Indian Journal of Agricultural Sciences **95** (7): 799–804, July 2025/Article
https://doi.org/10.56093/ijas.v95i7.156832

Seasonal occurrence of *Conopomorpha sinensis* (Gracillariidae: Lepidoptera) infesting litchi (*Litchi chinensis*) in Himachal Pradesh

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Received: 19 September 2024; Accepted: 16 May 2025

ABSTRACT

Litchi fruit borer [*Conopomorpha sinensis* (Bradley)] is one of the biggest threats to litchi (*Litchi chinensis* Sonn.) farmers causing severe loss in fruit production. The present study was carried out during 2021 and 2022 at five different locations, viz. Regional Horticulture Research and Training Station, Jachh and Litchi Mango Research Station, Nagrota Bagwan, Kangra; Regional Horticulture and Forestry Research and Training Station, Bhota, Hamirpur; Progeny-cum-Demonstration Orchard, Nihari Bilaspur and Pingla, Mandi, Himachal Pradesh to determine the pattern and degree of infestation and its relationship to abiotic factors, a survey was conducted on incidence and seasonal occurrence of litchi fruit borer on different cultivars. During the survey, the mean infestation of the litchi fruit borer ranged from a minimum of 20.25% in Bhota of Hamirpur district to maximum 53.79% in Nagrota Bagwan, Kangra district. The average fruit infestation per cent was least in the Dehradun variety (17.50%) and maximum in the McLean variety (64%). However, study on seasonal incidence on pooled mean basis showed lowest fruit infestation (8.15%) in month of March and highest (47.00%) in month of July in Dehradun cultivar of litchi. Similarly, in case of Calcuttia cultivar infestation of fruit borer ranged from 12.67–53.67% from March to July, respectively. Infestation on late maturing variety Calcuttia was found to be more than that of Dehradun variety of litchi. Fruit infestation was non-significantly correlated with maximum relative humidity and temperature and minimum relative humidity whereas, was significantly and positively correlated with minimum temperature and rainfall in both varieties which shows that abiotic factors like rainfall play a significant role in borer infestation.

Keywords: Abiotic, Fruit Borer, Infestation, Litchi, Seasonal occurrence

Litchi, (*Litchi chinensis* Sonn.) belonging to the family Sapindaceae, is a prevalent fruit found in subtropical regions. India ranks as the second biggest global producer of litchi, accounting for a significant portion of the total litchi output worldwide (NHB 2020). The National Horticulture Board (NHB) reported that litchi was cultivated in 96,000 ha in the country, with a total yield of 730,000 metric tonnes in 2020 (Mehta 2017). A recently developed litchi-producing state in India is Himachal Pradesh (6,229 metric tonnes yield from 6,354 ha) (Anonymous 2020). Notwithstanding the advancements in litchi cultivation in India, there exist certain limitations that must be surmounted. These limitations encompass severe temperatures, prolonged periods of rainfall throughout the flowering stage, and occurrences of pests and diseases. However, with diligent efforts and collaboration from the government and academic institutions, the litchi sector in India has significant potential for substantial expansion and advancement (Kumar *et al.* 2014, Kumar *et al.* 2015). Insect pests are the major biotic constraints in healthy litchi production. Nearly 42 insect and mite pests have been reported to attack litchi (Srivastava *et al.* 2015). Of these, borers, bugs, leaf rollers, loopers, weevils and mites are the important group of pests (Srivastava *et al.* 2020). The litchi fruit and shoot borer, *Conopomorpha sinensis* Bradley, is a significant pest to litchi, particularly during the fruit development stage (Srivastava *et al.* 2016). The infestation rate on the leaves and shoot was ranged between 9–70%, whilst on the fruits, it was between 25% and 60% (Srivastava *et al.* 2021). The pest exhibits notable temporal specificity, with the peak infestation observed during the months of July to November for shoot borers and March to May for fruit borers (Kumar *et al.* 2014, Srivastava *et al.* 2016). Although different strategies for managing *C. sinensis* have been followed, chemical control dominated the management options (Taher *et al.* 2021, Suman *et al.* 2024, Alam *et al.* 2019). An integrated strategy for pest

