"Management of Elm Bark Beetle, *Scolytus kashmirensis* Schedl Infesting Elm Trees (*Ulmus* species) in Kashmir"

DISSERTATION

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PARVEEZ AHMAD BHAT
M.Sc.

Under the Joint Supervision of

CO-SUPERVISOR
Dr. Abdul Ahad Buhroo
Sr.Asstt. Professor,
Department of Zoology,
University of Kashmir, Srinagar.

SUPERVISOR
Dr. Muni Parveen
Sr.Asstt. Professor,
Department of Zoology,
University of Kashmir, Srinagar.

Post Graduate Department of Zoology
Faculty of Biological Sciences
The University of Kashmir, Srinagar- 190 006
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Post Graduate Department of Zoology

The University of Kashmir

Hazratbal, Srinagar- 190 006

No:

Dated:

CERTIFICATE

This is to certify that the Dissertation entitled **''Management of Elm Bark Beetle, *Scolytus kashmirensis* Schedl Infesting Elm Trees (*Ulmus* species) In Kashmir''** embodies original work of ***Mr. Parveez Ahmad Bhat,*** a whole time M.Phil Research Scholar in P.G. Department of Zoology, University of Kashmir, Srinagar. This work has been carried out under the joint supervision of Dr. Muni Parveen, Sr. Assistant Professor, P.G. Department of Zoology and Dr. Abdul Ahad Buhroo, Sr. Assistant Professor, P.G. Department of Zoology, University of Kashmir, Srinagar.

The candidate has fulfilled all the requirements and formalities as required under the statutes of the University for the Submission of the Dissertation for the award of the Degree of **Master of Philosophy (M. Phil) in Zoology**. This work has not been submitted in part or full anywhere else and is being submitted first time to the University of Kashmir, Srinagar.

Dr. A. A. Buhroo	**Dr. Muni Parveen**
Co-Supervisor	**Supervisor**

Prof. R. C. Bhagat

(Head of the Department)

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(Parveez Ahmad Bhat)

DEDICATED

TO MY

BELOVED PARENTS

&

CARING BROTHER

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CHAPTER 1

INTRODUCTION

The state of Jammu and Kashmir is a fascinating geographical region situated in the northern-most niche of India. Geographically, it has three distinct regions: Jammu, Kashmir, and Ladakh, comprising the area of 2,22,236 sq. km (Vidyadhar, 2005). The land is the combination of mighty splendor of mountains, of lovely glades and lush green forests.

Set like a jewelled crown on the map of India, Kashmir Valley is many a faceted diamond, changing character with the season- always extravagantly beautiful. The Valley of Kashmir lies between 33^0.20" and 34^0.54" N latitudes and 73^0.55" and 73^0.35" E longitudes covering an area of 101387 sq. kms. The average height of the Valley above sea level is about 6000 feet (Majid, 1987). The Valley is asymmetrical fertile basin, stretching from northeast to north westerly directions. Its diagonal length (from southeast to northwest corner) is 187 km. while the breadth varies considerably being 115.6 km. along the latitude of Srinagar. Topographically, it is deep elliptical bowl shaped Valley bounded by the lofty mountains of the Pir-Panjal range in the south and southwest, and the great Himalayan range in the north and east, with 64% of the total area being mountainous (Koul, 1977). It is bestowed with salubrious temperate climate with wet and cold winters, and relatively dry and moderately hot summers.

The state of Jammu and Kashmir is liberally bestowed by nature with vast and replenishable natural timber resources in the form of forests whose importance in maintaining ecological balance and the vital role they play in the industrial development of the region can hardly be over emphasized.

Forests are one of the main resources of Kashmir Valley spreading over an area of 8128.00 sq. km. comprising of 50.97% to the total geographical area (State Forest Report, 2001).

With great diversity in species and varieties, the state forest catchment area of Kashmir is delimited into six vegetational zones: Fir, Deodar, Blue pine, Chir pine, Broad leaved and Shrub trees. The main species of economic forests are: *Acacia catechu, Abies pindrow, Betula utilis, Bombax ceiba, Cedrus deodara, Dalbergia sissoo, Juglans regia, Pinus roxburghii, P. wallichiana, Picea smithiana, Populus alba, P. cilliata, P. deltoids, Quercus spp., Ulmus wallichiana and Ulmus villosa*.

The major sectors of state economy are silviculture, agriculture and horticulture. To meet the growing demands of timber and fodder, various attempts have been made to replace uneconomic and slow growing tree species with the more useful and fast growing ones.

Elms (*Ulmus spp.)* are among the famous dine and shade trees of Kashmir, which, besides lending charm and healthful fragrance to the atmosphere, are a great factor of revenue to the Valley. The elm is preferred over most other tree species for the use of fodder for cattle (sheep, goat, cow, buffalo, etc.). Villagers plant elms near the house for a sustained yield of fodder, which is being dried and kept for winter usage (Heybroek, 1965). These trees are predominant in Kashmir mostly found in the forests, nurseries, along the streets, in graveyards, convents, tombs of Sufi saints and college campuses. It produces a good quality timber, with many uses (Gamble, 1922, Pearson and Brown, 1932). Being important forest trees, they yield timber for a variety of products, including, houseboats and paddles, vehicle stock, furniture, athletic equipments, boxes and crates, ploughs, oil-presses, and musical instruments etc. In Kashmir, there are two species of elm – *Ulmus wallichiana* Planch. (Kashmiri elm) and *U. villosa*. Brandis eXGamble (Cherry-bark elm) belonging to members of temperate-coniferous forests (Heybroek, 1965).

The Kashmiri elm, *Ulmus wallichiana*, is a deciduous tree ranging from Central Nuristan in Afghanistan, through Northern Pakistan and the Kashmir in northern India, to Western Nepal at 800-3000m above sea level. It grows to 30m tall, over 1.25m in diameter with a broad crown featuring several ascending branches. The bark of the trunk is grayish brown and longitudinally furrowed. The leaves are elliptic-accuminate, less than 13cm long and 6cm broad, with unequal base (Melville and Heybroek, 1971).

The Cherry bark elm, *Ulmus villosa*, is a native of the Indian Himalayas, and was formerly called as *U. laevigata* Royle (Santamour, 1979). It is a small leaved elm, capable of remarkable longevity, growing at elevations from 1200m to 2500m, but has become increasingly rare owing to its popularity as cattle fodder, and mature trees are now restricted to temples and shrines where they are treated as sacred. Some of these are believed to be aged over 800 years. It grows upto 25m tall and is lightly and pendulously branched; the bark is smooth, silver-grey coloured and eventually becomes coarsely furrowed. Leaves are oblong-elliptic-acute shaped, less than 11cm long and 5cm broad (Melville and Heybroek, 1971). Fire, fungi and insects are the greatest agents of destruction to our forests. All parts of trees, from roots to twigs, buds and leaves, flowers, and heartwood, are susceptible to insect attack. Some insects prefer saplings and young trees, some attack older ones, others infest unhealthy and dying trees, still others prefer dead material, while some attack only rotten wood. Yet another category of these insects select seasoned or processed wood for feeding and breeding.

Bark beetles (Coleoptera: Scolytidae), distributed worldwide are the most destructive insects of the forest trees. They are the most economically important forest insects with more than 6000 species have been described (Lieutier *et al.,* 2004). Adult bark beetles bore through the outer bark to the inner cambial layer, where they channel out galleries to lay eggs. Larvae hatch in these galleries and may excavate additional channels as they feed. As bark beetles carve out galleries, they introduce blue-stain fungi. These fungi grow in the wood, interfering with the tree's water transport system. Tree deterioration and eventually mortality result from tree girdling caused by the gallery excavation, and spread of blue-stain fungi (Brasier and Mehrotra, 1995).

Elm trees in poor physiological conditions are often attacked by species of the genus *Scolytus* (Coleoptera: Scolytidae) which, although they are secondary pests, are a major cause of trees decay (Felt, 1934; Rudinsky, 1962). Dutch Elm Disease (DED) (Gibbs and Brasier, 1973), caused by the fungus *Ophiostoma ulmi* (Schwarz) Nannfeltd [=*Ceratocystis ulmi* (Buisman) C. Moreau], is one of the most destructive plant diseases to affect elm trees (Brasier, 1991). The pathogen, by direct tyloses in water conducting vessels of infected wood, has caused the death of millions of elms in Western Europe and North America (Neumann and Minko, 1985). In the last few decades, the disease has also caused serious damage in Italy (Mittempergher and Ferrini, 1980; Mittempergher, 1982; Mittempergher et al., 1985; Mittempergher et al., 1996; 1998). The current and more devastating epidemics are instead due to the *Ophiostoma nova-ulmi* (Brasier, 1991). The Dutch elm disease pathogen present only in the Himalayas is *O. himal-ulmi* (Brasier and Mehrotra, 1995).

Although the disease may be transmitted in several ways (Schwarz, 1922., Westerdijk and Buisman, 1929; Smucker, 1935), insects are the best fungal vectors (Marchel, 1927; Jacot, 1934; 1936; Collins *et al.*, 1936). In particular, the elm bark beetles belonging to the genus *Scolytus* Geoffroy (Coleoptera: Scolytidae) have been demonstrated to be the most efficient vector of the fungal spores (Fransen, 1931; Gibbs, 1974; Lanier, 1978; Beyer, 1979; Sengonca and Leisse, 1984; Webber and Brasier, 1984; Neumann and Minko, 1985;

Webber, 1990; Basset *et al.*, 1992; Favaro and Battisti, 1993; Battisti *et al.*, 1994a; Faccoli and Battisti, 1997). In spring, young beetle adults emerging from dead elms fly towards the top of healthy elms for maturation feeding on the crotches young twigs (Gibbs, 1974; Webber and Brassier, 1984). The feeding activity carried by the infected beetles may cause the contamination of the host tissues and the consequent development and diffusion of the fungus within the xylem and vessels (Fransen and Buisman, 1935). Later beetles move to the trunk of elms attacked on twig crotches the previous year. Here the inner bark provides ideal breeding material on which larvae can develop (Parker et al., 1941). The bark also becomes contaminated with the spores of *O. ulmi* carried by infected beetles when breeding galleries are excavated. The maternal galleries are an ideal micro-environment both for the growth and sporulation of the fungus (Webber and Brassier, 1984). Fungal bark colonization is known as the saprophytic phase of the disease (Lea, 1997; Gibbs and Smith, 1978). Spores infect young adults of the new beetle generation emerging from the bark completing the cycle. Among the eight Italian elm bark beetle species belonging to the genus *Scolytus* (Faccoli et al., 1998), the smaller elm bark beetle [*S. multistriatus* (Marsham)] is the main vector (Webber, 1990). Spores are transported in special structures called mycangia situated on the insect tegument (Francke-Grosmann, 1963; Barbosa and Wagner, 1989).

Losses caused by the beetles are not confined to feeding activities alone but also intensifies by disseminating disease pathogens. Their population increases rapidly when there is abundance of decadent tree, wind fall and weakened tree due to water, diseases, nutrients or salt stresses (Wood, 1982).The distribution of bark beetles is largely determined by the distribution and abundance of their host tree species and climate (Lekander et al., 1977). The older, taller elms are preferred for feeding by the bark beetles and therefore much more likely to become diseased compared with younger trees (Sengonca and Leisse, 1984).

The trees infested by the bark beetles may be recognized at a distance by fading foliage of the tree, initially a light green then changing to a light straw colour in a few weeks, and eventually to yellowish-brown. Close inspection may show a fine reddish-brown boring dust in bark cervices and at the base of the tree (Webber, 1990).

Elsewhere in the world, various details of scolytid beetles have been worked out but no scientific information is available on various aspects of bark beetles except few reports of their occurrence in Kashmir and northern states of India (Stebbing, 1914; Beeson, 1941 and Schedl, 1957*)*. *Ulmus wallichiana* is the host of elm bark beetle, *Scolytus kashmirensis* Schedl (Schedl, 1957). *Scolytus kashmirensis* is the common shot-hole borer on elm trees in Kashmir Valley. It acts as a vector of *O. himal-ulmi*, the Dutch elm disease pathogen only present in the Himalayas (Brasier and Mehrotra, 1995). By destroying thousands of elm trees, these bark beetles have greatly disturbed man's economic and social life. Keeping in view the fact that no work has been done on elm bark beetle, *Scolytus kashmirensis* Schedl (Coleoptera: Scolytidae) and the damage caused by it to the host tree, *Ulmus spp*., with the following **objectives**, it is proposed to undertake a thorough investigation on its management, so that a way may be paved for tackling the infestation effectively:

1. To carry out biological observation of the *Scolytus kashmirensis* attacking elm trees in Kashmir Valley.

2. To carry out the management of the elm bark beetle, *Scolytus kashmirensis* by:

i) Chemical control.

ii) Cultural control.

