Predatory insects of *Adelges tsugae* Annand (Homoptera: Adelgidae) at Dhungkharka, Kavrepalanchok, Nepal

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Abstract

Predatory insects of *Adelges tsugae* Annand (Homoptera: Adelgidae) were studied in Dhungkharka, Kavrepalanchok. The study also assessed their seasonal abundance with respect to *A. tsugae* infestation and their feeding efficacy. Host plant selected for the study was hemlock plant. The predatory insects were collected by sweaping and beating. Two insects viz. *Syrphus* sp. (Syrphidae) and *Coccinella septempunctata* L. (Coccinellidae) were recorded as predators. *Coccinella septempunctata* was found more effective to control *A. tsugae*. The highest density of predators was recorded during May (8.9/branch) and June (9.2/branch) corresponding to abundance of pests. Result showed positive correlation between predator and pest population ($p<0.05$). Mean number of the pest consumed by male *C. septempunctata* (12.67±3.47 SD) was found less than that by female (16.87±4.39 SD). The difference in consumption capacity is statistically significant ($p<0.05$).

Key words: Hemlock, *Coccinella*, *Syrphus*, infestation, pest

Introduction

Hemlock Woolly Adelgid, *Adelges tsugae* Annand (Homoptera: Adelgidae) is parthenogenic aphid-like insect feeding on several species of *Tsuga* and *Picea* (Pinaceae). *Adelges tsugae* is dispersed by wind, birds, deer, and humans, and is moving north at a rate of about 30 km/year (McClure 1990). The most obvious symptom of infestation is the presence of white woolly egg sacs on the underside of hemlock needle, especially on new growth. Once established on a host, the adelgids feed on twigs of new growth by piercing at the base of needle (Young et al. 1995). Shortly after infestation, the feeding causes the desiccation of the needles and eventually results in the death and falling to the ground. Infested tree usually die

within 9 years, but the trees have been killed in as little as 4 years in case of heavy infestation (McClure 1987). The adelgid completes two generations per year each on host plants *Picea* and *Tsuga* (McClure 200l) and population grows very rapidly. Two generations develop simultaneously in the spring: winged (sexuparae) and non-winged (progrediens). Sexuparae developed into adult and it leaves hemlock in search of a *Picea* for oviposition. Progrediens develop during autumn and winter, following a summer aestivation. Nymphs of both types hatched in April (McClure et al. 2001).

Hemlock is a valuable timber species, it is used widely for pulp wood and for building barns, sheds and other structures. Canada balsam is obtained form eastern hemlock, *Tsuga canadensis*. It is commonly used as mounting medium for microscope preparation as its refractive index is approximately equivalent to that of glass (Sharma 1995). Hemlock spruce oil is essential oil which is extracted from hemlock and spruce plants. A number of products like rayon, transparent films, photographic films, artificial sponges and licquers are made from the wood pulp of *Picea* and *Tsuga* species. Hemlocks are long-lived, late successional climax trees that, if left undisturbed, eventually dominant stands. Its species occupies an important ecological niche. Hemlock stands provide cover for grouse, deer, snow-shoes hare and rabbit. Many birds use hemlock as a food source, nesting site etc.

Many species of predatory insects were reported from different parts of Asia and North America, but none of them were effective biological control agents to maintain hemlock woolly adelgid population below the economic injury level. 80 species of insects and 12 species of mites have been recorded as predators of *Adelges* from Himalayas (Rao and Ghani 1972), which includes the families; Anthocoridae: Hemiptera, Syrphidae: Diptera, Chamaemyidae: Diptera, Chrysopidae: Neuroptera, Hemerobidae: Neuroptera, Coccinellidae: Coleoptera and Acarina. The most significant natural predator of hemlock woolly adelgid is *Pseudoscymnus tsugae* (Coccinellidae:Coleoptera) which has been most effective predator in Japan and is mainly responsible for checking hemlock woolly adelgid population (Sasaji and McClure 1997). The oribatid mite, *Diapterobates humeralis* Hermann (Oribatida: Cerotozetidae) is especially effective in locating and destroying the cottony sacs which covers the eggs of adelgid in Japan (McClure 1995). *Laricobius nigrinus* (Derodontidae: Coleoptera) larvae primarily feed on eggs while adults feed on all stages, and

it has been evaluated as a potential biological control agent of hemlock woolly adelgid (Salom et al. 1999).

