Folia Forestalia Polonica, Series A – Forestry, 2020, Vol. 62 (3), 171–183

ORIGINAL ARTICLE

DOI: 10.2478/ffp-2020-0017

A review of the Indian species of genus *Polygraphus* Erichson, 1836 (Coleoptera: Curculionidae: Scolytinae) with bio-ecological notes on *P. major*, a pest of *Pinus wallichiana* A. B. Jacks (Pinaceae) in Kashmir, India

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Abstract

The Indian species of the genus *Polygraphus* Erichson, 1836 (Coleoptera: Curculionidae: Scolytinae) collected from various localities of the Western Himalayan region and the species available at the National Forest Insect Collection (NFIC), Forest Research Institute, Dehradun (India) were studied and are reviewed herewith. A key to Indian species of *Polygraphus* is provided. Detailed bioecological field and laboratory observations of *P. major* including mating behaviour, gallery pattern, life cycle and seasonal history are reported.

Key words

bark beetles, *Polygraphus*, bioecology, Kashmir

Introduction

Bark beetles (Coleoptera: Curculionidae: Scolytinae) are among the most economically important pests of the world's forests. Most of the 6000 described species attack and breed in dead or weakened trees (Raffa et al. 2015). Just less than 1% of them can cause the death of healthy trees (Kirkendall et al. 2015). The majority of species occur in tropical and subtropical regions (Knížek and Beaver 2004). Raffa et al. (2015) and Kirkendall et al. (2015) provide useful reviews of their biology, and Hulcr et al. (2015) of their morphology, taxonomy and phylogeny.

Received 19 December 2019 / Accepted 28 April 2020

The tribe Polygraphini Chapuis, 1869 today includes 154 described species; most of them (100) are included in the genus *Polygraphus* Erichson, 1836 (Wood and Bright 1992; Alonso-Zarazaga and Lyal 2009). This genus is most diverse in the Afrotropics, where 44 species are currently described. The Palearctic region has 40 species but the Nearctic region has only three species (Wood and Bright 1992; Alonso-Zarazaga and Lyal 2009; Knizek 2011). *Polygraphus* species are predominantly phloeophagous with polygamous mating systems (Kirkendall et al. 2015). Almost all Holarctic and Oriental species breed in Pinaceae but several species attack only angiosperms (Nobuchi 1979; Wood and Bright 1992; Krivolutskaya 1996). A single species *P. grandiclava* Thomson feeds on both conifers and cherry trees (Avtzis et al. 2008).

Among the most economically significant species in this genus (*Polygraphus*), the North American species *P. rufipennis* Kirby, can be noted as causing a significant mortality of spruce trees (Picea) weakened by droughts or defoliation (Raske and Sutton 1986; Bowers et al. 1996). Currently, the most destructive species in this genus is *P. proximus* Blandford. Over the past decade and a half, due to invasion from the Far East, it has become the main cause of the large-scale degradation of Siberian fir (*Abies sibirica* Ledeb.) forests on a territory covering 4,900,000 sq. km (Krivets et al. 2015).

The Oriental region has thirteen *Polygraphus* species, of which eight are actually recorded from India. All the Indian *Polygraphus* species (except *P. anogeissi*, a characteristic representative of tropical and subtropical forests) are found in the Himalayas feeding on different conifers: *Abies*, *Cedrus*, *Larix*, *Picea*, and *Pinus* trees (Stebbing 1914; Wood and Bright 1992; Maiti and Saha 2009; Knížek 2011).

In the Indian context, studies on the bioecology of *Polygraphus* species associated with different conifers are very scarce; only Stebbing (1914), Wood and Bright (1992) and Singh et al. (2001) have recorded a few conifer species as actual hosts of *Polygraphus* species. Therefore, the aim of the present study was to re-examine the species composition and summarize available data on Indian species of the genus *Polygraphus* with detailed bio-ecology of *P. major*, a pest of *Pinus wallichiana* A. B. Jacks (Pinaceae) in Kashmir.

Material and methods

The specimens of *Polygraphus* were collected from Jammu and Kashmir, Himachal Pradesh and Uttarakhand and all the *Polygraphus* species deposited in the National Forest Insect Collection, Forest Research Institute, Dehradun were studied. The information given for each species was taken from the original hand-written labels (holotype labels/paratype labels), and checked against information contained in the original descriptions or published articles (Stebbing 1914; Wood and Bright 1992; Maiti and Saha 2009). The specimens were examined under a LEICA M 205C stereozoom trinocular microscope (Leica Microsystems GmbH, Wetzlar, Hesse, Germany). The specimens were examined under a LEICA M205A stereozoom microscope (Leica Microsystems GmbH, Wetzlar, Hesse, Germany). Images of the types were taken with a LEICA DFC295 camera attached to the microscope and having LAS Montage Multifocus Software (version 4.10). Field images were taken using a Canon Power Shot SX60 camera fitted with a macro lens (Raynox MSN-505, 37 mm, Yoshida Industry Co., Ltd. Tokyo). Spatial information regarding sample site was recorded in the form of latitude and longitude with the help of handheld GPS (Garmin eTrex 10, India).

