On the Biology of the Bark Beetle *Scolytus nitidus* Schedl (Coleoptera: Scolytidae) Attacking Apple Orchards

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Abstract –– The biological characters of *Scolytus nitidus* were investigated both in the field and in the laboratory as well. This common shot-hole borer overwinters in larval stage on apple trees in Kashmir. After emergence the adults fly to suitable trees and undergo maturation feeding for 4-6 days. The copulation takes place at the entrance hole. The maternal gallery is one armed longitudinal, in average 4.6 cm long. The female lays 52 eggs on an average. The eggs hatch in 5 to 7 days. The larvae have 5 instars and complete their development in 38 to 50 days constructing larval galleries 5-8 cm in length. The larvae pupate for 6-18 days and finally the adults emerge to attack new suitable trees. The adults live for 45-60 days and the total life-span of this species ranges from 97 to 124 days. The seasonal distribution of various life stages and the number of generations were also recorded.

Bionomics / *Scolytus nitidus* / Scolytidae / apple trees

Kivonat – Az almafán károsító *Scolytus nitidus* Schedl (Coleoptera: Scolytidae) biológiája. Egy, az almafán károsító szúfaj, a *Scolytus nitidus* biológiai jellemzőit vizsgáltuk terepi és laboratóriumi körülmények között. A faj India Kasmír tartományában igen gyakori. Lárva alakban telel át gazdanövényén. A tavaszi kibújás után a nemzők megfelelő gazdanövényt keresnek és 4-6 napon át érési rágást végeznek. Ezt követi a párosodás. Az anyamenet egykarú, hosszirányú, átlagosan 4,6 cm hosszúságú. A nőstény bogár átlagosan 52 tojást rak le. A tojásból 5-7 nap múlva bújnak ki az álcák. Az álcastádium 38-50 napig tart, mialatt az ötször vedlő álcák 5-8 cm hosszúságú álcamenetet készítenek. A bábnyugalom 6-18 napig tart, amely után a frissen kifejlődő nemzők kirajzanak és költésre alkalmas fát keresnek. A nemzők 45-60 napig élnek, míg a faj teljes élettartama 97-124 nap közötti. A különböző fejlődési alakok pontos megjelenési idejét, valamint a generációk számát is meghatároztuk.

Biológia / *Scolytus nitidus* / Scolytidae / Malus domestica

1 INTRODUCTION

The scolytids are of great economic importance to forestry and horticulture in the temperate climatic zones including the valley of Kashmir. *Scolytus nitidus* Schedl is a predominant shot-hole borer which has caused considerable losses to fruit trees in the fruit growing areas of the valley since 1961 (Malik 1966) and its population has increased enormously during the past decade due to favourable environmental conditions, mainly, drought. On an average 5-10 per cent apple trees

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get damaged annually by the attack of this bark beetle species, which can increase upto 44 per cent in the mismanaged orchards during dry and hot weather conditions. The main damage to the tree is caused by adults entering the main branches and twigs during maturation feeding. After beetle attack, the infested branches or sometimes the entire tree may be killed during the establishment of the mother and larval galleries.

Scolytus nitidus is distributed in the Himachal Pradesh, Kashmir & Uttar Pradesh of India and Xizang (Tibet) of China on host trees – *Juglans regia, Prunus armeniaca, Pyrus malus & Cotoneaster microphylla* (Wood and Bright 1992). There is no systematic information on the various aspects of *S. nitidus* on temperate fruit tree species in Indian subcontinent except few reports of its occurrence in Kashmir (Beeson 1941, Malik 1966, Ahmad and Bhat 1987). The life history and behaviour of *S. nitidus* are complex and there is no detailed account of its biology since its taxonomic description by Schedl (1957).

Therefore, the objective of the present study was to investigate the detailed biology of *S. nitidus* in Kashmir apple orchards.

