

Life History and Biology of the Elm Bark Beetle *Scolytus kashmirensis* Schedl (Coleoptera: Curculionidae: Scolytinae) Infesting *Ulmus villosa* in Kashmir

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Received 19 February 2015; accepted 13 April 2015; published 17 April 2015

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Abstract

Elm bark beetle *Scolytus kashmirensis* is a key pest of elm nurseries in the social forestry ecosystem of Kashmir. The biological and morphological characters of this species were determined both in field and in the laboratory. The larvae remained inactive throughout the winter which resumed their activity from the third week of March. Pupation started from the first week of April and the first swarming adults appeared from the last week of April. After emergence, the adults fly to suitable trees and undergo maturation feeding for 8.4 (± 0.68 SD) days and females laid 46 (± 9.45 SD) eggs on an average. The eggs hatched after an incubation period of 11 - 13 days. The five larval instars were distinguished from each other on the basis of the width of head capsule measurements. The larvae completed their development in 40 - 46 days. The pupal stage lasted for 10 - 20 days and finally adults emerge that lived for 45 - 60 days. The single longitudinal maternal gallery measured 42.67 (± 11.07 SD) mm (on average) long and the larval gallery was 43 (± 10.96 SD) mm (on average) in length. The seasonal distribution of various life stages and the number of generations were also recorded.

Keywords

Biology, Morphology, *Scolytus kashmirensis*, *Ulmus villosa*, Gallery Pattern

1. Introduction

Elms (*Ulmus* spp.) are deciduous and semi-deciduous trees comprising over 30 species belonging to the genus

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Ulmus in the plant family *Ulmaceae*. In Kashmir, *Ulmus villosa* is grown as agro-forestry and social forestry tree. It is attacked by many pests and diseases, among them the bark beetle *Scolytus kashmirensis* Schedl, 1957 (Coleoptera: Curculionidae) is considered as a serious pest. The bark beetles and pathogens interact to cause expensive losses in forest trees. For example, *Ophiostoma himal-ulmi*, the Dutch elm disease pathogen occurring in the Himalayan region (Brasier & Mehrotra, 1995) is transmitted by *S. kashmirensis*. Oak dieback in Japan (Ito et al., 1998) is caused by ambrosia beetle, *Platypus quercivorus*. Spruces (*Picea* sp.) are destroyed by the great spruce bark beetle, *Dendroctonus micans* (Kug), which is a primary pest in Europe (Storer et al., 1997).

The biology of *S. kashmirensis* is very important towards investigation of its role as a possible vector of Dutch elm disease. Bark beetles prefer older elms for feeding and, therefore, much more likely to become diseased compared with young trees (Segonca & Leisse, 1984). The trees infested by bark beetles may be recognized at a distance by fading foliage of the tree, initially a light green then changing to a light straw color in a few weeks, eventually changing to yellowish-brown. Close inspection may show a fine reddish-brown boring dust in bark crevices at the base of these trees (Webber, 1990). The incidence of bark beetles is largely determined by the distribution and abundance of their host tree species and climate (Lekander et al., 1977). After mating, *S. kashmirensis* makes a breeding gallery whose form is fairly species specific. All the developmental stages feed under the inner bark. After maturation feeding, adults emerge from brood material and colonize healthy or stressed plants (Lieutier et al., 2004). Most of the species of bark beetles breed in slash, broken, fallen, dying, or large limbs of trees but some are capable of primary attack on healthy trees when conditions are favorable (Wood, 1982). Therefore, bark beetles are attracted by fresh stressed timber, while healthy trees normally defend by chemical or physical means (Speight et al., 1999).

Despite the potential serious damages of this pest on elm trees in Kashmir, there is no systematic information on the various aspects of *S. kashmirensis* except few reports of its occurrence in Kashmir (Schedl, 1957; Buhroo, 2011, 2012). Therefore, the main objective of the present study was to investigate the detailed biology and morphological characters of *S. kashmirensis*.