CHAPTER 2

REVIEW OF LITERATURE

As Scolytid beetles take a heavy toll of *Ulmus spp*., they have been extensively studied throughout the globe, but they have received no attention in the past except few reports of their occurrence in Kashmir (Malik *et al*., 1965; Rishi, 1998; Ahmad and Bhat, 1987). Therefore, it is important to review the work carried out on the biology and management of shot-hole borers associated with elm and other host plants, in different parts of the world.

Stebbing (1914) reported three species of scolytids- *Scolytus major, S. minor, S. deodara*, which are the worst insect pests to the deodar trees in north-west Himalaya. The author provided some details on their description and life history.

Martin (1946) studied the effect of phloem condition and phloem moisture on the entry of *Scolytus multistriatus* Marsham into elm logs in the United States. He concluded that live and decadent phloem attracted more beetles than phloem which had been dead for more than a month. The beetle's more positive reactions to live on decadent phloem for egg laying may be correlated with the inability of the early instars to develop in dead elm tissue. The data also indicated that moisture does not influence beetle entry into logs. When a correlation did appear, it was because moisture is incidently associated with phloem condition, which does not influence beetle entry. However, Fisher earlier in 1928 reported that adults of *Scolytus scolytus* F. and *S. multistriatus* Marsham were able to gauge in some manner the moisture content in a given tree or part of a tree, and can distinguish between trees too dry or too moist or in an intermediate state suitable for egg laying and the development of larva of a new generation. He determined that average moisture content of 32.1% for xylem region was too wet for the beetles, 28.6% was too low, while 31.8% was suitable.

Craighead (1950) and Keen (1952) discussed more than 50 species that attack living forest trees, the majority of which are coniferophagous, including phloem and wood borers in the roots, stems and branches; twig girdles; and gall forming species.

Linsley (1959) summarized that the adult long-horned beetles feed on variety of plant substrates, such as, flowers, bark, foliage, cones, sap, fruits, roots, and fungi. The author concluded that after copulation, males of many Cerambycid species remain with females as they search for and prepare oviposition sites, repeat copulation and fending off rival males.

Edwards (1961a,b) studied the biology of the immature stages of *Prionopus reticularis* and furnished a general account on the reproduction of Cerambycid beetles. He reported that in the subfamily Prioninae, gametogenesis is completed in pupal stage and gonads degenerate in non-feeding adults while in the subfamily Lamiinae, where adults feed, gamete production continues through adult life.

Stride and Warwick (1962) reported that stem girdling of *Mecas saturnine* enables its grubs to survive in the succulent green shoots.

Malik *et al*., (1965) investigated that the shot-hole borer scolytids in Kashmir orchards could be stopped by spraying the trees with 50% DDT (WDP) using 1 lb in 20 gallons of water during April and May after fortnightly intervals.

Beaver (1966) developed suitable sampling methods to determine both the changes in scolytid population with time and the causes of these changes. He demonstrated that most of the change in the total live population occurs in the 4^{th} and 5^{th} instar larva and that size of first generation, at least, depends on the mortality in these stages.

Malik (1966) reported that the most effective method of controlling shot-hole borers (*Scolytoplatypus sp*. and *Scolytus nitidus* Schedl.) is mixing 1 part of 10% BHC Powder with 6 parts of soil and plastering the entire infested area on trees covering up with paper and rope. This method had two advantages. Firstly, it prevented further infection and secondly forced the beetles and grubs in the burrows to escape and come out due to the fumigant nature of the insecticide. The thicker branches and trunks of the infested trees should be plastered in the beginning of May in Kashmir.

Beaver (1967) described the seasonal history of *Scolytus scolytus* (F.) on elm trees in Wytham wood, Berkshire. This species overwintered in the larval stage and the first generation adults emerged from the end of May throughout the whole summer to the beginning of September. From the galleries started by the earliest emerging of these adults, a partial second generation emerges from mid-August to mid-September. The adults construct galleries and the resulting larvae overwinter together with the remaining larvae produced by the first generation adults. Due to the prolonged emergence period and partial second generation there was a considerable overlap in the stages of development present at one time.

Beaver (1974) studied the intraspecific competition among bark beetle larvae (Coleoptera: Scolytidae). He showed that the major effects of intraspecific competition among larvae of *Scolytus scolytus, S. multistriatus* and *Tomicus piniperda* are an increase in mortality, and an increase and a decrease in mean adult weight.

Gibbs and Dickinson (1975) carried the fungicide injection for the control of Dutch elm disease (DED). The authors showed the superiority of the benzimidazole fungicides, and in particular of carbendazim (MBC), over other fungicides, on both artificially inoculated and naturally infected young elm.

King and Scott (1975) tested the dosage rates of Methoxychlor applied to healthy elms by helicopter for control of Dutch elm disease. Bioassays showed that only the highest rate, five gallons of 6% methoxychlor per tree achieved good control of maturation feeding by *Scolytus scolytus* (Fab.) for 6 weeks after spraying.

Cook and Solomon (1976) worked out the known biological information of major insect pests in cottonwood, *Populas deltoid* Bartr. They summarized that the trees of all size and age groups are subject to injury by insect pests and infestation varies greatly from locality to locality, but damage is generally greatest to open grown trees, stressed trees, and those grown in poor sites.

Novak (1976) provided valuable details on the occurrences of elm bark beetle, *Scolytus multistriatus* Marsh and *Scolytus scolytus* Fabr. on elm trees in North America. Both these bark beetles are known to swarm twice in a year; the first swarming is in the later part of spring, as a rule in May; the second swarming is in the first part of summer, in July or August, according to location. *Scolytus scolytus* forms a vertical mother tunnel, about 5 cm long and numerous tunnels which often attain a length of 10 to 15 cm. The author also reported that the birch sap wood borer *Scolytus ratzburgi* Jans emerges in June and July in nature and flies to old and weakened birch trees. It also attacks healthy trees during a mass outbreak.

Gibbs and Greig (1977) studied the consequences of the drought for DED. They reported that elm bark beetle, *Scolytus scolytus* was able to invade and successfully breed in apparently healthy, undiseased elms, thriving mainly on shallow soils over limestone, trees on chalk were not generally affected.

Hepting (1977) discussed the threatened elms and gave a perspective on tree disease control by combating Dutch elm disease and Elm phloem necrosis. During the study period, 42% of the DED samples proved to be the cases of *Cephalosporium* wilt. Another 4% of the samples indicated *Verticillium* wilt, a killing disease caused by either *Verticillium albo-atrum* or *V. dahlia*. Positive diagnosis could often be made only by determining whether slivers of infected wood cultured on nutrient agar produced *Ceratocystis ulmi*. In 1927, many elms had died in Dayton by the disease generally known as the Dayton elm disease. *V. rhizophagum* proved to be only a minor root-inhibiting fungus occurring on many kinds of trees, even pines. Within six to twenty-four months, clear symptoms of the new elm disease appeared in 75 to 90% of the grafted trees. In 1938, since the inner bark or phloem of diseased trees was particularly invaded by the virus. The disease became known as elm phloem necrosis.

Byers *et al.*, (1980) studied the pruning schedules and reported that wounding trees by pruning will attract the bark beetle vectors of Dutch elm disease. The authors recommended that ideally, routine pruning should be done in the dormant season or should be restricted to periods of beetle inactivity.

Byers *et al.*, (1980) worked on attraction of elm bark beetle to cut limbs on elm. They reported that smaller European bark beetle, *Scolytus multistriatus* is attracted to pruned limbs of European and Siberian elm compared to healthy non-pruned limbs.

Waters and Stark (1980) carried out studies on forest pest management and furnished an account that the adverse impacts should be prevented or kept at tolerable levels by ecological sound means, which are compatible with forest management objectives and practices.

Donley (1981) described an account on the control of red oak borer, *Enaphalodes rufulus* Haldeman. (Coleoptera: Cerambycidae) by removal of infested trees and reported 50% and 90% reduction in borer population after treatments in first and second generations respectively. Cultural control is effective in reducing the cerambycid borer infestation rate in forests and it reduced the treated red oak borer population by 63-68%, compared to untreated populations (Donley, 1983).

Sharma and Tara (1985b, 1986) evaluated some control measures and screened kerosene oil and para-dichlorobenzene mixture; carbon tetrachloride; carbon disulphide and para-dichlorobenzene mixture; chloroform; petrol, naphthalene and carbolic acid mixture; benzene; ethyl acetate; petrol and kerosene oil mixture; metasystox; ethylene dibromide and nuvan against insect pests of mulberry in Jammu. Singh and Prasad (1985) reported that the current years infestation of *Apriona cinera* Chevrolat (Coleoptera: Cerambycidae) can be prevented by pruning the host plants before their grubs enter the main stem and that of last year's infestation (old infestation) by fumigation.

Gibbs and Wainhouse (1986) reported that there are four main forest regions in the Northern hemisphere, each containing many of the same genera of trees. An organism (insect, fungus, etc) living in balanced relationship with its host tree in one of these forest regions may cause major damage if moved to another.

Anderbrant and Schlyter (1987) worked out the distribution and phenology of the Dutch elm disease vectors, *Scolytus laevis* and *S. scolytus*. By using the sticky traps (white cardboard), their results indicated a low proportion of dispersion beetles, and emergence from logs and trap catches showed a first peak in July in the three years studied and second peak of activity was evident in August in two of the years for *Scolytus scolytus*, indicatihg a second generation.

Houle *et al*., (1987) tested the infectivity of eight species of entomogenous fungi to the larvae of the elm bark beetle, *Scolytus multistriatus* (Marsham). They concluded that increased spore concentrations of the test fungi did not significantly affect percentage mortality with 7 of the 11 strains of the fungal species tested. Varying temperature produced complex effects on the host-parasite relationship.

Lanier (1988) suggested that pruning combined with fungicide gives better DED management than pruning or fungicide alone when dealing with a residual infection. He found that fungicides were most effective when injected directly into large limbs where an infection had been found, as well as into the hole.

Byers (1989) discussed the chemical efficacy of bark beetles in regard to host tree selection theories of random landing on trees or attraction to semiochemicals. He presented the olfactory perception of semiochemicals at both the electrophysiological and behavioral levels.

Mandal *et al*., (1989) furnished an account on the control measures of round headed stem borer, *Aeolesthes holosericea* Fabr. in tropical ecosystems. The authors explored the efficacy of five synthetic insecticides viz., dimethoate, phosphamidon, fenitrothion, aldrex, and cypermethrin against the stem borer.

Pajars and Lanier (1989) demonstrated that the commercial formulations of 4 Pyrethoid insecticides [fluvalinate (Mavrik), permethrin (Pounce), cypermethrin (Ammo) and esfenvalerate (Asana)] were 222-548 times more toxic to *Scolytus multistriatus* than was methoxychlor. Compared with methoxychlor, all of the Pyrethoids provided superior protection from twig feeding, cypermethrin and esfenvalerate killed all beetles contacting sample twigs and prevented twig feeding throughout an 18-week period of bioassays after spraying.

Jassim *et al*., (1990a, b) worked out the biological control of DED and larvicidal activity of *Trichoderma harzianum*, *T. polysporum* and *Scytalidium lignicola* in *Scolytus scolytus* and *S. multistriatus* reared in artificial culture. In control cultures, a natural mortality rate of 21.2% was found for *S. multistriatus* and 17.6% for *S. scolytus*. They proposed that with modifications, the method is applicable to other bark beetle pests.

Vite and Baader (1990) discussed the use of semiochemicals in pest management of bark beetles. They showed that the attractive compounds affecting the mass aggregation of bark beetle populations on host trees suitable for colonization usually consist of two obligatory components that act synergistically and species-specifically. Semiochemicals inhibiting response act on their own and seem less specific. They further stated that mass trapping should remain a worthwhile tool in preventing beetle damage in forest management intensive enough to remove excessive breeding material. In the long run, response-inhibiting semiochemicals resulting in the dispersal of pest populations (Ablenkstoffe) may gain wider application.

Knutson (1991) demonstrated that the activity of Copper sulphate pentahydrate (available as Phyton 27^R) is based on the fungicidal effect of metallic copper. He found a 22% higher level of copper in the leaves of a Phyton 27^R treated elm compared to leaves of untreated elms at 15 months after treatment. Leaf abscission is common following Phyton 27^R injection, but is usually followed by refoliation.

