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The first data on the biology of *Ips stebbingi* Strohmeyer, 1908 (Coleoptera: Curculionidae: Scolytinae), a pest of Himalayan blue pine

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Abstract

This paper deals with the studies on the biology and development of the bark beetle *Ips stebbingi* Strohmeyer, 1908 (Coleoptera: Curculionidae: Scolytinae), a pest of Himalayan blue pine *Pinus wallichiana* A.B.Jacks. in Kashmir Himalaya. This pest is an aggressive and notorious one, but little is known of its biology. This beetle pest overwinters in adult stage under the bark of host trees *P. wallichiana*. After emergence, the adults fly to suitable trees and undergo maturation feeding for 4–6 days. Reproduction is polygamous type; two to six females join a male in his nuptial chamber. After mating, each of the females makes one gallery with an average length of 10.76 (±3.30 standard deviation [SD]) cm. The female lays 23.16 (±7.03 SD) eggs on an average. The eggs hatch in 8–18 days. The larvae have five instars and complete their development in 30–45 days constructing larval galleries of 3.83 (±0.63 SD) cm in length. The larvae pupate for 18–28 days and finally the adults emerge to attack new suitable trees. The adults live for 45–70 days, and the total lifespan of this species ranges from 101 to 156 days. The seasonal distribution of various life stages and the number of generations were also recorded.

Key words

Ips stebbingi, *Pinus wallichiana*, Scolytinae, seasonal distribution

Introduction

Bark beetles (Coleoptera: Curculionidae: Scolytinae) comprise a large subfamily of insects, although only a small percentage of more than 6000 bark beetle species found worldwide are capable of causing significant economic impacts (Wood and Bright 1992). Among the most aggressive and notorious of these insects are species of the genus *Ips* DeGeer (Postner 1974; Wood and Bright 1992; Pfeffer 1995). *Ips* is one of the better-known bark beetle genera because of several species that are destructive to conifer forests and plantations (Chararas 1962; Furniss and Carolin 1992). Epidemic *Ips* populations can destroy thousands of hectares of forest (Furniss and Carolin 1992). In addition, some aggressive species, like *Ips pini* (Say) and *Ips paraconfusus* Lanier, kill the tops of healthy pine trees, which increase their susceptibility to attack by *Dendroctonus* spp. (Furniss and Carolin 1992).

According to faunistic estimates, *Ips* genus is composed of 37 species distributed in North America, Eu-

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rope, Asia and introduced into Australia and Africa (Cognato 2015). Fourteen *Ips* species occur in the Palaearctic region (Knizek 2011), of which only eight are endemic to Asia showing remarkable variation of aggressiveness and host preference. Buhroo and Lakatos (2011) provided a detailed morphological key to three Himalayan *Ips* species and highlighted that these species can build up high population levels when there is excessive supply of breeding material and favourable environmental conditions. All three Himalayan species are phloeophagous and oligophagous (Wood and Bright 1992; Buhroo and Lakatos 2011) and like other conspecifics, they have evolved adaptations to exploit Pinaceae despite formidable defences that these tree species can mount (Franceschi et al. 2005).

The bark beetle, *Ips stebbingi* Strohmeyer, 1908, is distributed in the transition zone between the Palaearctic and the Oriental areas of Asia – Bhutan, China (Xinjiang), Uttar Pradesh, Himachal Pradesh, Kashmir, Pakistan and Afghanistan (Cognato 2015). Despite its aggressive habit of utilising Pinaceae host trees (Stebbing 1914; Wood and Bright 1992; Buhroo and Lakatos 2011), a little is known on the biology of *I. stebbingi*, which is a significant obstacle to success in terms of the development and application of pest management programme in the field conditions (Khanday et al. 2018).

Based on the field and laboratory observations, this study presents the first detailed data on the mating behaviour, maturation feeding, gallery patterns, life cycle and seasonal distribution of *I. stebbingi* on Himalayan blue pine (*Pinus wallichiana*) in Kashmir.