Heavy infestation undoubtedly causes progressive weakening of the trees and makes them more susceptible to disease. Chemical control options available for use in landscaped settings are inappropriate for treating hemlocks in forest settings (McClure et al. 2001). Because stands are scattered, full insecticides coverage is hard to achieve, and the trees are often located in sensitive areas like near the streams. Current study on hemlock woolly adelgid is focusing on the identification of natural predators which will remain viable and effective at regulating hemlock woolly adelgid population in native home or in the outside world. Moreover the study deals with seasonal abundance of predators in relation to pest infestation and the feeding behavior of predators.

Materials and Methods

Study area

The study was carried out from April to August 2002 at Dhungkharka, Kavrepalanchok of central Nepal (85^0 30' 15" to 85^0 30' 45" E and 27^0 30' 15" to 27^0 30' 45" N). It is situated at 2400 m asl with sub-tropical climate and comprised temperate and alpine conifer forests. The site is a dominant himalayan hemlock forest but some other mixed hardwood trees (*Rhododendron*, *Pinus roxburgii, Pinus wallichii, Lyonia ovalifolia, Castonopsis*, etc) are also found. A few ephemeral streams were there in the beginning of the study as it was started in April, the semi-hot spring and they were about to be dried. Abundant hemlocks were infested by the *Adelges tsugae* but the infestation was not so severe to cause death.

Preliminary Field Survey

A preliminary field survey was conducted to locate the infestation of *A. tsugae* on hemlock plant in and around the main study area before the actual field work was started.

Field Setting

Three sites in Narayanthan community forests were selected for the study. All study sites were along north-east facing slope between 2100 to 2300 m. Five trees of *Tsuga dumosa* (about 3 to 4.5 m in height) were randomly selected from each site. Observation of pest and predators was made at an interval of 15 days for 5 months. Each tree was divided into upper,

middle and lower crowns to draw samples from three levels. The twigs from top, middle and lower crown were drawn. From each region, a twig is drawn from the area of 20 x 20 cm^2 (0.04 m^2) and the hemlock woolly adelgids settled in each sample crown were counted and recorded. Total sampled branch per tree was 4.5 sq. m. Only egg masses were taken into account in case the adults were missing due to disturbances.

Sweeping

Estimation of active flier predatory insects was made by sweeping of insect net (handle: 150 cm long hollow steel rod, steel wire ream: 30 cm diameter, bag: muslin cloth of 1 mm^2 mesh size and about thrice as long as the diameter of the ream). In each sample, sweeping was done around the sampled branch five times for the collection of insects. The captured predatory insects were counted and recorded for each sample.

Beating

The sampled branch was beaten by a stick for the estimation of predaceous beetles and other predatory crawler insects per branch following Oldroyd (1958). A white cotton cloth (2 x 2 m.) was stretched and placed under a tree. The predatory insects dropped on cloth were counted and summed it with total number of predators recorded in 3 crown samples of tree. Some infested twigs along with crawler of *A. tsugae* and predators (using mailing tube) were brought to the laboratory in live condition.

Laboratory Setting

Feeding behavior of the predatory beetle was studied in laboratory. The predators were kept in the petri-dishes (10 x 15 cm) with moistened filter paper at the bottom. The filter papers were replaced daily by new ones to avoid contamination. Male and female adult predatory beetles, maintained in different petri-dishes, were provided with 30 adelgids per day for feeding. The adelgids were replaced every morning by fresh ones. The number of adelgids consumed per day and that left uneaten were every morning.

Identification

The predatory insects were identified following Coccinelids of Nepal (Kapur 1958) and Fauna of British India (Brunetti 1923). The identification was verified by comparing with the specimens at Natural History Museum, Swoyambhu, Kathmandu and Nepal Agricultural Research Council, Khumaltar, Lalitpur.

Data Analysis

The data were analyzed using various statistical tools like mean, correlation and t-test following Flower et al. (1998).

Results

Predatory Insects of Adelgids

Adelges tsugae infestation was noticed from April to August, 2002. Only one species of Coccinellids predatory beetle, *Coccinella septumpunctata* L. and one genera of syrphids, *Syrphus* spp. were recorded during the study period. *Syrphus* spp. was observed in the beginning of the study, but relatively less in number; 0.6/branch in April, 0.4/branch in May and 0.1/branch in June (Figure 1). It was not noted in July and August. The high population density of *C. septumpunctata* was recorded in May (8.5 per branch) and June (9.1 per branch), and least in August (1.4 per branch) (Figure 1).

