Major Diseases and Pests of Blueberry in Guizhou Province and Progress in Their Prevention and Control

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Abstract As the blueberry industry continues to evolve, the effective control of its diseases and pests has become an essential component of local agricultural development. This paper provides a comprehensive overview of the principal types of blueberry diseases and pests in Guizhou Province, along with the corresponding control measures, in order to serve as a valuable reference for blueberry growers.

Key words Blueberries; Diseases and pests; Prevention and control; Guizhou Province

1 Introduction

Blueberries, also known as lingonberries, are small shrub-type berries native to the Americas. They belong to the genus *Vaccinium* of the Ericaceae family and have been cultivated for at least 13 000 years, making them one of the world's oldest fruits. The blueberry fruit is aesthetically pleasing and palatable; its outer layer is coated with a fine white powder, while the inner flesh is blue in color and possesses a delicate flavor. The seed is notably small, contributing little to the overall taste. Consequently, the edible portion of the fruit is high, approaching 100%[1]. As a novel fruit type that encompasses both nutritional and healthcare functions, blueberries are rich in a multitude of essential nutrients, including proteins, dietary fibers, carbohydrates, and a diverse array of minerals (calcium, iron, potassium, zinc, *etc.*) and vitamins (vitamins A, B, C, E, *etc.*). Furthermore, blueberries contain natural active substances (arbutin) and antioxidant enzymes (SOD). These components have anti-aging properties, enhance immunity functions, and function with other substances to promote cardiovascular health, anticancer effects, and overall bodily capacity. Blueberries are therefore regarded as "the king of fruits"[2].

In recent years, the cultivation of blueberries in the mountainous regions of Guizhou Province has emerged as a significant economic activity for local farmers, with the region's distinctive topography and climate offering a unique opportunity for this crop. Since the initial introduction of blueberries in Majiang County at the end of the 20th century, the province has witnessed a remarkable expansion in the cultivation of this fruit. By the end of 2023, over 70 counties (districts and cities) in 9 cities (prefectures) had planted blueberries, with a total area of up to 15 300 hm^2 and an annual output of more than 100 000 t. This has led to the province ranking among the top in China in terms of both area and output. Furthermore, the output value of fresh fruits has reached over 2 billion yuan, making it one of the most valuable agricultural sectors in the province. This has resulted in the development of sightseeing tours and the establishment of industrial chains, including deep-processing, with a total output value exceeding 3 billion yuan. The province is home to over 100 000 individuals engaged in the entire industry chain of blueberry cultivation, seedling rearing, and processing. This figure represents over 2 million employees in the upstream and downstream sectors, with an annual output value exceeding 1 billion yuan. Nevertheless, the continuous development of the blueberry industry has resulted in a significant decline in the quality of its growth due to the persistent damage caused by diseases and pests during the growth process. Additionally, there are notable differences in plant morphology and disease resistance among different blueberry varieties, which has led to the necessity of highly specialized cultivation techniques and effective pest prevention and control techniques.

The effective control of pests and diseases and the protection of blueberries from safe overwintering has become a significant aspect of local agricultural development. In the event of a blueberry pest infestation, it is imperative that growers employ scientific and effective control methods. This paper provides an in-depth analysis of the most prevalent types of blueberry diseases and pests and their control strategies in Guizhou, and also presents a series of control initiatives that can be utilized by blueberry growers as a reference.

2 Main diseases and pests of blueberry

Common diseases that affect blueberries during the growth process

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include downy mildew, powdery mildew, root rot, and frostbite. In addition to the aforementioned diseases, blueberries may also be affected by insect pests such as aphids, mites, longicorns, stinkbugs, and fruit flies. Following the census, the most prevalent diseases affecting blueberries in Guizhou Province include gray mold, anthracnose, and root rot[1]. The most common insect pests include fruit flies, scarabs, leaf-feeding tussock moths, eucleids, giant silkworm moths[3], inchworms, ermine moths that infest the tips of branches, and trunk-boring longicorns (Table 1)[4].