2 MATERIALS AND METHODS

2.1 Field studies

The biological data were obtained mainly from the study areas at Hazratbal, district Srinagar and from Bagh in Bandipora district consisting mainly apple trees. At both places, the orchards were having 20-45 years old trees with many cultivars like Red Delicious, Royal Delicious, Golden Delicious, American Apirouge, White Dotted Red, Benoni, Coxe's Organge Pippen, Lal Farosh, Razakh War, Chamura, Saharunpuri, Red Gold, Crimsen etc. Some felling had been done in the orchards in the previous year to initiate infestation by *S. nitidus.* In the following year trap logs were also put out as per the methods of Beaver (1967). These trap logs were cut periodically from April to September each year from 2000 to 2002. Observations of the various life stages were made once or twice weekly throughout the season on the trap logs and other infested branches of standing trees. 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.

At the Bandipora experimental site the entrance holes, that the newly emerged beetles started grooving, were marked on one main branch and some twigs of a declining apple tree (Red Delicious) during April-May. After the marking dates, 10 beetle entries were dissected each day and examined for eggs to determine female maturation feeding period.

2.2 Laboratory rearing

Three sizes of wooden rearing boxes of similar design were available for use in the laboratory. The boxes were $30 \times 30 \times 30$ cm, $46 \times 46 \times 46$ cm and $25 \times 30 \times 36$ cm in size having two screened, cross ventilated and three glass faces to facilitate entry of light. The branches naturally infested with *S. nitidus* were cut and placed in the rearing boxes. Fresh branches of 20-30 cm long and 2-4 cm in diameter were carefully removed from standing trees and their cut ends were sealed with wax. These uninfested branches were also put in these rearing boxes 10-15 days before adult emergence in order to induce fresh attack on them. This enabled the continuous rearing and examination of beetle development.

Few infested branches were also debarked regularly to study the various stages of the beetle under the bark. Characters of the different developmental stages including egg, larva, pupa and adult were recorded. Larval instars were separated by head capsule measurements (Beaver 1967). Mating behaviour, oviposition and gallery systems were also studied. Thus, developmental processes and durations of the pest's life stages were recorded and compared with the field results.

2.3 Scanning electron microscopy

Morphological characters were determined using scanning electron microscopy. Specimens were first placed in buffered glutaraldehyde (2.5%) for 2 hours followed by buffer washing for overnight. After this the specimens were treated with osmium tetroxide (1.0%) and then dehydrated in different alcoholic concentrations. In the next step specimens were kept in α-amyl acetate for 10 minutes followed by *Critical Point Drying* for 25 minutes using CO_2. After 2 days of open drying the specimens were mounted on stubs and coated with gold using the *Vacuum Evaporator* (HITACHI, HUS-5GB). Electron micrographs were taken with a S-3000H *Scanning Electron Microscope* (HITACHI, Japan).

3 RESULTS AND DISCUSSION

3.1 Mating behaviour

After host tree selection, the female of *S. nitidus* started to bore a small shot-hole on the bark of a declining branch. As soon as few beetles attacked, more and more flying adults of both sexes were attracted soon. The male was observed to but with his head against the abdomen of the female in the gallery a few times and then quickly turned round over the entry hole and copulation followed. Mating lasted for 30 to 90 seconds with an average of 57 seconds. However, mating lasts for 10-30 seconds in case of *S. scolytus* on elm trees (Beaver 1967). A female got mated several times by the same male or different males.

3.2 Maturation feeding

Bark dissections for female maturation feeding *(Figure 1)* showed that no eggs were collected from beetle entries on 1st and 2nd day; only 3/10 from 3-day-old entries yielded eggs; 6/10 from 4-day-old and 5-day-old entries contained eggs; while 7/10 from 6-day-old entries contained eggs; but all the 10 of 7-day-old beetle entries contained eggs. This indicated that newly emerged females mostly fed and oviposited in 4 to 6 days in the field. Maturation feeding for *S. mali* on apple trees is also completed in 4 to 6 days (Rudinsky et al. 1978). The successful maturation feeding occurred mostly on weakened trees or those with some dead branches. The feeding sites were then continued into the mother galleries.