Field studies

The biological data were obtained mainly at Nowpora village (33°61.078'N, 075°18.700'E and elevation, 1804 m) in Anantnag District, 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 (*P. wallichiana*) trees (Fig. 1A–C). The activity of bark beetles associated with *P. wallichiana* was observed by using trap logs over a period of two years (from March to November 2016 and from March to November 2017). The sampling procedure for monitoring bark beetle activity was similar to that adopted by Khanday and Buhroo (2015). Observations of various life stages were recorded weekly on trap logs and other infested branches of standing trees followed by installation of new fresh logs (Fig. 1D–G). 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 measure-

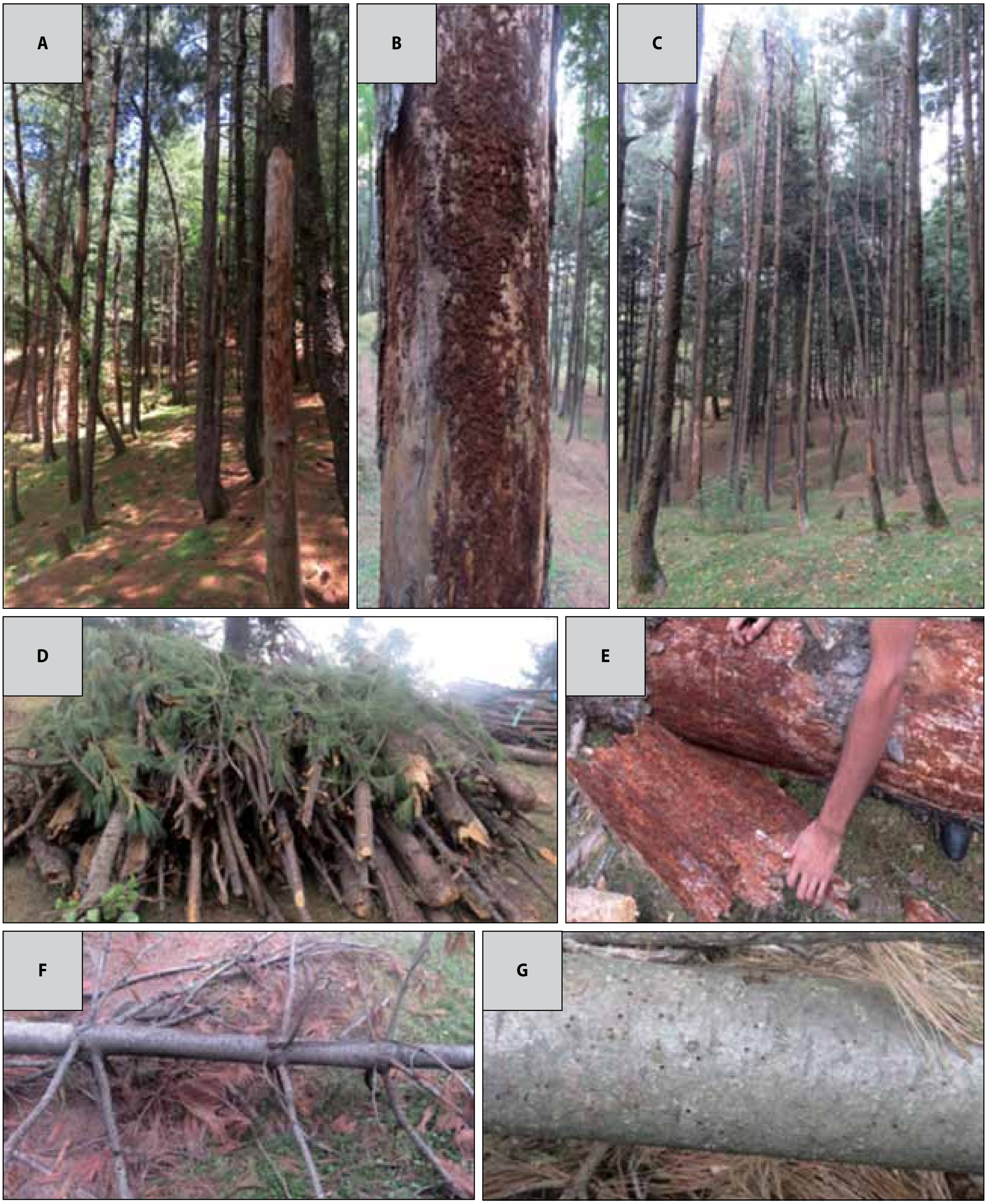

Figure 1. Collection locality and incidence of *Polygraphus major* Stebbing, 1903: A–C, Infested pine (*P. wallichiana*) stand attacked by *P. major*; D–G, Sampled branches infested by *P. major*

ment of galleries (both maternal and larval), a digital calliper scale was used. 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).

Laboratory rearing

The laboratory rearing of bark beetle species was accomplished by placing infested logs (25–45 cm long and 2–10 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, 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 (25–45 cm long and 2–10 cm in diameter) from the host tree (*P. wallichiana*) were placed in the rearing boxes to induce fresh attack, 5–10 days prior to 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 larval instars were separated from each other by head capsule measurements (Dyar 1890; Khanday and Buhroo 2015). The development process and duration of beetle life stages were recorded and compared with the field results using the methods of Buhroo and Lakatos (2007) and Khanday and Buhroo (2015).

Statistical analyses

Statistical analyses were performed using Origin Pro software (Version 2015).

Results and discussion

Genus *Polygraphus* Erichson, 1836: 57 type species *Bostrichus pubescens* Fabricius, 1792 (= *Dermestes poiigraphus* Linnaeus, 1758).

