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Protandrous behavior in the coffee white stem borer, *Xylotrechus quadripes*

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Abstract
The research aims to elucidate the *Xylotrechus quadripes* beetle's emergence patterns and their implications for effective management strategies. The examination of *X. quadripes* reveals a distinctive emergence pattern with two peaks in a single year, occurring in April–May and October–November. Contrary to historical perceptions that downplayed the significance of summer emergence, this study underscores its relevance in the pest's life cycle. Notably, winter emergence emerges as the predominant phenomenon, with a considerably higher number of beetles compared to the summer flight. The sex ratio dynamics, with males consistently appearing before females, align with broader trends in the Cerambycidae family and the genus Monochamus. Males consistently emerged prior to females. From a pool of 2000 infected stems, a total of 3524 beetles emerged in 2012, and 14374 beetles emerged in 2013, yielding an overall sex ratio of 0.46 and a distinct male bias. The observed sex ratios contribute to the understanding of insect population dynamics, with potential implications for pest management. Overall, this research enhances our comprehension of *X. quadripes* biology and behavior, laying the foundation for more targeted and effective control measures. The findings resonate beyond the Indian coffee plantations, offering valuable insights for coffee-producing regions worldwide facing similar challenges.

Keywords: Coffee, insect population dynamics, emergence patterns, sex-ratio dynamics, male bias

1. Introduction
With a global value of $10 billion, coffee (*Coffea* sp.) stands as one of the most widely traded agricultural commodities, providing sustenance for over 25 million people. In the intricate web of this labor-intensive industry, encompassing farming, harvesting, and processing, millions of individuals in rural areas are deeply involved. The two main coffee species cultivated for commercial purposes are robusta (*C. canephora*) and arabica (*C. arabica*). Despite their origin in eastern Africa, these species are presently cultivated and traded by over 60 nations, including India.

The challenges faced by coffee growers are multifaceted, ranging from diseases and pests to quality issues stemming from inadequate infrastructure, processing, and commercialization. These challenges contribute to a decrease in market pricing and/or an increase in costs. Among the myriad insect, invertebrate, and animal species found in India on coffee plants, only a small fraction holds significant economic importance.

In the case of the nation's arabica coffee crop, the menace posed by the white stem borer, *Xylotrechus quadripes* Chevrolat (Coleoptera: Cerambycidae), is particularly alarming, leading to a 2 to 20 percent reduction in economic yield (Veeresh, 1995) [20]. According to Reddy (2010) [14], the beetle exhibits two peaks in its emergence cycle: March–April and September–October. However, due to shifting climatic conditions over recent years, the emergence pattern has undergone alterations. Unfortunately, there is limited and unclear information available about the biology and behavior of this insect. A comprehensive investigation into its emergence pattern has been initiated to enhance our understanding for more effective management strategies.

2. Materials and Methods
X. quadripes infested coffee plants were specifically sourced from the coffee plantations of Mudigere and Mallenahalli in the Chikmagalur district, and transported to BCRL in Bangalore in March 2012 and 2013. These stems (totaling 2000) were meticulously arranged in upright

positions within screened cages, each measuring 10 meters in height, 10 meters in depth, and 10 meters in width. To safeguard against termite interference, termite baits were strategically placed around the net.

To prevent injuries resulting from confrontations, adult beetles emerging from the screened cages were extracted three times a day. Following sexual separation, these collected insects were individually housed in 100 ml plastic containers. A nourishing 10% honey solution was provided as sustenance. The containers were then stored in a controlled environment maintaining a mean relative humidity of 40% and a daytime temperature of 27 ± 2 °C.

3. Results

The annual percentage of beetle emergence was documented for the years 2012 and 2013. During the summer, beetle emergence reached relatively low peaks (8.14 percent and 12 percent, respectively, in 2012 and 2013), whereas in winter, from September 1 to January 1, it surged significantly (90 percent in 2012 and 88 percent in 2013). Despite the last beetles being collected in late May of 2013 and mid-June of 2012, the initiation of insect emergence occurred much earlier in 2013, starting in the final week of April. The first wintering individuals made their appearance in early September in both years, with the last ones emerging in late December of 2012 and early January of 2013 (Figure 1 and 2).

With the exception of the summer emergence in 2012, all males consistently appeared before females. A total of 3524 beetles emerged in 2012 and 14374 in 2013, from 2000 infected stems, resulting in an overall sex ratio of 0.46 and a notable male skew.