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management should be implemented to minimize the impact of this pest on litchi fruit growers using combination of culture, physical, and chemical control techniques (Siraj *et al.* 2023). Hence the present study was aimed to determine the pattern and degree of infestation and its relationship to abiotic factors, a survey was conducted on incidence and seasonal occurrence of litchi fruit borer on different cultivars

MATERIALS AND METHODS

The present study was carried out during 2021 and 2022 in major litchi growing districts of Himachal Pradesh at five different locations, viz. Regional Horticulture Research and Training Station (RHR&TS), Jachh (32.0711° N, 76.8851°E at an altitude of 428 amsl), Kangra; Litchi Mango Research Station (LMRS), Nagrota, Bagwan (32.0634° N, 76.9644° E at an altitude of 830 amsl), Kangra**;** Regional Horticulture and Forestry Research and Training Station (RHFRTS), Bhota (31.5703° N, 76.9256° E at 550 amsl altitude), Hamirpur; Progeny-cum-Demonstration Orchard (PCDO), Nihari, Bilaspur (31.3618° N, 76.7435° E; 650 amsl altitude) and PCDO, Pingla (31.7096° N, 76.9305° E with 911 altitude amsl) Mandi. at fruit harvesting stage i.e. (Last week of June to mid-week of July).

Ripening fruits (40–50 in number) from two varieties i.e. Dehradun and Calcuttia were collected from 10 randomly selected tree from each litchi orchard for observation of litchi fruit borer. The harvested fruits were examined for the presence of the borer larvae by peeling off the fruit skin at the pedicel end. Those containing larva/faecal matter just below the crown were considered as infested and the data so obtained were converted into per cent infestation. The observations recorded were pooled for mean borer infestation which was collected with help of following formula:

$$\text{Per cent infestation} = \frac{\text{Number of infested fruits in treatment}}{\text{Total no. of fruits taken per treatment}} \times 100$$

Field experiments on seasonal incidence were conducted during the fruiting season from fruit initiation to harvest stage (March–July) of litchi during 2021 and 2022 at two locations i.e. Regional Horticulture Research and Training Station, Jachh and Litchi Mango Research Station, Nagrota Bagwan. The trial was conducted on two main commercial cultivar of litchi at each location, viz. Dehradun and Calcuttia. Observations were recorded on monthly basis from March to July each year on randomly selected 20 trees of litchi in term of per cent infestation. Randomly 50 fruits from each tree were observed and analyzed for the larva infestation. Observations so recorded were pooled for mean monthly fruit infestation. The incidence of litchi fruit borer i.e. per cent fruit infestation were also correlated with the meteorological parameters i.e. minimum and maximum temperature, minimum and maximum relative humidity and rainfall collected from Krishi Vigyan Kendra, Kangra.

RESULTS AND DISCUSSION

Current study revealed that major species of borer, viz. *C. sinensis* , was found to infest litchi at all the locations. Data on the survey studies on the fruit infestation by the litchi fruit borer (*C. sinensis*) in five districts of Himachal Pradesh during the fruit harvesting season is presented in the Table 1. The mean infestation of the litchi fruit borer (*C. sinensis*) ranged from a minimum of 20.25% in Bhota location of Hamirpur district to maximum 53.79% in Nagrota Bagwan, Kangra district. The survey conducted in Bilaspur and Mandi district showed fruit infestation of 44 and 33.60%, respectively. Among the two most predominant varieties Calcuttia and Dehradun of all the locations, cv. Calcuttia recorded highest fruit damage of 23.00–54.66% as compared to Dehradun with fruit infestation range of 17.50–47.33 %. However out of the various varieties observed McLean was the most susceptible variety with mean per cent infestation of 64% followed by Rose Scented and Large Red with mean infestation of 56% and 55%, respectively .