Basset et al., (1992); Favaro and Battisti, (1993) conducted the experiments on the relative effectiveness of *Scolytus multistriatus* Marsham and *S. pygmaeus* Fabricius as vectors of *Ophiostoma ulmi (Ceratocystis ulmi)* in elms, in northeastern Italy. There was no significant difference in the transmission of the pathogen between the two-scolytid species. Favaro and Battisti (1993) determined the spore load on both sexes of *S. pygmaeus* and the effects of some abiotic factors (temperature, RH, and light) on the vitality of the spores. They reported that 57.5% of beetles carried the fungus at emergence. 68.75% males carried more spores than 55% females. The spore loads of adults artificially inoculated and exposed different conditions and between higher temperatures (20 and 24^{o}C) whereas the lowest temperature (13^{o}C) had no effect. Adults exposed to daylight for 6-12 hours showed a drastic decrease in spore load and became less effective vectors. The decline and death of *Elaegnus* spp. on the west coast of the Caspian Sea in Russia under the influence of Scolytus jaroshevskii and pathogenic microflora were described (Petrov and Kuz, 1994). The characteristics of cultured bacteria and the life cycle of the vector *S. jaroshevskii* were also described.

Cinti *et al.*, (1993) listed the insecticides and acaricides registered for use on principal pests of peach including *Scolytus rugulosus* in Italy, and presented details of their spectrum of activity, waiting period and toxicological class.

Ascerno and Wawrzynski (1994) described the native elm bark beetle, *Hylurgopinus rufipes* control via, sanitation, chemical, sampling, and pruning. They recommended that the chlorpyrifos applications to elm trees in mid-September are effective for killing beetles before they bore into healthy elms to construct overwintering sites.

Brasier and Mehrotra (1995) reported that the elm bark beetle, *Scolytus kashmirensis* Schedl act as vector of fungus, *Ophiostoma himal-ulmi*, the Dutch elm disease pathogen only present in Himalayas.

Hagen (1995) carried out the management of bark beetles in urban and rural areas of California. He recommended both chemical and cultural control against the effective eradication of the infestation of borers.

Li-JiangLin *et al.*, (1995) studied the control of *Scolytus seulensis* on fruit trees in Xinjiang and proposed enforcing quarantine and improving orchard management as control measures. They tested that spraying 2.5% Decis (deltamethrin) and 20% Sumicidin (fenvalerate) at 1000-2000 (dilution) onto tree stems during the period of peak adult occurrence of the pest resulted in >85% control.

Manojlovic and Sivcev (1995a) investigated the effect of elm bark thickness on the growth of *Scolytus scolytus* Fabricius under laboratory conditions at 27-29^0 C and 75% RH in Siberia (Yugoslavia). They showed that growth conditions for *S. scolytus* were most favourable under bark 5-8 mm thick i.e., in the lower part of middle-aged trees. The longest mother galleries per mother gallery occurred under bark of this thickness. The values were higher in the first than in the second generation and in both generations, the lowest number of mother galleries occurred under the thinnest bark. Duration of development increased with increasing bark thickness from 31 to 36 days in the first generation and from 34 to 39 days in the second. Obligatory diapauses of some population increased with increasing bark thickness.

Ben-Yehuda and Mendal, 1997 conducted the chemical control experiments of the buprestids *Capnodis spp*. and the scolytids, *Scolytus amygdale* and *S. rugulosus* in deciduous orchards in Israel. Prevention of the colonization of the roots by larvae of *Capnodis* was achieved by dusting the area around the stem with Mesurol (methiocarb) 5%, Cutanion (ethylazinofos) 8% and Marshal (carbosulfan) 2%. Acceptable results were also achieved by the application of Cutanion 4%, Chlorpyrifos 5%, and Deltamethrin 2%. Foliar sprays of Cutanion 0.2% wettable powder, Mesurol 0.1%, Silafluofen 0.2%, Confidor (imidocloprid) 0.05%, and Fipronil 0.02%, 0.03% or 0.04% against adults of *Capnodis* and bark beetles resulted in satisfactory results.

Paine *et al.*, (1997) studied the interactions among the scolytid bark beetles (Col., Scolytidae); their associated fungi, Ophiostomatoid fungi, *Ceratocystis* and *Ceratocystiopsis*, and infest conifers.

Goyer *et al.*, (1998) recognized the current and proposed technologies for bark beetle management in the Pacific regions. In the Pacific Northwest, thinning and selection of appropriate species have been the preferred management options, but pheromones- both attractants and antiaggregants show promise. In the Southwest slash management and thinning with semiochemicals and biological controls were proposed.

Haugen and Stennes (1999) injected trees with fungicides for the effective treatment of Dutch elm disease. They observed that the fungus infects the vascular tissue of elms, causing the vessels in the active, outer rings of xylem to become clogged and the injection can be effective in preventing or treating infection caused by the bark beetle inoculation. Injection of fungicide into trees can be effective by either making the infection court unsuitable (Preventive fungicide), or by stopping fungal growth within the tree (Therapeutic injection). Kondo (1978a), Campana (1977) and Stipes (1988) addressed some of the many factors that limit the effectiveness of fungicide injection.

Heliovaara and Peltonen (1999) described that the bark beetles (Coleoptera: Scolytidae) are distributed worldwide and form many cosmopolitan genera. They summarized that both biotic and abiotic factors are important in limiting species distributions and pest status. Temperature not only affects the biogeography and local distribution of the scolytids, but also regulates the onset of flight in spring, rate of development, number of generations as well as mortality, especially in winter.

Faccoli (2001) investigated the possibility for the combined control of *Ophiostoma nova-ulmi* and *Scolytus multistriatus* in Italy. Two elm clones [*Ulmus pumila* x *U. minor* (clone B) and *U. glabra* var.pendula grafted onto *U. pumila* x *U. minor* pollards (clone A)] were treated by stem injection of different blend or concentrations of fungicides and insecticides. Then, adults of *S. multistriatus*, either loaded with spores of two isolates of *O. nova-ulmi* (H328 and 182) or provided of their natural load of conidia, were forced to feed in twig crotches of the treated trees. After 48 hours, all insects were checked (dead or alive). The percentage of the fungal transmission obtained from insects carrying the natural load of conidia was lower than percentages obtained from beetles artificially loaded. The best results were obtained by injecting the Carbendazim and Acephate blend in the clone A. High chemical concentrations did not improve the general results.

Manojlovic *et al*., (2001) studied the impact of additional diet on the longevity, reproduction, developmental rate of the parasitoids (Hymenoptera: Braconidae) and the parasitizing of elm bark beetle (*Scolytus scolytus* Fab., *S. multistriatus* Marsh., S. pygmaeus Fab.). They found that Parker's diet had the most significant effect on the parasitoids and the parasitizing of the bark beetles.

O'neill and Evans (2001) described the cost-effectiveness analysis of three options within an Integrated Crop Management regime against great spruce beetle, *Dendroctonus micans* Kug. (Coleoptera: Scolytidae) in Great Britain. (i) Restriction on movement of infested timber and use of the imported predator beetle, *Rhizophagus grandis* Gyll. (Coleoptera: Rhizophagidae). (ii) Drop all attempts to reduce the spread of *D. micans*. (iii) Introduce a new east-west 'Dendroctonus Micans Control Area' (DMCA) to define the management area. The appraisal indicated that the current policy was the most cost-effective.

Solla and Gill (2002) investigated the xylem vessel diameter as a factor in resistance of *Ulmus minor* to *Ophiostoma nova-ulmi* in Spanish elms. Xylem vessel diameters and the proportion of large vessels were correlated with the susceptibility of *U. minor* to Dutch elm disease. They discussed the properties which influence the dispersal of the fungus, the sap flow and the tree's ability to compartmentalize the disease.

Anderson and Holliday (2003) studied the distribution and survival of overwintering adults of the Dutch elm disease vector, *Hylurgopinus rufipes* (Coleoptera: Scolytidae), in American elm trees in Manitoba. They applied residual insecticides to the lower part of elm tree trunks where the adult beetles overwinter and estimated that within the height range 0-190 cm, the proportion of living beetles declined steeply with increasing height.

Rodriguez *et al.*, (2003) tested different insecticides for the control of olive bark beetle, *Phloeotribus scarabaeoides* Bern. In mortality laboratory bioassays, the efficiency of organophosphorus insecticides has been ranked as follows: chlorpyrifos + dimethoate < formothion < methidathion. Deltamethrin inhibited the excavation of new reproduction galleries and induced a repellant effect on the olive pest. Ethylene, a plant hormone has been reported as an attractant for the olive bark beetle.

Buhroo *et al.*, (2004, 2006) investigated the population dynamics, seasonal abundance and an attempt on biological control of *Scolytus nitidus*, the shot-hole borer on Apple trees. The studies for seasonal populations of S. nitidus were determined by number of holes girdled by beetles, population of adult beetles collected from emergence boxes and counting of immature scolytids. The results regarding the girdling of holes indicated that no holes were perforated before April, 25 and October, 10 during the study period. It was observed that after emergence the beetles increased their population upto May, 10 and then gradually decreased on June, 10. It was concluded that the branches infected with the scolytid beetles should be sprayed with the spores of *Aspergillus versicolar, Penicillium aurantiogriseum, P. pallidium and P. putterillii* in the solutions of either distilled water, glycerin, or P.B.I wetting agent that could enter the branches through the insect entrance holes due to *to and fro* movements of beetles and running of males over the branch. These fungi could be formulated as useful mycopesticides in the management of temperate fruit borers.

Webber (2004) carried out the experimental studies on the factors influencing the transmission of DED. He concluded that the behavior of each beetle influences the transmission of *Ophiostoma nova-ulmi* and *O. ulmi* at many points in the disease cycle and affects the quantity and quality of pathogen spores carried by newly emerged beetle vectors. The resistance mechanisms of elms themselves also play a part in disease transmission including different resistance mechanisms operating in the feeding groove compared with the resistance mechanism in the vascular system.

Borden (2006) discussed semiochemicals and bark beetle populations and exploitation of natural phenomenon by pest management strategists. He gave three types of operational pest management programmes: prevention of pheromone production by excluding bark beetles from their hosts; suppression of bark beetle populations through the utilization of semiochemical-biated traps, trees, or logs; and the use of antiaggregation pheromones to protect vulnerable hosts from attack.

Batta (2007) studied the biocontrol of almond bark beetle (*Scolytus amygdale* Geurin-Meneville, Coleoptera: Scolytidae) using entomopathogenic fungus, *Beauveria bassiana* (Bals.) Vuill. (Deuteromycotina: Hyphomycetes) in Israel. The results obtained have demonstrated a significantly higher level of efficacy of formulated *B. bassiana* in invert emulsion against *S. amygdale* adults under laboratory and field conditions. The ingredients of invert emulsion used in the formulation of fungus had a negligible effect on the viability of formulated conidia when compared with the unformulated. This type of biocontrol of this insect may be used as an alternative means to chemical control for management of insects.

Buhroo and Lakatos (2007) investigated biological characters of *Scolytus nitidus* and reported that this shot-hole borer overwinters in larval stage on apple trees in Kashmir. At emergence the adults fly to suitable trees and undergo maturation, feeding for 4-6 days the female lays usually 52 eggs on the average. The eggs hatch in 5-7 days. The larvae have 5 instars and complete their development in 38-50 days. The larvae pupate for 6-8 days and finally emerge to attack new trees. The adults live for 45-60 days and total life span for this species ranges from 97-124 days.

Diez and Gil (2007) recognized the effects of *Ophiostoma ulmi* and *O. nova-ulmi* culture filtrates on elm cultures from genotypes with different susceptibility to Dutch elm disease in Spain. They concluded that the 'in vitro' assays cannot be used to evaluate resistance sources to DED in elms, or to assess specific pathogenicity of fungal isolates.

Barson (2008) demonstrated some effects of freezing temperatures (-7^0 C to -31^0 C) on overwintering larvae of the large elm bark beetle (*Scolytus scolytus*). The Lt_{50} for larvae removed from the bark (-20.5^0 C) was significantly different ($P<0.01$) from the Lt_{50} (-18.3^0 C) for larvae insulated by the bark (thickness of 7mm ± 2mm). Larvae with food in their digestive tract were more susceptible to freezing than the overwintering final instars, which had voided their stomach contents. Most of the larvae which survived the sub-zero treatments were able to pupate or reach the adult stage. The mean super cooling point of the overwintering larvae (-30.85^0 C) confirmed their cold-hardiness.

