Pakistan J. Zool., vol. 49(3), pp 1093-1105, 2017. DOI: http://dx.doi.org/10.17582/journal.pjz/2017.49.3.1093.1105

# Chemical Ecology of Asian Long Horned Beetle (*Anoplophora glabripennis*) - A Review

**Saqib Ali[1], Suliman Ali[1], Lina[1], Wen Zhou[1], Muhammad Irfan Waris[1], Ashfaq Ali[2] and Man Qun Wang[1,*]**

*[1]Hubei Insect Resources Utilization and Sustainable Pest Management Key Laboratory, College of Plant Science and Technology, Huazhong Agricultural University, Wuhan 430070, People's Republic of China.*

*[2]College of Horticulture and Forestry Sciences, Huazhong Agriculture University, Wuhan, China*

**Article Information**
**Received 28 November 2015**
**Revised 04 March 2016**
**Accepted 07 September 2016**
**Available online 25 May 2017**

**Authors' Contribution**
**SA wrote the article. L and WZ helped in life cycles and identification of beetles. MIW, SA and AA helped in writing of this article. MQW provided technical and financial support.**

**Key words**
**Long horn beetle, Wood borers, Pest management, Sex pheromones, Kairomones, Oviposition, Stimulants.**

## ABSTRACT

This review defines the prose associated with the chemical ecology of the Asian Long Horn Beetle (ALB), *Anoplophora glabripennis*. It further provides a brief impression of ALB's biological characteristics, ecology, chemical ecosystem, economic significance, and management. Beetles in the Cerambycidae family have implicit increasing importance as pests of green forest in addition to shade trees, shrubs, and pink wood products as well as vectors of tree ailments. The alien species related to hardwood packing substances have been remarkable tree destroyers in the urban and semi-urban areas of China. In forests flora and fauna inhabitant species take action against disturbances, for instance fires in addition to windstorms, and start the bio-worsening of woody tissue**.** The females lay eggs on the bark surface of the stems and branches of trees as a result rotten woody plants. The larval beetles characteristically feed in the phloem as well as later in the xylem. The females select living hosts for oviposition and thus destroy the vigour of the trees. However, at the early stage of intestation, detection of *Anoplophora glabripennis* and exposure will help to eliminate the pest in addition to prevent its establishment. Plantation with different tree species, the cultivation of fast-growing timber forest, the plantation of trap trees, sanitation, removal of the damaged trees and exact placement of insecticide saturated sticks into larval sites can reduce the spread of ALB in the regions of China. The ecological, in addition to biological uniqueness and development of sawyer beetles (*Monochamus alternates*) are also discussed.

## INTRODUCTION

The Asian long horned beetle (ALB) *Anoplophora glabripennis* (Motschulsky) is one of the newly introduced non inhabitant persistent species, which have caused ecological in addition to financial damages in the United States. Slight familiarity is known about their substance ecology. Awareness about their compound ecology has increased severely for many reasons. It tunnels the girdle of trees stems and branches. The most important congregated trees include species of maple (*Acer*), poplar (*Populus*), and willow (*Salix*). There is a critical need for information on the basic biology of *A. glabripennis*; in sequence on richness is especially imperative to recognize the population dynamics as well as forecast population increase of *A. glabripennis* (Bao *et al*., 1999).

The ALB is a serious pest in China, where it kills hardwood trees in roadside plantings, shelterbelts and plantations. At this time, the only effectual means to eradicate ALB is to remove infested trees in addition to obliterate them by chipping or burning. To prevent further spread of the insect, quarantines are conventional to keep away from transporting infested trees and branches from the area. Premature detection of infestations in addition to quick treatment response is essential to successful eradication of the beetle (Wang *et al*., 2004; Billings and Payne, 1992).

## LIFE CYCLE

The ALB has one generation per year. Adult pests are usually present from start of July till end of October, however can be originating later in the fall if temperature is warm. Adults frequently hang about on the trees from which they emerged otherwise they may scatter short distances to a new crowd to nourish in addition to reproduce. Every female frequently lays 35 to 90 eggs during her lifetime (15-20$^{o}$C, RH 47±8). Some are able to

* Corresponding author: mqwang@mail.hzau.edu.cn
0030-9923/2017/0003-1093 $ 9.00/0

lie more than that eggs. The eggs hatch between 10 to 15 days (25°C, RH 55±8). The larvae nourish below the bark in the living hankie of the tree for a period of time and then bore deep into the wood where they pupate. The adults emerge from pupation sites by boring a tunnel in the wood and creating a round exit hole in the tree. The female with highest fecundity (160 eggs) lived 105 days after her eggs hatched. This involves that the beetle population could rapidly increase under favorable environmental conditions (Gao *et al*., 1994).

Females lay few eggs during the first week of their maturation. The longer females lay more eggs. The highest daily (2 eggs) and weekly (12 eggs) productiveness occur during the 3rd week. Over the 1st five weeks, females lay an average of 1 egg per day. The majority females lay no eggs during the last two weeks of their life. Over a life span, females chew much depth (250) in the bark, but lay eggs only in 1/4 of the depths (Tang *et al*., 2001).

## BIOLOGICAL CHARACTERISTICS

Some species of ALBs share some biological characteristics that reduce their prospect of introduction. Larvae in these beetles develop in rotting wood and are rarely imported with wood products or living plants. It is expected that they are mainly introduced in the course of unintentional importation in industrial packages or in stocks of consumable vegetables. No more than a few species of ALB increasing on freshly cut down trees are likely to be successfully introduced through the wood trade. The preamble of living preserved plants is also a probable new trail for beetles seem more liable to introduction. Most species developed in living plants undertake their entire life-cycle in dead wood. The species in the genera can emerge from wood products even several years after importation (Tian *et al*., 2003; Wang *et al*., 2004).

On one occasion a population is introduced, the potential for natural spreading constitutes an important factor for establishment success. Some adults undertake a phase of mandatory maturation feeding on emergence of the larval congregation which may cause substantial damage to living trees (Zhang and Linit, 1998). Most female long horned beetles oviposit opportunistically in cracks and crevices in the bark otherwise cortex of plants. Eggs may be placed in clusters or singly as well as it appears that those species that prepare an egg niche deposit eggs singly. Larvae hatch within several weeks feed first in the phloem and then later in the xylem (sapwood and heartwood) forming elongated, irregular mines (Hanks *et al*., 1993). Larval development occurs exclusively in the host and can range in duration from several months up to eight years. Larvae usually pupate in cells near the outside of the sapwood, even though some species pupate in the soil or in "chip cocoons," oval pupal cells ringed with coarse fibers between the bark and the sapwood surface. The pupal stage is relatively short (weeks to months) and the adult emerges by tunneling through the host cortex (Yanega, 1996). Even though the information about the scattering behavior of sawyers beetles is still slightly limited in addition to mostly concerns only a few species of recent attackers such as *A. glabripennis* (Lu *et al*., 2004).

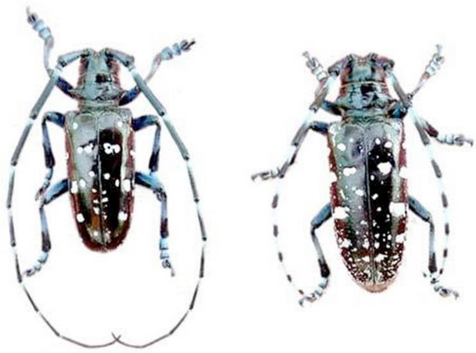


Fig. 1. Structure of adult male and female of Asian long horned beetle.