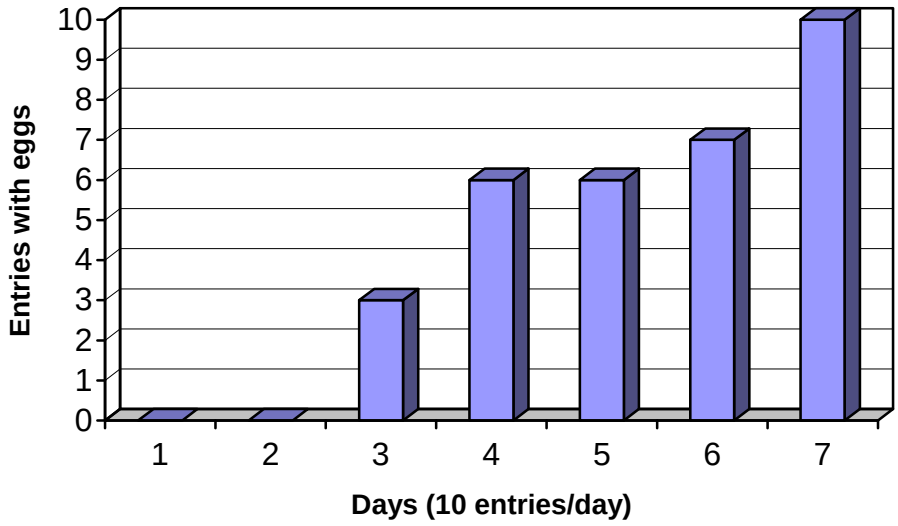

Figure 1. Female maturation period of S. nitidus

3.3 Gallery patterns

Mother gallery was made in an upward direction along the long axis of the attacked branch from which 50 to 70 larval galleries radiated, penetrating the inner bark and the sapwood surface. The vertical mother galleries ranged from 2.5 to 7.5 cm in length with a mean of 4.6 (± 1.45 SD) cm *(Table 1).* The larval galleries were measured to be 3-8 cm in length with a mean of 6.5 (± 1.41 SD) cm *(Table 1).* The mean difference in length between the mother gallery and larval gallery was found to be significant (P-value = 0.005). The mother galleries were made at equal distances from each other on the infested surface of the tree. The infested trunks and branches had thousands of exit-holes or shot-holes on the entire bark surface after the complete development.

Table 1. Measurement for length of gallery systems

Variable	N	Mean (mm)	SD (mm)	SEM (mm)	Minimum (mm)	Maximum (mm)
Mother gallery	12	4.625	1.448	0.418	2.500	7.500
Larval gallery	12	6.450	1.411	0.407	3.000	8.000

N= Number of observations

3.4 Life history

Bark dissections showed that eggs were deposited in small individual chambers on both sides of the mother gallery at regular distances throughout its length. On an average 52 (± 6.81 SD) eggs were laid per female, approximately 26 on each side of the mother gallery *(Table 2).* Mother galleries were completed in 10-15 days but thereafter the female remained in the tunnel until most of the larvae had developed. She finally died in the entrance hole. The egg is slightly oval, shining, pale white and minute about 0.64 (± 0.10 SD) mm in length and 0.48 (± 0.07 SD) mm in width *(Table 3).* The eggs in the egg niches were covered by the boring dust.

Table 2. Egg deposition by S. nitidus

Variable	N	Mean	SD	SEM	Minimum	Maximum
Eggs	6	52.00	6.81	2.78	40.00	60.00

N= Number of observations

Table 3. Measurements for developmental stages of S. nitidus

Variable	N	Mean (mm)	SD (mm)	SEM (mm)	Min. (mm)	Max. (mm)
Egg length	4	0.6449	0.0962	0.0481	0.5390	0.7700
Egg width	4	0.4813	0.0667	0.0333	0.4235	0.5775
Early larval length	4	0.7508	0.1618	0.0809	0.5775	0.9625
Early larval width	4	0.4524	0.0910	0.0455	0.3850	0.5775
Late larval length	3	5.7750	0.2700	0.1560	5.4670	5.9680
Late larval width	3	1.8865	0.1019	0.0588	1.8095	2.0020
Pupal length	4	4.0521	0.1584	0.0792	3.8500	4.2350
Pupal width	4	1.5978	0.0497	0.0249	1.5400	1.6555
Adult length	3	4.0040	0.1388	0.0801	3.8500	4.1195
Adult width	3	1.6812	0.0588	0.0340	1.6170	1.7325