1. *Polygraphus anogeissi* Wood, 1988b: 194 (Fig. 2A, B)
   (Beeson [1941] referred to the species as *P. bassiae* nomen nudum [Wood and Bright 1992]).
   Distribution: India (Maharashtra, West Bengal); Myanmar; Sri Lanka (Wood and Bright 1992).
   Hosts: *Anogeissus acuminate* (Roxb. Ex. DC) Guill and Perr. (Combretaceae), *Madhuca longifolia* (J. Koenig ex L.) J. F. Macbr. (Sapotaceae) and *Odina wodier* Roxb. (Anacardiaceae).
   Biology: Unknown.

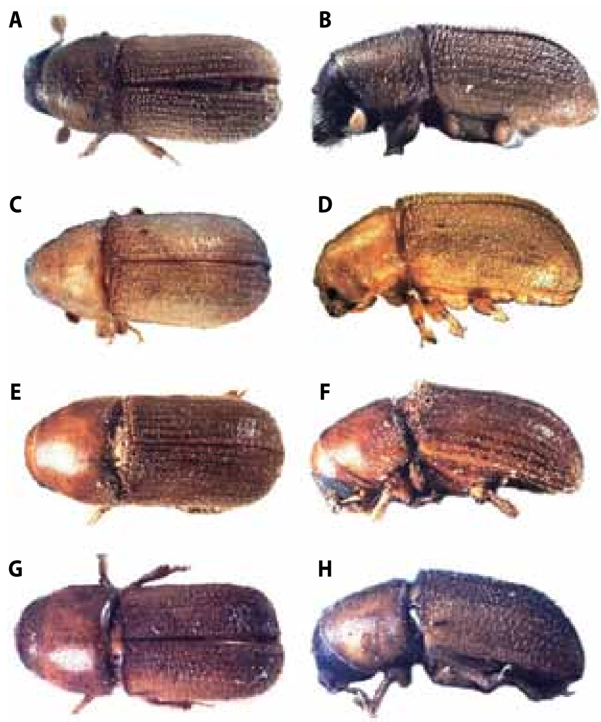

Figure 2. A and B: Dorsal and lateral view of *Polygraphus anogeissi* Wood. C and D: Dorsal and lateral view of *Polygraphus aterrimus* Strohmeyer. E and F: Dorsal and lateral view of *Polygraphus difficilis* Wood. G and H: Dorsal and lateral view of *Polygraphus longifolia* Stebbing

2. *Polygraphus aterrimus* Strohmeyer, 1908a: 69 (Fig. 2C, D)
   Distribution: India (Himachal Pradesh, Punjab, Uttarakhand); Thailand (Maiti and Saha 2009).
   Hosts: *Abies spectabilis* (D.Don) Mirb. (= A. webbiana), Cedrus deodara (Roxb. ex Lamb.) G.Don, *Pinus* roxburghii Sarg. and *Pinus wallichiana* (= *P. excelsa* = *P. griffithii*) (Pinaceae).
   Biology: Unknown.
3. *Polygraphus difficilis* Wood 1988b: 194 (Fig. 2E, F)
   (Beeson 1941 referred to the species as *Urdugraphus difficilis* nomen nudum [Wood and Bright 1992]).

Distribution: India (Himachal Pradesh, Uttarakhand, Punjab).

Host: *Pinus roxburghii* (Pinaceae) (Wood and Bright 1992).

Biology: Unknown.

4. *Polygraphus longifolia* Stebbing, 1903: 255 (Fig. 2G, H)

(Synonym; *Polygraphus himalayensis* Stebbing, 1908b: 8)

Distribution: India (Himachal Pradesh, Uttarakhand).

Host: *Pinus roxburghii* (Pinaceae).

Biology: Beeson (1961) reported some information on the biology and gallery system of the species. He suggested that the species only attacked newly killed trees. However, Singh et al. (2001) reported some economic damage to *P. roxburghii* in India (Haryana).

5. *Polygraphus major* Stebbing, 1903: 234 (Fig. 3A, B)

Distribution: Bhutan, China (Xizang), India (Himachal Pradesh; Punjab and Uttarakhand), Nepal (Maiti and Saha 2009).

New records: India: Kashmir; Anantnag district, Nowpora village (33°61.078' N, 075°18.700' E, elevation 1,804 m), coll. A.L. Khanday, 6.03.2015. Anantnag district, Bindoo Zalan Gam village (33°35.105' N, 75°18.288' E, elev. 1938 m), coll. A.L. Khanday, 17.04.2016. Bandipora district, Bonakoot village (34°29.320' N, 74°40.570' E, elev. 1790 m), coll. A.L. Khanday, 6.06.2016. Bandipora district, Mustan (34°37.728' N, 074°50.378' E, elevation 2563 m), coll. A.L. Khanday, 10.04.2016. Baramulla district, Boniyar village (34°07.405' N, 74°10.718' E, elev. 1955 m), coll. A.L. Khanday, 19.07.2016. Budgam district, Doodhpathri (33°52.897' N, 74°37.733' E, elev. 2673 m), coll. A.L. Khanday, 7.07.2016. Ganderbal district, Mammer village (34°13.675' N, 74°59.613' E, elev. 1906 m), coll. A.L. Khanday, 2.04.2017. Kulgam district, Guddar village (33°37.427' N, 74°59.734' E, 1835 m), coll. A. L. Khanday,16.07.2017. Kupwara district, Diwar lolab (34°26.654' N, 74°26.874' E, 1773 m), coll. A.L. Khanday, 16.08.2016. Pulwama district, Shikaargah village (33°53.867' N, 75°08.873' E, 1754 m), coll. A.L. Khanday, 16.09.2017. Shopian district, Kellar village (33°47.040' N, 74°46.233' E, 2127 m), coll. A.L. Khanday, 22.05.2016. Srinagar district, Dachigam (34°08.754' N, 74°55.604' E, 1709 m), coll. A.L. Khanday, 29.04.2017.

