# Range expansion: A case study of the bark beetle *Scolytus nitidus* Schedl (Coleoptera: Curculionidae: Scolytinae) in Kashmir

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**Abstract:** Many insects have expanded their host range to naive host trees, and thereby have become major pests. *Scolytus nitidus* (Coleoptera: Curculionidae: Scolytinae) is a polyphagous species that attacks different fruit trees in Kashmir and is reported for the first time to develop on Himalayan birch (*Betula utilis*) and thus extended its host range from primary host trees. In the present study, the status of incidence of the bark beetle *S. nitidus* on Himalayan birch (*B. utilis*) was also determined. Among the six sites (S1-S6) chosen for the study, the incidence of the borer was observed highest in the S3 and S4 i.e., 14.28% and 12.85% respectively followed by the S1 and S6 i.e., 12.29% and 9.38% respectively. The overall infestation recorded at these sites was 10.40%. The highest mean of trunk diameter at the breast height (d.b.h.) of the infested trees was observed at S4 and S3 i.e., 37.22 cm (±1.05 SE) and 36.86 cm (± 1.30 SE) respectively followed by the S1 and S2 i.e., 33.88 cm (± 2.21 SE) and 26.50 cm (± 2.50 SE) respectively. In our study, we also evaluated relationship between mean trunk diameter of infested trees and percentage of infestation by the beetle pest.

[Buhroo AA, Khanday AL. **Range expansion: A case study of the bark beetle *Scolytus nitidus* Schedl (Coleoptera: Curculionidae: Scolytinae) in Kashmir.** *Nat Sci* 2016;14(2):1-6]. ISSN 1545-0740 (print); ISSN 2375-7167 (online). http://www.sciencepub.net/nature. 1. doi:10.7537/marsnsj14021601.

**Keywords:** Range expansion, *Betula utilis*, incidence, *Scolytus nitidus*, Scolytinae

## 1. Introduction

Climate change is expected to influence the distribution and population dynamics of many insect pests, with potential severe impacts on forests. Preliminary studies indicate that the Himalaya seems to be warming more than the global average rate (Liu & Chen, 2000; Shrestha *et al*., 1999); increase in temperature is greater during winter and autumn than during the summer, and this rise in temperature is larger at higher altitudes (Liu & Chen, 2000). Responses of forest pests to changing climate are extremely rapid and it is assumed that insect herbivores will respond faster to climate change as evidenced by a rapidly increasing number of reports showing significant recent range shifts towards higher latitudes and higher elevations (Williams & Liebhold, 2002; Jepsen *et al*., 2008; Raffa *et al*., 2008). Climate change has direct influence on pest populations mainly because they are poikilothermic organisms and, therefore, quickly respond to changes in their thermal environment. *Scolytus nitidus* are also anticipated to increase their developmental rate and generations within a season at optimal temperatures and thus provide evidence that bark beetle populations may respond quickly to climatic variations. Climate change is also expected to influence the pest swarming activity, diapause and winter mortality. The temperature regime during autumn could have a decisive impact on the size of the swarming population in the next spring (Jonsson *et al*., 2009). 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). In addition, forest stands damaged by wind are especially important precursors to outbreaks as they quickly provide large quantities of optimal breeding material (Grodzki *et al*., 2006).

Temperature is one of the dominant factors affecting the growth rate and development of insect pests (Bale *et al*., 2002). Buhroo *et al*. (2004) studied the seasonal population trends of *S. nitidus* on apple trees in Kashmir and reported that the adult emergence occurs from middle of April to middle of October with two marked peaks of swarming in April-May and in July. The peaks of beetle populations were found to be correlated with higher temperatures. Depending on the species and their geographic location, the generation time for beetles can vary from multiple generations per year to one generation every one to two years. Buhroo & Lakatos (2007) investigated biological characters of *S. nitidus* and reported that this common shot-hole borer overwinters in larval stage on apple trees in Kashmir. This species produced 3 generations (the last a partial one) per year in Kashmir. It was also observed 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 2nd a partial one) only. This can be due to different environmental factors, mainly, temperature to which the infested logs are exposed. However, Khanday & Buhroo (2015) reported only 2 generations per year (the last a partial one) in case of *S. kashmirensis,* a common beetle pest of *Ulmus villosa* in Kashmir.

The difference in generations between the two bark beetle species might be because of difference in distribution of their host trees. Another reason may be the difference in host tree chemistry. Although little is known about specific temperature-dependent developmental processes of many bark beetle species, research suggests that at least two predominant strategies, diapause and direct temperature control, have evolved to maintain appropriate life-cycle timing. Each strategy may be differentially affected by climate change. Bark beetle population success will also be influenced indirectly by the effects of climate on the host tree. Trees that are water stressed may be more susceptible to bark beetle attacks. As tree species ranges shifted, so did the ranges of phytophagous insects such as bark beetles as they tracked environmental changes and followed host tree species (Seybold *et al*., 1995).