N= Number of observations

The eggs hatched after an incubation period of 5-7 days *(Table 4).* The larva on hatching was a minute white dot almost motionless, measuring 0.75 (± 0.16 SD) mm in length and 0.45 (± 0.09 SD) mm in width *(Table 3).* As soon as the feeding started the larva became curved, legless grub *(Figure 2)* and light creamy in colour. A full grown larva was 5.77 (± 0.27 SD) mm long and 1.89 (± 0.10 SD) mm wide *(Table 3).* The head capsule measurements *(Figure 3)* revealed that the larva passed through 5 instars before changing into pupa. The larval phase extended for 38-50 days *(Table 4).*

Figure 2. Larva of S. nitidus

Table 4. Developmental durations of S. nitidus on apple during 1999-2002

Developmental stage	Duration of generations (days)		
	1st	2nd	3rd (partial)
Egg	6-7	5-6	6
Larva	38-43	47-50	184-200 (overwintering)
Pupa	8-10	6-8	14-18
Adult	45-55	50-60	45-55
Total	97-115	108-124	249-279

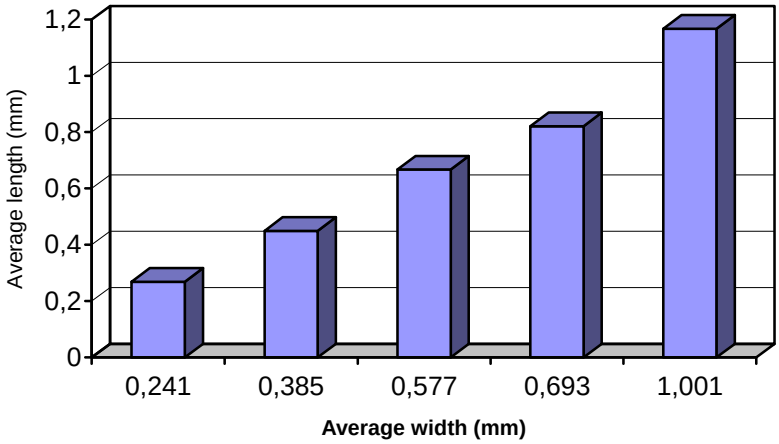

Figure 3. Head capsule measurements for different larval instars of S. nitidus

The pupation took place at the ends of the larval galleries in pupal cells. The pupa *(Figure 4)* was soft, white, averaging 4.05 (±0.16 SD) mm in length and 1.60 (± 0.05 SD) mm in width *(Table 3).* The pupal stage lasted for 6-18 days *(Table 4).*