2. Materials and Methods

2.1. Field Studies

The biological data were obtained mainly from the study areas viz. Larkipora (GPS position 33°38.738'N, 075°10.060'E and Elevation 5482 feet) and Halan (GPS position 33°29.365'N, 075°16.394'E and Elevation 7132 feet) in Anantnag district consisting mainly elm trees. At both places we randomly selected 40 - 60 year old elm trees suffering from bark beetle attack. The older trees were preferred for feeding by bark beetles, having poor physiological conditions as compared to young trees. The activity of *S. kashmirensis* was monitored by using trap logs during 2012-2013 as described by Beaver (1967). To initiate infestation some infested logs of previous year were also put near elm trees. In the 1st week of April, fresh elm logs (50 - 60 cm long and 10 - 15 cm diameter) were placed near the trunk of the infested alive tree with clear symptoms of bark beetle attack i.e. circular holes with frass in order to supplement the infested logs of previous year. Observations of various life stages were recorded weekly on the trap logs and other infested branches of standing trees followed by installation of the new fresh logs in the same fashion. New galleries were marked with a white dot. Further information was obtained by careful removal of bark sections both in the field and in the laboratory.

The correlation between the length of maternal galleries and the number of eggs deposited was worked out as per the method followed by Zeiri et al. (2011). Every week 5 - 8 galleries were dissected and the length of galleries were measured by digital calliper scale. The eggs were exposed carefully as they remained glued with wood dust and then counted in their individual chambers. The observations were repeated throughout the year so as to understand average fecundity of female.

2.2. Laboratory Rearing

The laboratory rearing of *S. kashmirensis* was maintained by placing infested logs (30 - 40 cm long and 8 - 10 cm in diameter) in rearing boxes of similar design with dimensions of 70 × 30 × 35 cm, 40 × 30 × 30 cm and 50 × 30 × 30 cm, made up of wood and glass and fitted with a muslin cloth on their top end. To maintain the culture, some fresh logs (30 - 40 cm long and 8 - 10 cm in diameter) were placed with the naturally infested logs inside the rearing boxes. The fresh logs at their cut ends were sealed with wax. After every month 2 - 3 fresh logs sealed with wax were put in these rearing boxes in order to induce fresh attack on them. This enabled the conti-

nuous rearing and examination of beetle development. Characters of the different developmental stages including egg, larva, pupa and adult were recorded. The different larval instars were separated from each other by head capsule measurements. Maturation feeding, gallery patterns and damage signs were also recorded. The different life stages of the pest were measured by using digital calliper scale and microscope with ocular micrometer. Thus, development process and duration of insect life stages were recorded and compared with the field results

2.3. Photography

Photographs during the study were taken by using DSLR camera (Canon EOS 600 D with 300 mm wide angle lens + macro lens). Analysis of digital images was done by using image J analysis software.

2.4. Statistical Analysis

Statistical analyses were performed using SPSS version 10.0. The data obtained during the present study were tabulated and graphically presented by the descriptive analysis. The correlation between maternal galleries and fecundity of females was analyzed by Karl Pearson's correlation method. Head capsule width of different larval instars was used to calculate total larval instars by Dyar's ratio (Dyar, 1890).

3. Results and Discussion

3.1. Egg Stage

Bark dissections showed that the eggs were deposited in small individual chambers on both sides of the mother gallery at regular distances throughout its length. The eggs (Figure 1) are slightly oval, shining and pale white in color. On an average $46 (\pm 9.45 \text{ SD})$ eggs were laid per female (Table 1). The eggs are about $0.78 (\pm 0.06 \text{ SD})$ mm in length and $0.53 (\pm 0.05 \text{ SD})$ mm in width (Table 2). The eggs in the egg niches were covered by the boring dust. The eggs hatched after an incubation period of 11 - 13 days (Table 3).

3.2. Larval Stage

The larva on hatching was legless, wrinkled, minute, cylindrical and creamy white in color (Figure 2). The mature larvae reached to an average length of $4.03 (\pm 0.14 \text{ SD})$ mm and width of $1.82 (\pm 0.06 \text{ SD})$ mm (Table 2).

Table 1. Egg deposition by *S. kashmirensis*.

Variable	N	Mean	SD	Minimum	Maximum
Eggs	20	46.600	9.44798	32.00	62.00

N = Number of observations.