Boone *et al.*, (2008) investigated that the competitors add to predator load of a tree-killing bark beetle and reported that the mountain pine beetle, *Dendroctonus ponderosae* is a major tree-killing bark beetle in North America. They evaluated how the subsequent arrival of a competing bark beetle, *Ips pini* influences the arrival of predators (*Temnochila chlorodia* and *Enoclerus sphegeus*) and their impact on both species. Secondary bark beetles that exploit the resource created by primary tree-killing species exert negative effects through both competition and increased predator load.

Buhroo and Ramamurthy (2008) described the seasonal history and activity of the bark beetle, *Scolytus nitidus* and reported that this beetle has three generations in a year on apple trees in Kashmir. The beetle overwinters in all its larval stages coinciding the dormancy of the host. The beetle resumes its activity at initial silver-tip stage in the Red-Delicious cultivar in the first week of March. The larvae pupates at the pink-bud stage and the first swarm of adults appears at the completion of petal fall in the 3rd week of April.

Finney and Mordue (2008) observed the susceptibility of the elm bark beetle, *Scolytus scolytus* to the DD-136 strain of *Neoaplectana* sp. The authors proposed that the adults and larvae of *Scolytus scolytus* were highly susceptible to the DD-136 strain of *Neoaplectana* sp. in the laboratory.

Masood *et al*., (2008) studied the characterization and damage patterns of different bark beetle species associated with Mango Sudden Death Syndrome (MSDS) in Punjab, Pakistan. It was observed that the bark beetle, *Hypocryphalus mangiferae* was most frequently found in diseased mango trees in early stages while *Xyleborus* sp. appeared in later stages. *Sinoxylon* sp. was only found in the wood of dead and dying trees. *Nitidulid* sp. was found occasionally on dried diseased trees. All the species made the holes of various sizes in tree trunk and made galleries of different shapes and sizes beneath the bark except *Sinoxylon* sp., which made longitudinal tunnels in trunk.

Skarpaas and Okland (2008) worked out the timber import and the risk of forest pest introductions. They found that many invasive species are introduced by trade and evaluated that the most effective measures for reducing introduction risk were those aimed at isolating the storage from forest (storage enclosure, location) followed by those reducing the available resources for forest pests (debarking, timber irrigation, rapid processing), whereas delayed import was least effective.

Borden (2009) discussed two tree baiting tactics for the management of bark beetles with semiochemicals. Baiting of trees with semiochemicals to contain and concentrate populations of the mountain pine beetle, *Dendroctonus ponderosae* and *Ips typographus* has been an effective tactic used in IPM programmes in Britain. They also suggested the combination of semiochemical baits with arsenical herbicides in single tree treatments for *Scolytus multistriatus* and an alternative tactic is to bait with semiochemicals of secondary bark beetles e.g., many *Ips spp*., to cause competitive displacement of beetles of an aggressive species already in a tree.

Dimitri *et al.*, (2009) studied the influence of mass trapping on the population dynamic and damage effect of bark beetles. They concluded that the clean-management is the best, most reliable and reasonable method against the propagation and the attack of the bark beetles.

Drumont *et al.*, (2009) described the semiochemicals and the integrated management of *Ips typographus* (L.) (Col., Scolytidae) in Belgium. Several pyrethroids with sufficient remanence have been provisionally selected for the use against *Ips typographus* and *Trypodendron lineatum*. Removal of infested material and trap tree deployment were witnessed standard methods for the management of spruce bark beetles.

Eidmann (2009) discussed the impacts of bark beetles in Sweden and the role and management of bark beetle breeding substrate. It was found that the *Tomicus piniperda* and *Ips typographus* have the greatest impact on forests. The heaviest losses were reduction of timber quality, unsalvaged timber, and the cost of control measures. They further stated that the economic impact of reduced growth depends on the shortening of rotation by insect attack and on interest rates.

Erbilgin *et al.*, (2009) studied that the bark beetle-mediated fungal infections of susceptible trees induce resistance to subsequent infections in a dose dependent manner. They determined that propagule loads (low, medium, high) on the twig beetles *Pityophthorus setosus* and *Pityophthorus carmeli* (Coleoptera : Scolytidae) influence the pathogen infection of the host tree in the Monterey pine- *Fusarium circinatum* system. The initial infection by beetles carrying high or medium propagule loads induced resistance to subsequent infections of the host, whereas infections caused by beetles with low propagule loads did not.

Hansen and Somme (2009) investigated the cold-hardiness of the elm bark beetle, *Scolytus laevis* Chapuis, 1873 (Col., Scolytidae) and its potential as Dutch elm disease vector in the northernmost elm forests of Europe. Frozen larvae became active shortly after thawing, but subsequently died or were unable to pupate at 21^0 C. The authors concluded that the cold-hardiness will not be the limiting factor for the distribution of the elm bark beetle within the limits of the elm tree.

Maksimovic and Motal (2009) carried out the investigation of the numbers of maternal and larval galleries made by three elm bark beetle species viz., *Scolytus scolytus, S. multistriatus and S. pygmaeus)* in trap logs. On the basis of data, they established the time of swarming, the relation of inlet holes to the number of maternal galleries, distribution of maternal galleries by the length and position of trap logs percentage with formed larval galleries to those without the larval galleries.

Martikainen *et al*., (2009) studied the population levels of bark beetles in non-epidemic conditions and compared between intensively managed forests in Finnish Karelia and extensively managed forests in Russian Karelia. The number of species and individuals of bark beetles did not differ between the countries but the species assemblages were, however, different. *Hylastes brunneus* and *Pityogenes bidentatus* were more abundant in Finland whileas *Crypturgus subcribrosus*, *Polygraphus punctifrons*, and *Hylurgops glabratus* were common in Russia. Bark beetles were most abundant in old mesic forests. The amount of decaying wood on the ground did not correlate with the numbers of bark beetles caught.

Mendel *et al*., (2009) worked out some foundations for the application of aggregation pheromone to control pine bark beetle in Israel. To optimize mass trapping of *Orthotomicus erosus* and *Pityogenes calcaratus* (Col., Scolytidae) in *Pinus halepensis* and *P. brutia*, some stand and soil characters of thinned pine plantations, time of thinning as related to bark beetle outbreak and various characters of trees susceptible to scolytid attack were investigated. Inspection of injury by *O. erosus* and *P. calcaratus* showed that the percentage of dead trees decreased with DBH. The average mortality due to an induced attack of trees biated with Pheroprax was higher in thinned plots as compared to unthinned plots. Knowledge of conditions, which may lead to an attack, viz., time of thinning, soil type, and time of the expected attack, is a help in improving mass trapping techniques as a part of forest management.

Nazir *et al*., (2009) studied the status of bark beetle, *Scolytus nitidus* (Schedl.) severity on apple trees of different age group and varieties under three situations undertaken in two districts of North Kashmir. The authors concluded that highest severity on trunks on apple trees was recorded from Baramulla block (41-8%) and lowest from Tangmarg block (16.9%). Highest pest severity (30.9%) was noticed in October and lowest severity of 23.7% in May. Apple trees of >30 year age were infested more severely as compared to the other age groups indicating that the older trees are more susceptible to bark beetle infestation.

Pawson and Watt (2009) described an experimental test of a visual based push-pull strategy for control of wood boring phytosanitary pests. Control 'push' lights had the highest average catch of *Arhopalus ferus*, whileas white 'push' light was most attractive to *Prionoplus reticularis*. The results obtained suggest that a push-pull strategy combining yellow site lighting with UV kill traps could provide site-specific control of wood borers.

Stephen *et al.*, (2009) studied the bark beetle-host tree interactions and prediction of its infestation growth. To use information in a management oriented predictive model, resistance properties of pines must be correlated to easily measurable tree and/or stand characters, resulting in improved predictions over a variety of site and stand conditions, thus leading to better management decisions.

Ulyshen and Hanula (2010) investigated that the patterns of beetle succession in dead wood remain unclear, particularly beyond the first several years of decay. The saproxylic beetles were sampled from loblolly pine (*Pinus taeda* L.) logs aged between 1month and 9 years old, using both emergence traps attached to logs in the field and rearing bags in the laboratory. Species richness peaked within the first year as a result of a diverse assemblage of bark beetles, wood-borers and predators associated with young logs. After the phloem phase, there were no significant differences in species richness among decay classes. Beetle communities differed significantly among decay classes, with 25 and seven species being significantly associated with young and old logs, respectively.

The studies on the ‘‘Management of elm bark beetle, *Scolytus kashmirensis* Schedl infesting elm trees (*Ulmus spp*.) were carried out in Kashmir Valley of Jammu and Kashmir state both in the field as well as in the laboratory during 2009-2010.

3.1. Study Sites:

Four Districts were selected from the Kashmir Valley and in each district two sites were marked (Fig. 1). The marked sites are:

S. No	District	Study Site
1.	Anantnag	Uttersoo
2.	Anantnag	Danter
3.	Shopian	Zainapora
4.	Shopian	Aglud
5.	Ganderbal	Nuner
6.	Ganderbal	Wayil
7.	Baramulla	Sangri
8.	Baramulla	Watrigam

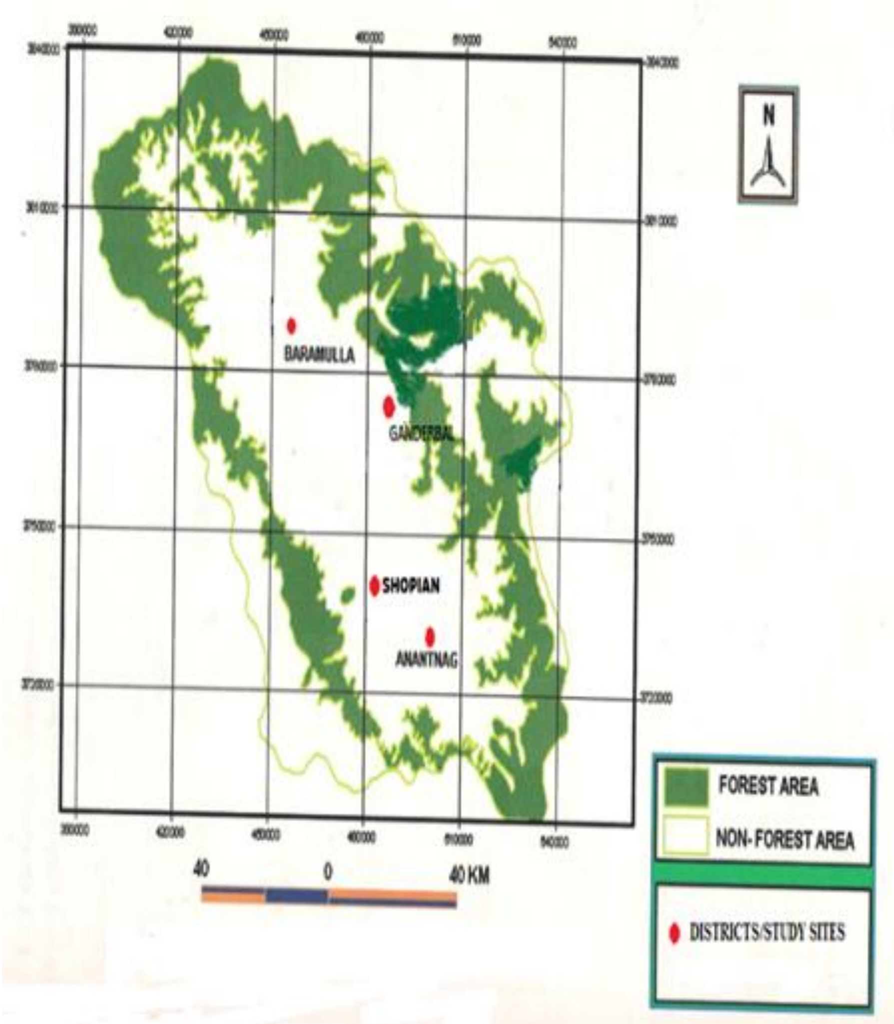

Fig. 1: Map of Kashmir Valley showing study sites

3.2. Incidence and Distribution of *Scolytus kashmirensis*:

To study the incidence and distribution of *Scolytus kashmirensis* of *Ulmus* spp. in Valley, monthly survey was conducted by fixed plot method. Frass indexing method was adopted to assess the borer infestation and rate of incidence of borers was calculated by the following formula:

Total number of trees infested

% infested = ———————————————— x 100

Total number of trees observed

Infestation of *S. kashmirensis* in *Ulmus* populations were observed on the basis of species specific symptoms. Shape and size of bore/ tunnel, outside through which faeces tunneling pattern, niche of the grubs, nature and distance between
sub tunnels-bores/tunnels arising from the main feeding tunnel which open and chewed wood is expelled out and presence or absence of frass in main feeding tunnel are species specific and serve to characterize the infested plants.