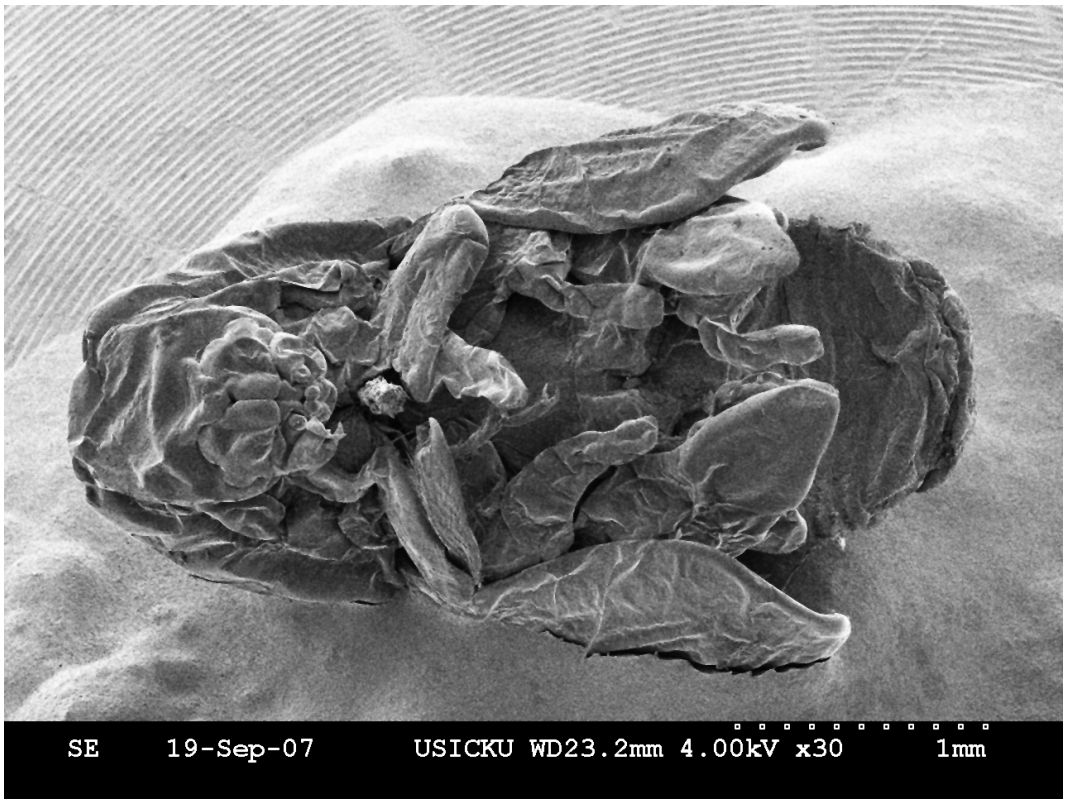

Figure 4. Pupa of S. nitidus

The adult emerged from the pupal chamber by tunnelling straight through the bark over it. After emergence, adults flew to the crown of other suitable trees to produce the next generation. The cylindrical adult *(Figure 5, 6)* averages 4.00 (± 0.14 SD) mm long and 1.68 (± 0.06 SD) mm wide *(Table 3).* It has a shining black pronotum and dark red brown elytra with declivous abdomen *(Figure 6).* The second abdominal sternite ascends abruptly

and perpendicularly with a minute pointed tubercle in the middle near its posterior border *(Figure 7).* The adults lived for 45-60 days *(Table 4).*

