ISSN: 2414-1895 DOI: 10.6919/ICJE.202208_8(8).0003

Current Status of Research on Control Methods of Monochamus Alternatus Hope (Co-leoptera: Cerambycidae)

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Abstract

Monochamus alternatus Hope (Coleoptera: Cerambycidae) as the main vector for the transmission of the pine wood nematode, Bursaphelenchus xylophilus(Steiner and Buhrer) Nickle, it has attracted more and more attention in recent years because of the gradual northward movement of infested forest areas. In the prevention and control process of the modern M.alternatus, traditional physical control and chemical control can no longer meet the needs of today's sustainable development. This paper presents a review of the impact of the M.alternatus on pine forest pests, with the aim of reducing the irreversible damage caused by chemical and physical control, basing on the control principle of M.alternatus, the present control challenges and countermeasures were compared.The results of field trials with different approaches are compared and analyzed and the future trends of M.alternatus control are discussed and prospected. In order to solve the problems of excessive labor cost of physical control and irreversible pollution to the local ecological environment caused by chemical control, this paper combines "biological control methods" with "physical control methods" and "chemical control methods" to find out the best control methods for different insect stages of M.alternatus, to bring into play the maximum potential of different control methods, to solve the pest expansion hazard in a targeted manner, and to provide help for those who are engaged in the control of M.alternatus in the future.

Keywords

Monochamus Alternatus Hope; Biological; Pathogenic Microorganisms; Natural Enemy Organisms.

1. Introduction

Monochamus alternatus Hope (Coleoptera: Cerambycidae), an insect of the genus Monochamus in the family Cerambycidea, is an important trunk-destroying pest of pine trees in China, mainly affecting Pinus massoniana Lamb, Abies fabri (Mast.) Craib,Cedrus deodara (Roxb.) G. Don and other forest trees in central and southern China[1]. It is found in central and southern China. M.alternatus will spend the winter in the xylem tunnels of pine wood, and the larvae like to damage the phloem and xylem of the pine tree branches. When the density of insects in the trunk is too high, it will cut off the transport tissue and affect the transportation of water and nutrients in the pine tree, causing the wood to die. In addition, after it develops into adults and flies out, it will eat the trunk and 1-2-year-old the bark of twigs to supplement the required nutrients[2].M.alternatus is also a major vector of the devastating disease pine wood nematode, which was originally found in North America and appeared in Nanjing, China in 1982. During the process of adult worm gnawing on trees, the disseminated 4th instar pine wood nematodes carried in the body infect trees. Once a pine tree is

Volume 8 Issue 8, 2022
DOI: 10.6919/ICJE.202208_8(8).0003

infected with the disease, it can wilt in a short period of time and cause extensive pine tree dieback when it is difficult to diagnose in advance. Once infected with the disease, it is basically incurable, causing serious economic losses to the area where the disease occurs. Due to its wide area of transmission, rapid speed, difficulty in eradication, high mortality rate and other characteristics, the pine wood nematode, which is the main vector of pine wood nematode disease in China, was included in the list of dangerous forestry pests by the State Forestry Administration of China in 2003[3].

The damage time of M.alternatus is relatively long, and it is related to the external environment. When the external environment is low, the larvae will bore directly into the xylem around the age of 2 to reduce the gnawing on the sapwood, while when the external conditions are high, the larvae will choose to bite directly into the flat and wide kidney-shaped pupal chamber in the sapwood area to wait for fledging. The eclosion time of M.alternatus is relatively concentrated from May to August, accounting for more than 95% of the annual number of eclosion. Due to the continuous high temperature in summer, pine wood nematodes parasitized in the M.alternatus create a new breeding ground for the pine wood nematodes. It is a good breeding condition and vector for propagation[4]. At the same time, pine wood nematodes and M.alternatus can work together, the accumulation of pine wood nematodes will promote the plumage of M.alternatus, and the earlier the plumage time of M.alternatus, the larger the weight of its larvae will be, and the more nematodes it will carry[5].Pine wood nematodes affect the developmental cycle of M.alternatus, so that both develop in unison and get a better chance of survival.At about 25°C, it takes 4-5 days for pine nematodes to develop into adults, and when the temperature reaches 30°C, it takes only three days to complete development[6]. Even though the behavior of the adult M.alternatus is inert, the large number of M.alternatus is sufficient to complete the parasite's infection by flying short distances during courtship and feeding[7].The adult M.alternatus carries an average of about 19,000 nematodes, which is so destructive that it can cause weakening, infection, and up to the death of pine forests in severe cases. Therefore, the control of M.alternatus has an important role in forestry management in China[8].

