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# Parasitoid complex and its efficacy in the management of shot-hole borer, *Scolytus nitidus* Schedl. (Coleoptera: Scolytidae) on apple trees

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**ABSTRACT:** Nine species of hymenopterous ectoparasitoids were found parasitizing the shot-hole borer, *Scolytus nitidus* Schedl. (Coleoptera: Scolytidae) on apple trees in Kashmir. The parasitoids with average coefficient of dominance were: *Macromesus harithus* Narendran (Pteromalidae) (72.70%), *Eurytoma morio* Boheman (Eurytomidae) (9.73%), *Spathius* sp. Nees (Braconidae) (8.74%), *Rhaphitelus maculatus* Walker (Pteromalidae) (6.67%) and *Cheiropachus quadrum* Fabricius (Pteromalidae) (2.15%). *Heydenia indica* Buhroo (Pteromalidae), *Eupelmus vindex* Erdos (Eupelmidae), *E. kashmiricus* Buhroo (Eupelmidae) and *E. valsus* Narendran (Eupelmidae) were occasional and arrived late in the development of their beetle host. The parasitization by *M. harithus* was the highest (52.88%) while the parasitization by other common parasitoids ranged from 1.75 to 7.08. The parasitoid maximum population was observed during April – May and August – September. Field releases of *M. harithus*, *Spathius* sp., *E. morio* and *C. quadrum* made at Bandipora for the management of *S. nitidus* increased the parasitism from 14.8 to 45.3 per cent, while at Naseem Bagh the increase in parasitism ranged from 15.4 to 41.5 per cent indicating the establishment of parasitoids on shot-hole borer.

**KEY WORDS:** Biological control, parasitism, parasitoid species, *Scolytus nitidus*, seasonal abundance

## INTRODUCTION

The shot-hole borer, *Scolytus nitidus* Schedl. (Coleoptera: Scolytidae) is among the key insect pests of temperate fruits in the Kashmir valley. The pest has caused considerable losses to fruit trees in the valley since 1961(Malik, 1966) and its population has increased enormously during the past few years due to drought. However, this scolytid is also subject to the attack of predaceous and parasitic insects throughout its development. The current interest in the development of management systems of this bark beetle requires information on its natural enemies and their role in pest population regulation. Hymenopterous parasitoids are among the most important natural enemies of bark beetles and have, therefore, received much attention (Bushing, 1965; Berisford *et al.*, 1970; Mendel and Halperin, 1981; Mendel, 1986a and 1986b; Mihajlovic *et al.*, 1994; Markovic and Stojanovic, 1996).

Documented literature on natural enemies of *Scolytus nitidus* from Kashmir is scanty, except for a recent report of its parasitoid complex (Buhroo *et al.*, 2001). Although some chalcidoid and other parasitoids of India and adjacent countries have been reported (Boucek *et al.*, 1979; Graham, 1969; Narendran and Anil, 1995) there is no substantial information on the establishment, host relationship, parasitism and seasonal incidence of *S. nitidus* parasitoids in temperate zones of India.

Therefore, the present study was conducted to generate the information on parasitoid complex of *S. nitidus* and their efficacy in the management of apple orchards in Kashmir.

## MATERIALS AND METHODS

The experiments were conducted at Bandipora and Naseem Bagh during 1999-2001 on the incidence of hymenopterous parasitoids of *Scolytus nitidus*. At both places, apple trees were 20-45 years old and infested with *S. nitidus*. These orchards had many cultivars of apple but Red Delicious was the most predominant. Besides few trees of pear, plum, peach, apricot and cherry were also scattered in the orchards.

### Laboratory studies

Three sizes of wooden emergence boxes 30 x 30 x 30 cm, 46 x 46 x 46 cm and 25 x 30 x 36 cm were used for laboratory studies. The boxes consisted of a wooden floor with two screen and three glass faces to facilitate cross ventilation and could be opened from one side. Cut shoots of apple trees naturally infested with *S. nitidus* and parasitoids were placed in emergence boxes to determine the species composition, emergence patterns, host relationship and seasonal history of major parasitoids along with their host. The occurrence of parasitoids was confirmed due to the presence of some exit holes made by the emerging parasitoids in the vicinity of the cut shoots and also few parasitoids being running on the surface of the bark. These sample shoots were cut in the orchards and brought to the laboratory from March to October during 1999 and 2000.