Table 1 Main diseases and pests in blueberry producing areas in some areas

Region	Insect pest	Disease
Majiang County	Scarab, mole cricket, *Zeuzera leuconolum*, *Drosophila melanogaster*, *Grapholita molesta*	Gray mold, root rot, anthracnose, canker
Qiandongnan Prefecture	*D. melanogaster*, scarab, stinkbug, *Clania vartegata*, wood-beetle, *Sardoscelis spenias*, tussock moth, psychid, *Gryllotalpa orientalis*, *Trabala vishnou guttata*, eucleid, cutworm, and stem borer	Gray mold, root rot, rust, branch blight, leaf blight, leaf scorch, mosaic disease, black spot, leaf rot, leaf spot and anthracnose
Liuzhi Special District	*Holotrichia parallela*, *Anomala corpulenta*, *D. melanogaster*, *Aromia bungii*, *Cicadella viridis*, *Cnidocampa flavescens*, *Nyctemera adversata*, inchworm, *Eysacoris guttiger*, *Ricania speculum*	Anthracnose, mummy, gray mold

3 Main diseases and pests and control measures

3.1 Main diseases and prevention and control methods

3.1.1 Gray mold, rust and mummy. (i) Agricultural control. Firstly, in order to reduce the source of bacteria, it is necessary to combine winter pruning with the removal of disease residues and the subsequent burning or burial of the materials at a depth of at least 15 cm. Secondly, during the flowering period, it is essential to perform thorough bud removal and timely weeding, increase ventilation and light, and reduce the humidity of the orchard. Thirdly, during the growing season, it is necessary to remove any diseased fruits, vines, or leaves. Additionally, it is important to remove the flower residue from the fruit in a timely manner, either through vibration or removal. Fourthly, the harvesting of fruit immediately following the freezing process can also significantly reduce the incidence of disease.

(ii) Chemical control. The primary objective is to implement early prevention strategies, which necessitates an accurate comprehension of the two pivotal periods of medication administration: the early flowering period and the fruit expansion period.

To prevent gray mold, a 0.3% eugenol SL can be diluted 600 times and sprayed after germination to the first flowering stage of blueberry. The prevention and control of rust disease can be achieved by spraying a solution comprising 25% triadimefon, which has been diluted to a concentration of 1 500 – 2 000 times. The prevention and control of mummy can be achieved by spraying a solution of 500 times the dilution of 70% mancozeb WP or 1 000 times the dilution of 70% thiophanate-methyl.

Prior to the onset of fruit expansion in blueberries following flowering, the growth of gray mold can be inhibited by the application of biological agents, including 100 million CFU of *Trichoderma harzianum* WP 500 times dilution, 10% polyoxins WP 70 – 120 g/667 m^2, and 0.3% eugenol SL 600 times dilution. The treatment of rust involves the application of various agents, including 25% triazolone (1 500 times dilution), 12.5% diniconazole (2 000 times dilution), 75% chlorothalonil WP (500 times dilution), and 15% triadimefon WP (1 000 times dilution) at a dosage of 60 – 75 kg/667m^2. The addition of 0.2% adhesive (such as laundry detergent, *etc.*) is recommended to enhance the effect. The agents are applied once every 10 d for a continuous period of 2 – 3 times. In the event of precipitation following the application of the agent, a further application is required once the weather clears. Prior to the onset of flowering, the application of 20% triforine can be employed to effectively control the initial and subsequent infections of mummy, with an efficacy of greater than 90%.

3.1.2 Fruit rot. Prior to harvesting, it is advisable to apply a calcium spray to increase the calcium content of the fruit, enhance its resistance to storage and resistance to rot. The optimal time for harvesting is also crucial. Harvesting using the rotary method is recommended to avoid breaking the skin and bruising, while simultaneously eliminating diseased fruits. It is imperative that storage facilities should be thoroughly disinfected and sterilized prior to the storage of any materials. During the storage period, it is crucial to employ measures such as low temperature, gas conditioning, and ozone sterilization to create an environment that is unfavorable to the growth of pathogens.

3.1.3 Canker. Heavily diseased trees are removed, while lightly diseased trees are pruned to remove diseased branches and leaves. Diseased spots are scraped, and diseased dead branches, fallen fruits, fallen leaves, and eradicated weeds are burned in the orchard. This is combined with other disease and pest control measures, such as the application of 0.8 – 1°Bé lime sulphur, with the objective of reducing or eliminating the source of diseases and pests.

3.1.4 Root rot. (i) Agricultural control. Firstly, it is necessary to implement a deep-turning of the orchard in the autumn months, accompanied by an increase in the application of organic fertilizers. This should be followed by a deepening of the soil layer. Secondly, in the case of diseased trees, it is first necessary to dig a trench to block the spread of the disease. This trench should be two feet deep and wide, and should be dug around the diseased and healthy trees. It is recommended that root irrigation should be performed with *Trichoderma* and Aolike. It is advisable to remove any severely diseased plants as soon as possible, and to dispose of the remaining roots by cleaning and burning them. Furthermore, the soil in the vicinity of the diseased plants should be sterilized. In the event that root rot has occurred, it is imperative that the pit soil be sterilized with chemicals following the removal of all rotting roots. Organic chemicals, such as *Trichoderma* and Aolike, or green chemicals, such as hymexazol · metalaxyl and hymexazol, should be employed.