The objective of our study was to work out the range expansion and incidence of the bark beetle *S. nitidus* in Kashmir. Understanding the behavior of *S. nitidus* on naive host tree species will help us to predict factors that promote such associations between plants and beetle pests.

## 2. Materials and Methods

### 2.1. Range expansion of *S. nitidus*

In order to study the host range expansion of *S. nitidus* in the Kashmir Valley, preliminary field surveys were conducted in April 2015. Six sites (S1-S6) were selected in three study areas (Table 1). At each site, trees were examined randomly within the birch forests and a tree was marked infested if there were visible exit holes on the trunk, or if it exhibited other symptoms of *S. nitidus* infestation.

### 2.2. Borer infestation on Himalayan birch

The rate of borer infestation was calculated by the following formula:

$$\text{Percent infested trees} = \frac{\text{Total number of trees infested}}{\text{Total number of trees observed}} \times 100$$

### 2.3. Host tree diameter infested by *S. nitidus*

At each study site, diameter at the breast height (d.b.h.) of the infested trees was measured. DBH is a standard method of expressing the diameter of the trunk or bole of a standing tree (Mackie & Matthews, 2006).

### 2.4. Relation between mean trunk diameter of infested trees and percent infestation by borer

Sampling procedure used for observing the relationship between variables was identical to those adopted by Zhang *et al*. (1992).

### 2.4. Data analyses

Observations made during the present study were statistically analyzed. The data were subjected to analyses of variance (ANOVA) using SPSS 11.5 (SPSS Inc., Chicago, IL, USA) and the means were separated by Fisher's least significant difference pair-wise multiple comparison test when $P < 0.05$. Quadratic regression was performed on the data to determine the relationship between variables.

## 3. Results

### 3.1. Range expansion of *S. nitidus*

Fig.1 shows the range expansion of bark beetle *S. nitidus* from its primary host trees to naive host tree species (*B. utilis*).The current observations also indicate that among the three *Scolytus* species found in Kashmir, *S. nitidus* has expanded its host range (Table 2).

### 3.2. Borer infestation on Himalayan birch

A total of 298 birch trees were observed in six sites (S1-S6) from the three districts in the Kashmir Valley. Out of these 298 trees, 31 were found infested with the shot-hole borer, *S. nitidus.* According to the survey results (Table 1), the incidence of the borer was highest in the S3 and S4 sites i.e., 14.28% and 12.85% respectively followed by the S1 and S6 sites i.e., 12.29% and 9.38% respectively. The overall infestation recorded in the sampling sites was 10.40%.

### 3.3. Host diameter infested by *S. nitidus*

*Scolytus nitidus* perceive the odor of their host plants by biting, chewing and boring into the bark. The mean of trunk diameter at the breast height (d.b.h.) of the infested trees are summarized in Table 3. Highest mean trunk d.b.h was found at S4 and S3 i.e., 37.22 cm (± 2.63 SE) and 36.86 cm (± 1.30 SE) respectively followed by the S1 and S2 i.e., 33.88 cm (±2.21 SE) and 26.50 cm (± 2.50 SE) respectively. Results of mean comparison among trunk diameters of infested trees by using Fisher's LSD test are shown in Fig. 2.

### 3.4. Relation between mean trunk diameter of infested trees and percent infestation by borer

The result of mean trunk diameter of infested trees vs. percent infestation by borer is shown in Fig. 3. The percentage of infestation by borer increased in quadratic relationship as the mean trunk diameter of infested trees increased, indicating a significant positive relationship ($R^2$- 0.705) between the two variables. These results demonstrate that percentage of infestation by borer is directly influenced by mean trunk diameter of infested trees.

## 4. Discussion

The present observations revealed that the bark beetle *S. nitidus* has extended its host range from primary host trees (fruit trees) to naive host trees (*B. utilis*) in the Kashmir valley. The infestation of Himalayan birch was most likely promoted by regional climatic changes combined with non-availability of primary host trees in the concerned region (Khanday & Buhroo, 2015). There are also reports that increased temperatures could also allow beetles to spread farther north or to higher elevations than their historic range (Logan & Bentz, 1999; Tran *et al*., 2007; Sambaraju *et al*., 2011). Thus, with climate change beetles may move to new geographic areas where hosts may be less defended, leading to increased beetle populations.