## ECOLOGY

The majority of ALB are the primary agents of woody bio-corrosion in forests. Larval tedious starts the corporeal process of breaking down woody tissue, creating infectivity courts for wood-rotting fungi. A number of beetles utilize gut symbionts to break down cellulose in wood. The adult beetles select healthy trees for oviposition other than damaged trees selected by a number of species. Majority of them attack living forest trees including phloem and woodborers in the roots, stem, and branches (Solomon, 1995). Larval boring in addition to related attack by wood rotting and discoloration fungi can result in significant economic defeat to wood products. According to previous literature, fruit and nut trees, grapes, coffee, vegetables and field crops are all attacked by *Oemona hirta* (F.) as a major pest on many tree and vine crops in New Zealand (Wang *et al*., 1998) and *A. malasiaca* (Thomson) as a serious pest of citrus, apple, pear, maple and willow in Asia (Wu *et al*., 1999; Lingafelter and Hoebeke, 2002). ALB, *A. glabripennis* (Motschulsky) attack and kill stressed trees where it has become a horticultural pest of cupressaceous trees. As a result, million Yens have been spent on eradication in addition to control the serious pest and removal or replacement of damaged trees in Japan. Aside from the social and economic penalty of the arrival of ALB in China there are potentially significant ecological implications for forest health (Fan, 2000; Tang *et al*., 2001; Wang *et al*., 2004).

## CHEMICAL ECOLOGY

Adult ALB are involved to plant explosive from inflorescences fed on by adults and from trunk as well as leaf unpredictable of larval hosts to the pheromones of bark beetles and to their own long in addition to short-range sex pheromones. Non-host chemicals in some cases keep away the beetles throughout host selection and some beetles may use suspicious compounds to avoid predation. Chemical signs as well control oviposition through inspiration at obtainable hosts as well as from first to last avoidance at engaged hosts. The skill of adult beetles to place high quality host material has staged fitness consequences. The preceding literatures suggest that the aptitude of adult ALB to establish high quality host material has a strong contact on fitness. Most beetles are discriminating about the physiological condition of their crowd material (Hanks, 1999).

The water content of host tissue of bark influences nutritional value in addition to host quality. The moisture content of freshly killed or strained as well as dying wood decreases with age and reduces the eminence of host material for larval growth. The neonate larvae are unable to become set up. The larval existence improves and adult fitness optimize under low moisture level (Paine *et al*., 2001). High larval density can also effect in destructive encounters flanked by larvae, important to low immature survivorship. The assortment should favor those folks that are clever to quickly place in addition to develop high quality hosts (Solomon, 1995). Fast crowd position and evaluation would be mitigated by substance cues and signals, showing the importance of semio-chemicals in almost all aspects of ALB life histories. Actually major impulsion for the progress of the field of chemical ecology has been created by the anticipation that recognized semio-chemicals could be used operationally in pest management plan. Besides a sympathetic of the vulnerability and confrontation of host plants to herbivores, knowledge of the chemical ecology of a pest species may guide to applications of active chemicals in finding, monitoring, and management (Hanks, 1999).

### *Attractants*

ALB generally oviposit in a colonize healthy, moribund, recently killed or decomposing woody plant material. However, most species are relatively host specific (Travakilian *et al*., 1997) and only attack material in a specific physiological state (Linsley, 1959; Hanks, 1999).

Found that although the host plants of ALB guilds (species sharing host plants) are taxonomically related and similar phytochemically, cerambycid guild members are not usually related. This suggests that in cerambycid beetles host-plant recognition is mediated by chemical cues originating from the plants. Putative primary attractants (kairomones) have been identified for many cerambycids (Table I, Fig. 2); these include floral volatiles, smoke volatiles, trunk and leaf volatiles, and bark beetle pheromones.

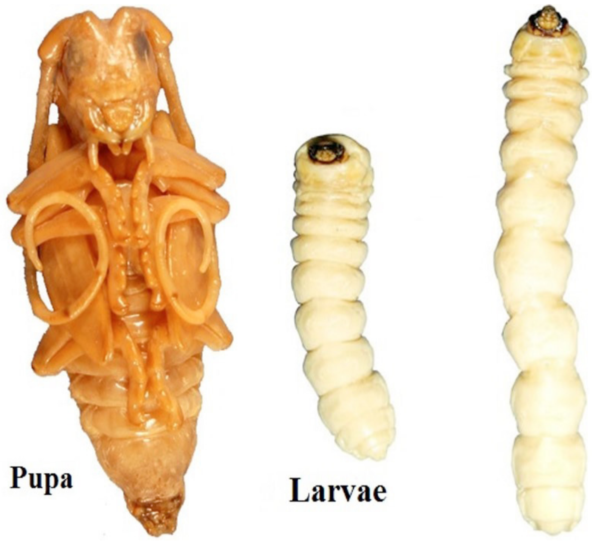


Fig. 2. Immature stage of Asian long horned beetle.

### *Floral volatiles*

Some anthophilous cerambycids are attracted by floral volatiles (Table I) and frequently visit flowers to feed on pollen and nectar (Lovell, 1915a, b; Garman, 1921; Burakowski, 1980; Scriven *et al*., 1986; Jeremy *et al*., 2004). Some have hair and body parts to which pollen adheres (Burakowski, 1980; Sawyer and Anderson, 1998), potentially facilitating pollination (Fægri and Van der Pijl, 1979). Nonetheless, although some flower-visiting Cerambycidae are minorpollinators, most are scavengers (Faegri and Van der Pijl, 1979; Sawyer and Anderson, 1998). Ikeda *et al.* (1993) tested 14 floral scent components or extracts for antennal stimulation and behavioral activity with *Anaglyptus subfasciatus* and *Demonax transilis* Bates. With the exception of α-pinene for male *A. subfascia tus*, and linalyl acetate, neryl acetate, and phenylethyl propionate for female *D. transilis*, all compounds stimulated antennae of both males and females. Field trials suggested that benzyl acetate (Fig. 2) was attractive for *A. sub fasciatus*, linalool benzyl acetate, and phenylethyl propionate were attractive for *D. transilis*.