Infestation rates were recorded separately for *Ulmus* spp. at the marked study site and analyzed statistically.

3.3. Collection and Preservation:

a) Immature stages:

The borer infested logs were cut and dissected to expose the grubs of different size and instars and pupae. Exposed grubs and pupae were killed in KAAD mixture or XA mixture and preserved in 70% ethyl alcohol. Direct preservation/killing in ethyl alcohol was avoided to prevent the darkening of specimens.

The standard method as described by Borror and Delong (1973) was followed for the preparation of the killing agents and their composition is:

KAAD mixture:

Kerosene Oil	10 ml
Ethyl alcohol (95%)	70-100 ml
Glacial acetic acid	20 ml
Dioxane	10 ml

XA mixture:

Xylene	50 ml
Ethyl alcohol (95%)	50 ml

Immature stages killed in either of these mixtures were stored in the respective mixtures for ½ to 4 hours, depending upon the size, before the final preservation in 70% ethyl alcohol.

b) Adults:

The elm bark beetles, *S. kashmirensis* were manually collected and killed in temporary killing bottles using ethyl acetate as a killing agent, because it is least toxic to human beings. The specimens were relaxed by dipping them in Barbers fluid, which is used as a relaxing agent. The preparation of relaxing fluid (Barbers fluid) is as under:

Ethyl alcohol (95%)	50 ml
Distilled water	50 ml
Ethyl acetate	20 ml
Benzene	7 ml

3.4. Identification:

The elm logs infested with the shot-hole borer were cut into pieces of about 12 inches in length, sealed at both ends with melted paraffin wax to avoid the moisture loss and transported to the laboratory. These logs were put in jars covered with muslin cloth to let the grubs to emerge as adults. The adults were removed from the jars and identified with the help of literature. These adults were then used for biological studies. Few infested logs were also tied with the fresh logs to ensure the availability of the material amply in the rearing boxes.

3.5. Photography:

a) Digital Photography: Field photography was done with Sony Cyber Shot 10 megapixel digital camera.

b) Microphotography: Morphological characters were determined using scanning electron microscopy (SEM). Specimens were first placed in buffered glutaraldehyde (2.5%) for two hours fallowed by buffer washing for overnight. 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 two days of open drying the specimens were mounted on stubs and coated with gold using the Vaccum Evaporator. Electron micrographs were taken with S-3000H *Scanning Electron Microscope*. (HITACHI, Japan). The photographs were then developed on Kodak high quality photo paper.

3.6. Management of Shot-hole borer, *Scolytus kashmirensis:*

Cultural and Chemical measures were evaluated for the management of the shot-hole borer.

3.6.1. Cultural control:

Cultural control was executed by the following methods:

i) Pruning

ii) Sanitation

iii) Removal of brood trees

Pruning:

Spring and Autumn pruning were made to investigate its impact on the infestation rate of the shot-hole borer among elm plants.

Sanitation:

It involved the prompt removal and disposal of dead and dying elms to reduce bark beetle breeding sites. The barked elm wood, leaves, twigs were completely disposed off along with their harboring beetles at two sites/locations during the present study in Autumn, 2009. The infestation rate was compared with the control site in the following season.

Removal of brood trees:

It involved the removal of brood trees (unrecoverable-infested trees) followed by their destruction along with harboring grubs. A small proportion of infested trees were sacrificed during the present study in spring and autumn of 2009. Brood trees were removed in two elm nurseries at two sites/locations and the infestation rate was compared with the control plot/site in the next season.

3.6.2. Chemical control:

The chemical control is the quick, effective and most popular method of control for the borer. Following synthetic chemicals/ insecticides were screened against the borer, *S. kashmirensis*.

i) Dichlorvos
ii) Endosulfan
iii) Imidacloprid
iv) Benzene hexachloride (BHC)
v) Monocrotophos
vi) Monocrotophos + Carbendazim

Three different concentrations (0.05%, 0.1% and 1%) of the above chemicals were used against the elm borer and Pearson's square method was adapted for dilution of chemicals.

For field evaluation a big elm plot was selected. Here alternative rows were selected and within each row, plants were selected alternatively and then tagged. This was done to avoid multiple spraying. The concentrations of all the treatments were sprayed with a hand-operated sprayer and five replications were maintained for every treatment level. A control was also maintained in each case. Data regarding pest population were recorded a day before spray (DBS) (Pre-treatment population) and 24 hours, 48 hours, 72 hours and 96 hours after treatment (Post-treatment population) (Nileson, 1957).

For laboratory evaluation, fresh un-infested logs were sprayed with above mentioned concentrations, air-dried and then placed in plastic jars. Ten *Scolytus kashmirensis* larvae collected from the field, were fed on the treated logs and then transferred to untreated logs for 24 hours. Each treatment was replicated thrice. A control set was also run simultaneously. All the jars were covered by muslin cloth and properly labeled. Observations on larval mortality were made at the end of 24, 48, 72, 96 and 120 hours (Malathi and Sriramula, 2000).

3.7. Data analysis:

The observations made during the current study were tabulated and graphically presented. The data was statistically analyzed by different methods. Arithmetic mean± SE (Standard error of mean) and Chi square (X^2) test were used to analyze the data. The means were compared by Student's t-test and the values were considered significant at $P \leq 0.05$.

Scolytids (Coleoptera: Scolytidae), the predominant shot-hole borers are the most charismatic of the megafauna, form an important group of wood boring insects that kill or damage trees by tunneling under the bark to reproduce. They attack healthy, weak, stressed, and dead host trees (Fig. 2). The current studies made on the **''Management of elm bark beetle, *Scolytuskashmirensis*Schedl infesting elm trees (*Ulmus* spp.) in Kashmir''** is hereby presented under the following subheadings:

*Scolytuskashmirensis*Schedl, 1958g.

4.1. Classification:

Phylum	Arthropoda
Class	Insecta
Order	Coleoptera
Family	Scolytidae
Genus	*Scolytus*
Species	*kashmirensis*

Fig. 2: Damage caused by *Scolytuskashmirensis* to elm trees.

4.2.Description:

The body of the adult borer is small, cylindrical, hard-bodied measuring about 3mm- 4mm in length. The head is partly hidden by the shining black protonum. Elytra are dark red-brown in colour. The interstices are finely punctured. The thorax is nearly as long as abdomen. The anterior margins of the elytra form a straight, transverse line and are unarmed by the crenulations or teeth. The scutellum is very large, triangular, and depressed. The sternites of the abdomen ascend steeply to meet the elytra. On the central underside of the second abdominal sternite, there is a minute tubercle and a lip like structure on the second sternite (Fig. 3). The egg is small, globular, shiny and pearl white in appearance, the larva is white, legless grub with brown head and C-shaped (Fig. 4), and the pupa is white initially, gradually darkens, wings folded under abdomen.

4.3. Biology:

Under the present investigation, the *Scolytuskashmirensis* overwintered in the larval form. The data (Table 1.) revealed that the larvae became active from 10th April. After few days the larvae changed into pupae at the ends of their larval galleries. The pupation period started from 15th April to 23rd April (8 days) and changed to adults in their pupal chambers. The adults were seen to infest the new logs of the elm from 1st May. After host selection, the female*Scolytuskashmirensis* bored a small hole on the bark of the declining branch. As soon as few beetles attacked, more and more flying adults of both sexes were attracted soon. The male was observed to butt with his head against abdomen of the female few times in the gallery and turned around over the entry hole and copulation was followed.

The female started to lay eggs from 5th May. 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 sap wood surface, the vertical mother galleries ranged from 2.3 - 7.6 cm in length (Fig. 5). After the completion of mother gallery, the female remained in the tunnel until most of the larvae had developed. The larval period lasted from 10th May to 20th June. Female finally died in the entrance hole. The pupation took place at the larval galleries in pupal cells. The pupal stage started from 21st June and lasted for 5 – 15 days. The adults emerged from the pupal chamber by tunneling straight through the bark over it. After emergence, first generation adults flew to the crownof other suitable trees to produce the next generation.The female beetle again started to lay eggs of the second generation from 12th July; the newly hatched eggs were seen on 18th July. The larval period started from 18th July and the larvae became inactive from 6th September onwards. This phase extended from 6th September to14th April of the next year. In this way, the shot-hole borer, *Scolytuskashmirensis* completed one full and second partial generations per year in Kashmir.

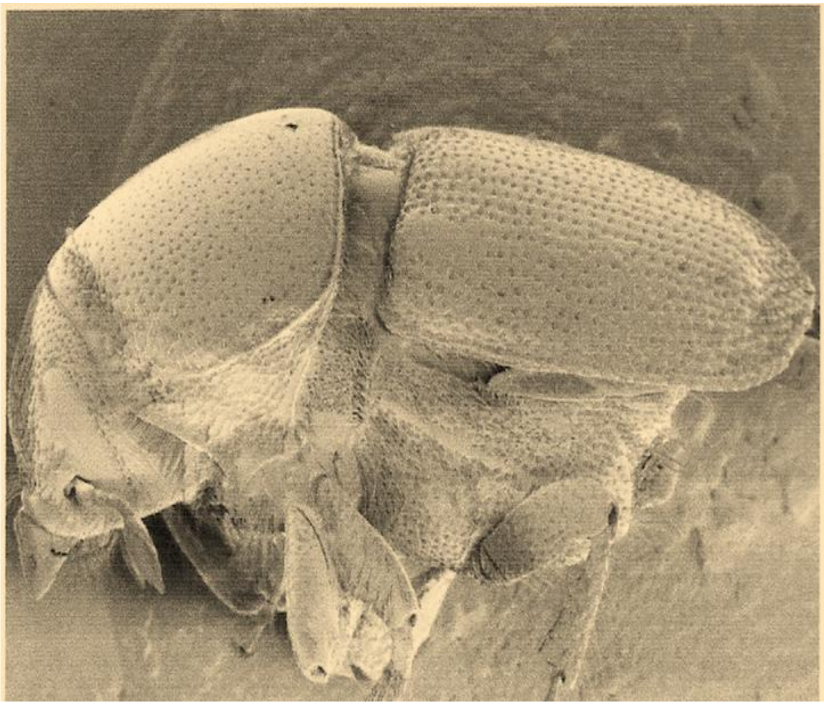

Fig. 3: **Lateral view of *Scolytuskashmirensis***

Fig. 4: Larva of *Scolytuskashmirensis*

Fig. 5: Gallery system of *S. kashmirensis.*

Table 1:Seasonal distribution of various stages of *Scolytus kashmirensis*during 2009-10

DEVELOPMENTAL STAGE	MEAN DISTRIBUTION PERIOD
Active larvae	10th April, 2009
Pupae	15th April, 2009
Adults	Ist May, 2009
Eggs	5th May, 2009
Initial larvae	10th May, 2009
Late larvae	20th June, 2009
Pupae	21st June, 2009
Adults	3rd July, 2009
Eggs	12th July, 2009
Initial larvae	18th July, 2009
Late larvae	Ist September, 2009
Inactive larvae	6th September, 2009
OVERWINTERING	6th September 2009 – 14th April 2010

4.4. Host selection and Oviposition preference:

Elm shot-hole borer perceived the odour of their host plants by biting, chewing and boring in the bark. This has been confirmed by supplying primary branches of elm and willow as oviposition material to ovipositing females. Females made bores on both elm and willow branches, but oviposited only on the elm branches (Table 2). Difference in the number of bores made on elm and willow is insignificant ($P > 0.05$), while as oviposited eggs in the two host plants is highly significant ($P < 0.05$), which confirmed host specificity of the shot-hole borer under investigation.

Table 2: Host specificity of *Scolytuskashmirensis*:

Oviposited material	**No. of bores**	**No. of oviposited eggs**
Elm (*Ulmus*)	198	137
Willow (*Salix*)	182	0
Chi Square (X^2)	0.62	137

Gravid females scurried over host plants, bore the primary branches 6-15mm in diameter, severed bark and phloem completely and xylem partially. Among bored cum oviposited branches, 14.13% of them were in group I (6-9mm in diameter), 63.04% in group II (diameter 9-12mm) and 22.83% in group III (diameter 12-15mm). Table 3 showed that females prefer to oviposite in group II branches, ranging 9-12mm in diameter.

