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RESEARCH ARTICLE

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Species and control of insect pests and major diseases of *Torreya grandis* Merrillii

Abstract From January 2001 to December 2004, the investigation on the species of insect pests and diseases in *Torreya grandis* Merrillii was conducted and integrated control technologies of the main insect pests and diseases were studied in Zhuji, Shaoxin, Shenzhou, Dongyang, and Jiande counties of Zhejiang Province. Via field survey, a system of regular observations, 55 species of insect pests belonging to 9 orders and 29 families, and 4 species of diseases were recorded. Among them, *Lepteucosma torreyae* and *Macrolygus torreyae* were found to be new species. The biological characteristics of the major insect pests and diseases, such as *Rhyncaphytoptus abiesis*, *Helicobasidium compacum, Erwinia carotovora*, *Chlorella* sp., *Macrolygus torreyae,* and *Lepteucosma torreyae*, were primarily recorded, and their outbreaks and epidemics were researched. The forecasting method for *Lepteucosma torreyae* was established. Based on strengthening cultivation and management, integrated control measures were put forward including physical, biologic and chemical methods. Medications with higher effect and lower toxicity were screened by comparing the effect of different pesticide treatments.

Keywords *Torreyae grandis* Merrillii, insect pests and diseases, biological characters, outbreaks and epidemics, integrated controls

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1 Introduction

Torreya grandis Merrillii is an evergreen tree belonging to genus *Torreya,* family Taxusaceae—a precious tree specially distributed in China. It distributes naturally in ten provinces in China, such as Zhejiang, Jiangsu, Anhui, Jiangxi, etc., and is cultivated in Zhejiang. Few of the insect pests and diseases on *Torreya* were reported abroad or domestically, except the controls of *Helicobasidium compacum* and *Erwinia carotovora* (Sun, 2002; Sun and Yang, 2003), *Torreya* pests in Anhui (Ding et al., 2003), environmental influence of *Torreya taxifolia* (Schwartz et al., 1995), and identification of the pathogen *Erwinia carotovora* (Cao, 1985). Many *Torreya* insect pests and diseases cause serious damage and yield loss; in addition, the *Torreya* seedling production is often affected. The *Torreya* seedling grows slowly, and may even die. Many *Torreya* trees are ancient and are hundred or even thousand years old. They die easily

once they are damaged by insect pests and diseases. In order to scientifically and reasonably control the damage to *Torreya* trees by insect pests and diseases, since 2001, we spent 4 years in Zhuji, Shaoxin, Shenzhou, Dongyang, and Jiangde, surveying *Torreya* insect pests and diseases and studying major pests integrated control technologies, to solve the major limitations affecting the development of the *Torreya* industry, pest control technology, environmental protection, food security, and protection of ancient trees.

2 *Torreya* insect pests and diseases

2.1 *Torreya* insect pests

After collection, management, and identification, 55 *Torreya* insect pests were found belonging to 6 orders, 29 families, including 1 family 1 specie of Isoptera, 2 families 2 species of Orthoptera, 7 families 10 species of Homoptera, 4 families 4 species of Hemiptera, 5 families 9 species of Coleoptera, 10 families 29 species of Lepidoptera (Table 1), 1 specie of *Torreya* gall mite (*Rhyncaphytoptus abiesis*), 2 species of *Mollusca*, *Fruticicola ravida*, *Agriolimax agrestis*, and so on. The above-mentioned species were identified by Prof. Xu from Zhejiang University; *Lepteucosma torreyae*, a new specie in Zhujiand, was identified by Dr Wu from CAAS; and *Macrolygus torreyae*, a new specie in Jiande, was identified by Prof. Zheng from Nankai University (Zheng and Lu, 2002).

2.2 *Torreya* diseases (Xu et al., 2005)

Four species of *Torreya* diseases were found, i.e., bacterial fruit rot (*Erwinia carotovora*), purpul root rot (*Helicobasidium compacum*, *Endothia parasitia*), and death of seedlings (caused by *Rhizoctonia solani, Pythium ultinum*, or *Fusarium culmorum*) (Table 1), which were identified by associate Prof. Lou from Zhejiang University, and so on; *Chlorella* sp. was found on *Torreya*.