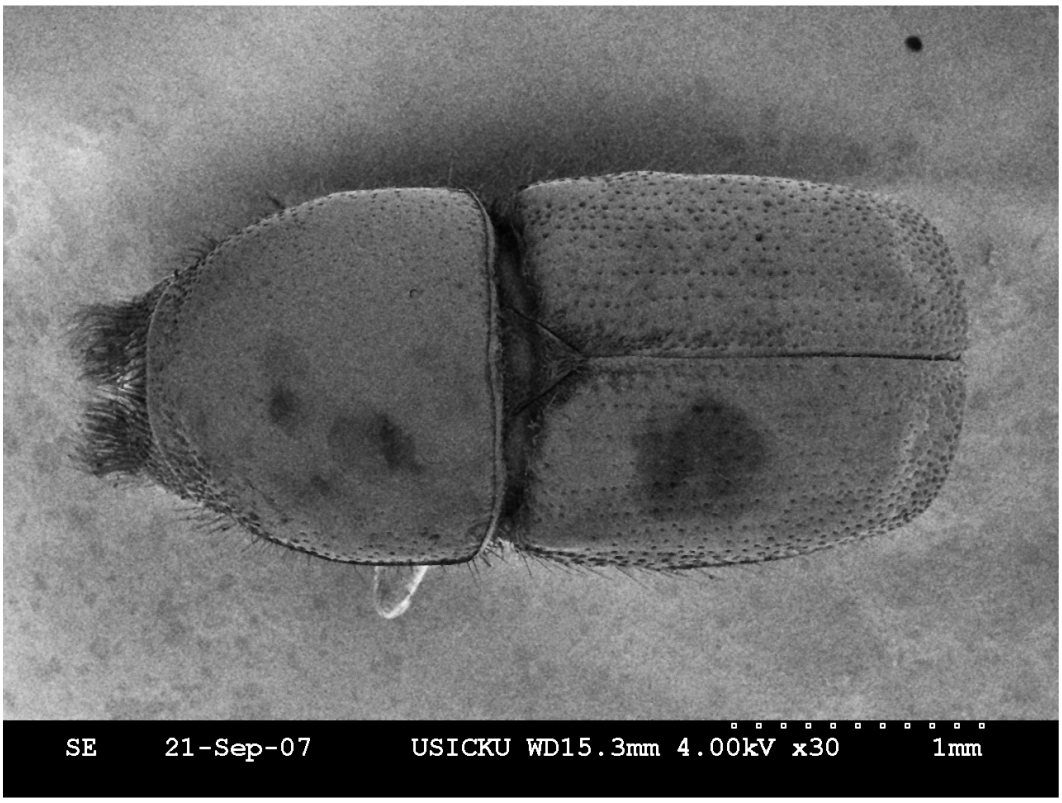

Figure 5. Adult of S. nitidus (dorsal view)

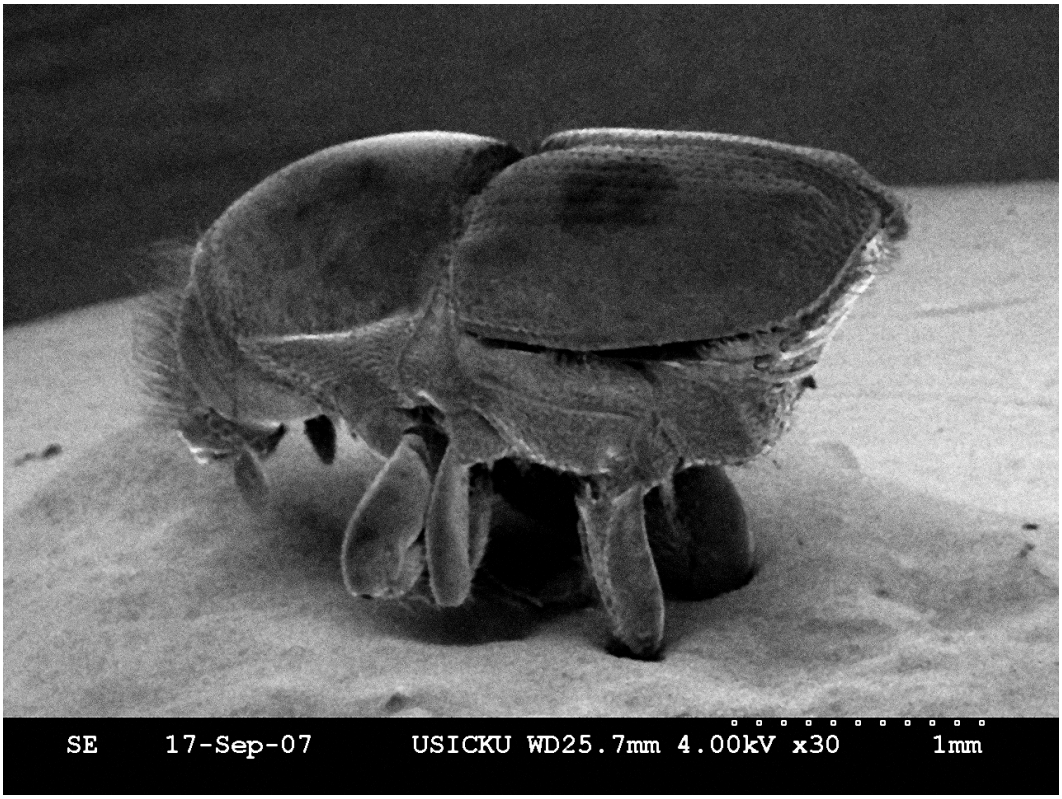

Figure 6. Adult of S. nitidus (lateral view)