Table 3 :Oviposition preference of *S. kashmirensis* on elm branches of different diameter.

Group	Branch diameter (mm)	Oviposited branches	%oviposited branches
I	6-9	13	14.13
II	9-12	58	63.04
III	12-15	21	22.83

4.5. Host seeking resistance:

Difference in the resistance of the two species of elm- *Ulmusvillosa* (Cherry bark elm) and *Ulmuswallichiana* (Kashmiri elm) to the shot-hole borer, *S. kashmirensis* was revealed by the feeding and infestation rate. The shot-hole borer preferred to the *Ulmuswallichiana* twigs (diameter 8-11mm) as compared to the *Ulmusvillosa* twigs (diameter 8-11mm). The below mentioned table-4 depicted low susceptibility and high resistance in case of *U. villosa* (Fig. 6 & 7).

Table 4: Susceptibility and resistance in *U.wallichiana* and *U. villosa*.

Host tree (Twig diameter 8-11mm)	**No. of twigs subjected to infestation**	**No. of twigs infested**	**Rate of infestation (%)**
U. wallichiana	10	9	90
U. villosa	10	4	40

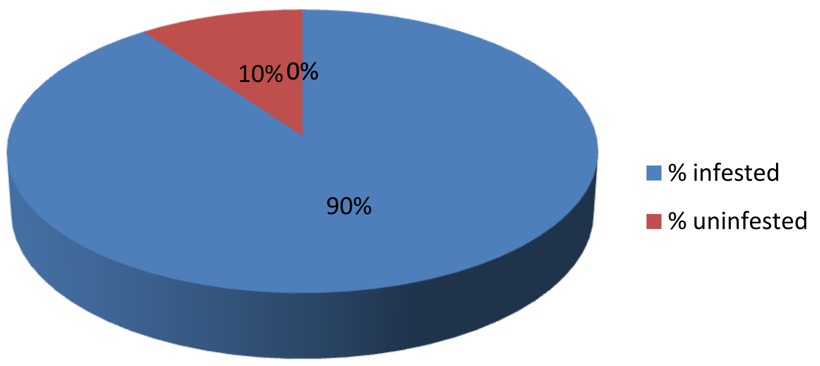

Fig.6: Percentage of infestation of *S.kashmirensis*in *Ulmuswallichiana.*

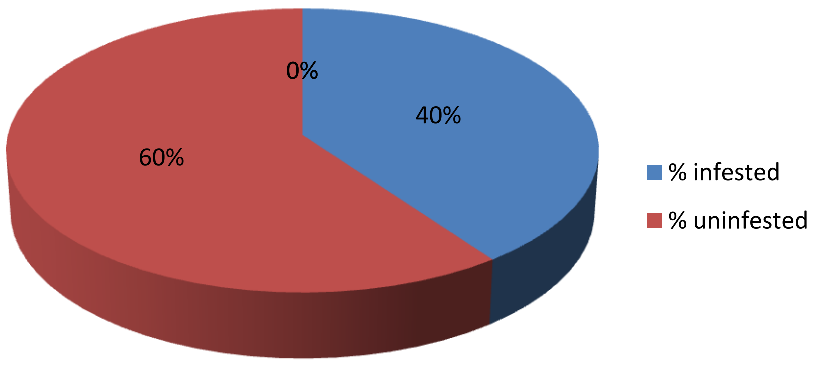

Fig.7: Percentage of infestation of *S. kashmirensis*in *U. villosa.*

4.6. Infestation:

A total of 650 elm trees were observed in 28 nurseries from the four districts of Kashmir Valley. Out of 650 trees, 136 were found infested with shot-hole borer, *S. kashmirensis* attack. According to the survey results, incidence of the borer was highest in Anantnag and Shopian districts i.e., 26.11% and 22.35%, respectively followed by Ganderbal and Baramulla i.e., 17.14% and 16.87%, respectively. The overall infestation recorded in these districts was 20.92%. (Table 5; Fig. 8).

Table 5: Shot-hole borer, *S. kashmirensis* infestation in elm nurseries recorded in four districts of Kashmir Valley.

Locations / Districts	GPS Position	No. of elm nurseries	Total no. of trees	No. of trees attacked by borer	% trees attacked with borer
Anantnag	33.73^{0}N 75.15^{0}E	10	180	47	26.11%
Shopian	33.72^{0}N 74.83^{0}E	7	170	38	22.35%
Ganderbal	34.23^{0}N 74.78^{0}E	5	140	24	17.14%
Baramulla	34.19^{0}N 74.36^{0}E	6	160	27	16.87%

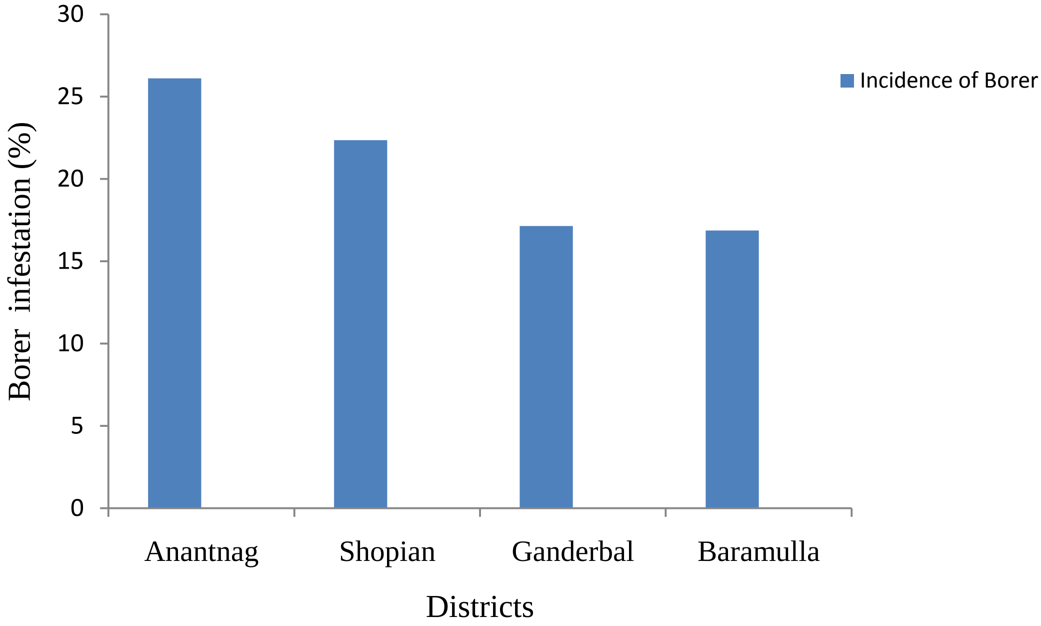

Fig. 8: *S. kashmirensis* infestation in elm nurseries recorded in four districts of Kashmir.

4.7. Nature of damage:

The shot-hole borer mine the inner bark (phloem-cambial region) on twigs, branches and trunks of elm trees. Small emergence holes in the bark was a good indication of the borer's presence (Fig.9). The infested branch withered and died, resulted in the stunted growth of the host plants. Both the adults and the grubs of the borer caused damage to elm plants. Though the adults of the borer caused relatively insignificant damage to their host plants, but the damage caused by the grubs is severe and in most cases goes unnoticed, due to their concealed nature, till death of the host plants(Fig. 10 and 11). Both the vertical mother galleries and larval radiated galleries in the stem reduce the yield and vigour of trees and ultimately lead the plants to die retrogressively.

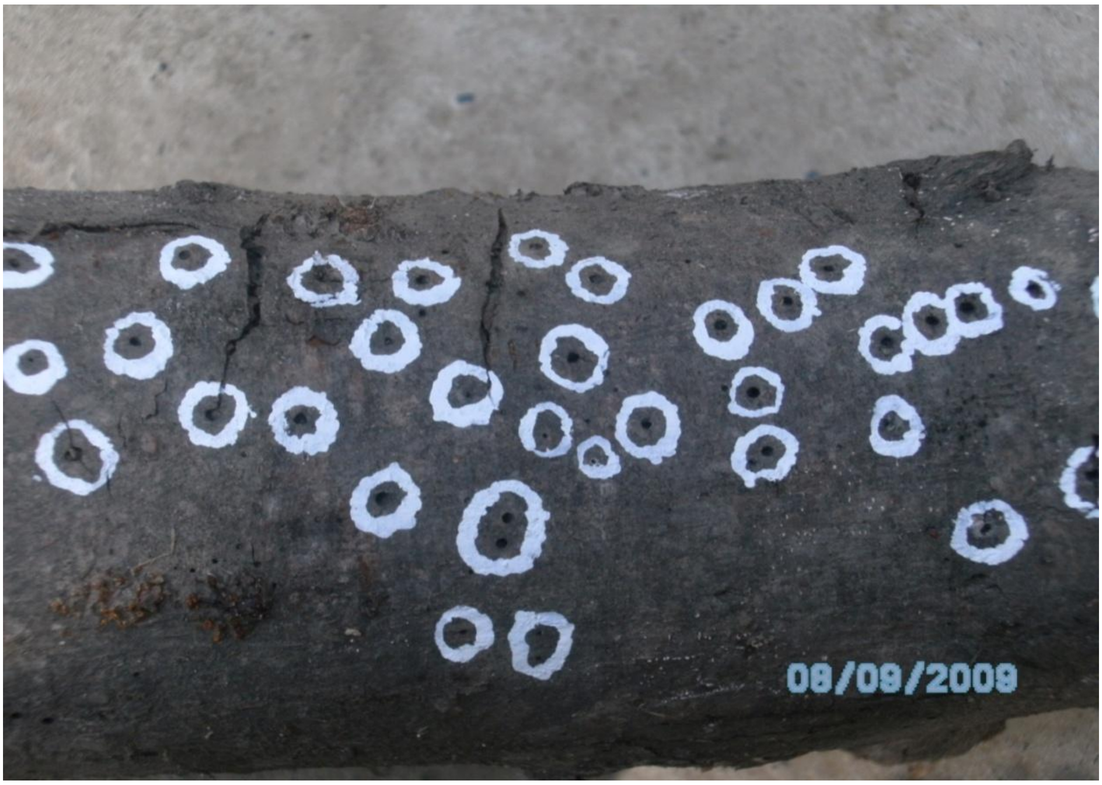

Fig.9: Perforations of *S. kashmirensis*on infested branch of elm earmarked by white paint

Fig.10: Immature larvae of *S. kashmirensis*and the extent of damage to elm log.

Fig.11: Damage caused by the larvae of *S. kashmirensis*to decayed elm log

4.8. Management of *Scolytuskashmirensis*:

4.8.1.Cultural control:

Cultural control encompasses all those practices that aim at reducing the pest infestation through the manipulation of regular farm practices. Cultural management practices, viz., seasonal pruning, sanitation,and removal of brood trees were evaluated against *S. kashmirensis*.

Seasonal pruning:

Autumn pruning reduced the borer infestation rate significantly ($P<0.05$) while as spring pruning gave insignificant results ($P>0.05$) (Table 6). Spring pruning reduced the infestation rate of elm shot-hole borer in the next generation by 2.33% as compared to the control plots, whereas autumn pruning reduced it by 63.67% (Fig. 12).

Table 6:Effect of Seasonal pruning on infestation rate of *S. kashmirensis*.

Pruning season	No. of sampled trees	% infestation in following spring	% reduction over control	t- value
Spring	50	19.43±1.00	2.33	0.40
Autumn	50	6.73±0.67	63.67	15.00
Control	50	19.66±0.76	0.00	0.00

Pruning is a usual farm practice which involves the removal of infested primary branches. The beetle under study deposited its eggs in the primary branches and the newly hatched grubs made their way into the main stem of the infested trees through the soft pith of these branches. Pruning prevented the newly hatched grubs to colonize in the main stem of elm trees as their earlier instars harbouring the primary branches were destroyed along with the pruned branches.