2. Principles and Challenges of Monochamus Alternatus Hope Control

2.1 Principle of Monochamus Alternatus Hope Control

He control of M.alternatus refers to the four insect states of eggs, larvae, pupae and adults of M.alternatus, and different methods are used to inhibit the growth, development and reproduction of M.alternatus according to its biological characteristics in different periods[9]. In this chapter, we will focus on the effective suppression of the M.alternatus.

For the adult M.alternatus, it does not have a strong tendency to migrate and spread and often does not choose to actively migrate, and the way of spreading is mainly short-distance flight. Therefore, limiting the flight of M.alternatus during this period can also inhibit its spread[10].M.alternatus has weak phototropism, and this characteristic can also be used to trap and kill it[11].In China, some scholars have also studied the color selectivity of adult M.alternatus for hosts, and the results showed that it has obvious selectivity for brown color, so this characteristic can be used to make special colored trapping cages to improve the probability of trapping, or to suppress the activity of M.alternatus by applying specific colors to specific areas[12].

It usually feeds on fresh young pine branches[13]. The growth and reproduction of the pine aspen can also be suppressed by modifying the composition of the trees in the forest. The pine aspen feeds on trees with a high degree of specificity, and it is possible to find specific lures to trap it based on this characteristic[14]. Most of the adult M.alternatus choose the lower part of the tree canopy for feeding on current year or annual branches, so chemical application in this area often gives better results[15].

The mating and spawning of M.alternatus like to be carried out at night.Both males and females can release pheromones, not only that, but the female body surface of it also has contact pheromones, which can be well used to create suitable chemical traps to trap it at night[16]. Another study pointed out that the females of M.alternatus would release egg-laying pheromone at the same time when they lay eggs, and the egg-laying behavior of M.alternatus can be effectively inhibited by artificially

ISSN: 2414-1895 DOI: 10.6919/ICJE.202208_8(8).0003

releasing the egg-laying avoidance pheromone. Research studies have shown that M.alternatus spawning is highly specific and can be influenced by volatiles from host trees. It is usually found in trees with moderate diameters to lay eggs. This is because trees with large diameters have thicker bark, making it difficult for adults to create egg troughs, and it is also difficult to find pine trees in trees with small diameters. This is because the wood segment is too small to supply the nutrients needed for the growth and development of the larvae of M.alternatus[17]. From this biological characteristic, the trapping agent and trapping location can be selected in a targeted manner.. In addition, some insects such as ants and snake lacewings also feed on the eggs of M.alternatus, and these insects are the main biological means of controlling it during the egg stage[18].

2.2 Challenges of Monochamus Alternatus Hope Control

M.alternatus is mainly active inside the host except for the adult stage, which makes it difficult to trap it[19]. At present, there are relatively few studies on the biological behavior and characteristics of M.alternatus in all stages, which makes it difficult to choose the right control method[20]. At present, there are few studies on the related induction hormone components of M.alternatus, so it is difficult to make a suitable inducer of M.alternatus[21]. The high concentration or toxicity of chemical agents may affect the insects and trees in the same area and damage the local ecological environment, and the high labor and time costs associated with manual control methods are challenges to be faced in the future[22].The control of M.alternatus still faces great challenges: ①In chemical control and physical control, although it can achieve the better control effect, it requires manual means to make holes, place traps, change the trap cores and spray insecticide regularly, so it leads to high labor cost, time-consuming and labor-intensive, and the holes will also cause some degree of damage to trees[23].②Most of the chemical insecticides are left in the surrounding soil, causing pesticide residue problems, which will have a greater impact on the environment and destroy the biodiversity of the pine forest environment[24]. Although biological control is less harmful to the environment and frees up most of the labor force, it is less efficient than other control methods and has great limitations because of its high environmental requirements such as temperature, moisture, and biological populations[25].

3. Prevention and Control Measures of Monochamus Alternatus Hope

So far, there are two main types of control techniques for M.alternatus: one is a combination of chemical control and physical control. Chemical fumigation, chemical spraying, and baited wood trapping were used to lure and kill the insects, together with the centralized use of traps, placing the insect-sensitive wood separately, burning, and alcohol soaking to further control the infected areas and prevent secondary parasitization of the pests[26]. The effect of control can be more than 95% with the cooperation of the two.

Another type of control method that has become popular recently is biological control. Compared with traditional methods, biological control is the use of organisms or their metabolic products to control the number, reproduction, and spread of pests in order to reduce the pest[27]. The application of biological control does not make the pests resistant and can safely and permanently suppress the pests without disturbing the ecological balance[28].