Material and methods

Field studies

The biological data were obtained mainly in Nowpora village (33°61.078'N, 075°18.700'E and elevation, 5920 ft.) in district Anantnag, Jammu and Kashmir. Based on the preliminary surveys, severe bark beetle infestations were observed in the study area, inhabited by almost 30–40-year-old blue pine trees. The sampling procedure for monitoring the *I. stebbingi* activity was adopted as per the methods of Buhroo and Lakatos (2007). By using trap logs and other infested branches of standing trees (Beaver 1967; Buhroo and Lakatos 2007; Khanday and Buhroo 2015), observations of the various life stages were made once or twice weekly throughout the experimental period. These trap logs were cut periodically from April to October each year from 2017 to 2018. Further information was obtained by careful removal of bark sections both in the field and in the laboratory. The eggs found in maternal galleries were exposed carefully and counted in their individual chambers. For measurement of galleries (both maternal and larval), a digital caliper scale was used (Khanday and Buhroo 2015). The correlation between the length of maternal galleries and the number of eggs deposited by beetle pests was worked out using the method of Zhang et al. (1992).

At the experimental site, the entrance holes that the newly emerged beetles started grooving were marked on one main branch and some twigs of a declining pine tree during May–June. After the marking dates, 15 beetle entries were dissected each day and examined for eggs to determine female maturation feeding period as per the method of Buhroo and Lakatos (2007).

Laboratory rearing

Laboratory rearing of *I. stebbingi* was accomplished by placing infested logs (30–50 cm long and 5–10 cm in diameter) in three rearing boxes of similar design made up of glass with dimensions of 75 × 35 × 40 cm, 45 × 35 × 35 cm and 55 × 35 × 35 cm. The top face of each box was fitted with white muslin cloth. Each box could be opened from the top to facilitate exchange of logs. After every month, cut branches (20–40 cm long and 2–8 cm in diameter) from the host tree (*P. wallichiana*) were placed in the rearing boxes to induce fresh attack, 5–10 days before the emergence of adults in every generation. This enabled continuous rearing and examination of beetle development. A few infested logs were also debarked at regular intervals (10 days) to study various stages of the beetle under bark. Measurements of various developmental stages including egg, larva, pupa and adult were recorded. The development process and duration of beetle life stages were recorded and compared with the field results as per our earlier methods (Buhroo and Lakatos 2007; Khanday and Buhroo 2015).

Photography

Photographs were taken during the field study using Canon PowerShot SX60 camera fitted with macro lens (Raynox MSN-505, 37 mm; Yoshida Industry Co., Ltd, Tokyo, Japan). Analysis of digital images was done using

ImageJ analysis software (Version 1.38f, 2006). For morphometric description of beetle life stages, images were taken with a Leica DFC295 camera (Leica Microsystems GmbH, Wetzlar, Germany) attached to a Leica M205A stereozoom binocular microscope having Leica Automontage Software (version 4.10). Spatial information regarding sample site was recorded in the form of latitude and longitude with the help of handheld global positioning system (GPS; Garmin eTrex 10, India).

Statistical analyses

Statistical analyses were performed using OriginPro software (version 2015). The gallery pattern and developmental stages were analysed using descriptive statistics (mean and standard deviation [SD]). The larval instars were separated from each other by head capsule measurements (Dyar 1890).

Results

Mating behaviour

After host tree selection, the male of *I. stebbingi* was observed to form an initial gallery known as nuptial chamber (Fig. 1). Many female beetles (two to six) successively entered the nuptial chamber through the tunnel made by the male and after copulation, excavated their individual egg galleries radiating away from the central chamber (Fig. 1).