The results revealed that among the commercially grown varieties Calcuttia and Dehradun late maturing varieties i.e. Calcuttia McLean and Large Red were more prone to the attack of the pest. Additionally, these results are confirmed by the findings of Nair and Sahoo (2006), who indicated that the pest from West Bengal caused damage to fruit ranging from 26.0–89.0%. According to Anonymous (2016), the level of infestation in late varieties was found to increase quickly and reached up to 54.5 ± 12.4% due to rain in the last week of May. These findings are in agreement with the findings of Anonymous (2016), who stated that

Table 1 Survey on the fruit borer incidence on different varieties of litchi in different locations of four districts of Himachal Pradesh

Location	Variety	Average fruit infestation (%)	Mean infestation (%)
Regional Horticulture Research and Training Station, Jachh, Kangra	Dehradun	47.33	50.99
	Calcuttia	54.66	
Litchi Mango Research Station,Nagrota Bagwan,Kangra	Dehradun	45.33	53.79
	Calcuttia	48.66	
	McLean	64.00	
	Large Red	56.00	
	Rose Scented	55.00	
Regional Horticulture and Forestry Research and Training Station Bhota, Hamirpur	Dehradun	17.50	20.25
	Calcuttia	23.00	
Progeny-cum-Demonstration Orchard, Nihari, Bilaspur	Dehradun	35.60	44.00
	Calcuttia	52.40	
Progeny-cum-Demonstration Orchard, Pingla Mandi	Dehradun	23.40	33.60
	Calcuttia	43.80	

the infestation level attained this level. According to the findings of a study carried out by Sharma *et al.* (2007), the greatest damage caused by nut borers on the Calcuttia variety of litchi during the fruit harvest stage was 91.8% in Punjab. This finding confirms to the conclusion that we have reached. The late varieties (Calcuttia, McLean, and Large Red) were found to be more susceptible to the attack of the borer in the current studies. The fruit damage was recorded to vary between 23.0 and 64.00%, which is consistent with the earlier findings reported by Bhatia *et al.* (2000), where these values varied between 33.3 and 85.7% on these varieties. Additionally, the findings of Singh and Sharma (2010), who reported the highest fruit damage (63.5–72.0%) due to borer infestation in the late maturing variety (Calcuttia) in the Sirmour district of Himachal Pradesh, confirmed the findings of the present study. In addition, Kumar and Kumar (2007) observed that there was a 24–32% infection of litchi fruit borer prior to harvest in the state of Bihar, indicating that there is a requirement for the systematic management of fruit borer. The extent of damage by the fruit borer (*C. cramerella*, Snellen) ranged between 24–49% fruit damage while leaf infestation varies from 7.2–72.5% as per Ranjan and Singh (2003) and Ranjan and Mukherjee (2008). More recently, litchi fruit borer damage was estimated at 48–74% in West Bengal, India (Chakraborti and Samanta 2005). Similarly, fruit infestation was found between 15–69% in main litchi growing areas of Himachal Pradesh (Pandey *et al.* 2019). In a similar study, Ramakrishnaiah *et al.* (2017) reported 48.4% *C. sinensis* incidence on litchi. The infestation was found to decrease with the increase in the fruit maturity after which the pest started to infest the tender litchi trees shoots. The female deposits eggs on the calyx of the fruit, and the larval stage penetrates the fruit and feeds on it. Furthermore, the larvae inflict harm onto recently newly emerged shoots between September and October, leading to the shoots' inability to produce flowers. Moreover, it causes punctures in the fruits between April and May, leading to significant losses through fruit drop and detrimental effects on fruit quality caused by larva feeding in the fruit and frass in the funicle during consumption (Kumar *et al.* 2011, Srivastava *et al.* 2017).

Data on seasonal incidence of fruit borer collected from two locations i.e. Regional Horticulture Research and Training Station, Jachh and Litchi Mango Research Station, Nagrota Bagwan for two consecutive years 2021 and 2022 from the month March to July is presented in Table 2; Fig. 1 and 2. The data showed that fruit infestation gradually increased from March to July at both the locations in both the varieties in both the years. At Regional Horticulture Research and Training Station, Jachh, seasonal incidence was found to be minimum 8.30% in March in Dehradun variety and was found to maximum 46.67% in July for same variety in same location for year 2021. Infestation was found to be 43.33% in June which was at par with that of July. Same trend was followed in year 2022 with infestation in same variety was found to be minimum 8% in March and maximum 47.33% in July. Infestation in April (13.33%) was at par with that of May (14.00%). Reason for the low incidence during this time was probably due to the reason that the pulp of fruit during at this stage was highly acidic and not preferred by the insect

However, in case of late maturing varieties like Calcuttia infestation was found to be little more than that of Dehradun variety of litchi and it was minimum 12.67% in March and was found to maximum 53.33% in July for Calcuttia variety in same location for year 2021. Infestation in April (16.00%) which was at par with that of May (15.33%). Same trend was followed in year 2022 with infestation in same variety was found to be minimum 12.66% in March and maximum 54.00% in July. Infestation in April (13.33%) was at par with that of May (14.00%). In a similar investigation it was reported that the litchi fruit and shoot borer make punctures on the litchi fruits starting from from April till the month of May resulting in direct losses through the dropping of fruits and reduction in the quality fruit production due frass in funicle while eating (Srivastava *et al.* 2017).