Table 1 The consolidated species of the insect pests and diseases of *Torreya grandis* Merrillii

Order	Family	Species
Insects		
Isoptera	Termitidae	*Odontotermes formosanus* (Shiraki) (Lewis, 1997)
Orthoptera	Acrididae	*Atractomorpha sinensis* Bolivar
	Gryllotalpidae	*Gryllotalpa orientalis* Burmeister
Homoptera	Flatidae	*Geisha distinctissma* (Walker)
	Dictyopharidae	*Dictyophara sinica* Walker
	Cicadellidae	*Cicadella viridis* (Linnaeus)
	Cicadidae	*Ryptotympana atrata* (Fabricius) *Oneotynpana maculaticollis* Motschulsky
	Diaspididae	*Unaspis yanonensis* Kuw *Chrysomphalus aonidum* (Linnaeus)
	Coccidae	*Ceroplastes rubens* Maskell *Ceroplastes ceriferus* Anders
	Margarodidae	*Drosicha corpulenta* (Kuwana)
Hemiptera	Pyrrhocoridae	*Physopelta gutta* (Burmeister)
	Pentatomidae	*Erthesina fullo* (Thunbery)
	Coreidae	*Cletus punctiger* (Dallas)
	Miridae	*Macrolygus torreyae* Zheng
Coleoptera	Cerambycidae	*Apriona germari* (Hope) *Anoplophora chinensis* (Forst.) *Anoplophora leechi* (Gahan)
	Rutelidae	*Anomala corpulenta* Motschulsky *Mimela splendens* (Gyllenhal)
	Melolonthidae	*Holotrichia trichopora* (Fairmaire)

(*Continued*)

Order	Family	Species
	Elateridae	*Campsosternus auratus* (Drury)
		Melanotus regalis Candeze
	Chrysomelidae	Chrysomelid
Lepidoptera	Tortricidae	*Lepteucosma torreyae* Wu et Chen
		Archips compacta Meyrick
		Acleris bifasciatis L
	Lithosiinae	*Agylla holochrea* Hampson
		Asura strigipennis (Herrich-Schaffer)
		Chionaema hamata (Walker)
		Chionaema distincta Rothschild
		Miltochrista striata Bremer et Grey
		Miltochrista ziczac (Walker)
		Miltochrista miniata (Forster)
		Miltochrista sinuate Fang
		Eilema nigripoda (Bremer et Grey)
		Stigmatophora flava (Motschulsky)
		Stigma tophora rhodophila (Walker)
	Arctiinae	*Spilarctia bisecta* (Leech)
		Spilarctia ubcarnea (Walker)
		Creatonotos transiens (Walker)
	Noctuidae	*Agrotis ypsilon* Rottemberg
		Prodenia litura Fabricius
	Notodontidae	*Phalera flavescens* (Bremer et Grey)
		Phalera fuscescens Bulter
	Geometridae	*Arichanna jaguararia* Guenee
	Lymantriidae	*Euproctis bipunctapex* (Hampson)
		Arctornis alba (Bremer)
		Lymantriidae sp.
	Psychidae	*Cryptothelea formosicda* Strand
		Clania minuscule Butller
	Phyllocnistidae	*Phyllocnistidae* sp.
	Gracilariidae	*Lithocolletis ringoniella* Matsumura
Mite		*Rhyncaphytoptus abiesis*
Disease	Diaporthaceae	*Endothia parasitia*
Sphaeriales	Auriculariaceae	*Helicobasidium purpureum*
Auriculariales	Pythiaceae	*Pythium ultinum*
Peronosporales	Agonomycetaceae	*Rhizoctonia solani*
Agonomycetales	Tuberculariaceae	*Fusarium culmorum*
Tuberculariales		*Erwinia carotovora*

3 Occurrence and control of major pests on *Torreya*

In order to find out the occurrence of the major pests on *Torreya*, in Zhongjialin village, Zhaojia town, Zhuji county; Vanjiashan village, Jidong town, Shaoxing county; Baimalin village, Gulai town, Shenzhou county; Xitan village, Hulu town, Dongyang county; and Daku village, Fenhuang town, Jiande county, five fixed long-term monitoring stations were set up; investigation and rearing of *Torreya* pests were carried out. Pathogens were isolated and reared, and reinoculated back into healthy *Torreya* trees; the infestation, symptom, and epidemiogenesis were observed.