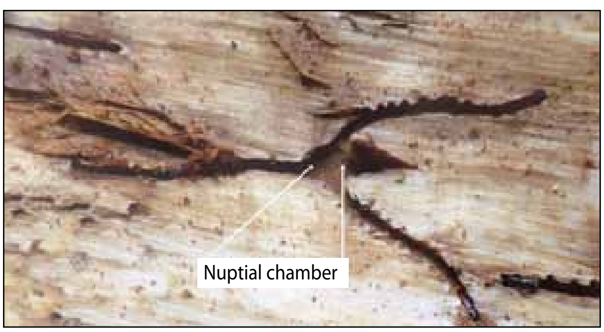

Figure 1. Initial gallery (nuptial chamber)

Maturation feeding

Bark dissections for female maturation feeding (Fig. 2) showed that no eggs were collected from beetle entries on the first and second days; only 4/15 from 3-day-old entries yielded eggs, 9/15 from 4-day-old entries contained eggs, while 13/15 from 5-day-old entries contained eggs, but all the 15 of 6-day-old beetle entries contained eggs. This indicated that newly emerged females mostly fed and oviposited in 4–6 days in the field. The feeding sites were then continued into the maternal galleries.

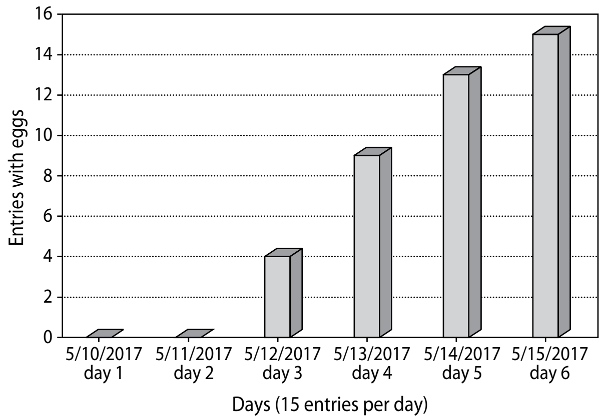

Figure 2. Female maturation period of *Ips stebbingi*

Gallery patterns

The gallery patterns are shown in Fig. 3. The average length of maternal galleries is 10.76 (±3.30 SD) cm (Fig. 3A, Tab. 1). Larval galleries radiate out from the maternal galleries. The average length of larval galleries is 3.83 (±0.63 SD) cm (Fig. 3B, Tab. 1). The larval tunnels are initially perpendicular to the maternal gallery, then radiate in different directions and can intersect (Fig. 3B). These tunnels are closely packed with the wood excreta passed out by the larvae during feeding.

Table 1. Measurement of gallery length

Variable	*n*	Mean (cm)	Standard deviation (cm)
Maternal gallery length	30	10.76	3.30
Larval gallery length	30	3.83	0.63

Note: *n* = number of observations.

Data based on the length of the maternal gallery and the numbers of eggs deposited indicate that there is a positive correlation ($y = 2.1686x - 2.315$, $r = 0.67$) between the two variables (Fig. 4). The number of eggs increases linearly with maternal gallery length.