**Table I.- List of floral and smoke volatiles.**

| Category and species affected | Stimulus | Behavioral activity | References |
|---|---|---|---|
| **Floral volatiles** | | | |
| *Anaglyptus subfasciatus, Demonax transilis* | Borneol, linalool, nerol, α-terpineol, benzyl acetate, linalyl acetate, neryl acetate, phenylethyl propionate, phenylethyl butyrate, camphor, citral, citronellal, α-pinene, Japanese cedar oil | All compounds stimulate antenna of males and females of both species, except α-pinene for male A. *subfascia* and linalyl acetate, neryl acetate, and phenylethyl propionate for female *D. transilis*. | Ikeda *et al*. (1993) |
| *A. subfasciatus, D. transilis* | Linalool, benzyl acetate, phenylethyl propionate | Activity for both species to all three compounds suggested by field tests. | Ikeda *et al*. (1993) |
| *A. subfasciatus* | Benzyl acetate, methyl phenoxyacetate, methyl phenylacetate | Traps baited with each compound caught more beetles than control traps in field tests. | Nakashima *et al*. (1994) |
| *A. subfasciatus* | Methyl phenylacetate | Field tests demonstrated activity for females. | Nakamuta *et al*. (1997) |
| **Smoke volatiles** | | | |
| *Monochamus sutor* (L) | Smoke | Attracted to a forest fire. | Palm (1949) (in Evans (1971) |
| *Monochamus scutellatus, Monochamus notatus, Monochamus mutator* LeConte*, Asemum atrum, Xylotrechus sagittatus* (Germar)*, Xylotrechus undulatus, Tetropium cinnamopterum* Kirby, *Acmaeops proteus* (Kirby), *Acanthocinus pusillus* (Kirby), *Rhagium inquisitor, Arhopalus agrestis* (Kirby), *Anoplodera chrysocoma, Anoplodera canadensis* (Olivier), *Callidium violaceum* (L.), *Neoclytus muricatulus* (Kirby), *Astylopsis sexguttata* (Say), *Pogonocherus mixtus* Haldeman | Unknown, possibly smoke | Larvae found and reared from burned timber, or adults observed on burned wood. | Gardiner (1957a) |
| *Monochamus galloprovincialis* (Olivier), *Acanthocinus griseus* (Fabricius), *Acanthocinus aedilis, Criocephalus tristis* (Fabricius), *Rhagium inquisitor, Pogonochaerus perroudi* Mulsant | Unknown, possibly smoke | Adults found on the bark of burned pines in moderate to high numbers. | |
| *Acmaeops proteus, Tetropium cinnamopterum, Anoplodera canadensis* and *Asemum atrum* | Smoke | Attracted to a wood chip fire. | Gardiner (1957b) |
| *Spondylis upiformis* Mannerheim *Tetropium cinnamopterum* | Smoke | Attracted to a campfire. | Hocking [pers. Obs. in Evans (1971)] |
| *Arhopalus asperatus* (LeConte) | Unknown, possibly smoke | Attracted to recently burned pines. | Wickman (1964) |
| Arhopalus tristis | Burnt bark volatiles | Activity observed in field cage tests with females (oviposition and trap catch tests). | Suckling, *et al*. (2001) |

More rigorous experiments confirmed that benzyl acetate attracted *A. subfasciatus* in the field, and also showed that traps baited with methyl phenylacetate (Fig. 2) and methyl phenoxy- acetate caught more *A. subfasciatus* than unbaited control traps (Nakashima *et al*., 1994). Both benzyl acetate and methyl phenylacetate have been identified as floral volatiles (Williams and Whitten, 1983; Omatav *et al*., 1991; Knudsen *et al*., 1993); however, neither was detected in hexane extracts of plants on which *A. subfasciatus* is commonly found (Nakashima *et al*., 1994). Traps baited with methyl phenylacetate plus synthetic sex pheromone captured significantly more female *A. subfasciatus* than traps baited with pheromone alone (Nakamuta *et al*., 1997). Shibata *et al*. (1996) captured more species and individuals in traps baited with benzyl acetate than in traps baited with α-pinene and ethyl alcohol; however, there were species (*e.g*. in the Lamiinae) that clearly preferred the latter. These results are confounded by the fact that traps baited with benzyl acetate were white while those baited with α-pinene and ethyl alcohol were black. Investigation of long-lived species, which mate on or near flowers, and maturation feed on floral resources, likely will lead to the identification of additional floral attractants.

*Smoke volatiles*

During and immediately after a forest fire some cerambycids are attracted to the site of the fire (Ehnström *et al*., 1995; Gao and Li, 2002). These insects specialize in post-fire habitats and oviposit in trees stressed by or freshly killed by fire (Evans, 1971). The detection and orientation toward the source of smoke volatiles as kairomones (Table I) may significantly improve the foraging efficiency of these woodborers by placing them in proximity to suitable hosts. In olfactometer bioassays, female *Arhopalus tristis* (F.) had a strong preference for the volatiles of burnt vs. unburnt pine bark (Knudsen *et al*., 1993; Lai *et al*., 2000; Suckling *et al*., 2001). Similarly, in field enclosures, traps baited with burnt *Pinus radiata* D. Don bark caught approximately twice as many beetles as traps baited with unburnt bark. Although *P. radiata* monoterpenes stimulate antennae of male and female *A. tristis* (Suckling *et al*., 2001; Zhao *et al*. 2004), and monoterpenes have been isolated from the volatiles of smouldering wood (Schütz *et al*., 1999), they also are released from healthy tissue. Derivatives of 2-methoxyphenol (guaiacol) specific to smouldering *Pinus sylvestris* L. have been found to stimulate antennae of the buprestid woodborer *Melanophila acuminata* (De Geer) (Schütz *et al*., 1999). Fire and smoke-specific compounds, have not been identified and tested behaviorally or electro-physiologically for any cerambycid.

*Repellents and deterrents*

One current paradigm for host selection by phytophagous insects argues that foraging insects should minimize their risks and costs by using all available sensory information. Accordingly, host-seeking insects should use long-range kairomonal cues associated with both hosts and non-hosts, particularly where hosts and non-hosts are contagiously distributed in mixed stands. Research on cerambycids has focused almost exclusively on attractive volatile cues that facilitate the perception and identification of hosts. However, as is increasingly evident for bark and ambrosia beetles (Dickens *et al*., 1992; Schroeder, 1992; Guerrero *et al*., 1997; Huber *et al*., 2000a, b; Huber and Borden, 2001a, b; Zhang *et al*., 1999, 2001), host selection by cerambycids may be driven in part by repellent volatile cues that signal the presence of non-hosts.

Studies on inhibitory or repellent semiochemicals in the Cerambycidae are few. Aojin and Qing'an (1998) reported that essential oils derived from non-host *Eucalyptus citriodora* Hook. and *Eucalyptus globulus* (Labille) leaves were repellent to adult *Apriona germari* (Hope), *Psacothea hilaris,* and *Monochamus alternatus*. Conophthorin a repellent angiosperm bark volatile for many coniferophagous bark and ambrosia beetles (Huber *et al*., 1999, 2000a, b; Zhang *et al*., 2001), reduced trap catches of *M. scutellatus* and *M. clamator* (Morewood *et al*., 2003). The addition of two green leaf volatiles, (E)-2-hexen-1-ol and (E)-2-hexenal , mixed in mineral oil in a 1:1:2 ratio caused a five-fold reduction in catches of *Arhopalus tristis* in traps baited with burnt host bark (Suckling *et al*., 2001). Similarly, application of this solution to burnt pine bark reduced oviposition by 98.5%. Green leaf volatiles, in particular (Z)-3-hexen-1-ol, stimulated the antennae of male and female *A. tristis* (Suckling *et al*., 2001). Barata *et al*. (2000) identified several volatile semiochemicals from the non-hosts *Pinus pinaster* Aiton and *Olea europeae* L. that were absent in Eucalyptus host trees, and that stimulated the antennae of the eucalyptus borer *P. semipunctata*. In contrast, the sesquiterpenoid (−)-germacrene-D is present in the leaf and trunk volatiles of the host of *M. alternatus* (*Pinus densiflora* Siebold and Zuccurin), but this compound disrupts the response of female *M. alternatus* in laboratory walking and flight assays (Zhao *et al*., 1995; Yamasaki *et al*., 1997).

## HABITAT

All natural or synthetic global ecology in addition to anthropogenic areas which be full of trees, bushes and wood products are probably occupied by sawyer beetles, organization in China is deliberated in man-made habitats todate, particularly in parks, gardens, agricultural lands and forests (Li, 1998; Keena *et al*., 2001). The species of ALB (*A. glabripennis*) have colonized natural habitats in trees include species of maple (*Acer*) and poplar (*Populus*) during the nearby occasion. The additional polyphagous species of sawyer beetles also have the possibility to live in urban areas; cultivated lanes planted with poplars and in natural forests where prospective host plants take place (Zhou *et al*. 1996; Li *et al*., 2003). On the other hand, spreading from man-made habitats to parks and natural forests become visible to be a slow progression. For one-fourth century since its onset in China, *A. glabripennis* has been restricted to trees in urban areas when it was found in natural forests dominated by *Acer* trees (Lingafelter and Hoebeke, 2002). However, such a progression has not yet been observed in China, there is a strong hazard that *Anoplophora* spp. will spread to naturally-forested scenery. The life cycle of mosquitoes requires the development of larvae and pupae in habitats containing its targeted population. Therefore, anticipation and control should be targeted by removal of damaged trees, reduction of adult sawyer beetles population and elimination of sawyer's larval habitats (Cheng *et al*., 2003).