Fresh and unattacked shoots of 20-30 cm long were also cut and used to induce attack by the *Scolytus* beetles in the emergence boxes and were kept available for parasitization before emergence periods to check the number of parasitoid generations. Both cut ends of sample shoots were sealed with wax. Adult beetles and parasitoids in the boxes were collected daily and counted until the emergence stopped. The parasitoids were listed, their number, parasitized percentage and the proportion of a particular species out of the total (i.e., dominance coefficient) were determined. The coefficient of dominance of a parasitoid species was calculated as follows:

$$\text{Dominance coefficient (\%)} = \frac{\text{Number of a particular species}}{\text{Total no. of parasitoids collected}} \times 100$$

### Biological control methods

The parasitism rate of the most abundant parasitoid species on *Scolytus* beetle was studied under field conditions. The hymenopterous parasitoids *Macromesus harithus*, *Spathius* sp., *Eurytoma morio* and *Cheiropachus quadrum* were reared on *S. nitidus* established on apple shoots at room temperature (12-30°C) during summer and at 4±5° C during winter. Main branches and shoots infested with *S. nitidus* and containing parasitoids were collected from the field in October and November and were kept in rearing cages during winter to await parasitoid and host emergence. Throughout the emergence period freshly cut shoots were again introduced into rearing cabinets, which helped in rearing and multiplication of parasitoids.

The adult parasitoids of each species were collected alternately and counted. These adult parasitoids were released from May to October in two experimental orchards at Bandipora and Naseem Bagh during 1999 and 2000, respectively (Table 1). Pre-release counts of combined parasitism were taken in April on 4 cm$^2$ patches of 5 infested branches from different apple trees regardless of degree of beetle infestation.

These experimental orchards were divided into 6 sub-blocks consisting of 50 trees each and 1-3 days old adult parasitoids were released by using glass tubes on the central tree of each block. Glass tubes containing parasitoids were tied to an infested

**Table 1. Field release of *M. harithus, Spathius* sp., *E. morio and C. quadrum* on apple trees at Bandipora (in 1999) and Naseem Bagh (in 2000)**

| Period of release | No. of releases | | No. of parasitoids released | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | *M. harithus* | | *Spathius* sp. | | *E. morio* | | *C. quadrum* | |
| | B | N | B | N | B | N | B | N | B | N |
| May | 5 | 4 | 730 | 715 | 710 | 691 | 110 | 95 | 91 | 75 |
| June | 4 | - | 470 | - | 11 | - | 31 | - | 21 | - |
| July | 7 | 6 | 1159 | 1260 | 11 | 110 | 190 | 221 | 31 | 131 |
| August | 10 | 9 | 1379 | 1489 | 1167 | 1244 | 890 | 790 | 41 | 141 |
| September | 9 | 8 | 1518 | 1398 | 280 | 181 | 220 | 202 | 31 | 33 |
| October | 5 | 4 | 910 | 818 | 30 | 28 | 11 | 21 | - | - |
| Total | 40 | 31 | 6166 | 5680 | 2209 | 2254 | 1452 | 1329 | 215 | 380 |

B= Bandipora, N= Naseem Bagh

branch and opened at both ends allowing the parasitoids to crawl out. Forty releases were made from May to October at Bandipora and 31 releases at Naseem Bagh (Table 1). A total of 6166 adults of *M. harithus*, 2209 *Spathius* sp., 1452 *E. morio* and 215 *C. quadrum* were released at Bandipora whereas 5680 adults of *M. harithus*, 2254 *Spathius* sp., 1329 *E. morio* and 380 *C. quadrum* were released at Naseem Bagh release site. At both the release sites the maximum numbers of parasitoids were released in August and September. Establishment of the parasitoids was determined at these release sites by recording the post-release counts of combined parasitism monthly from June to November during 1999 and 2000.

## RESULTS AND DISCUSSION

Nine species of hymenopteran parasitoids were recovered from *Scolytus nitidus* from infested trees and rearing cages in the present study. Among these, the chalcidoid parasitoids collected were: *Rhaphitelus maculatus* Walker, *Heydenia indica* Buhroo, *Macromesus harithus* Narendran, *Cheiropachus quadrum* Fabricius (Pteromalidae), *Eurytoma morio* Boheman (Eurytomidae), *Eupelmus vindex* Erdos, *E. kashmiricus* Buhroo, *E. valsus* Narendran (Eupelmidae). Apart from these parasitoids an ichneumonoid *viz. Spathius* sp. (Braconidae) was also found in the present investigations.