Table 2. Measurement of developmental stages of *S. kashmirensis*.

Variable	N	Mean (mm)	SD (mm)	Minimum (mm)	Maximum (mm)
Egg length	20	0.7770	0.06530	0.68	0.88
Egg width	20	0.5300	0.05140	0.44	0.62
Larval length	20	4.0300	0.13892	3.85	4.40
Larval width	20	1.8200	0.05726	1.74	1.96
Pupal length	20	3.9550	0.09660	3.80	4.14
Pupal width	20	1.7050	0.06329	1.62	1.88
Male length	20	3.8940	0.25771	3.40	4.10
Male width	20	1.7540	0.09121	1.62	1.88
Female length	20	4.0380	0.19281	3.68	4.30
Female width	20	1.7925	0.08735	1.68	1.92

N = Number of observations.

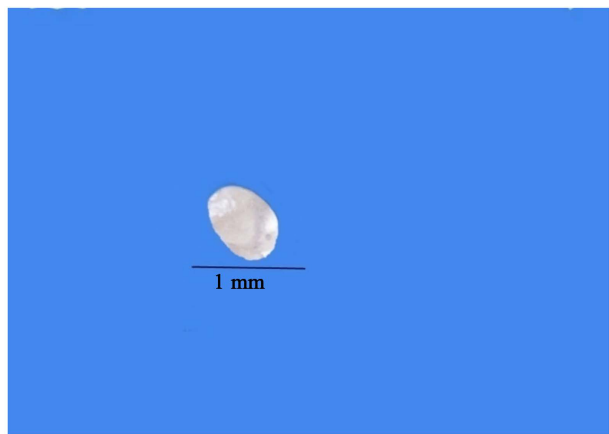


Figure 1. Egg of *S. kashmirensis*.



Figure 2. I and V instars of *S. kashmirensis*.

Table 3. Developmental durations of *S. kashmirensis*.

Developmental stage	Duration of generations (days)	
	1 st generation	2 nd generation
Egg	12 - 13	11 - 12
Larva	40 - 46	175 - 210
Pupa	18 - 20	10 - 12
Adult	50 - 60	45 - 55
Total	120 - 139	241 - 289

On the basis of the data recorded in the field, five larval instars were observed which was confirmed by expected head capsule width of each instar as determined by Dyar's ratio (Dyar, 1890) (Table 4). Each instar was progressively longer than preceding instar. Development from hatching to the prepupal larvae took 40 - 46 days (Table 3).

3.3. Pupal Stage

The pupation took place below the exit hole. The pupae (Figure 3) were soft and creamy white with $3.95 (\pm 0.10)$ SD) mm in length and $1.70 (\pm 0.06)$ SD) mm in width (Table 2). The pupal stage lasted for 10 - 20 days (Table 3).



Figure 3. Pupa of *S. kashmirensis* (lateral view).

Table 4. Comparison of observed (mean) and expected values of head capsule widths (mm) of the larvae of *S. kashmirensis*. Mean observed head capsule width of 1st instar larva (N = 20) = 0.60 mm; Mean observed head capsule width of 2nd instar larva (N = 20) = 0.78 mm. Growth ratio (Dyar's ratio) = $\frac{\text{Head capsule width of 2}^{\text{nd}} \text{ instar larva}}{\text{Head capsule width of 1}^{\text{st}} \text{ instar larva}} = 0.78/0.60 = 1.30$ mm. Mean observed head capsule width of 5th instar (mature larvae) (N = 20) = 1.74 mm.

Larval instars	Head capsule width (mm)			Difference (mm)
	Observed (Mean \pm SE)	Range	Expected ^a	
I	0.60 \pm 0.01118	0.55-0.70	0.60	0.00
II	0.78 \pm 0.00729	0.75-0.90	0.78	0.00
III	1.02 \pm 0.01441	0.95-1.20	1.01	0.01
IV	1.36 \pm 0.01882	1.25-1.60	1.32	0.04
V	1.74 \pm 0.01777	1.65-1.90	1.72	-0.02

^aExpected head capsule width established by Dyar's ratio (1.30). Multiplying Dyar's ratio with the observed head capsule width of 1st instar larva gives the expected head capsule width of 2nd instar which when multiplied again with Dyar's ratio gives expected head capsule width of 3rd instar and so on.