## DISPERSAL

ALB *A. glabripennis* (Motsch.), *A. nobilis* Ganglbauer, *Apriona germari* (Hope), and *Xylotrechus rusticus* Linnaeus share some biological individuality that decrease their possibility of introduction. Larvae in these subfamilies build up in rotting wood and are rarely imported with wood materials or living plants. Interceptions have shown that they are largely commenced through unintentional importation in industrial packages otherwise in stores of consumable vegetables. A small number of species of sawyer beetles increasing on newly cut down trees are probably to be effectively introduced through the wood trade. The folks do not characteristically disperse very far; some may take a trip to the extent that kilometer or two in a season in seek of new host trees. The introduction of living potted plants is also a possible new trail for most species seem more liable to preamble. Most species develop in living plants in addition to a number of *A. glabripennis* undertake their complete life-cycle in dead wood. Thus, sawyer beetles can easily stay alive throughout the importation process of living plants (Haack *et al*., 2000). Several species can emerge from wood products even several years after importation. On one occasion a population is introduced, the ability for natural dispersal comprises an important factor for institution success. Even though our information about the dispersal behavior of Asian longhorn beetles is still quite limited in addition to frequently concerns only a few species of newly invaders such as *A. glabripennis* and *A. chinensis* (Smith *et al*., 2001; Zhu, 2002).

## REPRODUCTION

The ABL can fly for continued distances of 370m or else more in search of a host tree. They have a propensity to lay eggs in the identical tree where they appeared as adults, migrating merely when inhabitants mass becomes too high. A mated adult of ALB female chews individuals from 35 to 90 depressions in to the host tree bark in addition to lay an egg in each of the pits during the summer months. The white larvae hatch out in 10 to 15 days. The larvae are in a straight line with their front ends to some extent broader than the rest of the body. This is trait of many Cerambycid larvae and so is the fact that as an alternative of using legs to find the way their tunnels, they have ample pads on their parts. They depress the pads next to the tunnels walls for grasp as they make bigger or contract their bodies (Gao *et al*., 1994; Wang *et al*., 1998; Zhang *et al*., 2003). They burrow into the tree's phloem as well as cambium layers under the tree bark. They tunnel bottomless into the tree's heartwood where they mature into pupae after a number of months. The entire development from egg to pupation takes 10 to 20 months depending on the season, environmental condition and the value of the food supplied by the tree. In general language, the phloem in addition to cambium is the best food sources other than more exposed to predators for instance woodpeckers and a lot wetter. Heartwood with even sapwood is less nourishing but more protected, so that is anywhere the immature larva digs its pupation chamber. They do not pupate before they have gain the essential accumulation to hold up their adult behavior and meanings. In the cold months, the pupal stage may last several months, causing the pupa to go into diapauses. The adults appear from the pupae close to the surface of the tree whilst the exterior weather causes them to break diapauses. They emerge from early of May to the end of November, depending on prevailing environment. The adult emerges from rounded exit holes that characteristically measure from 10 to 15mm in diameter (Zhang *et al*., 1999a, b; Tian *et al*., 2003).

## ERADICATION

The eradication method recognized for quarantine species intend to limit introductions even though only a few eradications have been formally reported globally, *e.g.* as for *A. glabripennis* in China and *A. chinensis* in France. Phyto-sanitary interceptions at borders are probable to

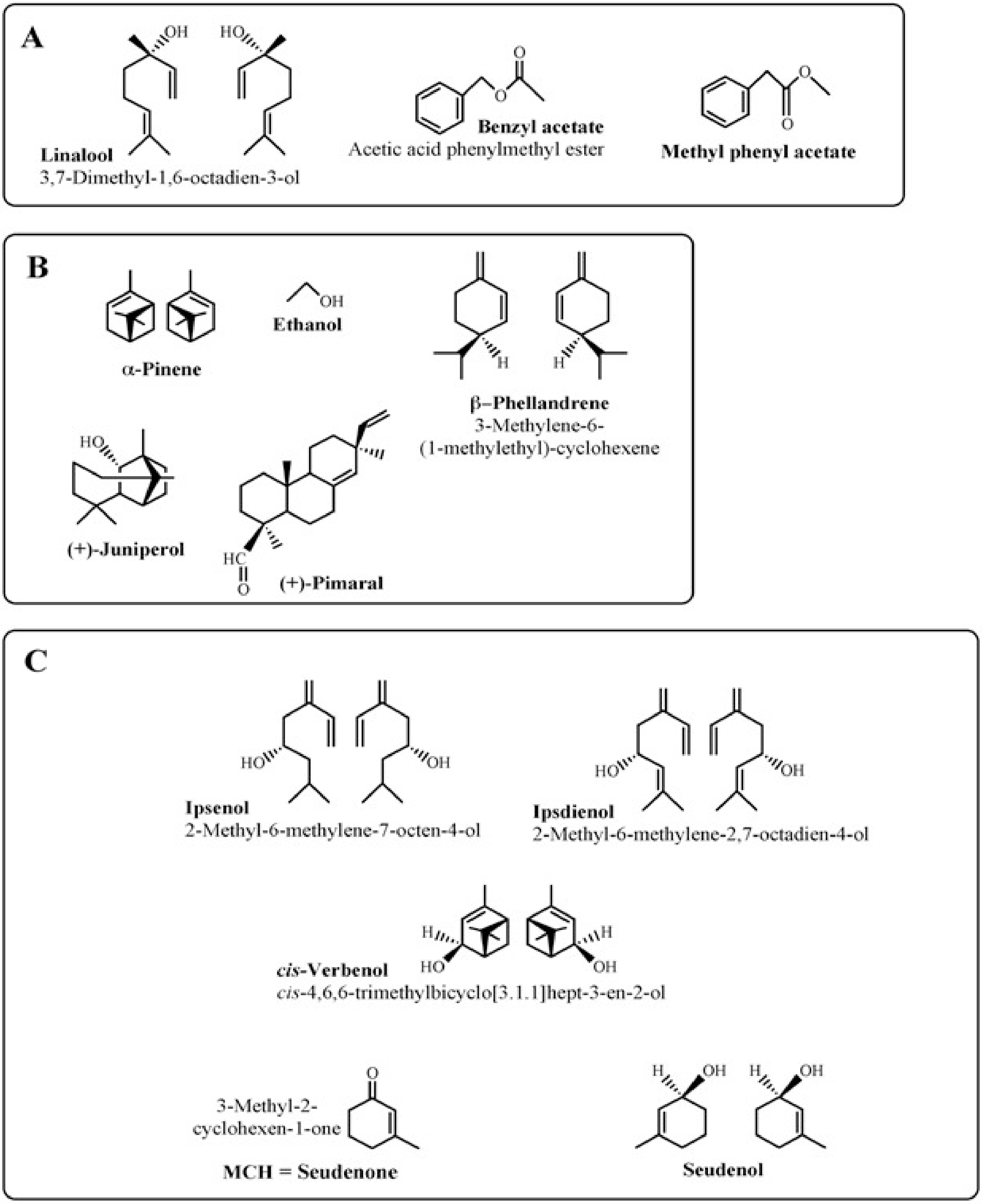


Fig. 3. Structures of different volatile compounds.

have prohibited a number of introductions and further establishments *e.g. A. glabripennis* and *A. chinensis* in several countries (Wang *et al*., 2002; Cocquempot and Lindelow, 2010). This demonstrates the importance of quarantine species, which should be protective and not only healing to be most effective. Human arbitrated dispersion should also be strongly prohibited during the eradication process. The eradication process could fail without owing admiration for control obligations. The long delay in applying control measures in addition to physically powerful management measures against sawyer beetles are unproductive eradication effectiveness (Wang *et al*., 2003a, b; Liu *et al*., 2003; Robert *et al*., 2010).