3.1 Occurrence and control of *Rhyncaphytoptus abiesis*

Adults and nymphs of *R. abiesis* cause damage on the upper surface of leaves. Damaged leaves (both old and new) are yellowish-red in color, and new leaves are worse if injured. As chlorophyll is damaged, photosynthesis decreases, which causes reduction in *Torreya* yield. *R. abiesis* grows 5–9 generations a year. During winter, eggs hatch from end of April to early June. As the new shoots grow, damage moves up gradually on trees. *R. abiesis* occurred from April to mid-October, but the most serious damages occurred from May to July. With regard to environment, usually the

trees on mountain ridges were less infested when compared to the trees in valleys; the trees on mostly clayey soil were seriously infested when compared to those on sandy soil; and the trees on flat land were mostly infested when compared to the trees on hills. The lower the density of trees, the lesser the infestation. The continuous rainfall restrained *R. abiesis*' reproduction. In the experiment, the spray of 150 g/kg pyridaben 2,500 times solution, 50 g/kg imidacloprid 1,000 times solution, Sendebao D and 200 g/kg Fenvalerate 1,000 times solution provided apparent control effects, in which 150 g/kg pyridaben 2,500 times solution and Sendebao D provided the best control effects. The effects increased over 9 % in 4 days (Table 2).

3.2 The occurrence and control of *Torreya helicobasidium purpureum* (THP)

THP mainly damages the roots of *Torreya* seedling and adult *Torreya* trees, and is a serious *Torreya* disease. The pathogen is a fungus belonging to Auriculariales, Auriculariaceae. It infests new roots in early April, and gradually enters older roots, or it may infest from wounds. It becomes an epidemic from July to August. The control experiment is indicative of nursery land. With fine management, using 700 g/kg Thiophanate-Methyl WP 500 times solution or 550 g/kg fenaminosulf WP 500 times solution, the control effects can reach 71.4%–80.0%. Especially, 550 g/kg fenaminosulf WP can reach 80% control effect economically (Table 3).

3.3 Occurrence and control of *Erwinia carotovora* (Ma and Cao, 1982; Cao and Fang, 1984; Tong et al., 1986)

Erwinia carotovora has strong adaptability, can transmit under high humidity, and also cause infestation under low temperature (0°C). It can infest both in fruit growth and in fruit reservation phases, and usually during winter on infested fruits (mummy fruit). It transmits by wind and rainfall in good conditions in the following year. It enters fruits via wounds or lenticels, and the latency phase is 5–10 days. The best temperature for pathogen development is 25°C approximately. The disease starts early May, and is often epidemic on fruit in the time close to maturity. Infested fruits start dropping in later May; most infested fruits drop in early June. Infested sources can be reduced effectively by removing the damaged fruits. The timing of chemical spray

Table 2 The control experiment of different pesticide treatments on *R. abiesis*

Pesticides	Solution	Branch	Population before spray (egg included)	Population after spray	
				In 2 days	In 4 days
15% pyridaben	2,500	6	240	18	8
5% imidacloprid	1,000	6	265	97(E)	24
20% fenvalerate	1,000	6	260	158(E, M)	23
Sendebao D		6	250	58(E)	5

Table 3 The control experiment of different pesticide treatments on THP

Fungicide	Solution	Before spray			After spray		Effect /%
		Total /pl	Infest /pl	Infest /%	Infest /pl	Infest /%	
70% hiophanate-Methyl WP	500	2,414	70	2.9	20	0.8	71.4
55% fenaminosulf WP	500	1,136	50	4.4	10	0.9	80.0
CK		1,930	110	5.7	270	14.2	

Table 4 The control experiment of different pesticide treatments on *Torreya* brown rot

Chemicals	Times	Total fruits	Healthy fruits	Damaged fruits	Damage rate /%	Effect /%
5% hydrochloride	800	1,000	975	25	2.5	90.4
"402"	1,000	1,000	880	120	12.0	53.8
Streptomycin	1,600	1,000	915	85	8.5	67.3
1:0.5 Bordeaux	200	1,000	860	140	14.0	46.1
50% tuzet	400	1,000	940	60	6.0	76.9
50%carbendazim	600	1,000	881	119	11.9	54.2
Control (CK)		1,000	740	260	26.0	—

should not coincide with the *Torreya* pollination phase; otherwise, *Torreya* pollination will be affected. Since late April, good control can be acquired by spraying once in 10 days, until the branches, stock, leaves, and fruits get wet; spraying should end in early July. The spraying solution can be either 50 g/kg hydrochloride 800 times solution, 500 g/kg carbendazim 600 times solution, 500 g/kg tuzet 400 times solution, 1:0.5 Bordeaux 200 times solution, "402" 1,000 times solution, or agricultural streptomycin 1,600 times solution. Among them 50 g/kg hydrochloride 800 times solution can provide the best effect at 90.4% (Table 4).