Seasonal Incidence at Litchi Mango Research Station, Nagrota Bagwan seasonal incidence was found to be minimum 7.67% in March in Dehradun variety and was found to maximum 45.33% in July for same variety in same location for year 2021. Infestation in April (14.00%) was at

Table 2 Seasonal incidence of litchi fruit borer at Regional Horticulture Research and Training Station, Jachh and Litchi Mango Research Station, Nagrota Bagwan

Month	Percent infestation							
	Regional Horticulture Research and Training Station, Jachh				Litchi Mango Research Station, Nagrota Bagwan			
	Dehradun		Calcuttia		Dehradun		Calcuttia	
	2021	2022	2021	2022	2021	2022	2021	2022
March	8.30 (16.34)	8.00 (16.43)	12.67 (20.82)	12.66 (20.82)	7.67 (16.07)	10.00 (18.37)	10.67 (19.03)	13.33 (21.32)
April	11.33 (19.60)	13.33 (21.16)	16.00 (23.54)	13.33 (21.32)	14.00 (21.69)	10.66 (18.93)	15.33 (23.03)	17.33 (24.58)
May	13.33 (21.39)	14.00 (21.82)	15.33 (22.97)	14.00 (21.93)	15.33 (23.03)	16.00 (23.46)	18.00 (25.07)	14.00 (21.82)
June	43.33 (41.14)	34.00 (35.64)	46.00 (42.68)	46.66 (43.06)	33.33 (35.23)	33.33 (35.24)	40.00 (39.19)	40.67 (39.60)
July	46.67 (43.06)	47.33 (43.45)	53.33 (46.90)	54.00 (47.27)	45.33 (42.29)	45.33 (42.27)	52.67 (46.51)	48.67 (44.21)
CD	4.23	5.49	4.48	5.00	4.44	5.89	3.96	4.02

Figures in parenthesis are angular transformed values.

par with that of July (15.33%). Same trend was followed in year 2022 with infestation in same variety was found to be minimum 10.00% in March and maximum 45.33% in July. Infestation in March (10.00%) was at par with that of April (10.66 %). The results are in consistence with those of Dalui and Sarkar (2021) who reported that the fruit infestation by this borer lasted up to harvesting of fruit that was 71 days after fruit set. However, in case of late maturing varieties like Calcuttia infestation was found to be little more than that of Dehradun variety of litchi and it was minimum 10.67% in March and was found to maximum 52.67% in July for Calcuttia variety in same location for year 2021. Infestation in April (15.33%) which was at par with that of May (18.00%). Same trend was followed in year 2022 here infestation in same variety was found to be minimum 13.33% in March and maximum 48.67% in July. Infestation in April (17.33%) was at par with that of May (14.00%). Another study by Dalui and Sarkar (2021) concluded that, the infestation (3.3%) was first observed at 21days (26 March 2018), and attack by the borer gradually increased and reached its peak (42.66 %) after 60 days of fruit set (4 May 2018). After that, a considerable decrease was observed.

Further, mean fruit borer infestation was presented in Fig. 2 and Fig. 3 was found to be lowest 8.15% in month of March and Highest 47.00% in month of July in Dehradun cultivar of Litchi whereas, in case of Calcuttia cultivar lowest 12.67% infestation of fruit borer was observed in month of March and highest 53.67%. At Litchi Mango Research Station, Nagrota Bagwan, mean fruit borer infestation in case of Dehradun cultivar was found to be lowest 8.89% in March and highest 45.33% in month of July. Similar trend was observed in case of Calcuttia cultivar which showed that lowest (12.00%) infestation of fruit borer in month of March and highest 50.67% in month of July. Additional research conducted by Ramakrishnaiah *et al.* (2017) revealed that around 48.4% of the fruit that was dropped was affected by *C. sinensis*. Furthermore, the fruit infestation was found to be declined as it reached maturity. Unlike previous studies, the majority of fruit borer damage was observed during the fruit color break stage (Schulte *et al.* 2007), which aligns with the findings of the present investigation.