**Table 1.** Borer infestation on Himalayan birch (*B. utilis*) at study sites

| **Study area** | **Dawar** | | **Gulmarg** | | **Sinthan top** | | **Total** |
|---|---|---|---|---|---|---|---|
| GPS location | $34.6333^0$ N, $74.8333^0$ E Elevation 8,460 ft. | | $34.0532^0$ N, $74.3856^0$ E Elevation 8,690 ft. | | $33.5914^0$ N, $75.2940^0$ E Elevation 12,500 ft. | | |
| Sample sites | S1 | S2 | S3 | S4 | S5 | S6 | |
| No. of sampled trees | 57 | 48 | 35 | 70 | 56 | 32 | 298 |
| No. of infested trees | 08 | 04 | 05 | 09 | 02 | 03 | 31 |
| Percent trees infested by borer | 12.29 | 8.33 | 14.28 | 12.85 | 3.58 | 9.38 | 10.40 |

**Table 2.** Host plant families for *Scolytus* spp. reported from Kashmir (*Khanday & Buhroo, 2015)

| **Species** | **Rosaceae** | **Juglandaceae** | **Ulmaceae** | **Betulaceae* (New record)** | **Pinaceae** |
|---|---|---|---|---|---|
| *Scolytus kashmirensis* | | | | | |
| *Scolytus nitidus* | | | | | |
| *Scolytus major* | | | | | |

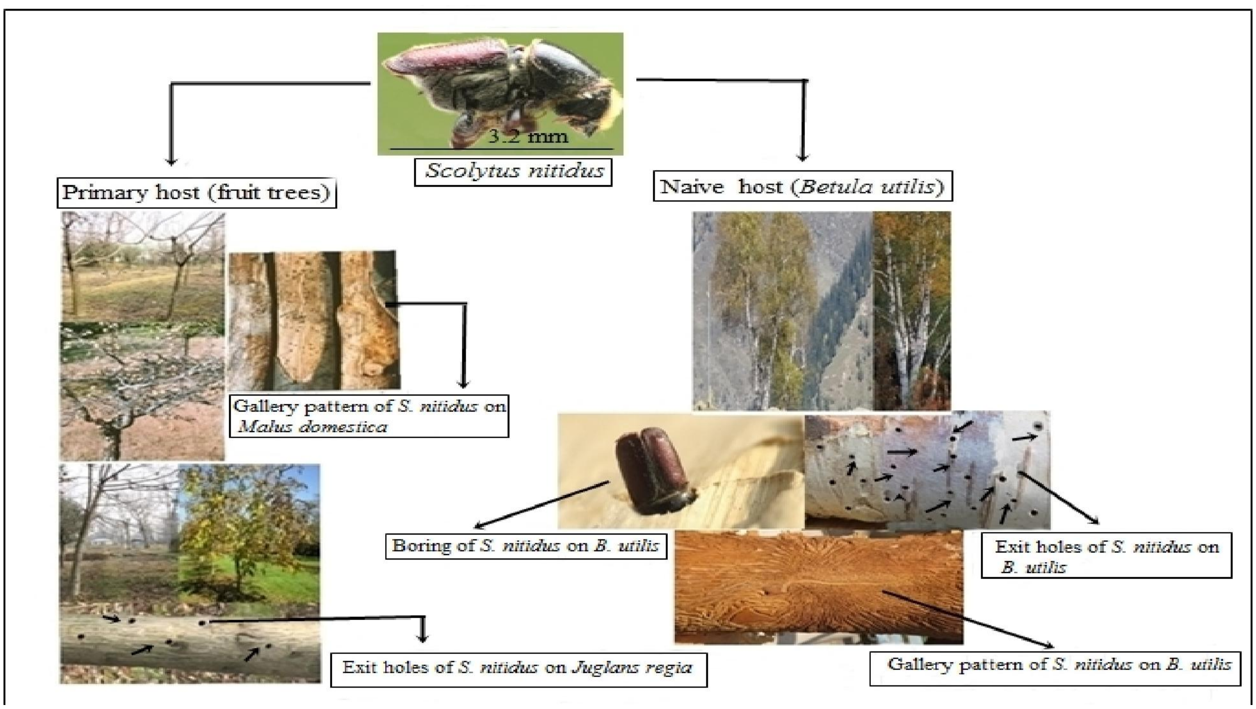


**Fig. 1.** Range expansion of *S. nitidus* on Himalayan birch (*B. utilis*)

Conversely, if suitable hosts are restricted to a smaller range or are not able to survive under changing climatic conditions, the beetles may perish due to the loss of their food source (Williams & Liebhold, 2002).