Hosts: *Abies fabri* (Mast.) Craib, *Cedrus deodara*, *Picea smithiana* (Wall.) Boiss., *Pinus gerardiana* Wall. ex D. Don and *Pinus wallichiana* (Pinaceae) (Wood and Bright 1992).

Biology: This beetle pest preferentially attacks *Pinus wallichiana* (Wood and Bright 1992). Stebbing (1914) and Beeson (1961) provide some biological information under field conditions.

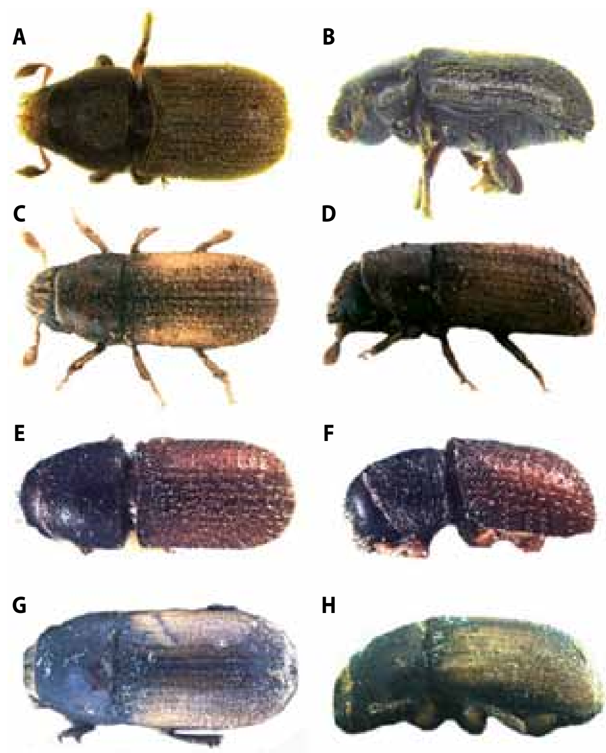

Figure 3. A and B: Dorsal and lateral view of *Polygraphus major* Stebbing. C and D: Dorsal and lateral view of *Polygraphus pini* Stebbing. E and F: Dorsal and lateral view of *Polygraphus setosus* Schedl. G and H: Dorsal and lateral view of *Polygraphus trenchi* Stebbing

6. *Polygraphus pini* Stebbing, 1914: 522 (Fig. 3C, D)

(Synonym; *Polygraphus minor* Stebbing, 1903a: 234 [preoccupied by Lindemann, 1875:242]).

Distribution: India (Himachal Pradesh, Kashmir, Punjab, Uttarakhand).

Hosts: *Abies spectabilis*, *Cedrus deodara*, *Picea smithiana*, *Pinus wallichiana* (Pinaceae) (Wood and Bright 1992).

Biology: Most commonly associated with *Pinus wallichiana*. Stebbing (1914) and Beeson (1961) described some aspects of its life history. The beetles breed in the trunk of trees as well as in smaller branches.

7. *Polygraphus setosus* Schedl, 1979b: 128 (Fig. 3E, F)

Distribution: Himachal Pradesh, Punjab and Uttar Pradesh.

Hosts: *Pinus wallichiana* and *P. roxburghii* (Pinaceae) (Wood and Bright 1992).

Biology: Unknown.

8. *Polygraphus trenchi* Stebbing, 1905: 6 (Fig. 3G, H)

Distribution: India (Punjab), Pakistan.

Host: *Pinus gerardiana* (Pinaceae).

Biology: Stebbing (1914) reported some bionomic aspects of this species.

Key to the Indian species of genus *Polygraphus* Erichson, 1836

1. Body length more than 3.00 mm 2
2. Body length less than 3.00 mm 4
   Elytra 2 × as long as wide; antennal club obtuse . . . . *aterrimus* (Fig. 2C, D)
   Elytra less than 2× as long as wide; antennal club acute 3
3. Posterior margin of frontal surface truncate with dense hairs; prothorax with distinct, raised medial longitudinal carina; legs brown to black . . . . . . *P. major* (Fig. 3A, B)
   Posterior margin of frontal surface not truncate with a pair of tuft hairs; prothorax without, raised medial longitudinal carina; legs yellow . . . . *P. trenchi* (Fig. 3G, H)
4. Frons transversely impressed with a pair of distinct transverse tubercles in both sexes; antennal club obtuse . . . . *P. anogeissi* (Fig. 2A, B)
   Frons not transversely impressed, without a pair of transverse tubercles; antennal club variable 5
5. Elytral interstriae with a row of widely spaced, erect, longer setae; elytra 1.6× as long as its maximum width . . . . *P. setosus* (Fig. 3E, F)
   Elytral interstriae without a row of longer, erect setae; elytra more than 1.6× as long as its maximum width 6
6. Frons with curled tuft of hairs in females; elytra black, 1.9× as long as its maximum width . . . . *P. pini* (Fig. 3C, D)
   Frons without curled tuft of hairs in females, but with long hairs; elytra brown, 1.3–1.55× as long as its maximum width 7
7. Elytral disc and declivity indistinctly roughened; head black; antennal club not ovate . . . . *P. longifolia* (Fig. 2G, H)
   Elytral disc and declivity smooth; head reddish brown; antennal club ovate. . . . . *P. difficilis* (Fig. 2E, F)