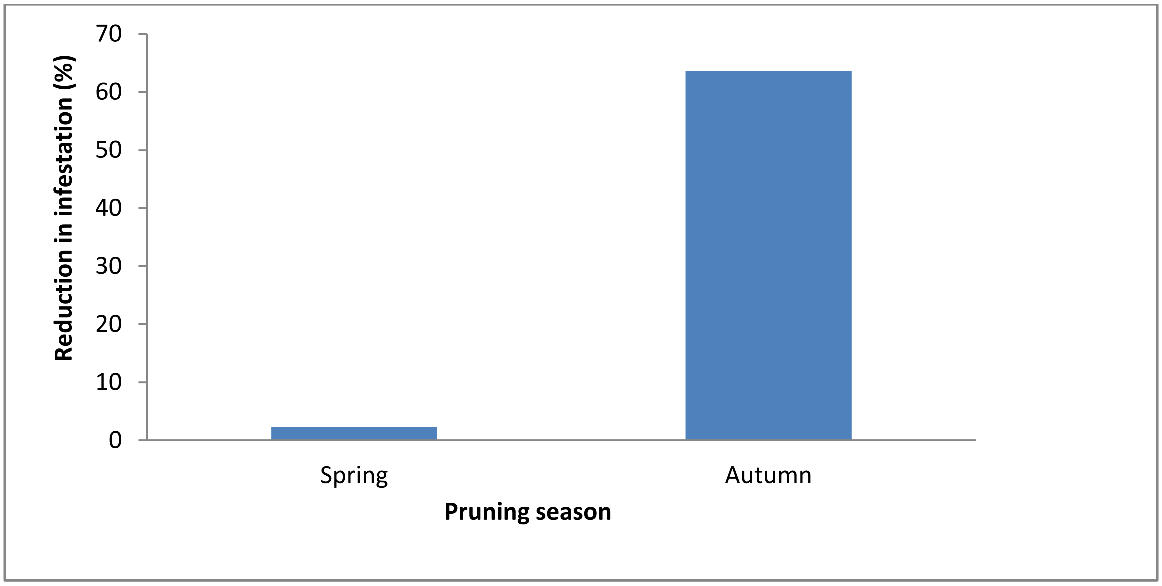

Fig.12:Effect of seasonal pruning on infestation rate of *S. kashmirensis*.

Sanitation:

Sanitation in two elm plots/nurseries reduced the borer infestation rate by 61.02% in I plot and 63.49% in II plot as compared to control plot/ nursery (Table 7). Reduction in the borer infestation rate over control was ascribed to the sanitation of elm plots/nurseries (Fig. 13).

Table 7: Effect of sanitation on elm plots/nurseries.

Treatment in elm plots	No. of trees ascribed to sanitation	Infestation rate (%) in following spring	% reduction over control	t-value
I	100	8.77±0.68	61.02	15.33
II	100	7.55±0.57	63.49	16.00
Control	100	10.43±0.58	0.00	0.00

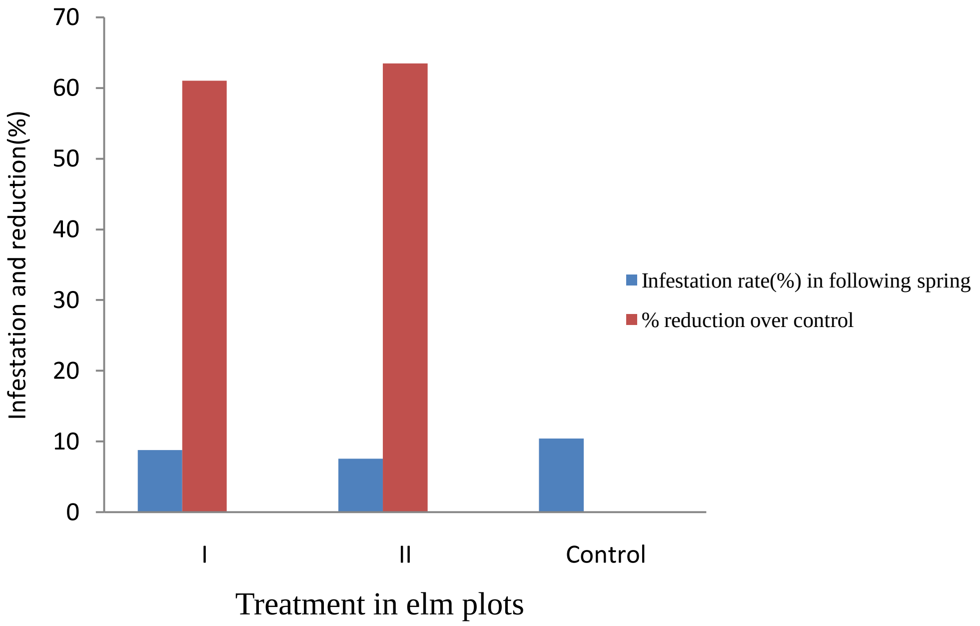

Fig.13: Control of *S. kashmirensis* by sanitation.

Removal of brood trees:

The infestation rate of the borer was reduced in the elm nurseries/ plots significantly ($P<0.05$) (Table 8)by the removal of brood/ infested trees. During the study period, in the treatment plots the borer infestation rate was reduced by 42.41% while as in control plot infestation rate increased by 5.45%, however, the latter is statistically insignificant ($P>0.05$).

First treatment involved the removal of 10.33% infested trees and reduced the infestation rate by 17.30%, while as in second treatment 11.55% infested trees were sacrificed which resulted in the reduction of borer attack by 27.31%. A total of 21.88% infested trees were removed and the harboring grubs were killed which in turn resulted in the failure of shot-hole borer populations to regain pretreatment densities which resulted in curtailed mating and subsequent egg laying and finally reduced infestation rate (Fig. 14).

Table 8: Efficacyof brood tree removal against *S. kashmirensis*.

Treatment	Pre-treatment infestation (%;mean±SE)	Post-treatment infestation (%;mean±SE)	Reduction over previous generation (%)	t-value
I	20.65±0.62	17.35±0.30	17.30	5.16
II	17.37±0.30	13.29±0.60	27.31	7.43
Control	19.44±0.40	20.50±1.20	-5.45	0.83

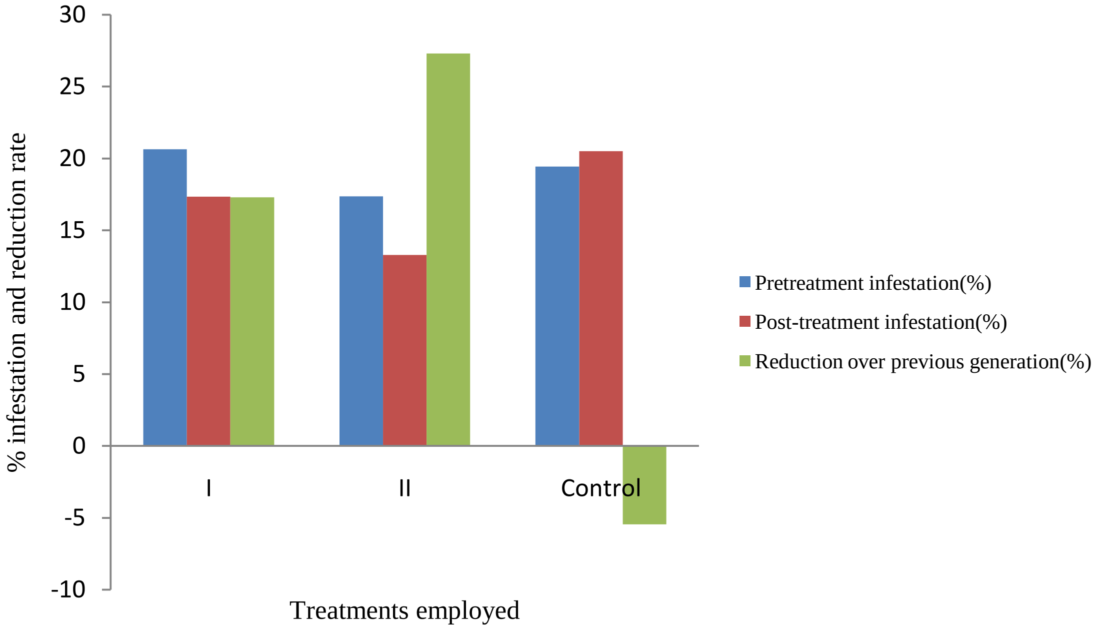

Fig. 14: Effect of brood tree removal against *S. kashmirensis*.

4.8.2. Chemical control:

Each of the chemicals viz., Dichlorvos, Imidacloprid, Monocrotophos, Carbendazim, Endosulfan and Benzene hexachloride (BHC) screened against the shot-hole borer, *S. kashmirensis*were effective at 0.1% and 1.00% concentrations, however, 0.05% of each of them were ineffective to control the borer population significantly ($P<0.05$). The technical data concerning the treatment are reported below in table 9.Dichlorvos 1% was the most effective to rest of the chemicals tested against the borer population, controlled 92.70% borer population followed by Monocrotophos and Carbendazim mixture which controlled 86.33% (Fig. 15). The rest of the chemicals though controlled a good proportion of the borer population, but were significantly less effective than Dichlorvos and the mixture of Monocrotophos and Carbendazim.

Table 9: Efficacy of synthetic chemicals against the*S.kashmirensis*.

Insecticide	Mortality (%;mean±SE) at concentrations		
	0.05%	**0.1%**	**1.0%**
Dichlorvos	20.33±4.3	69.00±4.3	92.70±3.3
Imidacloprid	13.67±3.1	56.33±3.3	70.00±4.0
Endosulfan	12.70±4.2	57.33±3.3	72.33±3.0
BHC	13.33±4.0	60.0±5.6	80.33±3.1
Monocrotophos	15.67±4.0	61.70±2.6	78.00±2.0
Monocrotophos+ Carbendazim	14.00±2.0	62.67±4.6	86.33±3.1
Control (Water)	8.00±3.3	8.00±3.3	8.00±3.3

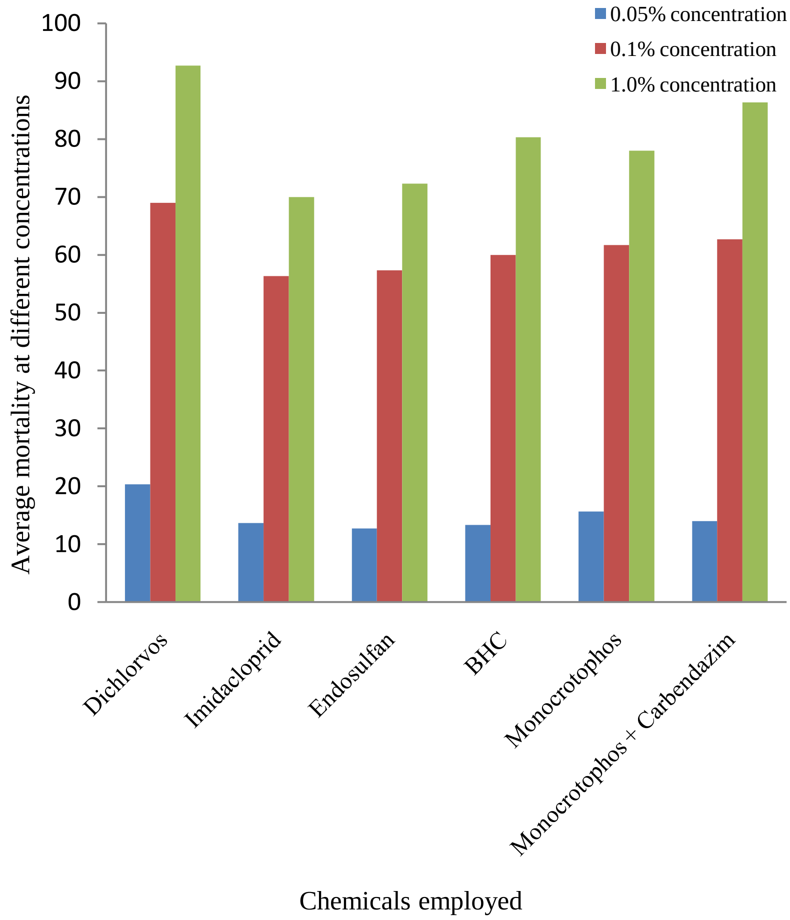

Fig. 15: Efficacy of chemicals employed against *S. kashmirensis*.