**Table 3.** Measurement of trunk diameter of infested trees

| Sample sites | N | Mean trunk diameter of infested trees (cm ±SE) |
|---|---|---|
| S1 | 8 | 33.88±2.21 |
| S2 | 4 | 26.50±2.50 |
| S3 | 7 | 36.86± 1.30 |
| S4 | 9 | 37.22±2.63 |
| S5 | 2 | 24.00±2.00 |
| S6 | 3 | 23.33±3.18 |

N= Number of observations

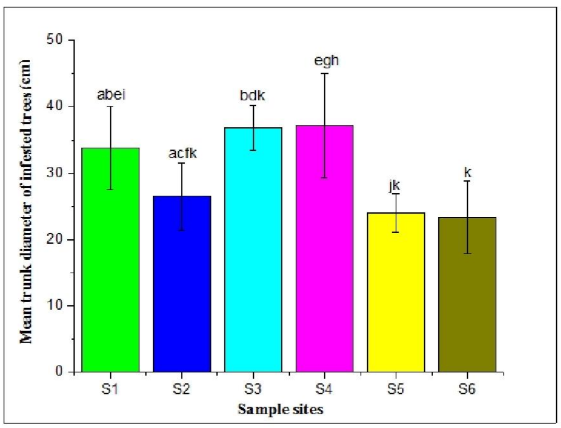


**Fig. 2.** Comparison of mean trunk diameter of infested *B. utilis*

Bars that do not share the same superscript are significantly different at $p < 0.05$ as indicated by Fisher's LSD pair-wise multiple comparison test.

In this study, the incidence of the borer was observed highest in the S3 and S4 i.e., 14.28% and 12.85% respectively followed by the S1 and S6 i.e., 12.29% and 9.38% respectively. The overall infestation recorded in these sites was 10.40%. Buhroo in 2012 studied the incidence and host susceptibility of the bark beetle *S. kashmirensis* infesting elm trees and reported that incidence of *S. kashmirensis* varies among four districts of the Kashmir valley.

Our observations are also at par with the results of Webber (2004) who showed that changes in temperature, humidity, elevation and season affect bark beetle infestations and the incidence of diseases. The highest mean of trunk diameter at the breast height (d.b.h.) of the infested trees was found at S4 and S3 i.e., 37.22 cm and 36.86 cm respectively followed by the S1 and S2 i.e., 33.88 cm and 26.50 cm respectively. Overall comparison of trunk diameters in infested trees using Fisher's LSD pair-wise multiple comparison test indicates both significant and non-significant differences. The significant difference ($p<0.05$) among trunk diameters of infested trees indicates that at each sampling site host trees belong to different age classes. This shows that beetle pests are able to attack any age class of host trees. The results of trunk diameters of infested trees and percentage of infestation by borer showed a significant positive correlation ($R^2$- 0.705) between the variables. The importance of log diameter on host reproduction has been noted for a number of bark beetle species (Parker & Stevens, 1979). Diameter has also been noted as the primary factor predicting host selection by Douglas-fir beetle *Dendroctonus pseudotsugae* in Douglas-fir (Ried & Glubish, 2001).

As per the information available till date, *S. nitidus* has still a good reproductive success within its primary host trees; we suggest that this species has only undergone a host range expansion rather than a host shift.

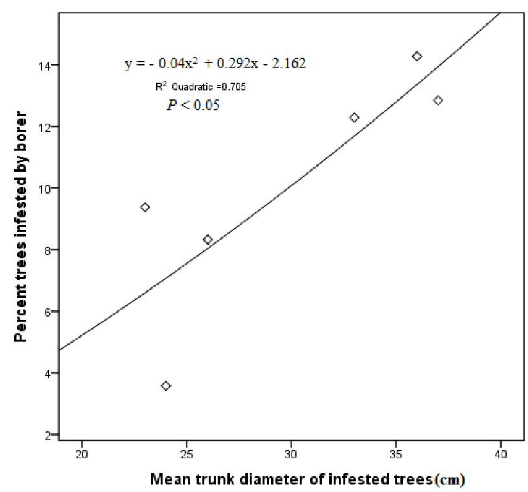


**Fig. 3.** Relationship between mean trunk diameter of infested trees and percent trees infested by borer.

## 5. Conclusions

Range expansion of *S. nitidus* is likely to have been a key reason for the rapid population build up that resulted in unprecedented host tree mortality over huge areas in the Kashmir valley. The range expansion thus provides an example of how beetle pests, driven by climate change, can have potentially disastrous consequences. Since an increased reproductive success is likely to accelerate the progression of outbreaks, it is particularly critical to manage forests for the maintenance of a mosaic of species and age classes at the landscape level in the areas where host tree populations are naive to eruptive herbivores.

Future research on bark beetles and their range expansion on naive host populations in Kashmir would help us to predict how these novel interactions occur and what factors promote such associations between plants and beetle pests. Moreover such studies in future will provide an excellent opportunity to study the evolutionary relationships between bark beetles and their host plants in Kashmir Himalaya.

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