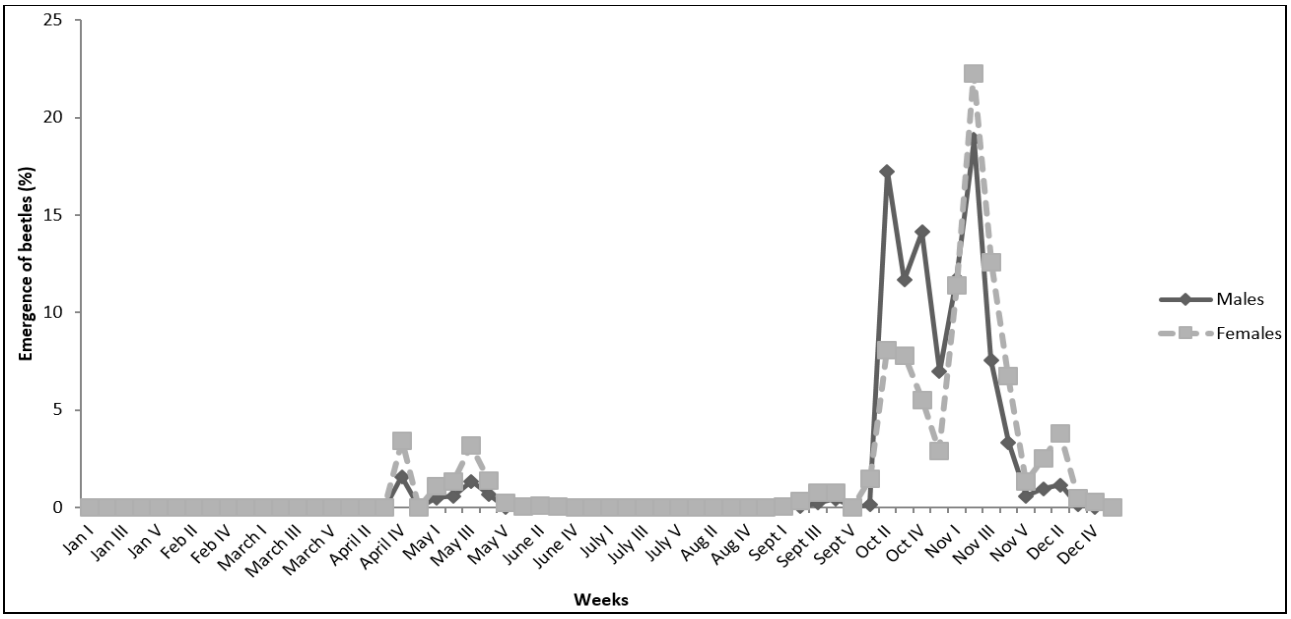

Fig 1: Emergence of CWSB beetles from January to December 2012

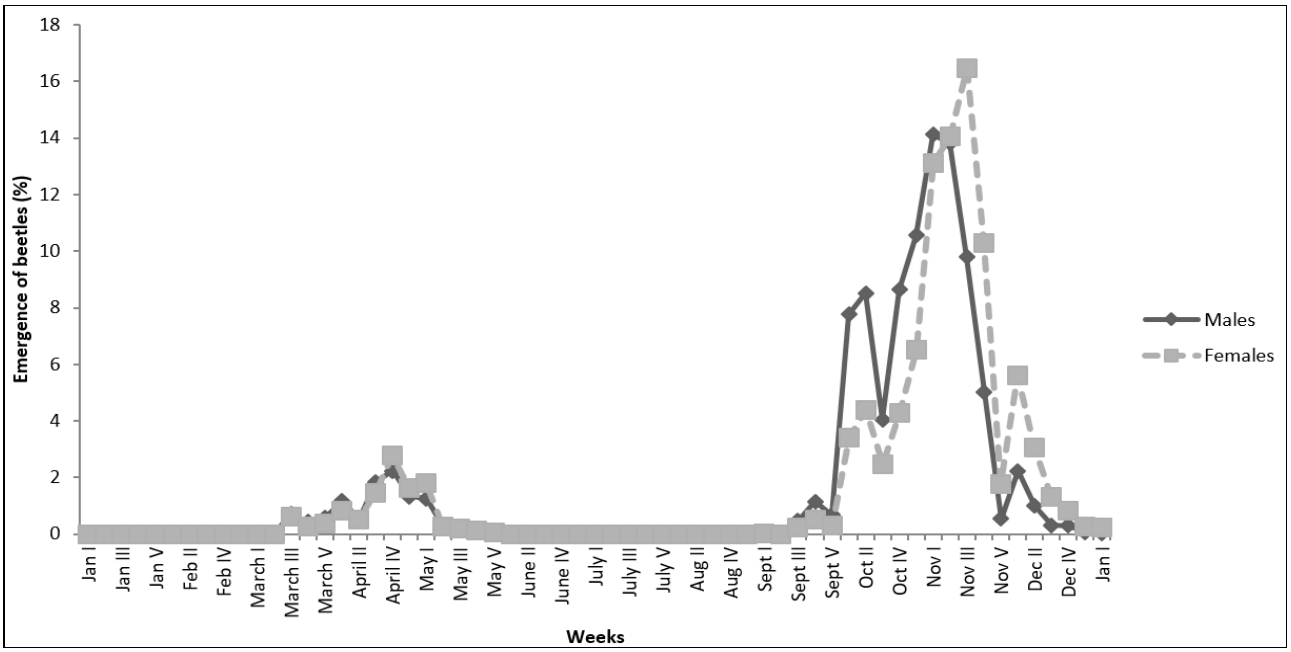

Fig 2: Emergence of CWSB beetles from January 2013 to January 2014.

4. Discussion

In the examination of the *X. quadripes*, it was observed that the species exhibits two distinct emergence peaks within a single year. The first peak occurs in April–May, while the second one takes place in October–November. Notably, the winter flight period was found to be longer than the summer flight, as indicated by the study data. Previous studies by Reddy (2010) [14] and Mayne (1943, 1945) also acknowledged the presence of two flight periods in CWSB. However, several earlier researchers tended to downplay the significance of summer emergence, deeming it of little consequence. Consequently, they did not advocate for control measures, attributing greater damage to the winter emergence (Duport, 1918; Subramaniam, 1941; Srinivasan, 1942; Pattabhiram, 1948; Ramanathan *et al*., 1951) [1, 18, 17, 12, 13].

As observed in the current study, the winter emergence proves to be the predominant one, with a considerably higher number of beetles emerging compared to the summer flight. The summer emergence, in contrast, occurs over a significantly shorter duration than its winter counterpart. In southern Siberia, the adult emergence of *Xylotrechusaltaicus*, a species that preys on Larix species, is confined to the months of July and August, transpiring only once a year (EMPPO, 2006) [2]. These adults overwinter from August to the following July, presumably due to Siberia's harsh climatic conditions.

Within the Cerambycidae family, it is a common trend for males to emerge before females (Linsley, 1959) [7]. This pattern is also evident in the genus *Monochamus*, as documented by Togashi and Magira (1981) [19], Schoeman *et al*. (1998) [15], and Shibata (1998) [16]. Males employ this strategy to locate the typically scarce oviposition sites, which they subsequently guard until the arrival of females. Subramanian (1941) [18] reported an excess of males over females, while Mayne (1940) [8] observed that females outnumbered males by a factor greater than 1.5.