Bioecology of *Polygraphus major* Stebbing, 1903

Mating behaviour and gallery pattern

The mating behaviour observed for *P. major* in the field was similar to harem polygynous congeners such as: *P. poligraphus*, *P. subopacus* Thomson and *P. rufipennis* Kirby, where the male beetle bores the initial gallery known as pairing-chamber (Fig. 4A) (Stebbing 1914; Simpson 1929; Kirkendall 1983). Many female beetles (2–5) successively enter the pairing–chamber through the tunnel made by the male, and after copulation, proceed to excavate their egg galleries (Fig. 4C). Each of the females makes one gallery and each takes a different direction. The gallery patterns are shown in Figures 4A, B.

The average length of maternal galleries of *P. major* is 5.61 (±1.91 SD) cm (Tab. 1). In contrast, the average length of *P. poligraphus* maternal galleries is only 30 mm Lekander (1959). In the monogynous species *P. proximus*, the total length of the galleries excavated by one female is about 5 cm. Similar to other species of this genus, the pattern of maternal galleries was found to be irregular and could be of different shapes (Lekander 1959; Lieutier et al. 2004; Kerchev 2014). Larval galleries radiate out from the maternal galleries (Fig. 4D). The average length of larval galleries meas-

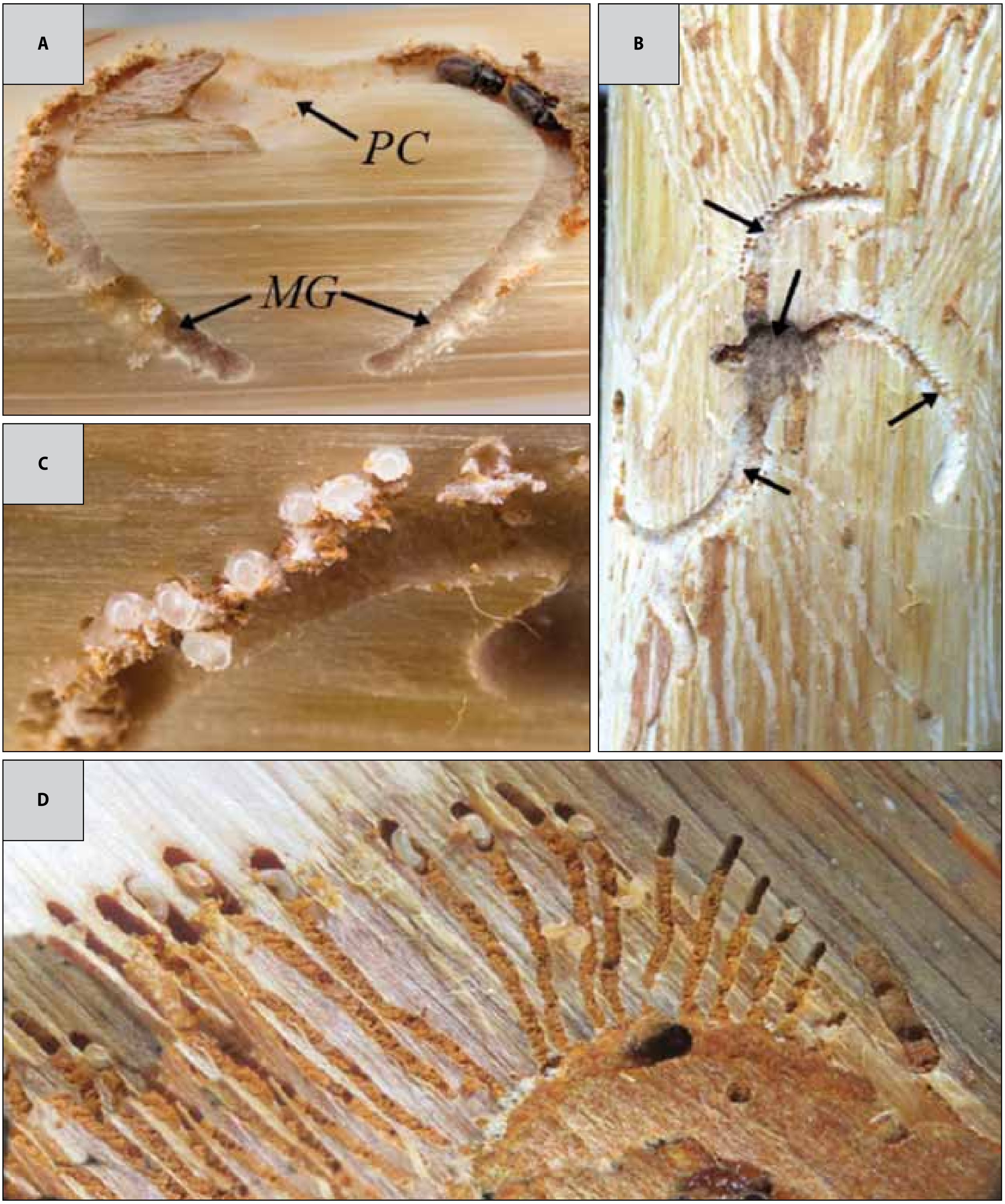

Figure 4. Gallery pattern of *Polygraphus major*. A, B: maternal galleries; C: egg deposition; D: larval galleries [*PC* – pairing chamber, *MG* – maternal gallery]

ures 2.63 (± 0.34 SD) cm in length. The larval tunnels are initially perpendicular to the maternal gallery, then radiate in different directions and can intersect. These tunnels are closely packed with the wood excreta passed out by the larvae in feeding.