Bark beetles are distributed worldwide occupying a wide range of niches on woody and herbaceous plants. The species of genus *Scolytus* (Coleoptera: Scolytidae) attack elm trees (*Ulmus* sp.) in poor physiological condition and are a major cause of tree's decay (Felt, 1934; Rudinsky,1967). Most species of the family are polyphagous causing wide spread mortality among host tree species (Craighead,1950). There is no information available on *Scolytus kashmirensis*, a serious shot-hole borer of elm trees in Kashmir. In the present study, the *S. kashmirensis* was registered to attack elm trees in Kashmir and the observations related to its management are discussed under different subheadings as under:

5.1. Distribution:

The present observations revealed that the bark beetle, *S. kashmirensis* infested elm trees in Kashmir. Geographically it is distributed in the Himalayas (Brasier and Mehrotra,1995). It is common shot-hole borer of elm trees in Kashmir (Schedl,1957). The other species of the same genus, *Scolytus* has also been reported from India, China and Japan (Grune,1979; Maslov,1970). The distribution of bark beetles is largely determined by the distribution and abundance of the host tree species and climate (Lekander et al., 1977). The foregoing discussion revealed that the elm bark beetle, *S. kashmirensis* is restricted to the temperate regions of Himalayas. The incidence of the borer was highest in Anantnag and Shopian districts of Kashmir Valley i.e., 26.11% and 22.35% respectively followed by Ganderbal and Baramulla i.e., 17.14 % and 16.87% respectively. The present study is at par with the Webber (2004) who showed that changes in temperature, humidity, elevation and season influence the bark beetle infestation and disease incidence.

5.2. Biology:

Scolytus kashmirensis became active from second week of April upto the first week of September in Kashmir and larvae underwent into overwintering phase in the first week of September. It completed two generations (2nd partial one) in a year. These results are in agreement with the two generations of *Scolytus Scolytus* on elm (Beaver, 1967) and also of *S. mali* (Rudinsky et al.) under European conditions. However, Buhroo and Lakatos (2007) determined that *S. nitidus* completed three generations (3rd being partial) per year on apple trees in Kashmir. While as *Scolytus amygaldi* had four generations annually on fruit trees in Baluchistan (Janjua and Samuel, 1941). The pattern of the mother gallery of *Scolytus kashmirensis* was same as reported by Novak (1976) in case of *Scolytus Scolytus* and *Scolytus multistriatus*.

5.3. Host selection, oviposition and infestation rate:

Host selection in *Scolytids* is very critical because the larvae are legless and incapable of moving between hosts. Sex pheromones, they produce aids elm bark beetle to locate their host tree (Svihra, 1982; Blight et al., 1983). The present observation is that elm bark beetle perceived the odour of host plants. The beetle under study, chewed the scars on twigs of both the plants (host and tentative non-host plants) supplied to them in cages, but laid eggs in only one of them (host plant). It was also demonstrated that both the species of elm (*Ulmus wallichiana* and *U. villosa*) were susceptible to the borer attack, however, *U. villosa* showed low susceptibility and high resistance as compared to *U. wallichiana*. Host plant selection by olfaction in *Scolytids* is well documented (Vite and Baader, 1990; Borden, 2006; Drumont, 2009; Mendel, 2009). Ethylene, a plant hormone, has been reported as an attractant for the Olive bark beetle, *Phloeotribus scarabaeoides* Bern (Rodriguez et al, 2003). *Monochamous* sp. is attracted by pine terpenoids, monoterpenes and ethanol (Chenier and Philogene, 1989). Fransen (1939b) showed that *Scolytus* sp. can have distinct feeding preferences for particular elm species and these findings have been extended more recently (Colin, 2004; Sacchetti et al., 1990; Webber, 2000; Webber and Kirby, 1983). Certain trees appear to be highly attractive and act as 'sinks' for large number of beetles which alight and then feed. Such trees may have high levels of chemical feeding stimulants in the bark, and a bark texture that also encourages feeding activity (Webber, 2004). Siberian elm is highly susceptible to the elm leaf beetle, as is the Japanese *zelkova (*Sinclair et al, 1987). This demonstrates that beetle preferences do operate in natural systems

5.4. Management of *Scolytus kashmirensis*:

5.4.1. Cultural control:

Seasonal pruning:

Pruning of trees is a cultural operation, an economical tool employed in integrated pest management of perennial plants. The pruning cut for the removal of the branch should be made approximately 10′ behind the point at which healthy wood is first observed (Lanier, 1988). Wounding trees by pruning will attract the bark beetle vectors of Dutch elm disease (Byers et al., 1980).

The findings of the current study is at par with that of the Lanier (1988) who suggested that ideally, routine pruning should be done in the dormant season or should be restricted to the periods of beetle inactivity and of Donaldson and Seybold (1998), and Sanborn (1996) who recommended that elm trees should not be pruned from March to September. Spring and Autumn pruning reduced infestation rate of the elm borer by 2.33% and 63.67% respectively.

Autumn pruning prevented the elm trees from the borer infestation by destroying the harboring grounds of overwintering larvae along with the pruned branches, thus restricting the infestation in the next season.

Spring pruning could not prevent the elm plants from the borer infestation as the twigs sprouted from the spring pruned plants are the preferred oviposition sites for elm shot-hole borer.

Pruning in the management of *S. kashmirensis*, the shot-hole borer under study is appealing for several reasons viz., reduced the borer infestation rate significantly; no environmental hazard encountered; does not interfered in the economics of silviecosystem.

Sanitation:

This is the most important element of management program for existing elms because it removes the elm bark beetles breeding habitat from the system. It consists of the immediate removal of any dead or wounded branches, and the debarking of branches stored for use as lumber and fuel. The present study is at par with the Schreiber and Peacock (1974); Van Sickle and Sterner (1976) who suggested that the most effective control measures against the elm bark beetles to date have been based on sanitation programs consisting of prompt removal of recently dead or dying trees, as well as the speedy destruction of all elm material infested by beetles. Lanier (1988) suggested that no borer infestation and thereof Dutch elm disease management program will be successful without good sanitation. Sanitation prevented elm trees from borer infestation as it destroyed the overwintering harboring grounds of the borer. It reduced the borer infestation rate by 61.02% in I elm plot and 63.49% in II elm plot as compared to control plot. Lanier (1988) suggested that sanitation including pruning combined with fungicides gives better disease management than sanitation, pruning or fungicides alone when dealing with a residual infection. Sanitation should be viewed as a community-wide management tactic.

Control by the removal of brood trees:

The control measure reported here is based on locating and subsequent removal of heavily infested trees (brood trees) that are unrecoverable which is an attempt to work out the control strategy against the shot-hole borer under study. Brood trees after removal were dissected and the harboring grubs were exposed and killed which in turn resulted in the failure of elm borer to regain pretreatment densities, thus infestation rate automatically reduced. Removal of heavily infested trees reduced elm borer, *S.kashmirensis* attack by 42.41% in two treatments.

Elm trees (*Ulmus* sp.) stressed by unfavorable environmental conditions, disease, defoilation, age, or poor tree care are most susceptible to bark beetle attack (Hagen, 1995). Heavy infestation of Lamiine species cause widespread mortality among host tree species (Yang et al, 1995; Ertain, 2003). Donley (1981) showed that the control of red oak borer, *Enaphalodes rufulus* by removal of infested trees reduced 50% and 90% borer population after treatments in first and second generations respectively.

The removal of heavily infested trees which are destined to death, does not disturb the economy of the silviculture industry.

5.4.2. Chemical control:

Chemicals for elm bark beetle control, the vectors of Dutch elm disease, have been researched since the 1940's (Zentmeyer et al., 1946; Diamond et al., 1949). Synthetic chemical treatment have been potentially useful for suppression of infestation of elm bark beetles (Davis and Dimon,1952; Beckman,1959; Smalley,1962). Faccoli (2001) used Carbendazim (8%), Monocrotophos (52%), Ometoato (50%), Methomil (35%), Acephate (42%) against the elm bark beetle, *Scolytus multistriatus*. Nishijima (1977) showed that Carbendazim is temporary very mobile within the tree, is quickly distributed to the foliage and it is lost as the leaves drop. Palaniswamy et al (1977) used Dieldrin. Carbaryl, BHC and DDT at 0.5% concentrate of each insecticide to control the red spotted longihorn beetle in Tamil Nadu. Malik (1965, 1966) used 50% DDT and 10% BHC against the Scolytus spp. in Kashmir orchards. Pajars (1989) used pyrethoid insecticides against the *Scolytus multistriatus*. Sharma and Tara (1985b, 1986) recommended the injection of kerosene oil and para-dichlorobenzene mixture; petrol, naphthalene and carbolic acid mixture; benzene; ethyl acetate; petrol and kerosene oil mixture; metasystox; ethylene dibromide and nuvan against insect pests of mulberry in Jammu. Lanier (1988) suggested that pruning combined with fungicide gives better Dutch elm disease management than pruning or fungicide alone when dealing with a residual infection. Nielson (1981) pointed out the limited vulnerability of borers to insecticides. This is partially true of species such as *Scolytus kashmirensis* that attack elm trees in Kashmir and spend much of their life cycle in the heartwood. The vulnerability of borers is positively correlated with its concentration (Cavalcaselle, 1972; Baksha, 1990; Smith, 1996).

The present observation revealed that the efficacy of the screened insecticides at different concentrations against *S. kashmirensis* varied significantly among themselves. 1.00% concentrate of all the screened chemicals were effective with Dichlorvos ranking first in efficacy against the borer under study. Dichlorvos was 92.70±3.3% efficient followed by a mixture of Monocrotophos and Carbendazim, BHC and Monocrotophos which killed 86.33±3.1%, 80.33±3.1% and 78.00±2.0% grubs respectively. However, Imidacloprid was least effective followed by Endosulfan. Technically 0.05% concentrate of these chemicals was ineffective whereas 0.1% solution controlled the pest population significantly. The results showed that the injection of 5ml of 1.00% solution of Dichlorvos or a mixture of Monocrotophos and Carbendazim per live bore could be used to control the infestation rate of *S. kashmirensis* effectively.

Plants are subjected to incessant onslaught of insects. Bark beetles have been reported as potential or regular pests of forests in the Kashmir and are of great silvicultural importance. Preliminary investigators reported that elm plants are prone to the attack of insect pests which affect its economic product. The study entitled "Management of elm bark beetle, *Scolytus kashmirensis* Schedl infesting elm trees (*Ulmus* spp.) in Kashmir" was carried out during 2009-10 and the findings thereof are summarized as follows:

6.1. Description:

The present investigation revealed that the shot-hole borer (*Scolytus kashmirensis*) infested elm trees (*Ulmus wallichiana* and *U. villosa*) in Kashmir. Both the *Ulmus* spp. are susceptible to infestation but vary in degree. *Ulmus wallichiana* was found highly susceptible and low resistant as compared to *U. villosa*. The aforementioned borer exploited one or the other tissues of elm plants. The borer, *S. kashmirensis* mine the inner bark (the phloem-cambial region) on twigs, branches or trunks of elm trees and resulted in the stunted growth of infested host tree. The *S. kashmirensis* is of great economic importance as it attacks the living/healthy but weakened elms, lead them to ultimate death and also feed on the dead and dying plant tissues, so plays a significant role in the host plant physiology and/or economy.

6.2. Biology:

The shot-hole borer, *Scolytus kashmirensis* overwintered in the larval phase. The larvae were seen to be active from 10th April and after few days they changed into pupae at the end of their larval galleries. The pupation period started from 15th April and the adult emerged from 1st May. The adults were seen to infest the new logs of elm trees and deposited eggs of the first generation. The first generation extended from 5th May upto 3rd July. The second generation eggs were laid from 12th July and this was a partial generation and the larvae entered into a overwintering phase. The overwintering phase extended from 6th September to 14th April of the next year. *Scolytus kashmirensis* completes one full generation and second partial generations per year in Kashmir.

6.3. Management strategies:

Management practices which included cultural and chemical operations reduced the infestation rate significantly. Seasonal pruning reduced infestation of *S. kashmirensis* significantly; Spring and Autumn pruning reduced it by 2.33% and 63.67% respectively. Sanitation reduced the borer infestation rate by 61.02% and 63.49% in two treated elm plots. Removal of the brood trees reduced *S. kashmirensis* infestation rate by 42.41%. None of the two species of the genus *Ulmus* (*U. wallichiana* and *U. villosa*) offered complete resistance to the attack of the borer under study, however, *U. villosa* though prone to their attack showed slight resistance as compared to the *U. wallichiana* screened in the region which are more or less equally susceptible to the borer. The synthetic chemicals viz., Dichlorvos, Endosulfan, Imidacloprid, BHC, Monocrotophos, and a mixture of Monocrotophos and Carbendazim screened against the elm shot-hole borer are effective, but their efficacy is proportional to their concentration.

Eventually, the present study generated the basic knowledge covering the Management of elm bark beetle, *Scolytus kashmirensis* infesting elm trees in Kashmir and this effort can be used as a foundation for much deeper understanding of the beetle if we are to manage this beetle and the Dutch elm disease more effectively and see a healthy return of the mature elm to our landscape.

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