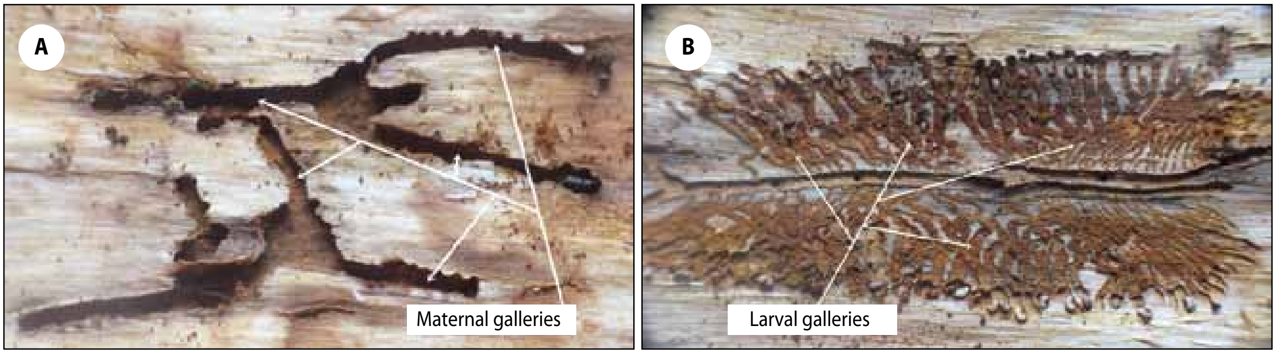

Figure 3. A typical gallery pattern of *Ips stebbingi* excavated in *Pinus wallichiana*: maternal galleries (A), larval galleries (B)

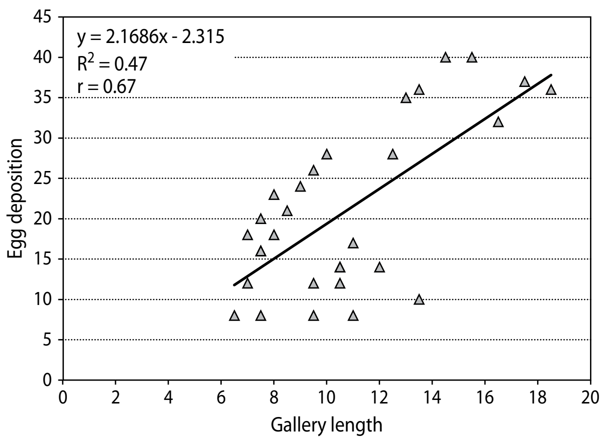

Figure 4. Relationship between the length of maternal galleries (cm) and eggs per gallery in *Ips stebbingi*

Developmental stages

Egg

After copulation, each female bores out her tunnel, gnaws out little notches at the side and places an egg in each (Fig. 5). These notches are not made so symmetrically as in the case of the monogamous bark beetle species, with the eggs being laid usually more on one side than on the other. On an average, 23.16 (±7.03 SD) eggs were laid per female (Tab. 2). The eggs were about 0.72 (±0.03 SD) mm in length and 0.48 (±0.02 SD) mm in width (Tab. 2). The eggs hatched after an incubation period of 8–18 days (Tab. 3).

Figure 5. Egg of *Ips stebbingi*

Table 2. Egg deposition and measurement of developmental stages of *Ips stebbingi*

Variable	*n*	Mean (mm)	Standard deviation (mm)
Eggs deposited	30	23.16 (number)	7.03
Egg length	30	0.72	0.03
Egg width	30	0.48	0.02
Larval length	30	3.00	0.13
Larval width	30	1.35	0.04
Pupal length	30	2.37	0.08
Pupal width	30	1.02	0.06
Female length	30	4.08	0.07
Female width	30	1.78	0.04
Male length	30	3.74	0.05
Male width	30	1.72	0.08

Note: n = number of observations

Table 3. Developmental duration of *Ips stebbingi*

Stage	Duration of generations (days)		
	First generation	Second generation	Third generation
Egg	9–15	8–14	8–18
Larva	35–45	30–38	30–40
Pupa	20–26	18–24	21–28
Adult	60–70	45–60	140–175
Total	124–156	101–136	199–261

Table 4. Comparison of observed (mean) and expected values of head capsule widths (mm) of the larvae of *Ips stebbingi*

Larval instars	Head capsule width (mm)			Difference (mm)
	observed (mean ± SD)	range	expected*	
I	0.36 ± 0.04	0.11	0.36	0.00
II	0.46 ± 0.03	0.11	0.45	0.01
III	0.57 ± 0.03	0.12	0.58	–0.01
IV	0.72 ± 0.02	0.13	0.72	0.00
V	0.84 ± 0.03	0.11	0.91	–0.07

Mean observed head capsule width of first instar larva (n = 30) = 0.36 mm

Mean observed head capsule width of second instar larva (n = 30) = 0.46 mm

Growth ratio (Dyar's ratio) $\frac{\text{Head capsule width of second instar larva}}{\text{Head capsule width of first instar larva}} = \frac{0.46}{0.36} = 1.27$ mm

Mean observed head capsule width of fifth instar (mature larvae) (n = 30) = 0.84 mm

* Expected head capsule width established by Dyar's ratio (1.27). Multiplying Dyar's ratio with the observed head capsule width of the first instar larva gives the expected head capsule width of the second instar, which when multiplied again with Dyar's ratio gives the expected head capsule width of the third instar and so on.