Table 1. Measurement of gallery length

Variable	N	Mean	Standard Deviation
Maternal gallery length	30	5.61	1.91
Larval gallery length	30	2.63	0.34

N = Number of observations (Length in centimetre [cm])

Data based on the length of the maternal gallery and the numbers of eggs deposited indicate that there was a positive correlation between the two variables (Fig. 5). The number of eggs increases linearly with maternal gallery length. In trees with thick phloem, beetles possibly lay more eggs per centimetre of the maternal gallery, experience less intraspecific competition among larval stages, and thus, produce larger brood beetles compared to bark beetles in trees with thin phloem (Amman and Cole 1983). The decline of maternal gallery length and oviposition with increasing attack density is partially due to intraspecific competition. There are reports of intraspecific competition at high breeding densities, which results in shorter maternal galleries, and thus, reduced oviposition (Schroeder and Weslien 1994). It has been shown that offspring number per female decreases at higher attack densities (Anderbrant et al. 1985).

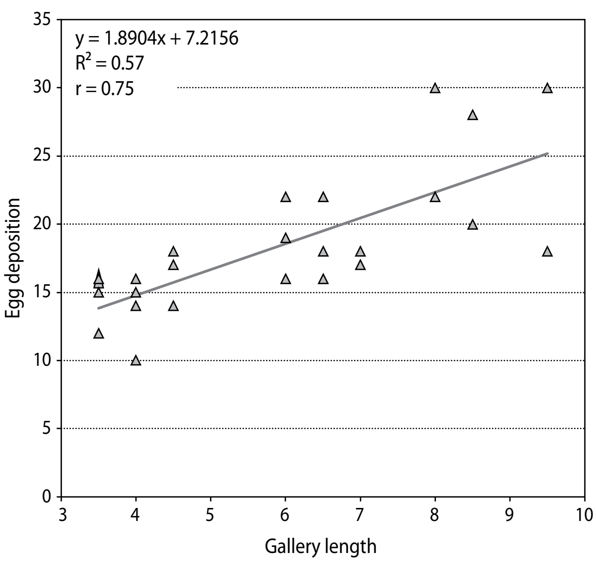

Figure 5. Relationship between the length of maternal galleries (cm) and eggs per gallery in *P. major*

Life cycle

Egg stage (Fig. 6A). After copulation, each of the female bores out her tunnel, gnaws out little notches at the side and places an egg in each notch. These notches are not made so symmetrically as in case of the monogamous bark beetle species, there being usually more on one side than on the other. On an average, 32.16 (±5.53 SD) eggs were laid per female (Tab. 2). The eggs were about 0.57 (± 0.04 SD) mm in length and 0.34 (±0.03 SD) mm in width (Tab. 2). The eggs hatched after an incubation period of 5–11 days (Tab. 3). The duration of development depends on the environment conditions, but apparently, the average values are close to other representatives of scolytine species (Kerchev 2014; Khanday and Buhroo 2015).

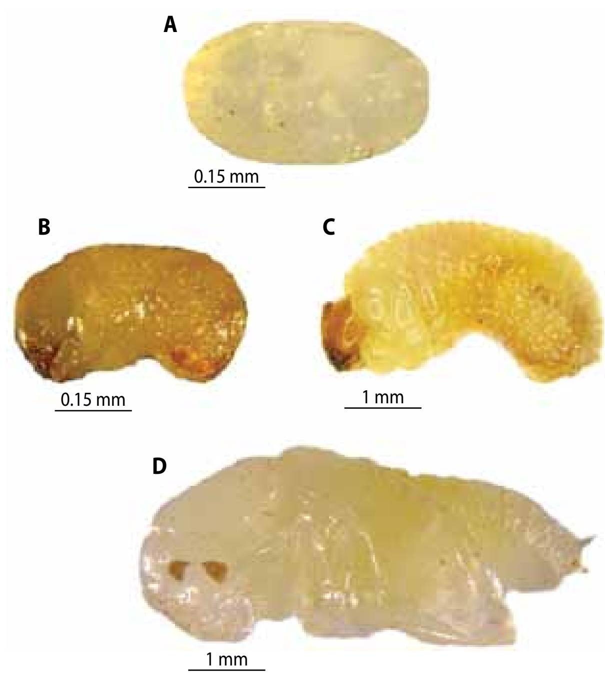

Figure 6. Life stages of *Polygraphus major.* A: Egg stage; B and C: 1st and 5th Instars; D: Pupal stage

Larval stage (Fig. 6B–C). The larva on hatching was apodous, wrinkled, minute, cylindrical and creamy white in colour. The mature larvae reached an average