## POSSIBLE OUTCOME FROM INFESTATION

ALBs are damaging to any ecological unit they occupy. More or else less 40% of poplar plants have been injured; the allegation the wood is good quality merely for protective material in China. More than 50 million trees were cracked during three years period because of the sawyer beetles. These beetles have the capability to considerably change the sonata of North American hard wood forests in the province of Ningxia. It can be predictable that a large number of wood trees would be shattered in the United States if sawyer beetles (*A. glabripennis*) were to spread all through the country. The potential for extensive increase allocation in North America in addition to the assault of a wide variety of congregation trees is too very probable (Liu *et al*., 2002; Li *et al*., 2003).

## DESCRIPTION

The sawyers beetle, bullet-shaped adult is about 1 to 1.5 cm long with uneven sized in addition to shaped white spots. Its black-and-white banded antennae are frequently longer than its body. Its elongated feet are black with a whitish-blue upper surface. However, its size and mandibles may cause it to become visible threatening; the beetle is not dangerous to humans as well as pets. Adult females make use of their mandibles to chew up a pit and then deposit an egg into it. The larva tunnels under the bark, ultimately tunneling bottomless into the tree. Larval tunneling produces frass that consists of feces and wood fibers like sawdust. The bulky, light cream-colored larva that lives completely within the wood of trees is the mainly damaging phase of beetle (Liu *et al*., 2002; Li *et al*., 2003).

## DAMAGE

The ALB larvae turn off deep into well deciduous hardwood trees such as maple, boxelder, birch, horse chestnut, poplar, willow, elm, hackberry, sycamore, mimosa, and ash and ultimately killing them. The impact on many of Wuhan's native hardwood species is at present indefinite. Round exit holes, about 3/8 of an inch in diameter, located on trunks and branches, egg laying sites, frass at the base of infested trees or in branch crotches and sap leaking from wounds on the tree may be the first clue to an invasion. An infested tree may have unexpected die back of larger branches. Leaf signs showed when the larva indemnity tissues that transfer water in addition to nutrients to the abundant covering (Xu *et al*., 1999a, b, 2002a, b).

## ECONOMIC AND ENVIRONMENTAL IMPACTS

The founding of sawyers beetle in China especially in the surroundings of China could cause more financial damages than other plant pests like chestnut blight, codling moths and gypsy moths combined by destroying a huge area of precious hardwoods, including forest, park, and backyard trees. Consistent with the Department of Agriculture in United States, the beetle is a hazard to lumber, nursery as well as tourism industries, with the possible economic impact of billion dollars damages in the western United States, a lot of swarm trees are important components of landscapes, watersheds, and ecosystems (Gao *et al*., 1997). The institution of this pest could have an important negative impact on urban landscapes in addition to natural assortment. The decrease of shade trees can have a noteworthy energy costs in urban areas along with reduce property values. The deceased and disappearing trees may significantly increase fire vulnerability.

## MANAGEMENT

Asian long horned beetle (sawyers beetle) is not presently well-known in the whole region of China. It is complicated to monitor quarantine in addition to control ALB successfully as the adult stage may only last one month as well as it is difficult to find and control ALB at the premature stage of damage during the concealed larval stages. However, the adequate approach to control is eradication. At the beginning stage, detection of sawyers beetle and exposure will help agencies to eliminate the pest in addition to prevent its establishment (Luo *et al*., 2002; Robert *et al*., 2010).

## CONTROL MEASURES

In China, the management of long horned beetles (ALB) has been found many years ago. Since the 1980s many events have been adopted by the government for the control of ALB and the State Forestry Administration (SFA) carried out demonstration projects for management of ALB. In 1991 a five year integrated management project against ALB was carried out in Shaanxi, Gansu, Ningxia, Inner Mongolia and Shanxi provinces and autonomous regions. The direct control measures for ALB were carried out in Inner Mongolia by SFA during the period of 1998 to 2000. A national project for all poplar long horned beetles was started in Shaanxi, Gansu, Qinghai and Heilongjiang provinces in 2000-2002. "The poplar pest and disease control project", which included ALB, was carried out in 2003 (Zhang *et al*., 1994; Långström and Hellqvist, 1995; Cheng *et al*., 2003; Lu *et al*., 2004).

Plantation with different tree species for the control of pests, resistant tree species to regulate the structure of the forest. Miscellaneous forests are created and trap trees are used to control the spread of ALB.

The cultivation of fast-growing timber forest, planted trees grow much faster with careful tree selection and tending. The revolution of the tree is condensed and the chance of being damaged by ALB is supposedly reduced.

The plantation of trap trees to kill ALB protects high value trees. Trap trees, which are preferred by ALB, are planted to attract ALB to lay eggs which are then destroyed.

Sanitation felling is used to remove damaged trees to reduce breeding sites. This is essential for ALB management but it is necessary to treat and/or remove the damaged trees after clearing to reduce the chance of inferior infestations.

To consider the ecological benefits and the welfare of the farmers, events can include removal of the damaged fraction of the tree trunk from breast height; grafting Chinese white poplars following elimination of the damaged trunk; otherwise cutting the damaged tree as early as possible to control the increase of ALB.

The exact placement of insecticide impregnated sticks into larval sites and overcrowding the larvae (frass) holes with insecticide impregnated mud, spraying pesticides in a straight line on to adults, application of trunk injections with pesticides to attempt to kill the larvae and capturing the adults in addition to actually killing eggs and larvae.

## CONCLUSION AND RECOMMENDATIONS

1. *Intensified monitoring work on ALB:* It is essential to improve accessible monitoring events, to develop new observation techniques for ALB in planting areas. It is also obligatory to know the dynamics of ALB populations in addition to provide appropriate prediction results in order to manage new outbreaks.

2. *Quarantine actions:* Farmers should be aware how to prevent the spread of ALB and to make stronger in addition to enforce quarantine measures. Rules and regulations is one of the major restricting methods in the spread of ALB. Phytosanitary measures have been imposed for the transfer of wood and quarantine measures imposed in production areas. In an infested area, quarantine is essential to restrain the pest and prevent spread. In non-infested areas, quarantine is necessary to make sure for the absence of insects whichever on infested seedlings or by other means. The moving of ALB through human activities is prohibited through strict quarantine measures including transportation of logs, seedlings as well as inspection of packaging materials. The destroyed trees need to be treated in addition to movement restricted to prevent the increase of ALB to non-infested sites.

3. *IPM with stress on avoidance:* It is supposed that only control measure cannot be used to manage ALB and arrest its further spread. An incorporated approach is required to confine the spread and manage infested areas.