Larva

The larva on hatching was apodous, wrinkled, minute, cylindrical and creamy white in colour (Fig. 6). The mature larvae reached an average length of 3.00 (±0.13 SD) mm and a width of 1.35 (±0.04 SD) mm (Tab. 2). On the basis of the data recorded in the field, five larval instars were observed (Tab. 4). The expected head capsule width of each instar was also determined by Dyar's ratio (Dyar 1890), which asserts that the growth ratio remains constant between the moults. Each instar was progressively longer (length) than the preceding instar. Development from hatching to the prepupal larvae took 30–45 days (Tab. 3).

Figure 6. Larva of *Ips stebbingi*

Pupa

Pupation took place at the end of the larval galleries in pupal chambers. The pupae were soft and creamy white measuring 2.37 (±0.08 SD) mm in length and 1.02 (±0.06 SD) mm in width (Fig. 7, Tab. 2). The pupal stage lasted for 18–28 days (Tab. 3). After pupation, the adults fed for a short time in the phloem before emerging from the pupal chamber by tunnelling straight through the bark over it. After emergence, adults flew to suitable trees to produce the next generation.

Figure 7. Pupa of *Ips stebbingi*

Adult

Body is oblong, shining and blackish brown (Fig. 8A, 8B). Antennae and legs are piceous brown. Head is smooth, shining on vertex, which has few scattered fine punctures on it; the front portion is flat and roughly punctate, and there are two tubercles placed transversely on the face (Fig. 8C). Elytra is truncate posteriorly; the declivous portion is concave and dull, sometimes slightly shining and finely punctate towards the bottom. The sides are furnished with four teeth, of which the upper one (1) is very small and set at a distance from 2; 2 is close to 3 and is larger than 1; 3 is the largest with a swollen head to it. Tooth 4 is prominent and sharp and smaller than 3 and set farther from 3 than 3 is from 2 on one side and a less distant from the lower margin (Fig. 8D). Elytra laterally and edges of declivity are fringed with long and yellow spiny hairs. The adult females had an average body length of 4.08 (±0.07 SD) mm and width