3.4 The occurrence and control of *Torreya Chlorella* sp.

Chlorella sp. grows a layer of greenish-grey muscus-like material on leaves, decreases the normal photosynthesis, and causes fruit dropping and yield reduction. The investigation shows that *Chlorella* sp. mostly occurs on older leaves, and rarely occurs on new leaves. It often occurs on 51%–64% of leaves; in most cases it lightly occurs. It easily occurs during the rainy season and is epidemic from mid-June to mid-July. *Torreya* trees cultivated in wet and warm conditions, north of hills, dark and wet valleys, high density and crowding are good for development of *Chlorella* sp.. Spraying of Lime sulphur 800 times solution will provide good control effects; the effect can reach 85.7%, nine days after spraying.

3.5 The occurrence and control of *Macrolygus torreyae*

3.5.1 Biological characteristics

In 2001, the bug was recorded first in Fenghuang town, Jiande county, Zhejiang province. These bugs injured 85%–100% of the *Torreya* trees. When their population increased, they caused large amounts of dead shoots and dropping of fruits. The bugs span two generations in a year in Jiande. During winter, eggs appear, and when *Torreya* tree buds generate in early April the following year, the eggs start hatching; most eggs hatch in mid-April. The adults of the winter generation emerge in early May, and most adults emerge in mid-May. The nymphs of the first generation occur from May 10 to May 15, and most nymphs occur around May 20. The adults of the first generation emerge in the later part of June. New hatched nymphs are active, run fast, without gathering feeding habits. Low instar nymphs hide among young leaves and suck juice, causing upper leaves to turn yellow and die, cause yellow patches on young fruits, seriously damaging young shoots, and cause welting and dropping of young fruits. The adults suck juice of new shoots, leaves, and young fruits. The adults show weak phototaxis, thus light traps have the worst effect. The adults prefer flying, but usually short distances, about 50–60 m, without syncope. When disturbed, they usually fly 2–4 m and then return. During winter, adults lay eggs in young shoots.

3.5.2 Control of Macrolygus torreyae

1) Culture measures. Cleaning weeds under the trees in early spring to eliminate eggs laid during winter. (2) Protection of spiders. (3) Insecticide spray. In late April, 200 g/kg imidacloprid 1,500 times solution, or 500 g/kg sumithion 1,000 times solution, can be used and effects can reach 95.7% and 94.4 % efficiency, respectively. Plant source insecticide 6.3 g/kg Yansenjian 500 times solution reaches an effect of 78.1%.

3.6 Occurrence and control of *Lepteucosma torreyae*

3.6.1 Lepteucosma torreyae biology

Lepteucosma torreyae is a major insect pest on *Torreya*; the larvae feed on young shoots and leaf tissues. It occurs twice a year; matured larvae weave a cocoon during winter in the rifts of *Torreya* tree trunks, falling leaves, and muscus under corona. In February next year, they start developing and pupation occurs; the adults emerge in early March and lay eggs. After hatching, the larvae bore *Torreya* buds from late March to mid-May, and the larvae pupate in May. The adults of the first generation emerge in early and mid-June; the females lay eggs in late June. The larvae of the second generation remain in leaves after hatching. Most larvae hatch in mid-July; after damaging, the larvae attain maturity during winter in November. There are two types of adults: summer type and winter type. The adults show phototaxis during the day, but no phototaxis in the night, and have craw up habitats; they can also jump short distances and fly.

3.6.2 Lepteucosma torreyae prediction methods

Phenology and calender prediction: usually *Torreya* trees germinate in mid-February; during winter, larvae start developing. In early and mid-March, when *Torreya* leaf buds elongate 1 cm or so, most adults emerge. After emerging, adults start mating and laying eggs. After 30 days, the low instar larvae of the first generation emerge, and after 50 days the larvae start causing serious damage. The first generation larvae make damage bracts from April to May, and pupate in damage bracts in mid-May. The prediction technology is that from early May to June, 20 damage bracts are collected every 5 days. The bracts are dissected to calculate the pupation rate; the first generation pupation fastigium occurs when the pupation rate reaches 50%. Fifteen days later, adult fastigium occurs. Thirty days after adult fastigium, young larvae fastigium of the second generation occurs. The best times for spraying are the first generation adult and the second young larvae fastigiums. Population

density prediction: from February to March, quick rise in temperature and enough rainfall are beneficial for the development of winter *Lepteucosma torreyae*, and first generation population will increase; then serious damage occurs from April to May. In November, the slow decrease in temperature helps the second generation larvae to mature during winter in comparison with a fast decrease, and results in increase in the next year's population. If there is a cold wave and the temperature decreases suddenly, then the larvae are affected during winter. For prediction, ten trees of *Torreya* of different ages, health conditions, and directions can be selected; from each tree, four directions of branches can be selected to examine damaged bracts. Data can be accumulated for several years, and can be used for regression prediction of the population density.