4. *Host knowledge of plant diversity:* Modification in conventional plantation in addition to encourage the use of rationalized economic measures for a forestation with fast growing resistant tree species should be required. It is necessary to sum up obtainable information as well as to develop improved technologies. The flexibility, confrontation and protection functions should be careful together.

5. *Erect understanding of the benefited trap trees:* The apt proportion of trap trees like, maple, elm and Populus opera should be determined in order to exert a pull on beetles in high value areas. The ratio of trap trees is frequently concerning 10 to 20%.

6. *Biological control:* Biological control agents such as *Scleroderma guani*, *Dastarcus helophorides* and entomopathogenic fungi are careful agents against beetles and should be considered for control of ALB. Simultaneously, new biological control techniques should be studied especially in the pilot areas of further research work areas.

## REFERENCES

Aojin, Y. and Qing'an, T., 1998. Repellency effects of essential oil derived from *Eucalyptus* leaf against three species of sawyers (Abstract in English). *J. Nanjing Forest. Univ.,* **22**: 87–90.

Barata, E.N., Pickett, J.A., Wadhams, L.J., Woodcock, C.M. and Mustaparta, H., 2000. Identification of host and nonhost semiochemicals of eucalyptus woodborer *Phoracantha semipunctata* by gas chromatography-electroantennography. *J. chem. Ecol.,* **26**: 1877–1895. https://doi.org/10.1023/A:1005548824429

Bao, S. Li, F. and Li, Z., 1999. The resistance of fourteen poplar species to *Anoplophora glabripennis* (Motsch.). *J. Beijing Forest. Univ.,* **21**: 97-100.

Billings, R.F. and Payne, T.L., 1992. Green leaf volatiles interrupt aggregation pheromone response in bark beetles infesting southern pines. *Experientia,* **48**: 523–524. https://doi.org/10.1007/BF01928180

Bradbury, P.M., 1998. The effects of the burnt pine longhorn beetle and wood-staining fungi on fire damaged *Pinus radiata* in Canterbury. *N. Z. Forest.,* **43**: 28–31.

Burakowski, B, 1980. Immature stages and bionomics of *Vadonia livida* (F.) (Coleoptera: Cerambycidae). Ann. Zoologici **35**: 25–42

Cheng, H., Meng, X. and Chen, J., 2003. Evaluation on control efficacy of *Scleroderma guani* against borer. *Chin. Med. Plant.,* **26**: 1-3.

Cocquempot, C. and Lindelow, A., 2010. Long horn beetles (Coleoptera, Cerambycidae). Chapter 8.1. *BioRisk*., **4**: 193–218.

Cocquempot, C. and Lindelöw, Å., 2010. Longhorn beetles (Coleoptera, Cerambycidae). Chapter 8.1. *BioRisk*, **4**: 193.

Dickens, J.C., Billings, R.F. and Payne, T.L., 1992. Green leaf volatiles interrupt aggregation pheromone response in bark beetles infesting southern pines. *Experientia*, **48**: 523–524. https://doi.org/10.1007/BF01928180

Ehnström, B., Långström, B. and Hellqvist, C., 1995. Insects in burnt forests – forest protection and faunal conservation (preliminary results). *Ent. Fenn*., **6**: 109–117.

Evans, W.G., 1971. The attraction of insects to forest fires. In: *Proceedings of the tall timbers conference on ecological animal control by habitat management* (ed. E.V. Komarek Sr) vol. 3. Department of Entomology, University of Florida,. FL-Tallahassee: USA, pp. 115–127.

Fan, J., 2000. The technical regulations and rules of integrated management for *Anoplophora glabripennis* Motsch. *China-US workshop on Asian longhorned beetle*. Yinchuan, pp. 154-156.

Fægri, K. and van Der, P.L., 1979. *The principles of pollination ecology*. Pergamon Press, NY, New York, USA,

Gardiner, L.M., 1957a. Deterioration of fire-killed pine in Ontario and the causal wood-boring beetles. *Can. Entomol.,* **89**: 241–263. https://doi.org/10.4039/Ent89241-6

Gardiner, LM, 1957b. Collecting woodboring beetle adults by turpentine and smoke. *Bimon. Prog. Rept. Sci. Serv. Can. Dept. Agr*., **13**: 2 pp.

Garman, H., 1921. The relation of the Kentucky species of *Solidago* to the period of activity of the adult *Cyllene robinae*. *Kentucky Agric. Exp. Stat. Bull.,* **231**: 3–22.

Gao, R. and Li, G., 2002. *Integrated pest management of poplar fast-growing and high-yielding plantations* China-US workshop on Asian longhorned beetle, Yingchuan, pp. 42.

Gao, R., Liu, C. and Lu, Y., 1994a. A preliminary study on the causes and use of preference of *Apriona germari* adult's supplementary nutrition for mulberry and paper mulberry. *Scien. Silv. Sin.,* **30**: 376-380.

Gao, R. Lu, Y. and Liu, C. 1994b. Predation of woodpecker on some pests in poplar plantation. *Fores. Res.,* **7**: 585-588.

Gao, H., Yang, X. and Zhou, J., 1997. A study on the establishment of sustainable shelter forests of econmic ecology type without the plague of Longicorn. *J. Northw. Forest. Univ.* **12**: 7-11.

Guerrero, A, Feixas, J, Pajares, J, Wadhams, L.J, Pickett, J.A, Woodcock, C.M, 1997. Semiochemically induced inhibition of behavior of *Tomicus destruens* (Woll.) (Coleoptera: Scolytidae). *Naturwissenschaften*, **84**: 155–157. https://doi.org/10.1007/s001140050369

Haack, R.A., Poland, T.M. and Gao, R.T., 2000. The United States experience with the exotic Cerambycid Anoplophora glabripennis detection, quarantine and control. In quarantine pests, risk for the forestry sector and for their effects on foreign trade. *Proc. CD-Room Silvotecna Conf*., **14**: 27-28.

Hanks, L.M., McElfresh, J.S., Millar, J.G. and Paine, T.D., 1993. *Phoracantha semipunctata* (Coleoptera: Cerambycidae), a serious pest of *Eucalyptus* in California: Biology and laboratory-rearing procedures. *Annls. entomol. Soc. Am.,* **86**: 96–102. https://doi.org/10.1093/aesa/86.1.96

Hanks, L.M., 1999. Influence of the larval host plant on reproductive strategies of cerambycid beetles. *Annu. Rev. Ent.,* **44**: 483–505. https://doi.org/10.1146/annurev.ento.44.1.483

Huber, D.P.W., Gries, R., Borden, J.H. and Pierce, H.D., 1999. Two pheromones of coniferophagous bark beetles (Coleoptera: Scolytidae) found in the bark of nonhost angiosperms. *J. chem. Ecol.,* **25**: 805–816. https://doi.org/10.1023/A:1020892700653

Huber, D.P.W. and Borden, J.H., 2001a. Protection of lodgepole pines from mass attack by mountain pine beetle, *Dendroctonus ponderosae*, with nonhost angiosperm volatiles and verbenone. *Ent. exp. Appl*., **92**: 131–141.