(ii) Chemical control. The most effective method for preventing blueberry root rot is to identify it at an early stage, monitor its progression, and employ a collaborative approach involving scarab and ant control at the initial stages of the disease. For the purpose of organic prevention and control, the following substances may be employed: Aolike (100 – 150 mL), Genjibao (50 mL), garlic oil (30 mL), Wofengsu (25 mL), 0.1% urea, and *Metarhizium anisopliae*. The aforementioned substances should be added with 15 kg of water prior to irrigating the roots. It is important to pay direct attention to the capillary root zone and the stem base. Once the liquid has permeated the soil, it is advisable to cover the topsoil with a thin layer of soil. In March, the entire orchard is treated with *Trichoderma* + *Bacillus thuringiensis* or nuclear polyhedron (800 – 1 000 mL), and hymexazol · metalaxyl + *B. thuringiensis* or nuclear polyhedron (800 – 1 000 mL) + *M. anisopliae* is selected for green control. The recommended dosage for hymexazol, *B. thuringiensis*, and *M. anisopliae* is one packet of each diluted with 10 kg of water for root irrigation. For small trees, the dosage is 1.5 kg per tree, while for large trees, it is 2.5 kg per tree. The agents are applied via spraying once every 5 – 7 d, with a total of 2 – 3 applications.

3.1.5 Anthracnose. (i) Agricultural control. Following the clearance of the orchard in winter, the first-emerging diseased fruits should be removed and deeply buried and burned. In summer, pruning should be undertaken to improve ventilation and light penetration. Additionally, the soil, fertilizer, and water should be managed to enhance the tree's ability to resist disease. Particular attention should be paid to the supplementation of phosphorus, potassium, and calcium fertilizers in July and August, and the drainage of the orchard in rainy seasons[5].

(ii) Chemical control. A 600-fold dilution of tebuconazole, Liangguo'an, and carvacrol is applied to the blueberry orchard at 10 d post germination, the flower dew red period, 7 – 10 d after flower shedding, and from the summer solstice to the fall equinox, respectively.

3.2 Main insect pests and prevention and control methods

3.2.1 *Sardoscelis spenias*, psychid, wood-beetle, silkworm moth in Lepidoptera and scarabs in Coleoptera. (i) Agricultural control. The initial approach entails combining winter fertilization with the excavation of the blueberry orchard. The application of decomposed cow manure is accompanied by the use of phoxim or *M. anisopliae* to neutralize the fertilizer. Alternatively, phoxim granules can be applied with the fertilizer. Secondly, the use of light, sugar and vinegar, and the sweet wine brewing method has been demonstrated to be effective in trapping adults. Solar energy has been shown to be an effective method for trapping Lepidoptera and Coleoptera moths. The sugar and vinegar liquid method employs a ratio of 1∶3∶2∶4 for brown sugar, vinegar, wine, and water, respectively, with the addition of a small quantity of trichlorfon. The sweet wine brewing method employs sweet fermented rice and a small quantity of trichlorfon. Thirdly, the adults can be captured. In the early morning and evening, when adult insects are unearthed, insect nets are hung on the edges of blueberry gardens or on both sides of production roads in order to kill adult insects. Alternatively, the tree trunk or fork may be scraped to reveal worm dung, which can then be used to identify the wormhole. Once located, the hole can be plugged with a 50% ammonia water toxic cotton solution to poison the larvae of longicorn or woodbeetle. Orifice fumigation may also be employed to fumigate closed orifices with fumigant in order to fumigate larvae.

(ii) Chemical control. Pesticides such as *B. thuringiensis*, *M. anisopliae*, *Beauveria*, and phoxim can be formulated as a liquid and then applied to the roots via irrigation or broadcast application. At the early stage of larval hatching or low larval stage, the following concentrations of insecticides can be applied: 600 – 800 times dilution of 0.3% azadirachtin EC, 500 times dilution of 1.5% natural pyrethrin EW, 500 – 1 000 times dilution of *B. thuringiensis* WP, and 1 500 – 2 500 times dilution of *Beauveria bassiana* WP. For the purpose of trapping aphids and thrips, it is recommended that yellow boards should be hung at a density of 30 boards/667 m^2 to trap aphids, while blue boards should be hung at the same density in order to trap thrips. Upon reaching the control index, the application of 0.3% azadirachtin EC, diluted 500 times, or 0.5% veratrine, diluted 500 – 800 times, can be considered for spraying.