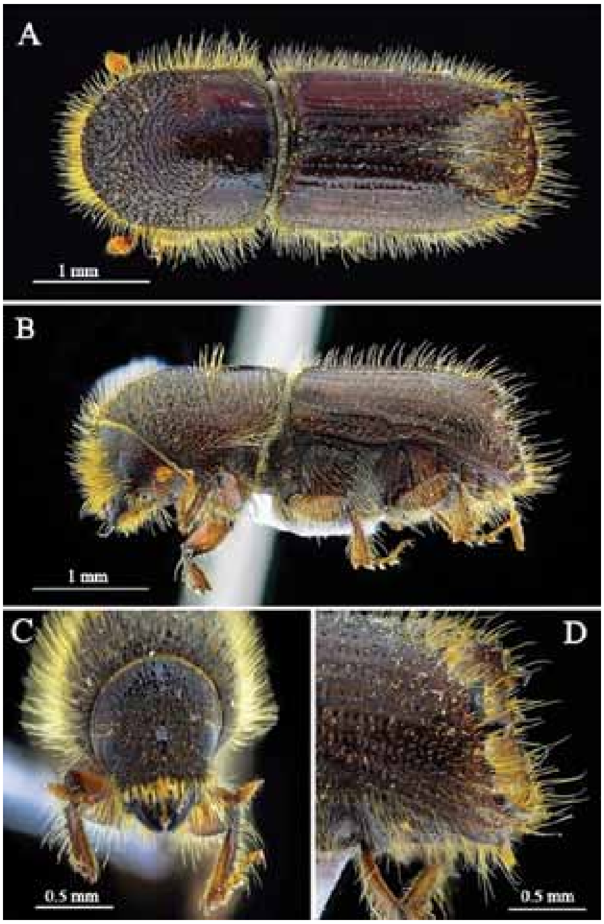

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Figure 8. Adult of *Ips stebbingi*: habitus, in dorsal view (A); habitus, in lateral view (B); head, in frontal view (C); abdominal declivity (D)

of 1.78 (±0.04 SD) mm, and the body length of male was 3.74 (±0.05 SD) mm and its width was 1.72 (±0.08SD) mm (Tab. 2). The adults lived for 45–70 days (Tab. 3).

Seasonal incidence

The results of the present observations showed that *I. stebbingi* overwintered in adult stages in their respective galleries from the last week of October (Fig. 9). The adults remained inactive throughout the winter and resumed their activity from the second week of March onwards. The species produced three generations per year in Kashmir (Fig. 9). The first generation lasted from the last week of March to August, having a total life span of 124–156 days (Tab. 3). The second generation lasted from the second week of June to October, having a total life span of 101–136 days, while the third overwintering generation took 199–261 days and extended from August to May of the following year (Tab. 3). Laboratory observations also confirmed three generations with a little difference in developmental process and duration of insect stages.

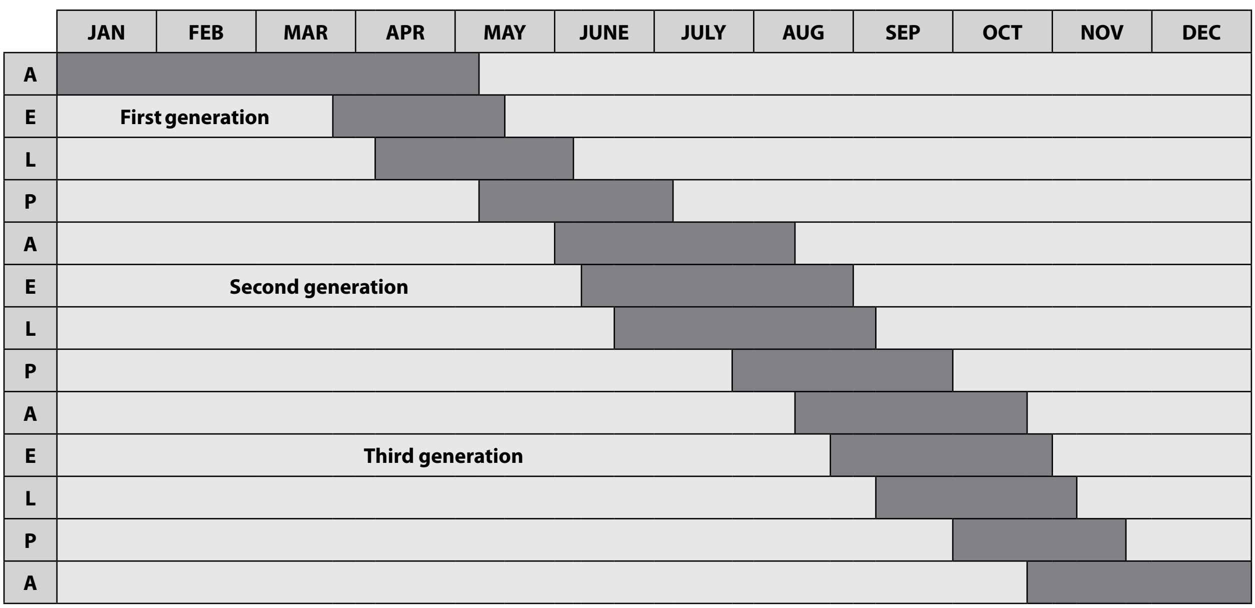

Figure 9. Seasonal distribution of *Ips stebbingi* on *Pinus wallichiana* in Kashmir (E – egg, L – larva, P – pupa, A – adult)