Table 2. Egg deposition and measurement of developmental stages of *P. major*

Variable	N	Mean	Standard Deviation
Egg deposition	30	32.16	5.53
Egg length	30	0.57	0.04
Egg width	30	0.34	0.03
Larval length	30	3.51	0.32
Larval width	30	0.86	0.05
Pupal length	30	3.08	0.16
Pupal width	30	0.83	0.08
Female length	30	3.16	0.15
Female width	30	0.82	0.10
Male length	30	3.20	0.13
Male width	30	0.81	0.08

N = Number of observations (Length and width in millimetre [mm])

Table 3. Developmental duration of *P. major*

Duration of generations (days)				
Stage	P. major			
	1st generation	2nd generation	3rd generation	4th generation
Egg	7–10	6–9	5–10	8–11
Larva	25–30	23–27	24–30	25–30
Pupa	15–25	14–20	14–22	16–23
Adult	40–45	40–46	38–45	125–145
Total	87–110	83–102	81–107	174–209

length of 3.51 (± 0.32 SD) mm and width of 0.86 (± 0.05 SD) mm (Tab. 2). On the basis of the data recorded in the field, five larval instars were observed (Tab. 4). Recently, Khanday and Buhroo (2015) recorded five larval instars for the elm bark beetle, *Scolytus kashmirensis*. However, Lekander (1959) reported only three instars for *P. poligraphus*. The expected head capsule width of each instar was also determined by Dyar's ratio (Dyar 1890), which states that the growth ratio remains constant between the molts. Each instar was progressively longer (length) than the preceding instar. Development from hatching to the prepupal larvae took 23–30 days (Tab. 3).

Pupal stage (Fig. 6D). Pupation took place at the end of the larval galleries in pupal chambers. The pupae were soft and creamy white with 3.08 (± 0.16 SD) mm in length and 0.83 (± 0.08 SD) mm in width (Tab. 2). The pupal stage lasted for 14–25 days (Tab. 3). Pupal chambers were sunk into sapwood as in *P. proximus* (Kerchev 2014). The adults emerged from the pupal chamber by tunnelling straight through the bark over it. After emergence, adults flew to the suitable trees to produce the next generation.

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

Mean observed head capsule width of 1st instar larva (N = 30) = 0.26

Mean observed head capsule width of 2nd instar larva (N = 30) = 0.36

$$\text{Growth ratio (Dyar's ratio)} = \frac{\text{Head capsule width of 2nd instar larva}}{\text{Head capsule width of 1st instar larva}} = 0.36/0.26 = 1.38$$

Mean observed head capsule width of 5th instar (mature larvae) (N = 30) = 0.82

Larval instars	Head capsule width (mm)			Difference (mm)
	Observed (Mean ± SD)	Range	Expected[a]	
I	0.26 ± 0.02	0.10	0.26	0.00
II	0.36 ± 0.03	0.12	0.35	0.01
III	0.50 ± 0.03	0.12	0.49	0.01
IV	0.63 ± 0.04	0.11	0.69	–0.06
V	0.82 ± 0.03	0.13	0.86	–0.04

[a] Expected head capsule width established by Dyar's ratio (1.38). 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 the expected head capsule width of 3rd instar and so on.

Adult stage (Fig. 3A, B). The adult females have an average body length of 3.16 (± 0.15 SD) mm and 0.82 (± 0.10 SD) mm width and male body length is 3.20 (± 0.13 SD) mm and width is 0.81 (± 0.08 SD) mm (Tab. 3). The adults lived for 38–46 days (Tab. 3).

Seasonal incidence

During the present study, freshly cut trap logs were used to observe the activity pattern of *P. major* for a period of two years under both field and laboratory conditions. Earlier, trap logs were proven to be an efficient