Immature adults after emergence from pupae were initially white and later changed into light brown to dark brown in color. The adults emerged from the pupal chamber by tunneling straight through the bark over it. After emergence, adults flew to the suitable trees to produce the next generation.

3.4. Adult Stage

The adults are cylindrical with shining black pronotum and dark red-brown elytra (**Figure 4**); male having an average body length of 3.89 (± 0.26 SD) mm and width of 1.75 (± 0.09 SD) mm and female has average body length of 4.04 (± 0.19 SD) mm and width of 1.79 (± 0.09 SD) mm (**Table 2**). This species can be diagnosed by the sternites of the abdomen ascending steeply to meet the elytra; in male, the second abdominal sternite near its anterior border has a low blunt tooth-like structure, posterior margin is armed with a lip-like extension in the middle and with a knobbed tooth on each side (**Figure 5(a)**). In females, the median tooth much larger, the lip-like structure strongly reduced, the lateral teeth on the posterior border much smaller and farther apart from each other (**Figure 5(b)**). The adults lived for 45 - 60 days (**Table 3**).

3.5. Maturation Feeding

After the emergence from pupae, immature adults undergo maturation feeding for full sclerotization. Maturation feeding period lasted for 8.4 (± 0.68 SD) days (**Table 5**). In field experiments, bark dissection (at the entrance



Figure 4. Adult of *S. kashmirensis*.

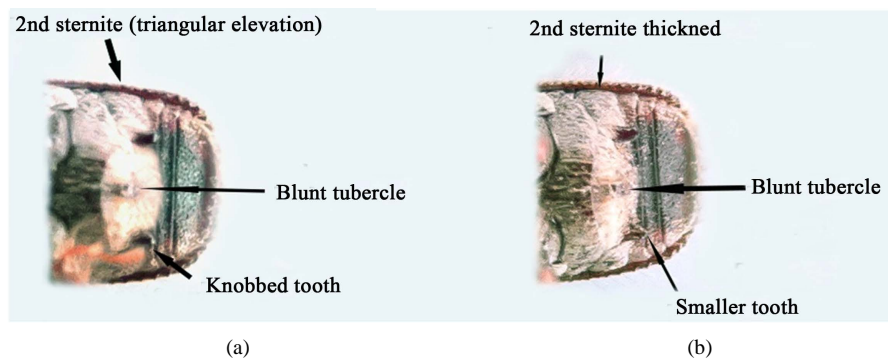


Figure 5. Abdominal declivity of *S. kashmirensis* ((a) male; (b) female).

Table 5. Maturation period (days) for *S. kashmirensis*.

Variable	N	Mean	SD	Minimum	Maximum
Maturation feeding	20	8.4000	0.68056	8.0000	10.00

N = Number of observations.

holes) revealed that during maturation feeding immature adults (light brown in color) changed into mature adults (dark brown in color). Maturation feeding for *S. mali*, *S. nitidus* and *Hypocryphalus mangiferae* was completed in 4 to 6 days (Rudinsky et al., 1978; Buhroo & Lakatos, 2007; Masood et al., 2009). The successful maturation feeding occurred mostly on weekend trees or those with some dead branches. The maturation feeding is very critical in the life cycle of bark beetle as this acts as a carrier of disease spores for further disease transmission (Atkins, 1966; Lieutier et al., 2004; Christiansen & Bakke, 1988; Persson et al., 2009).

3.6. Damage and Signs

The *S. kashmirensis* bore the inner bark (the phloem-cambial region) on twigs, branches, or trunks of elm trees. This activity often starts a flow of tree sap. The sap flow is accompanied by frass created by the beetles. Frass accumulates in bark crevices or falls down on the ground. Small emergence holes (Figure 6) in the bark are a good indication that bark beetles were present. Removal of the bark with the emergence holes often reveals dead and degraded inner bark.