Huber, D.P.W. and Borden, J.H., 2001b. Angiosperm bark volatiles disrupt the response of Douglas-fir beetle, *Dendroctonus pseudotsugae*, to attractant baited traps. *J. chem. Ecol.*, **27**: 217–233. https://doi.org/10.1023/A:1005668019434

Huber, D.P.W., Gries, R., Borden, J.H. and Pierce, Jr. H.D, 1999. Two pheromones of coniferophagous bark beetles (Coleoptera: Scolytidae) found in the bark of nonhost angiosperms. *J. chem.. Ecol.,* **25**: 805–816. https://doi.org/10.1023/A:1020892700653

Huber, D.P.W., Gries, R., Borden, J.H. and Pierce, Jr. H.D, 2000a. A survey of antennal responses by five species of coniferophagous bark beetles (Coleoptera: Scolytidae) to bark volatiles of six species of angiosperm trees. *Chemoecology*, **10**: 103–113. https://doi.org/10.1007/PL00001811

Huber, D.P.W., Borden, J.H., Jeans-Williams, N. and Gries, R., 2000b. Differential bioactivity of conophthorin on four species of North American bark beetles (Coleoptera: Scolytidae). *Can. Entomol*., **132**: 649–653. https://doi.org/10.4039/Ent132649-5

Ikeda, T., Ohya, E., Makihara, H., Nakashima, T., Saitoh, A., Tate, K. and Kojima, K., 1993. Olfactory responses of *Anaglyptus subfas- ciatus* pic and *Demonax transilis* bates (Coleoptera: Cerambycidae) to flower scents. *J. Jap. Forest. Soc.,* **75**: 108–112.

Jeremy, D.A., John, H.B. and Steven, J.S., 2004. A review of the chemical ecology of the Cerambycidae (Coleoptera). *Chemo-ecology,* **14**: 123-150.

Keena, M., Steve, U. and Laura, L., 2001. *Anoplophora glabripennis* (Coleoptera: Cerambycidae) development on cut logs of four species of *Acer. Presented at the USDA Interagency Research Forum on Gypsy Moth and Other Invasive Species,* January in Annapolis, MD.

Knudsen, J.T., Tollsten, L. and Bergström, L.G., 1993. Floral scents – a checklist of volatile compounds isolated by head-space techniques. *Phytochemistry,* **33**: 253–280. https://doi.org/10.1016/0031-9422(93)85502-I

Lai, Z., Xu, Y. and Wang, Z., 2000. Chemical control of *Anoplophora chinensis* larvae harmed on *Salix babylonica*. *J. Zhejiang Forest. Univ.,* **17**: 341-343.

Långström, B. and Hellqvist, C., 1995. Insects in burnt forests – forest protection and faunal conservation (preliminary results). *Ent. Fenn.,* **6**: 109–117.

Li, H., Huang, D. and Yang, M., 2003. Selection of super poplar clones with high resistance to *Anoplophora glabripennis*. *J. North E. Forest. Univ.,* **31**: 30-32.

Li, Y., 1998. Integrated management of poplar long horned beetle in Hebei. *China-US workshop on Asian long horned beetle. Yingchuan*, pp. 115.

Lingafelter, S.W. and Hoebeke, E.R., 2002. Revision of *Anoplophora* (Coleoptera: Cerambycidae). Entomology Society Washington USA, Washington, DC: USA.

Linsley, E.G., 1959. Ecology of Cerambycidae. *Annu. Rev. Ent.* **4**: 99–138. https://doi.org/10.1146/annurev.en.04.010159.000531

Liu, H., Chang, Q. and Ma, F., 1998. Field test on control of *Anoplophora glaripennis* (Motsch.) and *Melanophila decastigma* Fabr. by *Steinernema carpocapsae*. *Ningxia Agric. Forest. Sci. Tech.,* **5**: 15-17.

Liu, J., Zhou, L. and Song, H., 2002. Planting trap trees to control *Anoplophora glabripennis*. *China-US workshop in Asian long horned beetle*, *Yinchuan.* pp. 46-48.

Liu, X., Li, Y. and Zhang, S., 2003. Effects of irradiation on mating ability of *A. glabripennis. Acta Agric. Nucleat. Sin.,* **17**: 402-404.

Lovell, J.H., 1915a. The origin of anthophily among the Coleoptera. *Psyche,* **22**: 67–84. https://doi.org/10.1155/1915/91986

Lovell, J.H., 1915b. A preliminary list of the anthophilous Coleoptera of New England*. Psyche,* **22**: 109–117. https://doi.org/10.1155/1915/64853

Lu, W., Hu, M. and Hu J., 2004. Discussion on severity and control of Asian long horned beetle (ALB) on poplar trees in the three North Protection Forest Program. *Protect. Forest. Sci. Tech*., **77**: 39-40.

Luo, Y., Liu, R. and Xu, Z., 2002. Sustainable management strategies and technologies of poplar long horned beetle. *China-US workshop on Asian long horned beetle. Yinchuan*, pp. 68.

Morewood, W.D., Simmonds, K.E., Gries, R., Allison, J.D. and Borden, J.H., 2003. Disruption by conophthorin of the kairomonal response of sawyer beetles to bark beetle pheromones. *J. chem. Ecol.,* **29**: 2115–2129. https://doi.org/10.1023/A:1025690519818

Nakamuta, K., Leal, W.S., Nakashima, T. and Tokoro, M., 1997. Increase of trap catches by a combination of male sex pheromones and floral attractant in the longhorn beetle, *Anaglyptus subfasciatus*. *J. chem. Ecol.,* **23**: 1635–1640. https://doi.org/10.1023/B:JOEC.0000006427.56337.6c

Nakashima, T., Nakamuta, K., Makihara, H., Ohya, E., Nakanishi, M. and Ikeda, T., 1994. Field response of *Anaglyptus subfasciatus* Pic (Coleoptera: Cerambycidae) to benzyl acetate and structurally related esters. *Appl. Ent. Zool.,* **29**: 421–425.

Omatav, A., Yomogida, K., Nakamura, S., Hashimoto, S., Arai, T. and Furukawa, K., 1991. Volatile components of *Plumeria* flowers. Part 1. *Plumeria rubra* forma *acutifolia* (Poir.) Woodson cv. 'Common Yellow'. *J. Flav. Fragr.,* **6**: 277–279. https://doi.org/10.1002/ffj.2730060407

Paine, T.D., Millar, J.G., Paine, E.O. and Hanks, L.M., 2001. Influence of host log age and refuge from natural enemies on colonization and survival of *Phoracantha semipunctata*. *Ent. Exp. Appl.,* **98**: 157–163. https://doi.org/10.1046/j.1570-7458.2001.00770.x

Robert, A.H., Franck, H., Jianghua, S. and Jean, J.T., 2010. Managing invasive populations of Asian long horned beetle and citrus long horned beetle: A worldwide perspective. *Annu. Rev. Ent.,* **55**: 547-568.

Sawyer, N.W. and Anderson, G.J., 1998. Reproductive biology of the carrion- flower *Smilax herbacea* (Smilacaceae*). Rhodora,* **100**: 1–24.

Schroeder, L.M., 1992. Olfactory recognition of non-hosts aspe and birch by conifer bark beetles Tomicus piniperda and Hylurgops palliatus. *J. chem. Ecol.,* **18**: 1583–1593. https://doi.org/10.1007/BF00993231

Schütz, S., Weissbecker, B., Hammel, H.E., Apel, K.H., Schmitz, H. and Bleckmann, H., 1999. Insect antenna as a smoke detector. *Nature,* **398**: 298–299. https://doi.org/10.1038/18585

Scriven, G.T., Reeves, E.L. and Luck, R.F., 1986. Beetle from Australia threatens eucalyptus*. Calif. Agric.,* **40**: 4-6.

Smith, M.T., Bancroft, J., Li, G., Gao, R. and Teale, S., 2001. Dispersal of *Anoplophora glabripennis* (Cerambycidae). *Environ. Ent.,* **30**: 1036-1040. https://doi.org/10.1603/0046-225X-30.6.1036

Shibata, E., Sato, S., Sakuratani, Y., Sugimoto, T., Kimura, F. and Ito, F., 1996. Cerambycid beetles (Coleoptera) lured to chemicals in forests of Nara prefecture, central Japan. *Annls. entomol. Soc. Am.,* **89**: 835–842.