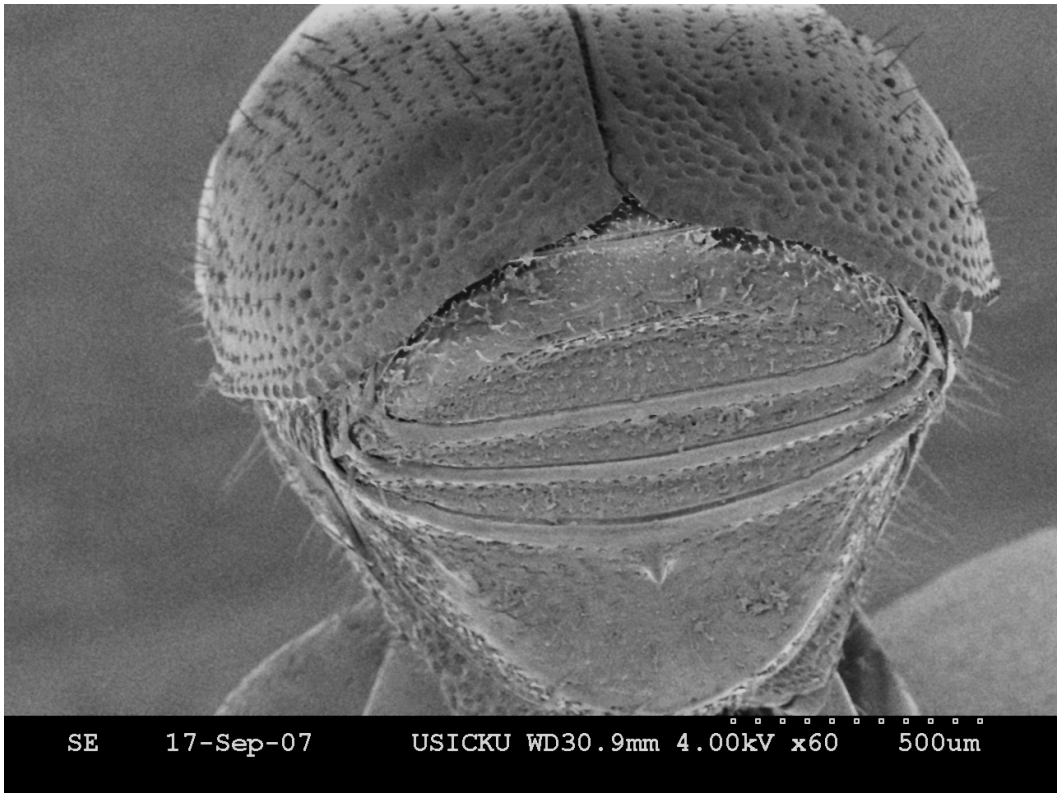

Figure 7. Adult of S. nitidus (abdominal view)

3.5 Seasonal distribution

The results of the present observations *(Figure 8)* showed that *S. nitidus* overwintered in all the larval stages at the ends of their respective galleries from the end of November. The larvae remained inactive throughout the winter which resumed their activity from the first week of March of the following year. Pupation started from the first week of April and the first swarming adults appeared from the third week of April. The species produced 3 generations (the last a partial one) per year in Kashmir *(Figure 8)*. The first generation lasted from the last week of April to July having a total life span of 97-115 days *(Table 4)*. The second generation occurred from the first week of July to the middle of October with a total life span of 108-124 days while the third overwintering generation took about 249-279 days and was extended from September to May of the following year. It was also observed *(Figure 8)* that some late hatching larvae of second generation could not complete their development but overwintered as such in the last week of November and succeeded in completing 2 generations (the 2^{nd} a partial one) only. There was a considerable overlap of 2^{nd} and 3^{rd} partial generations. The adults can be seen throughout the emergence period as the adults of one brood of *S. nitidus* have been reported to emerge for about 3 months (Buhroo et al. 2004). This can be due to different environmental factors, mainly, temperature to which the infested logs are exposed.