3.7. Gallery Patterns

Like many other bark beetles the female (Figure 7) bored the mother gallery in the cambium and the sapwood.



Figure 6. Emergence holes of *S. kashmirensis*.



Figure 7. Boring of *S. kashmirensis*.

The maternal gallery is single longitudinal type facing upward on the infested branch (**Figure 8**). Sometimes, the maternal gallery has a slight deviation across its length (**Figure 9**). The maternal gallery measures 42.67 (± 11.08 SD) mm (on average) in length (**Table 6**). The dissection of the bark showed that eggs were deposited in small individual chambers regularly on both sides of the mother gallery. The correlation between the length of the maternal gallery and the number of deposited eggs showed that the correlation coefficient R^2 is 0.539 (**Figure 10**). There is no correlation between the two variables.

The larval galleries (**Figure 8**) measure 43 (± 10.96 SD) mm (on average) in length and these showed variability in the measurement of width which increases from 0.54 (± 0.06 SD) mm to 1.85 (± 0.07 SD) mm (on average) as the larvae grow in size (**Table 7**). The larval tunnels were initially perpendicular to its mother gallery, then radiated in different directions and could intersect. Larval galleries end with pupal cells where larvae pupate.

3.8. Seasonal Distribution

During this study, freshly cut trap logs were used to observe the activity pattern of the *S. kashmirensis* throughout the year. The monitoring of beetles using trap logs has proven to be efficient method in monitoring of *Scolytus* beetles (Beaver, 1967; Buhroo & Lakatos, 2007). The visual observations by dissecting the bark showed that *S. kashmirensis* overwintered in all larval stages at the end of their respective galleries. This species overwintered from the second week of October in Kashmir. The larvae remained inactive throughout the winter which resumed their activity from the third week of March. Pupation started from the first week of April and the first swarming adults appeared from the last week of April. This species has 2 generations (the last a partial one) per year in Kashmir (**Figure 11** and **Figure 12**). The first generation started from the last week of April to June

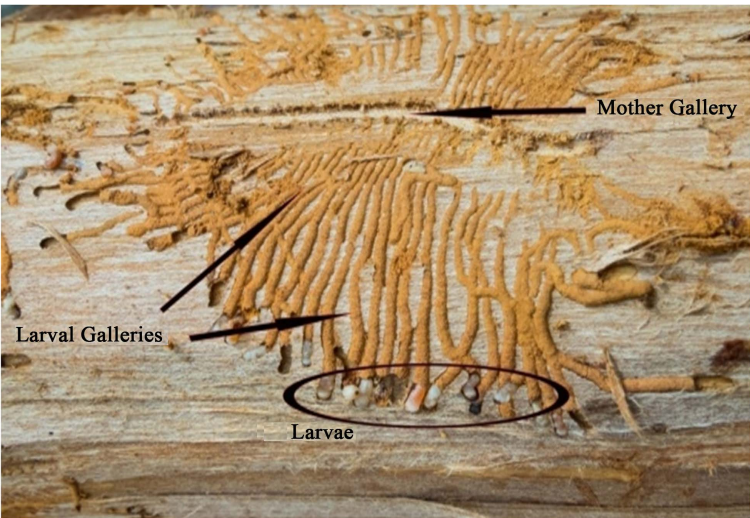


Figure 8. Gallery pattern of *S. kashmirensis*.

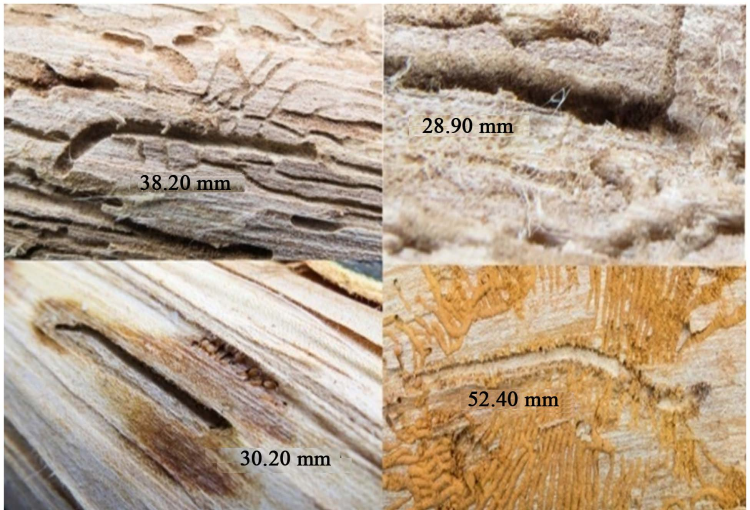


Figure 9. Gallery shapes of *S. kashmirensis*.