3.1 Combination of Physical Methods and Chemical Methods Prevention and Control

As the adult period of M.alternatus is relatively concentrated, and its adults are inert and other characteristics, methods such as bait and wood trapping or traps can be used to guide the adults to lay eggs in a concentrated manner, and the adults, eggs and larvae of M.alternatus are eliminated in a centralized manner[29]. The two need to be combined to apply, the method is easy to use, safe and low cost[30]. The application of large areas can significantly reduce the population density of M.alternatus, which is the main control method in the infected areas in China nowadays[31].To take advantage of the characteristics of the aspen gathering to the weak wood or fallen wood, you can choose the weak plants as bait wood, the lure will be injected at 30-40 cm above the ground at an angle of 30 ° along with the knife to one centimeter deep xylem[32]. Nowadays, more plant-derived lures, sex pheromone lures and multiple pheromone combinations are used, using a combination of lures and traps, and the traps should be put in place by the end of April[33], and the trapping should be concentrated during the feathering period from May to July[34]. There are two types of traps on the market, one is M.alternatus lure F1 and S1, M1, F2 and F8 three generations of products and M.alternatus trap BF-1 type and BF-8 type two products, the other is the APF-1 new lure and trap[35]. Among them, APF-1 lure and traps have the best effect, but because the lure is bagged, the service life is short and needs to be replaced from time to time[36].APF-1 lure is bottled, which has a relatively longer life span and is suitable for forests that do not have time to change lures often[37].

Since the application of M.alternatus lure will cause the aspen to gather at the trap as the center, the baited wood should be selected in as open territory as possible, or selected as an isolated tree for hanging to try to control the scope of the outbreak[38]. After use, the trap cores should be sealed in plastic bags to avoid the artificial spread of the epidemic and prevent the spread of the insect source[39]. For the attracted longhorn beetle and the longhorn beetle larvae in the diseased wood, they should be burned or soaked in alcohol to prevent the nematodes in their bodies from causing secondary parasitism on neighboring pine wood. During the trapping process of baited wood trapping or traps, trap maintenance, core replacement, collection of adult M.alternatus, hanging position, hanging height, etc. can cause changes in trapping effect[40]. After harvesting insect-eaten pine, it is necessary to strengthen the enclosure management. It must be treated before it can be circulated. The lack of plants should be replanted in time to ensure ecological balance. The trapping efficiency can be maximized by timely hanging, timely adjustment of trapping cores or addition of trapping agents, and strict handling of the collection and treatment of adult insects[41].

3.2 By Biological Methods Prevention and Control

In the main infected areas of China, the most widely used method is chemical control[42]. Chemical control has high environmental pollution and irreversible effects, and its residues can damage the ecology and soil environment, and even affect the safety of local organisms and destroy the ecosystem structure[43]. The use of fungi to cause disease in the M.alternatus or the use of natural enemies to change the inter-and intra-species relationships to regulate the population density of M.alternatus is more environmentally friendly and not destructive to the environment and can be combined with other control methods to reduce and control the local population of M.alternatus more efficiently. Therefore, the use of biological control to control the harm of M.alternatus has become an important measure in forestry protection in China[44].

At present, there are two main ways of biological control. Among them, the most used method is to artificially release natural enemies in the pest-infested area for control. The common natural enemies of Monochamus alternatus Hope are Dastarcus helophoroides (Coleoptera:Bothrideridae), Sclerodermus guani (Hymenoptera: Bethylidae) and the predatory birds, etc. The release of natural enemies is also the most commonly used method in the biological control of M.alternatus.The second method is the use of pathogenic microorganisms[45]. The use of fungus parasitized on adult insects or larvae as new insecticides instead of traditional chemical reagents is gradually being applied to the pollution-free biological control of M.alternatus Hope in China.

3.2.1 By Pathogenic Microorganisms Methods Prevention and Control

Beauveria bassiana has a wide range of hosts, among which, B.bassiana, as the main component of fungal insecticides, plays an important role in the control of M.alternatus. The average daily food intake of M.alternatus infected with B.bassiana decreased significantly.The spores of B.bassiana secrete a sticky substance by specific adsorption, which makes them better adsorbed on the epidermis of M.alternatus. After reaching a suitable environment, the conidia begin to germinate and during the germination process secrete enzymatic components that can dissolve the insect epidermis, allowing the mycelium to penetrate the body wall and enter the insect. After entering the body of the insect, B.bassiana multiplies due to the suitable temperature and sufficient nutrient reserve, and intersperses in the organs of M.alternatus at all levels, damaging the tissues of the insect and slowing down or stopping its metabolism at all levels. While absorbing the nutrients in the M.alternatus, the flora produced the small molecule toxin of the cyclic depsipeptide, which led to its death of it.

The infestation of B.bassiana is highest when the ambient temperature is maintained at 25°C. The temperature is just similar to the growing season of M.alternatus, so the number of B.bassiana colonies in the field can be increased to meet the control needs. Due to the inertness of M.alternatus, it can be divided into separate areas and sprayed at a fixed point to infect M.alternatus in the area in a targeted manner to reduce the infection of other insects and avoid the local ecological structure being broken, to maintain the local ecological balance. Because the control effect of B.bassiana is good, the spores can be produced in large quantities through bagasse, the cost is low, and a good control effect can be achieved without affecting the local ecological environment. This technology is also widely used in the control of other agricultural pests[46].

