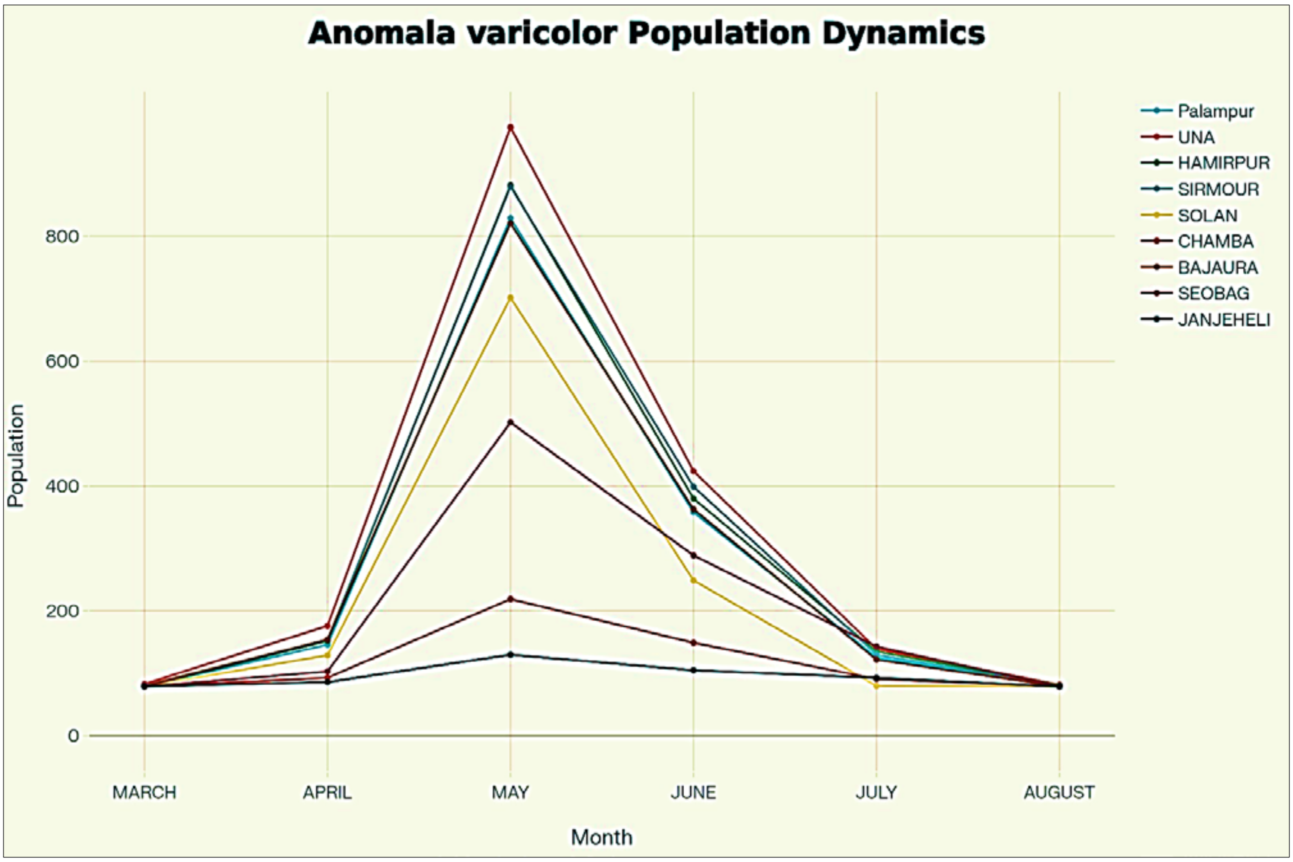

Fig 9: Anomala varicolor Seasonal Abundance from Himachal Pradesh

Discussion

The seasonal abundance of *Anomala varicolor* in Himachal Pradesh aligns closely with established ecological principles governing the population dynamics of scarab beetles, with support for the observed phenological patterns provided by studies indicating that climatic factors such as temperature, rainfall, and humidity play pivotal roles in the emergence and activity levels of these beetles. Specifically, consistent with the findings of GC *et al*. (2009), both *Anomala varicolor* and its congeners displayed pronounced activity spikes aligned with warmer temperatures and increased soil moisture, particularly during the peak flowering season of host plants. The notable unimodal flight pattern witnessed, culminating during May, demonstrates the synchronization of adult emergence with favorable environmental conditions that promote plant growth, thereby enhancing food availability for the beetles as adults; this synchrony is further corroborated by research conducted by Pathania *et al*. (2015), which illustrated that the abundance of scarabaeids in particular agro-ecosystems is significantly influenced by the availability of both host plants and suitable climatic conditions, ultimately determining their life cycle stages. In line with the results detailed in the study of white grubs by Sreedevi *et al*. (2017), it is plausible that the cycling of precipitation and humidity during late spring serves not only to hydrate the soil but also to stimulate the growth of their primary food sources, such as maize and various legumes, thereby supporting higher population densities during critical emergence periods. Furthermore, the decline observed post-peak is reminiscent of the findings of Murugan *et al*. (2011), whereby high temperature and lower humidity levels in the following months lead to decreased activity and eventual dormancy as environmental conditions become less favorable for foraging and reproduction. This has important implications for Integrated Pest Management (IPM) strategies, as it emphasizes the necessity for synchronizing pest monitoring and control measures with the ecological cycles of these beetles; thus, the capacity to predict and manage populations of *Anomala varicolor* based on seasonal climatic conditions and life cycle dynamics offers significant advantages for pest forecasting. Future IPM efforts can benefit from understanding local variants of climatic patterns and utilizing this knowledge to time interventions precisely when beetle activity peaks, thereby minimizing crop damage while maximizing the efficacy of pest management strategies, reinforcing the importance of considering ecological variables when planning agricultural practices in the region.

Summary

The research focused on the seasonal abundance of *Anomala varicolor* in Himachal Pradesh, aiming to elucidate its population dynamics and ecological implications within agricultural ecosystems. The study was conducted from March to August across nine sampling sites representing diverse climatic zones, utilizing a combination of light traps and hand collection methods to gather data on beetle abundance. The findings revealed a pronounced unimodal distribution of *A. varicolor*, with the peak populations occurring in May, where evaluations indicated a maximum of 896 individuals in the UNA site, reflecting a strong correlation with favorable climatic conditions such as increased temperatures and soil moisture during the host plants' flowering season. Subsequent months demonstrated significant declines in activity, with a near-total cessation by August. The research elucidates the critical influence of climatic variables on the life cycles and behaviors of scarab beetles, highlighting the importance of understanding these dynamics for effective pest management strategies.

Conclusion

The study concludes that the population dynamics of *Anomala varicolor* are profoundly influenced by seasonal climatic conditions, emphasizing the need for integrated pest management strategies that align with these ecological cycles. By recognizing the life cycle phases of *A. varicolor* and integrating meteorological data into pest forecasting, agricultural practices can be optimized to minimize crop damage and enhance management measures. Future research is recommended to investigate the impacts of climate change on the phenology of *A. varicolor* and to explore the interactions among beetles, host plants, and environmental factors to develop more effective pest management frameworks in the North-Western Himalayan region.

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