### Parasitoid abundance and parasitism

Among the parasitoids of *S. nitidus*, the five most abundant parasitoids were: *M. harithus*, *E. morio*, *Spathius* sp., *R. maculatus* and *C. quadrum* (Table 2). The other parasitoids were rare and occasional. *M. harithus* was the predominant parasitoid throughout the season (Table 2). Its coefficient of dominance ranged from 24.17 per cent to 99.24 per cent with an average of 72.70 per cent. Its percentage of parasitization was 14.47 to 87.88 ( average 52.88). This was followed by *E. morio* with dominance coefficient from 0.66 to 36.76 per cent, on average 9.73 per cent. Its per cent parasitization ranged from 0.60 to 35.79 (average 7.08). The dominance coefficient of *Spathius* sp. was 0.48 to 68.13 per cent with an average of 8.74. Its per cent parasitization range was 0.35 to 40.79 and average 6.36. The coefficient of dominance for *R. maculatus* was 0.85 to 67.86 per cent with an average of 6.67 per cent and its per cent parasitization range 0.28 to 57.57 (average 4.85). The dominance coefficient of *C. quadrum* was from 1.41 to 44.12 per cent, on an average 2.15 per cent

Table 2. The number of adult insects from sample collections and per cent parasitization and dominance of *S. nitidus* parasitoids

| Sampling dates | *S. nitidus* | *M. harithus* | | | *E. morio* | | | *Spathius sp.* | | | *R. maculatus* | | | *C. quadrum* | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N | N | P | D | N | P | D | N | P | D | N | P | D | N | P | D |
| 10 April | - | 45 | - | 71.43 | 1 | - | 1.59 | 1 | - | 1.59 | 2 | - | 3.17 | 14 | - | 22.22 |
| 20 April | 5 | 77 | 40.53 | 41.62 | 68 | 35.79 | 36.76 | 27 | 14.21 | 14.59 | 7 | 3.68 | 3.78 | 6 | 3.16 | 3.24 |
| 30 April | 40 | 90 | 30.72 | 35.57 | 87 | 29.69 | 34.39 | 76 | 25.94 | 30.04 | - | - | - | - | - | - |
| 10 May | 61 | 22 | 14.47 | 24.17 | 2 | 1.31 | 2.20 | 62 | 40.79 | 68.13 | 1 | 0.66 | 1.10 | 4 | 2.63 | 4.39 |
| 20 May | 30 | 13 | 20.31 | 38.23 | - | - | - | 5 | 7.81 | 14.70 | 1 | 1.56 | 2.94 | 15 | 23.44 | 44.12 |
| 30 May | 18 | 22 | 47.83 | 78.57 | 2 | 4.35 | 7.14 | 1 | 2.17 | 3.57 | 3 | 6.52 | 10.71 | - | - | - |
| 10 June | 3 | 26 | 81.25 | 89.65 | - | - | - | 1 | 3.12 | 3.45 | 1 | 3.12 | 3.45 | 1 | 3.12 | 3.45 |
| 20 June | 5 | 9 | 27.27 | 32.14 | - | - | - | - | - | - | 19 | 57.57 | 67.86 | - | - | - |
| 30 June | 4 | 42 | 79.24 | 85.71 | 3 | 5.66 | 6.12 | - | - | - | 2 | 3.77 | 4.08 | 2 | 3.77 | 4.08 |
| 10 July | 29 | 42 | 45.16 | 65.62 | 20 | 21.50 | 31.25 | - | - | - | - | - | - | 2 | 2.15 | 3.12 |
| 20 July | 87 | 56 | 35.44 | 78.87 | 10 | 6.33 | 14.08 | 1 | 0.63 | 1.41 | 3 | 1.90 | 4.22 | 1 | 0.63 | 1.41 |
| 30 July | 235 | 110 | 31.25 | 94.02 | 4 | 1.14 | 3.42 | - | - | - | 1 | 0.28 | 0.85 | 2 | 0.57 | 1.71 |
| 10 August | 161 | 115 | 40.92 | 95.83 | 2 | 0.71 | 1.67 | 1 | 0.35 | 0.83 | - | - | - | 2 | 0.71 | 1.67 |
| 20 August | 125 | 131 | 50.97 | 99.24 | - | - | - | 1 | 0.39 | 0.76 | - | - | - | - | - | - |
| 30 August | 23 | 164 | 70.39 | 78.09 | 8 | 3.43 | 3.81 | 1 | 0.43 | 0.48 | 37 | 15.88 | 17.62 | - | - | - |
| 10 September | 16 | 57 | 53.27 | 62.64 | 4 | 3.74 | 4.39 | 4 | 3.74 | 4.39 | 23 | 21.49 | 25.27 | 3 | 2.80 | 3.30 |
| 20 September | 39 | 439 | 78.53 | 84.42 | 20 | 3.58 | 3.85 | 22 | 3.93 | 4.23 | 39 | 6.98 | 7.5 | - | - | - |
| 30 September | 15 | 137 | 82.03 | 90.13 | 1 | 0.60 | 0.66 | 4 | 2.39 | 2.63 | 10 | 5.99 | 6.58 | - | - | - |
| 10 October | 7 | 75 | 84.27 | 91.46 | - | - | - | 3 | 3.37 | 3.66 | 4 | 4.49 | 4.88 | - | - | - |
| 20 October | 2 | 29 | 87.88 | 93.55 | 1 | 3.03 | 3.22 | - | - | - | 1 | 3.03 | 3.22 | - | - | - |
| 30 October | - | 36 | - | 81.82 | 2 | - | 4.54 | 1 | - | 2.27 | 5 | - | 11.36 | - | - | - |
| 10 November | - | 18 | - | 90 | - | - | - | - | - | - | 2 | - | 10 | - | - | - |
| Mean | - | - | 52.88 | 72.70 | - | 7.08 | 9.73 | - | 6.36 | 8.74 | - | 4.85 | 6.67 | - | 1.57 | 2.15 |