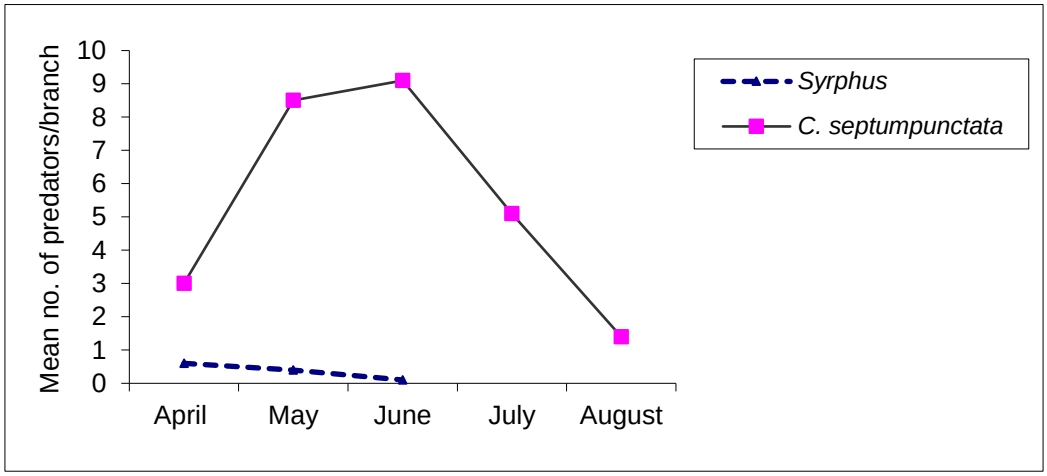

Figure 1. Abundance of predatory insects in late spring and summer.

Seasonal Abundance of Pest and Predator

Population of predator and prey was inconsistent in different seasons. *Adelges tsugae* population was maximum in early-summer (1060/branch) and the population decreased form mid-summer and recorded least in early-autumn (242.5/branch) (Table 1). Similarly, the maximum number of predators was recorded in early summer (8.9/branch) and mid summer (9.2/branch) while the lowest in early autumn (1.4/branch) (Table 1).

Table 1. Seasonal Abundance of pest and predator per branch.

Month	Total pop^{n} of *A. tsugae*	Mean No. of *C. septumpunctata*	Mean no. of *Syrphus* spp.	Total pop^{n}. of predators
April	880.0	3.0	0.6	3.6
May	1060.0	8.5	0.4	8.9
June	665.0	9.1	0.1	9.2
July	465.0	5.1	-	5.1
August	242.5	1.4	-	1.4

Feeding Potential of *C. septumpunctata*

The feeding efficiency of male and female of *C. septumpunctata* was studied separately in the laboratory. The result showed dissimilar feeding potential in male and female. Average number of A. tsugae consumed per day was 12.67±3.47 and 16.87±4.39 for male and female repectively (Figure 2). Difference in feeding efficacy of male and female was found to be statistically significant ($p<0.05$).

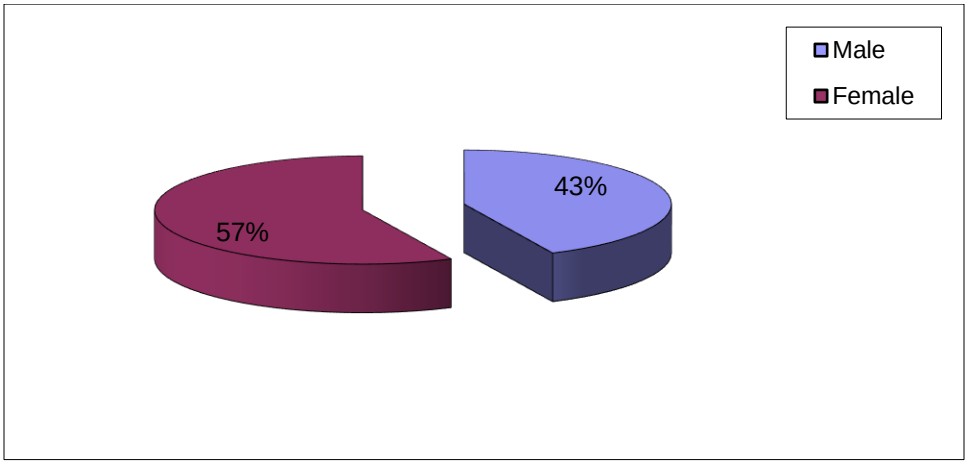

Figure 3. Feeding capacity of male and female *C. septumpunctata* in percentage

Discussion

Only two species of adults predatory insects were found in association with *Adelges* in Dhungharka. These species are *Syrphus* sp. and *C. septumtunctata*. *Coccinella septumpunctata* feeding on *Adelges* spp. observed by Laidlaw (Nagarkatti and Ghani 1972) in Scotland. Among two recorded predators, *Syrphus* spp. is evaluated as less important predator because it was recorded less in numbers, 0.6, 0.4 and 0.1 per branch from April to June respectively. Whereas the number of *C. septumpunctata* was found to be ranged form 1.4–9.1 per branch during the study period (Figure 1). Only the larval stages of *Syrphus* feed upon *Adelges* but both larval and adult stages of *C. septumpunctata* are the effective predators of *Adelges*. These findings are similar to those of Rao and Ghani (1972) who reported syrphids as the less effective predator than coccinellids.