Table 6. Measurement of gallery length.

Variable	N	Minimum (mm)	Maximum (mm)	Mean (mm)	SD (mm)
Maternal gallery	30	15.00	69.30	42.6753	11.07946
Larval gallery	30	18.00	70.00	42.9577	10.96664

N= Number of observations.

Table 7. Measurements of the width of 20 larval galleries of *S. kashmirensis* after every 10 mm.

Measurement	0 mm	10 mm	20mm	30 mm	40 mm	50 mm
Mean	0.5425	0.6550	0.8805	1.1310	1.4880	1.8465
S.D	0.0567	0.07082	0.04796	0.05543	0.11687	0.07043
Variance	0.003	0.005	0.002	0.003	0.014	0.005

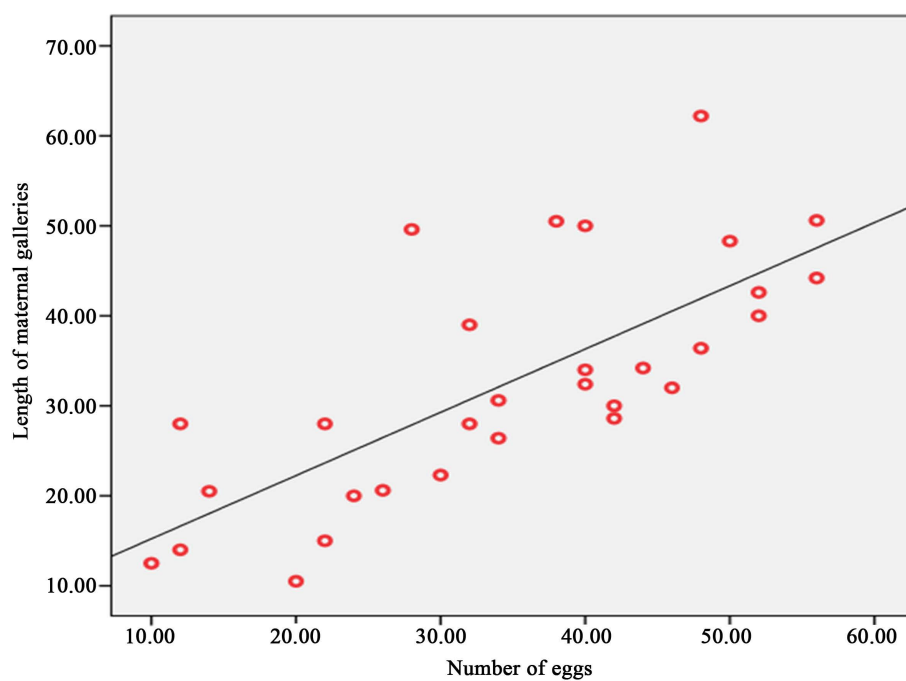


Figure 10. Correlation between the length of maternal galleries (mm) and the number of eggs in *S. kashmirensis*.