N= Number of adult insects; P= parasitized percentage; D= dominance coefficient (%)

and the percentage of parasitization by this species ranged from 0.57 to 23.44 with an average of 1.57. This parasitoid complex differed from that of parasitoid populations on fruit trees from Israel (Mendel, 1986a) and from Serbia (Mihajlovic *et al.*, 1994).

**Parasitoid emergence and seasonal history**

Figure 1 shows the emergence patterns of common parasitoids and their beetle host. This data indicated that the parasitoids emerged before the beetle brood in the second week of April and continued for about 4 weeks. After establishing the parasitoids again emerged in the last week of June and produced a second generation. The third emergence of parasitoids occurred from last week of August onwards and peaked in the 2nd and 3rd week of September. The emerging population gradually declined until the end of October. The larvae of the third parasitoid brood overwintered from December to February of the following year. Despite the fact that the parasitoid populations along with their host varied in density throughout the year; it can be concluded that there were two peaks for population densities of combined parasitoids in April – May and August – September during 1999 (Fig. 1). The major parasitoids completed 3 annual generations (last a partial one) on 2 to 3 generations of their beetle host. The parasitoids can, therefore, increase their populations very rapidly during shot-hole borer outbreaks.

The data of the field studies (Table 3) show that the common parasitoids of first brood emerged in the second week of April and the first beetle brood in the last week of April. Again the parasitoids of second brood emerged in the last week of June followed by the emergence of second beetle brood in the first week of July. Thus, the parasitoids of first and second brood emerged approximately 10.3 and 4.7 days before the onset of first two beetle broods, respectively. So these parasitoids usually used their host generation for a single parasitoid generation. It was also observed that third brood of parasitoids emerged in the last week of August followed by the emergence of third beetle brood in the middle of September. The third brood of parasitoids emerged about 12 days before parasitoids also developed on the 3rd generation of their beetle host. The parasitoids, therefore, increased their populations very rapidly in the later part of the season. This finding was supported by Mendel (1986a) reporting that parasitoids of *Pityogenes calcaratus* (Eich.) could use the beetle brood for a single parasitoid generation while the early emerging parasitoids of *Phloeosinus armatus* Reiter can establish a new generation on the same host population in Israel.

**Establishment of parasitoids**

At Bandipora the pre-release count of parasitism of *S. nitidus* on an average was 14.8 per cent in April, which consequent upon the release of a total 10042 combined parasitoids increased to a maximum of 45.3 per cent in September (Table 4). Similarly after release of 9643 adults of combined parasitoids at Naseem Bagh there was also an increase in parasitism from 15.4 per cent in April to 41.5 per cent in September (Table 4), confirming the establishment of parasitoids on shot-hole borer.