Abundance of predators with *A. tsugae* infestation was different in different months. An infestation of hemlock woolly adelgid was noticed maximum in May with 1060 adelgids per branch and minimum in August with 242.5 per branch (Table 1). A steady decrease in *A. tsugae* population was observed from May to August. The steady reduction in population is due to absence of spruce plant in forest as the sexuparae adults oviposit in the spruce plant and progrediens generation go for summer aestivation. McClure (1991 and 2001) also reported the adults of sexuparae generation oviposit in the spruce plant and progrediens generation go for summer aestivation.

Mean population of all predators reported during the study period ranged from 1.4 to 9.2. The maximum number of predators noted in May–June and minimum number in August which coincide with the out break of *A. tsugae* population in May. The correlation analysis of number of pest and predators showed that the predator population was positively correlated with the number of pests. Thus it indicates the predators' (*C. septumpunctata* and *Syrphus* sp.) population increases with the increase in hemlock woolly adelgid population in different months. These findings are similar to those of Nagarkatti and Ghani (1972) who reported the appearance of *C. septumpunctata* in large numbers synchronising with increase of *Adelges* population in early or mid spring in Dalhousie region.

Present study showed that the female beetles consumed more *Adelges tsugae* (16.866±4.39/day) than male (12.666±3.47/day) during the adult stage. The number of

Adelges consumed by the female and male ranged from 9 to 25 and 6 to 18 respectively. The difference in the consumption capacities of the male and female is statistically significant ($p>0.05$). Kakkar et al. (2000) also reported the different consumption capacities of male and female and in their study, the adult male and female *C. septumpunctata* consumed 95.04 and 122.44 cereal aphid, *Sitobion avenae* respectively. Singh and Malhotra (1979) also reported the difference in consumption of aphid per day by male (95) and female (110).

Adelges tsugae attain high population density in May on Himalayan hemlock but not a single plant was gone to be threatened by the infestation of hemlock woolly adelgid in Dhungkharka. The population of pest was kept in check by the natural enemies like *C. septumpunctata* and *Syrphus* larvae and may also be due to the other factors like other predators not observed during the study period and plant resistance. In Asia, hemlock woolly adelgid number are kept in check by the presence of natural enemies and by host plant resistance (McClure 1995; Sasaji and McClure 1997).

Conclusion

Based on the field observation of *Adelges tsugae* attacks on the hemlock plant in every stages form seedlings to adult trees, assessment of predators in the field and evaluation of feeding potentials of the predator in laboratory following conclusions were made:

- The population of *A. tsugae* reach in peak by late spring or early summer. The infestation is not so severe to threat the existence of the host plant in the study area.
- The *Syrphus* sp. (syrphidae) and *C. septumpunctata* (coccinellidae) are the predators feeding on *A. tsugae* in Dhungharkha. Among these recorded predators, *C. septumpunctata* is an effective predator of hemlock woolly adelgid.
- The availability of hemlock woolly adelgids' predator depends upon the pest out break. The population of predator is positively correlated with the pest population.
- *Coccinella septumpunctata* is ploy phagous predatory beetle with consideralbe feeding efficiency on hemlock woolly adelgid so it could be the very important predator in keeping the population of adelgids in check.
- The male and female of *C. septumpunctata* have significantly different feeding potentials. The female are the more effective predators in terms of feeding capacity.

Recommendation

Relying on the findings of the study, the following recommendations have been made for the concerned authorities, researchers and other personnel particularly interested in the field:

- Though the pest number found below the economic injury level during the study period, any disbalance in natural predatory fauna may result in the outbreak of the pests and cause severe damage of the forest. So, proper conservation strategy should be made for the protection of hemlock forests from the attack of adelgids.
- More studies on the biology of hemlock woolly adelgids should be carried. The researchers are suggested to start their studies from early spring.
- The biological control of pest in forest setting is more stable than other methods. So further researches intented to find the potential biological control agents of hemlock woolly adelgid could be more worthy.
- Mass rearing and release of *C. septumpunctata* into the field to check the pest population could be valuable.
- Additional studies on oviposition, development and larval feeding efficiency on *Adelges* predatory flies, *Syrphus* sp. are suggested.
- Till date forest conservators and other concerning agencies have not realized the effects of *Adelges* in Nepal. Therefore, the concerned agencies are suggested to view the hemlock woolly adelgids as a pest of hemlock plant.

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