Discussion

In the present study, the detailed biology of *I. stebbingi* has been worked out in the pine forest ecosystem of Kashmir Himalaya. The species shows a polygamous mating system. The male initiates gallery construction by excavating a nuptial chamber in the phloem. While doing this, the male also emits aggregation pheromones attracting conspecifics of both sexes to intensify the attack and subsequent colonisation at the site. After mating, each female carves her own tunnel radiating outwards from the central nuptial chamber and lays its eggs in individual niches along the sides of the gallery. Data based on the length of the maternal gallery and the numbers of eggs deposited indicate that there is a positive correlation between the two variables. The number of eggs increases linearly with maternal gallery length. The decline of maternal gallery length and oviposition with increasing attack density can be partially due to the intraspecific competition. For the first time, this study described the duration of developmental passage of *I. stebbingi* through individual stages and determined the number of instars using the distribution of head capsule widths (Dyar 1890; Caltagirone et al. 1983). The galleries of *I. stebbingi* contain all developmental stages from egg to adult, whose general qualitative characteristics are similar to those described for other scolytines (Wood 2007; Jordal 2014). This species overwinters in the adult stage under the bark. In the spring, adults spend a period of time (maturation feeding) under the bark, often in their galleries before dispersal, and the newly emerged females mostly feed and oviposit in 4–6 days in the field.

The present study results show that *I. stebbingi* produces three generations per year in Kashmir in contrast to *Ips typographus* having mostly univoltine generation in Europe (Ohrn 2012). The bark beetle attacks have increased during the past few decades in the northwestern Himalaya as a result of poor forest management systems and climate change. Currently, the climate changes are predicted to significantly affect the frequency and severity of disturbances in the forest ecosystems (Bentz et al. 2010). Temperature can be the most crucial factor in controlling insect life in the temperate forests. In response to higher temperatures and drought, the bark beetles, in general, and *I. stebbingi*, in particular, may show improved performance in trees and have a synergistic negative effect on the pine forest as water shortage weakens the host defence. The increased temperature will also promote earlier emergence in spring and faster preimaginal development. Under adverse conditions of climate change (prolonged droughts, floods and storms), the forest stands are susceptible to increased stresses and damages mostly by bark beetles (McNichol et al. 2021).

We can expect higher population outbreaks of *I. stebbingi* doing more damage to a less-defensive host tree in a future warmer climate. The forest management system has to be planned in view of increased wind damages, severe drought and higher population levels of bark beetles in the Himalayan region.

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Conflict of interest

The authors declare that there is no conflict of interest other than publication of this paper.

References

Beaver, R.A. 1967. Notes on the biology of the bark beetles attacking elm in Wytham Wood, Berks. *Entomologist's Monthly Magazine,* 102, 156–162.

Bentz, B.J. et al. 2010. Climate change and bark beetles of the western United States and Canada: Direct and indirect effects. *BioScience,* 60 (8), 602–613.

Buhroo, A.A., Lakatos, F. 2007. On the biology of the bark beetle, *Scolytus nitidus* Schedl (Coleoptera: Scolytidae) attacking apple orchards. *Acta Silvatica et Lignaria Hungarica,* 3, 65–75.

Buhroo, A.A., Lakatos, F. 2011. Molecular and morphological diagnostic markers for the Himalayan *Ips* DeGeer species (Coleoptera: Curculionidae: Scolytinae). *Zootaxa,* 3128, 47–57.