Due to consistent and judicious use of pesticides in Kashmir, no control orchards could be made available in the present studies so as to compare the results with control plots. But it can be concluded that the constant increase in parasitism at both the release sites was certainly due to multiplication of parasitoids, which can be attributed to their periodic releases. There are no comparative data on the releasing and establishment of scolytid parasitoids in the literature. However, before releasing these parasitoids into a new environment a more detailed knowledge of their biology is necessary.

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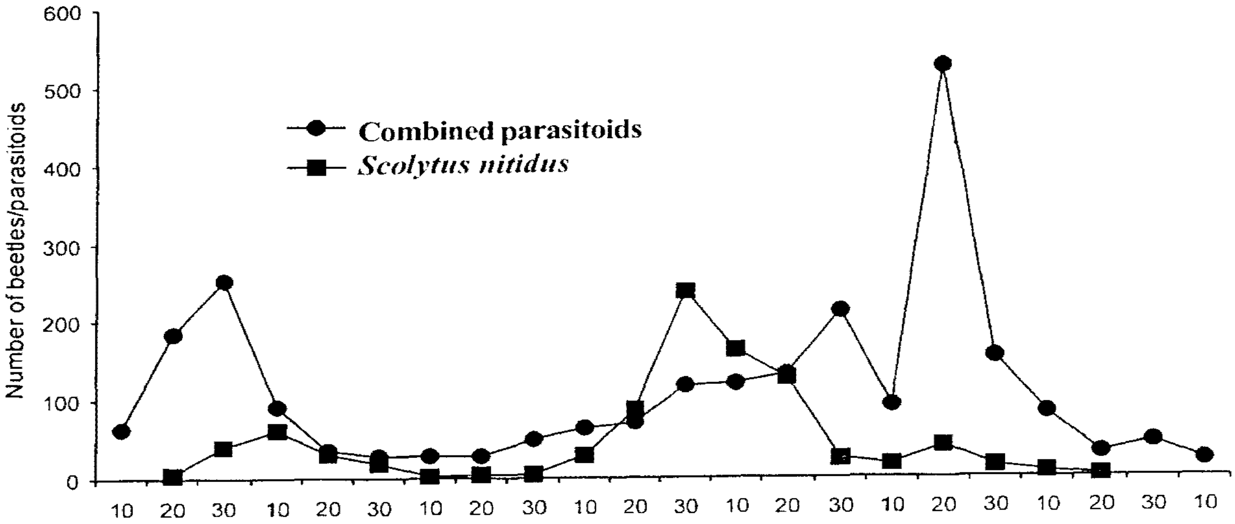


**Fig 1. Emergence patterns of combined parasitoids and their host after transfer of infested apple branches into emergence boxes**

**Table 3. Initial emerging dates for each brood of common parasitoids and beetle host**

| Year | Brood | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | I | | | II | | | III | | |
| | Parasitoid (emerging dates) | Host (emerging dates) | Difference (days) | Parasitoid (emerging dates) | Host (emerging dates) | Difference (days) | Parasitoid (emerging dates) | Host (emerging dates) | Difference (days) |
| 1998 | 20/4 | 26/4 | 6 | 27/6 | 4/7 | 7 | 4/9 | 20/9 | 16 |
| 1999 | 6/4 | 17/4 | 11 | 25/6 | 1/7 | 6 | 20/8 | 5/9 | 16 |
| 2000 | 5/4 | 19/4 | 14 | 15/6 | 16/6 | 1 | 22/8 | 26/8 | 4 |
| Mean difference ± SEM | | | 10.3 ± 2.33 | | | 4.7 ± 1.85 | | | 12 ± 4.001 |

**Table 4. Establishment of combined parasitoids on *S. nitidus* in Kashmir**

| Bandipora (1999) | | Naseem Bagh (2000) | |
|---|---|---|---|
| Period | Parasitism (%) | Period | Parasitism (%) |
| 4 April | 14.8 | 15 April | 15.4 |
| 18 June | 21.7 | 10 June | 23.9 |
| 13 July | 23.9 | 10 July | 26.1 |
| 20 August | 24.4 | 8 August | 26.6 |
| 9 September | 45.3 | 5 September | 41.5 |
| 20 October | 16.7 | 20 October | 12.9 |
| 15 November | 34.1 | - | - |

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