In the tables that were presented earlier, it was discovered that the infestation of *C. sinensis* was particularly severe during the months of June and July, which is when fruit begins to ripen, in comparison to other months of the year. From March to April, it was discovered that the percentage of infestation had increased. Both kinds had the same percentage of infestation in May as they had in April. This was seen in both varieties. Then, all of a sudden, an all-out infestation emerged. The month of July was found to have a similar increase. In accordance with our findings, Dalui and Sarkar (2021) stated that the infestation of litchi fruit borer was 3.3% after 21 days (26 March 2018), and that it continuously rose until it reached its peak (42.66%) after 60 days of fruit set (4 May 2018). The findings of our research are also supported by Pandey *et al.* (2019), who reported a fruit infestation rate ranging from 15.00–69.20%. Additionally, Suman *et al.* (2024) reported that this pest is the most prominent one in litchi, and that it remains active throughout the year, with the peak period occurring from July to November as a shoot borer and from March to May as a fruit borer.

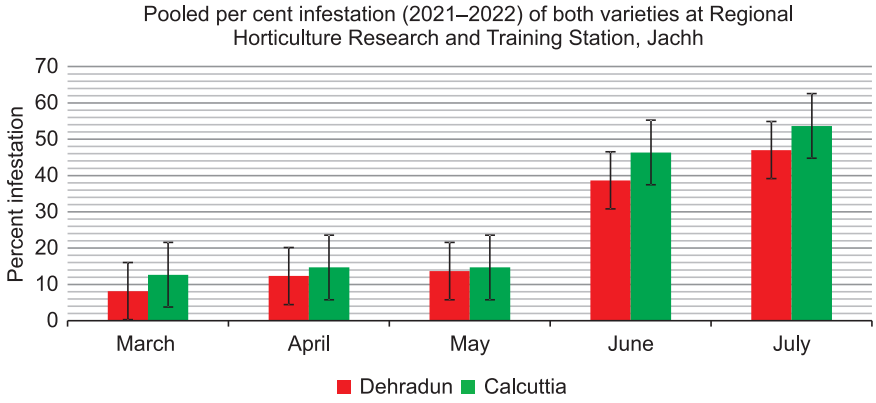

Fig. 2 The mean infestation of fruit borer in Dehradun and Calcuttia at Regional Horticulture Research and Training Station, Jachh.

Fig. 1 (A) Litchi fruit borer, *Conopomorpha sinensis* larvae feeding at pedicel end; (B) Fruits infested by borer at harvesting stage.

Correlation analysis of fruit borer infestation of both the litchi varieties Dehradun and Calcuttia at both the study locations for two consecutive years with meteorological parameters is presented in Table 3. According to the findings, there was no correlation between the fruit infestation in the case of Dehradun and Calcuttia cultivars at Regional Horticulture Research and Training Station, Jachh and Litchi Mango Research Station, Nagrota bagwan and the maximum temperature, the maximum humidity,

Table 3 Correlation coefficient of fruit infestation with meteorological parameters for Dehradun and Calcuttia varieties of litchi

Fruit infestation (%)	Location	Temperature °C		Relative humidity (%)		Rainfall (mm)
		Max.	Min.	Morning	Evening	
Regional Horticulture Research and Training Station, Jachh						
	Dehradun	0.611^{NS}	0.691^{*}	0.569^{NS}	0.473^{NS}	0.779^{**}
	Calcuttia	0.570^{NS}	0.642^{*}	0.605^{NS}	0.556^{NS}	0.766^{**}
Litchi Mango Research Station, Nagrota bagwan						
	Dehradun	0.555^{NS}	0.679^{*}	0.617^{NS}	0.526^{NS}	0.850^{**}
	Calcuttia	0.575^{NS}	0.665^{*}	0.580^{NS}	0.522^{NS}	0.811^{**}

* and **Significant at 1% and 5% level of significance.