3.6.3 The control of Lepteucosma torreyae

The study results showed that, in late July, with a spray of 200 g/kg Fenvalerate EC 3,000–5,000 times solution, imidacloprid 2,000 times solution, the control effects reached 96% after 3 days; with chlorfluazuron 3,000 times solution, the control effects reached 100% after 6 days; and with Senle WP 3,000 times solution, control effects reached 100% after 3 days.

4 Integrated pest control technology for *Torreya* major pests

4.1 Integrated pest control technology for *Torreya* major pests

1) Culture measures: the first is cleaning of weeds in a *Torreya* forest to decrease the competition of weeds with *Torreya* trees for fertilizers; the second is cleaning the drainage furrow to drain surplus water; the third is ploughing in time, increasing soil ventilation, and killing insect pests in soil during winter; the fourth is focusing on organic fertilizers and using more P\K fertilizer. 2) Physical measures: cleaning *Torreya* forests in time, removing dead branches and falling leaves and burning them outside the forest; using lime 5 kg + sulphate 1 kg + solt 1 kg + water 18 kg for making compounds to whiten trunks; using light traps in moth occurrence phase for decreasing pest population. 3) Chemical control: on the basis of prediction, using chemicals to control *Lepteucosma torreyae*, *Rhyncaphytoptus abiesis*, and *Erwinia carrotovora*. 4) Biological control: using abamectin, Senle to control *Torreya* pests, to protect natural enemies and the enviroment for sustainable development of *Torreya*, to raise *Torreya* yields and quality.

4.2 Control calendar for *Torreya* major pests

The first stage—*Torreya* trees grow slowly. From December of the previous year to end of February. Main measures: cutting and removing disease infested and insect pest damaged branches, weak branches, keeping reasonable quantity of fructifying branches, cleaning of *Torreya* forest, and whitening using 30 g/kg lime.

The second stage—when fructified branches germinate, flower, and form fruits. From March to late April. Main measures: shallow ploughing, cleaning of weed, spraying fertilizers in time, NPK compound fertilizer 0.5–1.0 kg per plant for young trees, applying 2.0–2.5 kg per plant for other trees, enhancing prediction, mainly control of *Lepteucosma torreyae, Macrolygus torreya,* and *Erwinia carrotovora*. When *Torreya* leaf buds elongate to 1 cm in March, spraying Senle WP 2,000 times solution or sumithion 1,500 time solution to control adults of winter generation.

The third stage—growth of fruits. From early May to mid-July. Main measures: in the dry summer season when typhoons occur, developing a good drainage system, monitoring the weather change, irrigating in time in dry conditions. According to current condition of fruits and the age of the tree, from late June to early July, fertilizer to be sprayed is NPK compound fertilizer 300–450 kg/hm^2 + Phosphoros fertilizer 75 kg/hm^2 + Potash fertilizer 75 kg/hm^2. The occurrence of *Macrolygus torreya, Rhyncaphytoptus abiesis*, and *Erwinia carrotovora* should be controlled. Watering 50 g/kg carbendazim 500 times solution can control *Rhizoctonia solani*. To scale down insect damage in the *Torreya* forest, 100 g/kg imidacloprid 1,000 times solution can be used to kill newly hatched nymphs. Bisultap 800 times solution can be sprayed on seedling beds for controlling *Acleris bifasciatis*. *Rhyncaphytoptus abiesis* and *Lepteucosma torreyae* can be controlled by spraying Senle WP 2,000 times solution and sumithion 1,000 times solution plus hexythiazox 2,000 times solution; if termites are found, termite poison package can be sprayed on termite affected areas to kill the pests.

The fourth stage—the fruit filling stage. From late July to late August. Main measures are the same as given in the third stage.

The fifth stage—the fruits ripen. From early September to late November. Main measures: cleaning of dead branches and falling leaves, ploughing land to a depth of 20 cm or so, preparing for harvest. After harvest, use enough base fertilizer for the new tree, apply manure 25 kg per plant, NPK compound fertilizer 1–3 kg per plant, and zala 10–15 g per plant; for highly productive trees, apply manure 5 kg per plant, NPK compound fertilizer 5–10 kg per plant, and zala 5 g per plant that produces dry fruits of 1 kg per plant, application method is triped application. Covering with soil in time after application. Control of *Leptocausma torreyae*. Cleaning of *Torreya* garden after November, removing damaged branches, leaves, and fruits.

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