3.2.2 Fruit flies. (i) Agricultural control. Firstly, the implementation of effective horticultural management practices is crucial to ensure the timely removal of landing, rotten, damaged, or overripe fruits during the harvesting period. This is essential to reduce the appeal of fruit flies. It is recommended that a thick soil or trichlorphon spray should be applied to prevent female flies from laying eggs. Additionally, pests and diseases, dead branches, stiff fruits, fallen leaves, and weeds should be removed from the orchard in the winter following harvesting in order to maintain optimal orchard hygiene. Secondly, it is recommended that conditional orchards should be ridged in winter and covered with a ground cloth or reflective membrane in order to reduce the overwintering quantity of diseases and pests and inhibit the occurrence of fruit flies. Thirdly, insecticidal lamps can be employed to achieve the desired results. The phototaxis of fruit flies can be exploited to trap adult insects, thereby interfering with mating and reducing the initial population quantity. Furthermore, the use of chemical pesticides can be reduced. Fourthly, sweet and sour liquid or sweet fermented rice can be employed as a trapping agent. In late April, sweet and sour liquid or sweet fermented rice can be suspended to eliminate fruit fly adults. In addition, it is advisable to remove and replace the baits on a regular basis. Fifthly, it is recommended that natural enemies of insects should be protected and utilized, and that the food chain should be employed for the purpose of biological control[6].

(ii) Chemical control. In the initial stages of spring, when the temperature rises to above 10 ℃ and before the blueberry fruit reaches its optimal ripening point, the chemical matrine or azadirachtin is selected for the purpose of spray control. The conventional pesticides include cypermethrin, while the organic control pesticides include matrine and azadirachtin. Green control entails the use of a 1 500-fold dilution of cypermethrin to spray the entirety of the orchard following the conclusion of the blueberry harvest. At the point when the fruit reaches a medium level of maturity, matrine or azadirachtin is added with fruit calcium to spray the fruit tree.

3.2.3 Mole cricket. The initial method is the utilization of a horse manure trapping technique. A square pit measuring 30 cm on each side and 20 cm deep should be dug in the orchard. The pit should then be filled with wet horse manure, covered with grass. It is recommended that mole crickets should be captured in the morning to reduce its density in the orchard. The second method is the poison bait killing method. The method employs 5 kg of bean cake or wheat bran, which are fried, or 5 kg of blighted grains, which are boiled to semi-dry. Subsequently, the ingredients are combined with 150 g of 90% crystal trichlorfon and an appropriate quantity of water to create the poison bait. The application of poison bait at a rate of 1.5 – 2.5 kg/66.7 m^2 to ground or mulch is sufficient to achieve the trapping and killing of pests.

3.2.4 *Grapholita molesta*. In late July to early August, the sugar and vinegar liquid baiting method is employed in conjunction with manual removal of damaged branches, which are subsequently relocated to the exterior of the orchard for treatment. It is recommended that control efforts should be concentrated on the second and third generation larvae. A spray containing 100 times dilution of *B. thuringiensis* emulsion, with a concentration of more than 12 billion bacteria/mL, should be applied after fruit picking.

3.2.5 Aphid. (i) Agricultural control. The first step is to clean the orchard, eliminating overwintering insect sources. The second step is to apply a silver gray film to prevent aphids from infesting the orchard. The third step is to protect ladybugs, lacewings, and other natural enemies. In late March or early April, the yellow sticky board lure should be installed in order to attract and trap the yellow-winged aphids.

(ii) Chemical control. In the spring, the leaf-spreading stage (late March) and the autumn shoot stage (early September), a solution of 95% mineral oil EC + Zhibingling at a 1 000-fold dilution is applied, or alternatively, a solution of 10% imidacloprid WP at a 3 000-fold dilution is applied 2 – 3 times.

3.2.6 *Anomala corpulenta*. (i) Agricultural control. Firstly, plots with heavy grubs (scarab larvae) are tilled in late fall or early winter to expose a large number of grubs on the ground surface, thus allowing for their elimination by nature or natural enemies[7-8]. Secondly, the phototaxis of grubs is employed to install vibration frequency insecticidal lamps in the orchard, with the objective of trapping and killing adult insects. Thirdly, since adults exhibit the characteristics of feigning death, plastic sheeting is employed beneath the tree canopy. This is done by shaking or vibrating the tree trunk, thereby enabling the collection of adult insects that have fallen to the ground.