3.2.2 By Natural Enemy Organisms Methods Prevention and Control

Compared with the control of pathogenic microorganisms, natural enemy organisms can search for hosts independently and have better control effects in harsh and changing environments. D.helophoroides is the natural enemy insect with the best control effect on M.alternatus.It has a long lifespan, fast reproduction and a high parasitic rate. After the release of D.helophoroides, the mortality increased significantly of M.alternatus[47]. It mainly parasitizes the larval stage and pupae stage of M.alternatus. S.guani mainly parasitizes the 1st and 2nd instar larvae of M.alternatus, so releasing it together with D.helophoroides can maximize the utilization of space resources and control the number of it in each instar of the population[48]. The cost of artificial breeding of D.helophoroides and S.guani is mature and low, and the population density of M.alternatus can be significantly reduced and maintained at a certain ecological balance by releasing the natural enemy insects continuously for many years under stable environmental conditions[49]. Due to the relatively small size of S.guani. Therefore, it is not easy to be paralyzed to lay eggs when parasitizing M.alternatus, and often it takes three or four S.guani to subdue one M.alternatus, so D.helophoroides contributes more to the reduction of M.alternatus population[50]. If only one type of natural enemy is released alone, the control effect will be affected by sudden change of environment. In order to meet the diverse ecological environment of the forest, the types and numbers of larvae released can be regulated according to different times of the year[51]. Choose the right time, release method and breeding technology to improve the parasitism rate of natural enemies such as D.helophoroides and S.guani to a certain extent, so that the control effect can meet the control needs of different seasons[52].In addition to releasing natural enemies, it is also necessary to release them. While releasing natural enemies, we should also pay attention to the local ecological structure to prevent the proliferation of natural enemy organisms from causing new pests.

3.2.3 Compatibility of Pathogenic Microorganisms with Natural Enemies

In the biological control of M.alternatus, a variety of organisms can be applied in combination to enhance its control effect. Compared with the traditional single biological control, the control effect will be more significant when different control means are applied in combination. At a concentration of 1×108 spores/mL, B.bassiana had a strong parasitic effect on M.alternatus while having no significant virulence effect on the D.helophoroides[53]. Forest lethality of B.bassiana-carrying S. guani against M.alternatus increased from 40.8% to 61.1% . It can be proved that B.bassiana has good compatibility with the D.helophoroides and S.guani in a certain concentrations, and can be applied in the forest to achieve pest control. However, the carrying capacity and lethal concentration of different parasitic insects to different strains of the fungus need to be further investigated[54] . The differences of infestation of the same fungicide on different parasitic insects also need to be further investigated to provide a theoretical basis for the combined biological control of M.alternatus.

4. Summary and Outlook

By fully understanding the damage principle of M.alternatus, we can start from the root cause and use different control methods in different development periods of it. Due to the constraints of the above-mentioned factors, the prevention and control of M.alternatus currently can only be based on prevention. From this point of view, rapid separation and identification at an early stage are important for the prevention of pine wood nematodes, and the elimination of long-distance transmission through human factors is also an important part of the control of pine wood nematodes. Therefore, The following measures can be taken to control M.alternatus: ①The introduction of advanced artificial intelligence in the trap of M.alternatus can effectively reduce labor costs. ②The application of high-efficiency traps and low-toxicity slow-release control agents can reduce the risk to the environment. While improving the efficiency of biological control, it reduces the harm of chemical drugs to the local environment, expands the delivery cycle of physical control and reduces labor costs. It can also slow down the invasion of pests due to migration to a certain extent.

Nowadays, the control methods based on biological control and supplemented by other control methods have gradually become the mainstream. By exploring the compatibility of parasitic fungi, parasitic insects and predatory birds with the local ecological structure, we can develop a release plan and add physical control and chemical control for different periods, which will become the main strategy for future control. Therefore, the correct choice of combining different control methods can bring out their maximum potential and better solve the problem of M.alternatus control in China.

Acknowledgments

This work was supported by the Natural Science Foundation of Heilongjiang Province under Grant (grant number LH2019C055), the Project funded by China Postdoctoral Science Foundation under Grant (grant number 2019M651316), the Heilongjiang Provincial Postdoctoral Science Foundation under Grant (grant number LBH-Z18261), the Department of Education of Heilongjiang Province under Grant (grant numbers 2020-KYYWF-1031, 2020-KYYWF-1030, 2020-KYYWF-1029, 135409216), and Heilongjiang University Student Innovation and Entrepreneurship Project (grant number 202110212002).

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