Two generations of *S. scolytus* on elm (Beaver 1967) and also of *S. mali* on apple (Rudinsky et al. 1978) were described under European conditions. Both these species overwinter in the larval stages. However, *S. amygdali* had 4 generations annually on fruit trees of Baluchistan (Janjua and Samuel 1941) and 5 generations per year on pear trees in Egypt (Kinawy et al. 1991). The developmental durations and generations of *S. nitidus* do not coincide with its related species worked out by other researchers (Beaver 1967, Janjua and Samuel 1941, Kinawy et al. 1991, Li-JiangLin et al. 1995, Mustaga 1991). The differences in the

life history of scolytid species can be explained by both species-specific variation and different environmental factors as well the variation of the biochemical composition of host trees.

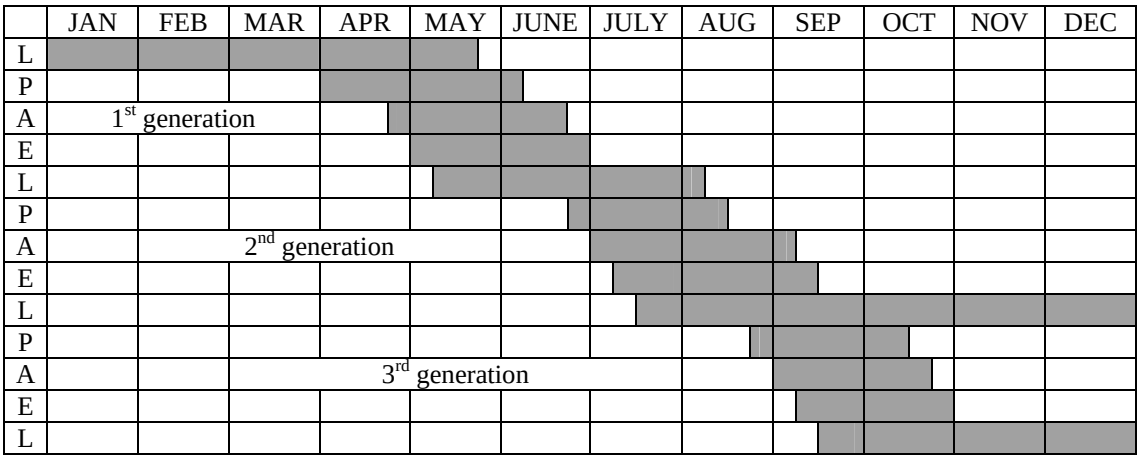

Figure 8. Seasonal distribution of S. nitidus on apple in Kashmir (E: egg, L: larva, P: pupa and A: adult)

4 CONCLUSIONS

The common shot-hole borer *Scolytus nitidus* overwinters in larval instars at the ends of their respective galleries. After emergence in April-May the adults fly to the crown of neighbouring trees and start maturation feeding for 4-6 days. Females start boring small entrance holes through the bark of declining branches to initiate copulation with the male. Mating takes 30 to 90 seconds. After being mated several times by one or more males at the entrance hole, the female constructs mother gallery in an upward direction along the long axis of the attacked branch. The maternal gallery, in average 4.6 cm long, is made through the phloem slightly grooving the sapwood surface. The female lays 52 eggs on an average. The eggs are placed in small individual chambers regularly spaced on both sides of the mother gallery and are surrounded by fine particles of wood-dust. The eggs hatch in 5-7 days and the larval galleries radiate more or less away from the mother gallery and almost the entire phloem surface is eaten. The lengths of the larval galleries vary from 3 to 8 cm. The head capsule measurements show 5 instars during the larval phase which extends from 38 to 50 days. The larvae pupate in pupal cells at the ends of their galleries. Pupal stage lasts for 6-18 days. The pupal cells are cut in the phloem and outer bark or sometimes even in the outer layers of the sapwood. The adults live for 45-60 days. This species has two complete and a 3rd partial generations per year in Kashmir.

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