Naves *et al*. (2008) [11] reported a sex ratio of 0.48 for *M. galloprovincialis*, comparable to the 0.50 found by Francardi and Pennacchio (1996) [3] for fewer insects. Korean pine trees in the Republic of Korea exhibited sex ratios ranging from 0.48 to 0.54 (Lee *et al*., 2004) [6] and 0.58 (Han *et al*., 2007) [4], while Japan's Japanese pine sawyers displayed ratios of 0.41 to 0.64 (Togashi and Magira, 1981; Kishi, 1995) [19, 5]. Visitpanich (1994) [21] suggested a sex ratio of 0.62 for CWSB, whereas Reddy (2010) [14] reported a ratio of 0.89. Similar to the Japanese pine sawyer, the coffee white stem borer in the present study exhibited a sex ratio of 0.46 upon emergence from infected coffee stems. It is postulated that environmental changes or variations in subsequent generations may influence the observed sex ratio.

5. Conclusions

The comprehensive analysis of *X. quadripes* emergence patterns over the years 2012 and 2013 provides valuable insights into the life cycle dynamics of the species. The study reveals distinct seasonal trends, with summer beetle emergence exhibiting relatively low peaks compared to the significant surge during the winter months. The findings challenge previous assumptions that downplayed the importance of summer emergence, emphasizing its relevance in understanding the species' ecology. Notably, the winter emergence emerges as the predominant phenomenon, with a substantial increase in the number of beetles compared to the summer flight. This aligns with the longer winter flight period, contrasting with the shorter duration of summer emergence. The observed male predominance, consistent across both years, corroborates broader patterns within the Cerambycidae family and the genus *Monochamus*, where males typically emerge before females. The sex ratio variations reported in this study contribute to the broader understanding of insect population dynamics, with potential implications for pest management strategies. As sex ratios are influenced by environmental factors and generational changes, further research is warranted to explore these dynamics in the context of evolving ecological conditions. Overall, this study underscores the importance of considering both summer and winter emergence in pest management strategies for *X. quadripes*.

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7. Conflict of interest: The authors declare that they have no conflict of interest.

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