Solomon, J.D., 1995. Guide to insect borers of North American broadleaf trees and shrubs. *Agric. Handbook No 706* Washington, USA.

Suckling, D.M., Gibb, A.R., Daly, J.M., Chen, X. and Brockerhoff, E.G., 2001. Behavioral and electrophysiological responses of *Arhophalus tristis* to burnt pine and other stimuli. *J. chem. Ecol.,* **27**: 1091–1104. https://doi.org/10.1023/A:1010355710509

Tang, H., Jiang, W. and Chen, M., 2001. Preliminary research of sterility on the irradiated female imago of *Anoplophora glabripennis*. *Forest. Pest. Dis.,* **2**:10-11.

Tang, H., Kang, Z. and Zhang, Y., 2001. Adopting chemosterilant CS in field control against the longicorm, *Anoplophora glabripennis*. *J. Nanjing Forest. Univ.* **25**: 69-71.

Tian, R., Yu, J. and Zhao, W., 2003. On the function of *Elaeagnus angustifolia* L. to induce and control *Anoplophora glabripennis* (Motsch.). *Inner Mongolia Forest. Sci. Tech.,* **4**: 23-25.

Travakilian, G., Berkov, A., Meurer-Grimes, B. and Mori, S., 1997. Neotropical tree species and their faunas of *Xylophagous longicorns* (Coleoptera: Cerambycidae) in French Guiana. *Bot. Rev.,* **63**: 303-355. https://doi.org/10.1007/BF02856596

Wang, C., Luo, N. and Dong, G., 2002. Study on control of longicorn adults with pesticide micro-capsules. *China-US workshop on Asian long horned beetle*. *Yinchuang*, pp.140-142.

Wang, Q., Shi, G. and Davis, L.K., 1998. Reproductive potential and daily reproductive rhythms of *Oemona hirta* (Coleoptera: Cerambycidae). *J. econ. Ent.,* **91**: 1360–1365. https://doi.org/10.1093/jee/91.6.1360

Wang, Y., Wang, X. and Xu, L., 2004. Primary study on microwave irradiation of wood packing material to destroy *Anoplophora nobilis*. *Pl. Quarant.,* **18**: 200-2003.

Wang, Y., Zhan, G. and Wang, X., 2003a. Preliminary study on efficacy of heat treatment against *Anoplophora nobilis* in poplar wood. *Pl. Quaran.,* **17**: 326-329.

Wang, Y., Zhan, G. and Wang, X., 2003b. Primary study on the phosphine fumigation of poplar timber infested with *Anoplophora nobilis* Ganglbauer. *Pl. Quaran.,* **17**: 129-132.

Williams, N.H. and Whitten, W.M., 1983. Orchid floral fragrances and male euglossine bees: methods and advances in the last sesquidecade. *Biol. Bull.,* **164**: 355–395. https://doi.org/10.2307/1541248

Wickman, B.E., 1964. Freshly scorched pines attract large numbers of *Arhopalus asperatus* (Coleoptera: Cerambycidae) adults. *Pan-Pacif. Entomol*., **40**: 59–60.

Wu, Z., Zhu, G. and Zhu, C., 1999. The experiment of injecting pesticide into wormhole to control the big larvae of *A. glabripennis* (Motsch.) in *Populus nigra*. *Guangxi Forest. Sci.,* **28**: 142-144.

Xu, Z., Chen, X. and Tian. H., 1999a. Experiment on the control of *Anoplophora glabripennis* (Motsch.) and *A. nobilis* Ganglbauer with Confidor. *Forest. Pest Dis.,* **4**: 11-12.

Xu, Z., Luo, Y. and Li, J., 1999b. Study on prevention of spread of *Anoplophora glabripennis* by piling and thinning of damaged poplar-log. *Pl. Quaran.,* **13**: 65-68.

Xu, Z., Yan, S. and Wu, T., 2002a. A study on high efficient trunk coating in control of poplar long horned beetles. *China-US workshop on Asian long horned beetle. Yinchuan*, pp. 91-92.

Xu, Z., Yan, S. and Wu, T., 2002b. A study on the dynamic variations of Imidaclaprid residues in poplar. *China-US workshop on Asian long horned beetle. Yinchuan,* pp. 94.

Yanega, D., 1996. Field guide to northeastern long horned beetles (Coleoptera: Cerambycidae). *Illinois Natural History Survey, Manual* 6, USA.

Yamasaki, T., Sato, M. and Sakoguchi, H., 1997. Germacrene D: Masking substance of attractants for the cerambycid beetle, *Monochamus alternatus* (Hope). *Appl. Ent. Zool.,* **32**: 423–429.

Zhang, B., Bai, Y. and Mitsuaki, S. 1999a. Microbial control of *Anoplophora glabripennis* of non-woven fabric strips with *Beauveria bassiana* and *B. brongniartii*. *J. Northw. Forest. Univ.,* **14**: 68-72.

Zhang, B., Liu, Y. and Bai, Y., 1999b. Pathogenic fungi of *Anoplophora* spp. (Coleoptera: Cerambycidae) in Ningxia Hui Autonomous Region and their virulence. *J. Beijing Forest. Univ.,* **21**: 67-72.

Zhang, C., Yan, A. and Xia, C., 1999c. A study on controlling tests of contacted-breaking microcapsules to *Anoplophora nobilis* Ganglbauer and *A. glabripennis* (Motsch.). *J. Nanjing Forest. Univ.,* **23**:73-75.

Zhang, S., Xia, X. and Shu, H. 1994. An experimental study on the control of *Anoplophora grabripennis* (Motsch.) with stem injection of insecticides. *J. Inn. Mongolia Inst. Agric. Anim. Husb.* **15**: 15-20.

Zhang, X. and Linit, M.J., 1998. Comparison of oviposition and longevity of *Monochamus alternatus* and *M. carolinensis* (Coleoptera: Cerambycidae) under laboratory conditions. *Environ. Ent.,* **27**: 885–891. https://doi.org/10.1093/ee/27.4.885

Zhang, Y., Li, G. and Dai, J., 2001. Research on controlling larvae of *Anoplophora glabripennis* Motsch. by auto-flowing trunk injection. *Acta Agric.,* **10**: 87-89.

Zhang, Y., Wang, Y. and Zhang, L., 2003. Preliminary study on a new pathogen (*Nosema glabripennis* Zhang) parasitizing the long horned beetle *Anoplophora glabripennis* (Motsch.). *Scient. Silv. Sin.,* **39**: 171-173.

Zhao, H., Liu, M. and Xie, S., 2004. Study on high voltage shock to kill *Anoplophora nobilis*. *Pl. Quaran.,* **18**: 5-8.

Zhao, X., Li, G. and Li, Z., 1995. Study on selecting new type of insecticide by the new technique of injecting trunk strongly for controlling adults of Capricorn beetle. *J. Ningxia Agric. Coll.,* **1**: 71-73.

Zhou, J., Yang, X. and Sun, C., 1996. Discussion on the establishment of sustainable protection forests without the plague of longicorn. *Shanxi Forest. Sci. Tech.,* **4**: 2-5.

Zhu, Y., 2002. A Forestry investigation on the natural control of *Anoplophora nobilis* Ganglbauer by Wood pecker. *J. Northw. Forest. Univ.,* **7**: 72-74.