(ii) Chemical control. Small early morning activity of *A. corpulenta* can be exploited to achieve effective control of the pest by spraying a solution of 90% crystal trichlorfon at a dilution of 800 – 1 000 times. This should be applied once every 7 d for a total of 3 applications during the flowering period. The results are clearly observable.

3.2.7 *Cnidocampa flavescens*. The first approach is to eliminate overwintering insect sources and concentrate on the destruction of removed leaves. The second is to install insecticidal lamps in the orchard to trap adult insects. A 4.5% lambda-cyhalothrin EC 80 – 100 mL solution can be diluted with 100 L of water for spraying during the larval hatching period.

3.2.8 *Eysacoris guttiger*. In the winter months, it is advisable to remove any dead branches, vines, fallen leaves, and weeds from the orchard. Once these have been cleared, the bark can be scraped and composted or burned. Concurrently, the false death of adult worms should be induced by shaking the branches and vines, allowing them to fall to the ground, and subsequently placing them into glass bottles to seal their demise. A 10% imidacloprid WP at a dilution of 1 000 times should be sprayed during the peak larval hatching period.

3.2.9 *Drosophila melanogaster*. (i) Agricultural control. Firstly, in the blueberry fruit harvest period, it is imperative to remove and dispose of insect-infested fruits in a manner that ensures their complete destruction. Secondly, during the period of expansion preceding the harvest, fruit fly lures are hung in a large area in a plum blossom-type arrangement with the objective of trapping adult insects and reducing the number of eggs laid. Thirdly, chemotaxis is employed for the purpose of trapping adults. A solution of sugar, vinegar, wine, water, and trichlorfon is prepared at a ratio of 5 ∶ 10 ∶ 10 ∶ 20 ∶ 1. This solution is then loaded into a beverage bottle, which is subsequently placed at a density of 5 boards/667 m^2. The bottle is changed once every 4 – 5 d, and should be changed more frequently in rainy conditions.

(ii) Chemical control. At the peak of the adult season, 25% buprofezin WP 2 000 times dilution is employed to suppress the adult insects.

3.3 Prevention and control principles and recommendations

The prevention and control of blueberry pests and diseases should be approached in accordance with the principle of prevention first and integrated control. First, the implementation of ecological regulation enables the creation of an ecological environment conducive to the growth of blueberries and one that is inhospitable to the proliferation of pathogens, thus facilitating the control of diseases and pests. Second, field management is enhanced through the implementation of agricultural control measures, including the rational fertilization, watering, weeding, and other techniques designed to enhance the blueberry's resistance to diseases and pests. Third, physical control measures are utilized to trap pests and reduce the necessity for late prevention and control measures. Fourth, when the pests and diseases reach the control index, biological pesticides and chemical pesticides with high efficacy, low toxicity, and low residue are the preferred choice. Plant protection drones, electrostatic sprayers, and other advanced application equipment are employed for prevention and control. Drugs are used alternatively in a scientific and rational manner. Fifth, it is imperative that no pesticides can be used at all during the 20 d period before the ripening of blueberry fruit and the period before the end of the fruit-picking season. At the same time, pesticide residue testing for blueberry fruits must be conducted.

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(To page 7)

4 Discussion

The genus *Phyllosticta* is widely distributed globally and comprises a diverse group of pathogenic and endophytic fungi associated with a broad range of plant hosts[9-10]. It is possible for endophytes to be transformed into pathogens, as evidenced by the case of *P. capitalensis*, which has been reported to cause a disease on the leaves and pseudobulbs of *Bifrenaria harrisoniae* in Brazil[11], on the leaves of *Musa* spp. in Guangxi of China[12], *Rubus chingii* in Guizhou of China[13] and *Ligustrum japonicum* in Iran[14], and on the fruits of *Diospyros kaki* in Taiwan of China[15] and *Psidium guajava* in Mexico[16]. *P. musarum* and *P. cavendishii* have been reported to be associated with banana freckle disease in Hainan, China[17-18]. To date, no reports have been available for *P. capitalensis* isolates associated with banana in Hainan, China. The prevalence of banana freckle disease was found to be above 80% at the field level. The pathogen *P. capitalensis* was mainly observed in samples of the disease collected from the banana orchards in Hainan, with a detection rate of 100%. The pathogen *P. capitalensis* may pose a significant threat to banana cultivation in the future. The identification of *P. capitalensis* as the causal agent of the observed freckle disease on Cavendish banana is crucial for the prevention and control of this disease in the future.

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(From page 4)

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