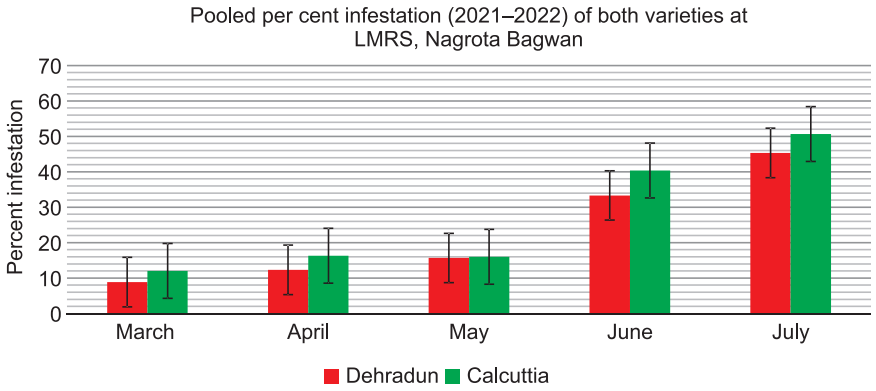

Fig. 3 Mean fruit borer infestation in Dehradun and Calcuttia at Litchi Mango Research Station, Nagrota Bagwan.

or the minimum relative humidity. The fruit infestation, on the other hand, was found to have a significant and positive correlation with the minimum temperature and rainfall. This finding was in line with the findings of a study conducted by Dalui and Sarkar (2021), which found that the activity of the pest species has a significant influence on temperature and is positively correlated with factors such as temperature and relative humidity. When it comes to fruit infection, it was discovered that relative humidity had a less impact than the average temperature. Rainfall has a minimal impact on the occurrence of these insects. On the other hand, it was a widely held belief that the incidence of fruit infection suddenly surged whenever there was a pre-monsoon rainfall in the months of May and June.

Late maturing varieties of litchi is most prone to pest attack. Calcuttia which is main variety of litchi was most affected by the borer. Weather parameters also affected the pest incidence in the orchard. It is evident from the present study that the activity of the pest species has a profound influence of temperature and is positively correlated with the factors like temperature and relative humidity. Relative humidity was found to have less impact than average temperature on fruit infestation. This study will provide valuable insights into the *C. sinensis* seasonal dynamics and its relationship with meteorological parameters. These insights open up several avenues for future research and management strategies to mitigate the impact of this destructive pest. By pursuing these future perspectives, researchers and stakeholders can work together to develop a comprehensive and sustainable approach to managing the litchi fruit borer.

This will not only help reduce economic losses for growers but also contribute to the long-term sustainability of litchi production. Further, the seasonal patterns in the population dynamics of *C. sinensis* were influenced by several ecological factors, including the presence of natural enemies, competition for resources among herbivores, and seasonal variations in environmental factors affecting both pest and natural enemy populations. Comprehending the seasonal patterns of *C. sinensis* can facilitate the formulation of focused pest management measures. By pinpointing peak infestation periods, cultivators can execute prompt interventions, such as biological control strategies or targeted pesticide applications, thereby reducing crop damage and enhancing yield quality. Given that *C. sinensis* also impacts related hosts such as longan (*Dimocarpus longan*), the findings from this study can be utilized to manage pests in analogous crops. The interdisciplinary use of knowledge can augment pest management tactics across various fruit crops, hence enhancing agricultural resilience. Moreover, since climatic conditions evolve and influence pest dynamics, comprehending seasonal patterns might aid in forecasting alterations in pest behavior and population trends. This forecasting ability is essential for adjusting management strategies to reduce potential losses from climate-related variations in pest prevalence. This study establishes a foundation for additional research on the biology and ecology of *C. sinensis*. Future research may investigate genetic resistance in litchi and related crops, create biocontrol agents, and enhance cultural practices that mitigate pest effects while preserving ecological equilibrium. The results endorse the creation of an Integrated Pest Management system specifically designed for litchi agriculture, integrating biological control, chemical management, and cultural practices informed by seasonal

incidence data. This comprehensive strategy can improve production while mitigating environmental effects. This study tackles urgent issues associated with *C. sinensis* infestations while establishing a basis for sustainable approaches that will enhance litchi production and allied horticulture crops in the future.

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