Caltagirone, L.E., Getz, W., Meals, D.W. 1983. Head capsule width as an index of age in larvae of navel orangeworm, *Amyelois transitella* (Lepidoptera: Pyralidae). *Environmental Entomology,* 12, 219–221.

Chararas, C. 1962. Etude biologique des scolytides des conifers. Encyclopedie Entomologique, Ser. A, Nr. 38. Paul Lechevalier, Paris.

Cognato, A.I. 2015. Biology, systematics, and evolution of *Ips.* In: Bark beetles. Biology and ecology of native and invasive species (eds. F.E. Vega, R.W. Hofstetter). Academic Press, London, 351–370.

Dyar, H.G. 1890. The number of molts of lepidopterous larvae. *Psyche: A Journal of Entomology,* 5, 420–422.

Franceschi, V.R., Krokene, P., Christiansen, E., Krekling, T. 2005. Anatomical and chemical defenses of conifer bark against bark beetles and other pests. *New Phytologist,* 167, 353–375.

Furniss, M.L., Carolin, V.M. 1992. Western forest insects: United States Department of Agriculture Forest Service. Miscellaneous Publication, No. 1339, Washington, D.C.

Jordal, B.H. 2014. Scolytinae. In: Handbook of zoology. Band IV Arthropoda: Insecta. Part 38: Coleoptera, Beetles. Vol. 3 (eds. R.A.B. Leschen, R. Beutel). deGruyter Press, Berlin, 349–358.

Khanday, A.L., Buhroo, A.A. 2015. Life history and biology of the elm bark beetle *Scolytus kashmirensis* Schedl (Coleoptera: Curculionidae: Scolytinae) infesting *Ulmus villosa* in Kashmir. *Open Journal of Forestry,* 5, 443–453.

Khanday, A.L., Buhroo, A.A., Ranjith, A.P., Kerchev, I.A. 2018. Evaluating the efficacy of entomopathogenic fungi against the bark beetle, *Ips stebbingi* Strohmeyer (Coleoptera, Curculionidae: Scolytinae) in India. *Entmological Review,* 98, 985–994.

Knížek, M. 2011. Scolytinae. In: Catalogue of Palaearctic Coleoptera. Vol. 7 (eds. I. Löbl, A. Smetana). Apollo Books, Stenstrup.

McNichol, B.H. et al. 2021. Relationships between drought, coniferous tree physiology, and *Ips* bark beetles under climatic changes. In: Bark beetle management, ecology, and climate change (eds. K.J.K. Gandhi, R.W. Hofstetter). Elsevier, Amsterdam, The Netherlands, 153–194.

Ohrn, P. 2012. Seasonal flight patterns of the spruce bark beetle (*Ips typographus*) in Sweden. Phenology, voltininsm and development. Licentiate thesis, Swedish University of Agricultural Sciences, Sweden.

Pfeffer, A. 1995. Zentral-und Westpaläarktische Borken-und Kernkäfer. Pro Entomologia, c/o Naturhistorisches Museum, Basel.

Postner, M. 1974. Scolytidae (=Ipidae), Borkenkäfer. In: Die Forstschädlinge Europas. Bd. 2 (ed. W. Schwencke). Paul Parey Verlag, Hamburg Berlin, 334–482.

Stebbing, E.P. 1914. Scolytidae. In: Indian forest insects of economic importance Coleoptera. Eyre and Spottiswoode, Ltd. London, 457– 610.

Wood, S.L., Bright, D.E. 1992. A catalog of Scolytidae and Platypodidae (Coleoptera). Part 2: Taxonomic index. *Great Basin Naturalist Memoirs,* 13, 1–1553.

Wood, S.L. 2007. Bark and ambrosia beetles of South America (Coleoptera: Scolytidae). Brigham Young University, Provo.

Zhang, Q.H., Byers, J.A., Schlyter, F. 1992. Optimal attack density in the larch bark beetle, *Ips cembrae* (Coleoptera: Scolytidae). *Journal of Applied Ecology,* 29, 672–678.