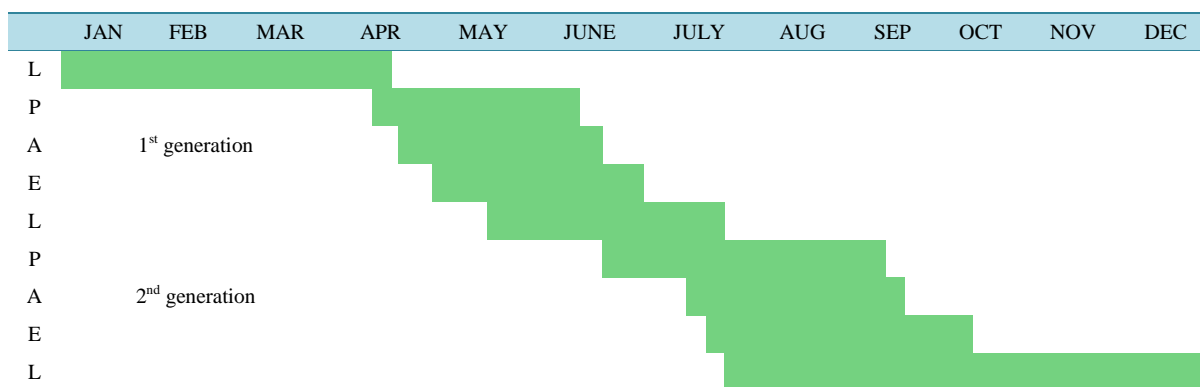


Figure 11. Seasonal distribution of *S. kashmirensis* (in field). (E: egg, L: larva, P: pupa and A: adult).

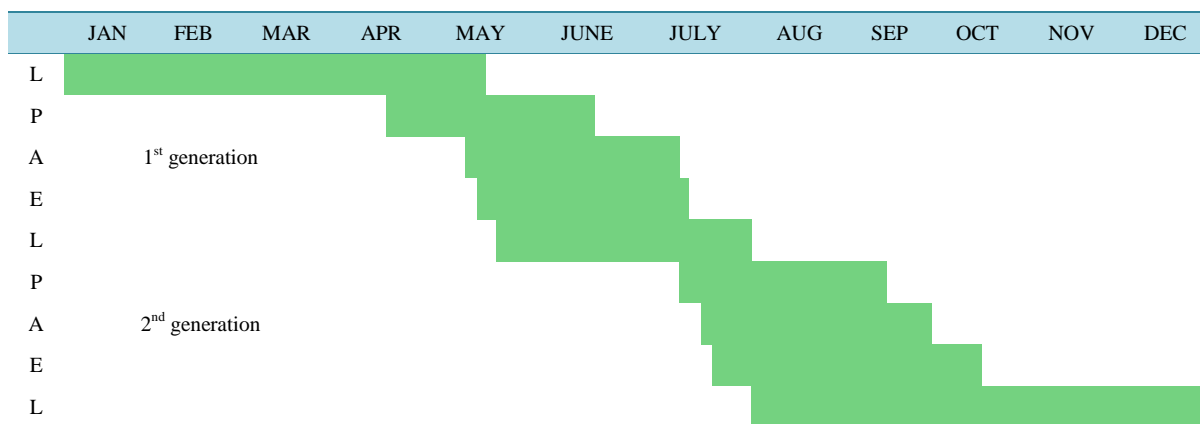


Figure 12. Seasonal distribution of *S. kashmirensis* (in laboratory). (E: egg, L: larva, P: pupa and A: adult).

having a total life span of 120 - 139 days while the overwintering generation took about 241 - 289 days (**Table 3**) and was extended from July to April of the following year. Laboratory observation (**Figure 12**) also confirmed 2 generations (the last a partial one) with little difference in development process and duration of insect stages. The developmental durations and generations of *S. kashmirensis* do not coincide with its related species worked out by other researchers (Beaver, 1967; Youssef et al., 2006; Buhroo & Lakatos, 2007; Masood et al., 2009; Zeiri et al., 2011). The above differences in the life history of scolytine species around the world could be due to environmental factors as well as the variation of biochemical composition of host trees.

4. Conclusion

Bark beetles (Scolytinae) are among the most deteriorating agents affecting conifer forests as well as broad leave trees throughout the world. Many of these beetles use the inner bark of their host trees as food and substrate for rearing their young. The act of boring into live trees introduces fungi into tree tissues which often leads to the trees' death. The genus *Scolytus* has not only a holarctic distribution but has also been introduced around the world to the South Africa, Australia, New Zealand and temperate South America (Smith and Cognato, 2013). The *Scolytus* species are included among the many Scolytines that occur in economically important forest trees of the Himalayan region that could harbor new biodiversity, if explored further.

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