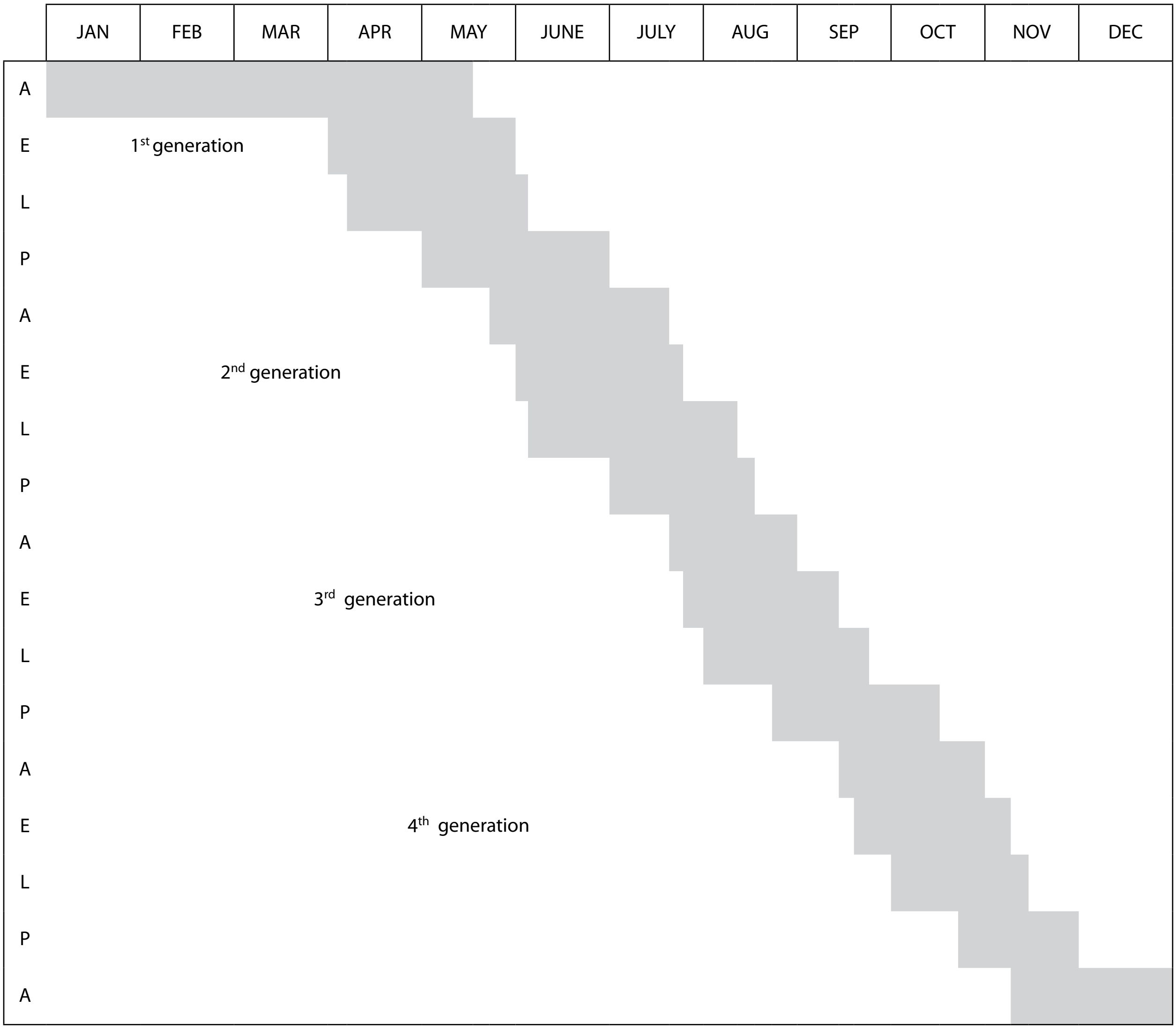

Figure 7. Seasonal distribution of *Polygraphus major* (A – adult, E – egg, L – larva, P – pupa)

method to monitor the seasonal activity of *Scolytus* beetles (Beaver 1967; Buhroo and Lakatos 2007; Khanday and Buhroo 2015). Visual observations by dissecting the bark showed that *P. major* overwintered in adult stages in their respective galleries from the last week of October. The adults remained inactive throughout the winter but resumed their activity from the second week of March. In the present study, we are reporting that *P. major* produced four generations per year in Kashmir (Fig. 7). The generations were also found to overlap to some extent; however, further studies are warranted in this aspect, especially under field conditions. The adults lived for 38–46 days (Tab. 3). The first generation developed from the first week of April to July having a total life span of 87–110 days, the second generation extended from the first week of June to August having a total life span of 83–102 days and the third generation from the last week of July to October having a total life span of 81–107 days, while the overwintering generation took 174–209 days (Tab. 3) and extended from September to May of the following year. Laboratory observations also confirmed four generations with little difference in the development process and duration of insect stages.

The question of the number of generations produced per year by representatives of *Polygraphus* is very controversial. The main difficulty is caused by overwintering of larvae with adults, which ultimately leads to an extended period of dispersal flight and mixing of stages (Lekander 1959; Kerchev 2014). Earlier, Stebbing (1914) reported that the exact time of appearance of the various life stages of *P. major*, and the number of life-cycles passed through in a year, depend to a considerable extent on elevation and climatic conditions. In our study, the developmental durations and generations of, *P. major* do not coincide with other scolytine beetles (Beaver 1967; Youssef et al. 2006; Buhroo and Lakatos 2007; Masood et al. 2009). The developmental stages of *P. major* were shorter in summer generations than in spring and autumn, which seems to be an adaption of this beetle pest to the dry seasons. Similar results were obtained by Levieux et al. (1985) on *Dendroctonus micans* (Kugelann); that larval developmental stages at higher temperatures (24°C) are shorter (9 days) than at low temperatures (31 days at 14°C). Earlier, Bentz et al. (1991) also reported that the development of *D. ponderosae* Hopkins larvae increases with increasing temperature but rates seem to be instar specific, which helps the species to synchronize emergence and mass attack, and entry into winter at the proper time.

In the present study, we found that the adults of *P. major* are more active during day time and tunnels into the host tree on almost any side is contrary to other scolytine beetles that are sensitive to sunlight, and thus, the shaded side remain usually uninfected (Stebbing 1914). The beetles attack both felled green trees and green branches of the host tree (*P. wallichiana*), and are not so susceptible to the rapid drying of host material, as is the case of *Scolytus kashmirensis* (Buhroo and Khanday 2015). At times, this can necessitate control and management strategies (Khanday et al. 2018a, b, 2019). The results of the present study throw light on various aspects of the bark beetle pest (*P. major)* and its susceptibility towards host tree and provides a basis for future studies of the Himalayan bark beetle fauna and their economic importance in forestry, timber production and crop tree plantations.

Acknowledgements

We would like to acknowledge Science and Engineering Research Board (SERB), Govt. of India, New Delhi for providing financial assistance under their project number EMR/2015/000888. We sincerely thank Roger A. Beaver for his reviews on the earlier drafts of the manuscript especially in the taxonomic part. Finally, we are grateful to the reviewers of our manuscript for their valuable comments.

Conflict of interest

The authors declare that they have no conflict of interest.

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