Pathogenesis, Prevention and Control of Coffee Black Fruit Disease (*Fusarium solani*)

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Abstract Coffee black fruit disease causes great harm to the yield and quality of coffee. Multiple factors, such as climate factors, insect pests, pathogen infection, physiological disorders, improper planting density, *etc.*, can cause coffee black fruit disease, which can be categorized into three types: pathogen infection type, physiological disorder type and insect pest type. Through the analysis of pathogenesis, the prevention and control methods and techniques of the disease corresponding to different types are put forward.

Key words Coffee, Fruit, Black fruit disease, Pathogenesis, Control technique

1 Introduction

Coffee (*Coffea* spp.) is an important cash crop in the world. Yunnan is the main producing area of coffee in China, followed by Hainan Province, Guangxi Autonomous Region and Taiwan Province, while Guangdong Province and Fujian Province have a small amount of introduced cultivation. Generally, the impact of diseases on the yield and quality of coffee in China is less than that of insect pests, but the harm caused by coffee black fruit disease (*Fusarium solani*) is far greater than that of insect pests[1]. Ten years ago, *Coffea arabica* was introduced from Taiwan Province by Zhaoqing City, Guangdong Province, which has good growth performance. However, *Zeuzera coffeae*, *Xylotrechus quadripes* and *Acalolepta cenaruinus* are important pests of coffee, and coffee black fruit disease needs high attention.

2 Symptoms of infection

Reddish-brown spots appear on pericarp of young coffee fruit in the initial stage, and gradually expand into nearly circular patch surrounded by light green halo, and will extend to the entire surface of the fruit in severe cases. In the late stage, the patches become black and the pericarp is shriveled and sunken. In most cases, coffee fruits have intact appearance and normal development, but are black or bluish black with rotten flesh inside (Fig. 1), especially due to the infection by *F. solani*. When the disease is serious, the branches will also be infected, which are water-soaked rot, with putrefactive odor.

3 Pathogenesis

3.1 Climatic factors Due to high temperature, large precipitation, short illumination time, high relative humidity, and frequent formation of dews at night, the period from late June to late September is suitable for the growth of *F. solani*, being the first peak period of black fruit disease. The second peak period is from mid-November to early mid-December, when the relative humidity is higher than 95%. This is mainly due to the high frequency of dense fog in the morning and night, which can last for more than 20 d in Yunnan Province. Since it is close to the red fruit harvest period at this time, the disease can not be prevented and controlled timely.

Fig. 1 Symptoms of black fruit disease in coffee fruits (cross section)

3.2 Pathogen *F. solani* is the pathogen causing coffee black fruit disease, and two strains (CPE5 and CPE12) have been isolated and identified. The colonies on PDA medium are round, sparsely distributed, with panniform, grayish white mycelia, and the back is light yellow. There are small and large conidia: small conidia are reniform and large ones are falciform. The optimum temperature for the growth of *F. solani* is 28 ℃. The pathogen has the highest utilization rate of carbon source mannitol, nitrogen source beef extract, glycine and urea, and the strain will be killed at 70 ℃ for 10 min[2-3]. It has been reported that *Cercospora coffeicola*, *Fusarium sporotricoides* and *Colletotrichum coffeanum* are the pathogens causing coffee black fruit disease. However, the test

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content of Koch's method has not been reported, so the reliability is doubtful.

3.3 Malnutrition Insufficient nutrition of coffee plant easily leads to the occurrence of black fruit disease. Potassium (K) is the most prominent element, with the critical nutrition value of 1.2% – 1.5%. The K content of coffee plants infected by black fruit disease is generally below the critical value. K is involved in many important physiological activities of coffee plant, which should be absorbed in large quantity. K element deficiency will easily lead to nutritional physiological disorders, resulting in the occurrence of black fruit disease. The test results showed that the K content of coffee fruits infected by black fruit disease was 13.8% lower than that of normal fruits, the K content of leaves was 47.4% lower than that of normal plants, and the K content of roots was 17.33% lower than that of normal plants; the content of Cl and Fe elements in black fruit was also low[4].

3.4 Planting density Coffee is a semi-shaded crop, and the planting density affects the light condition, which has a great influence on the occurrence of black fruit disease. *C. liberica* is more light tolerant than *C. arabica*. The impact on the occurrence of black fruit disease varies with light intensities. When the light intensities are 100% (control, full day light), 80%, 60%, 40% and 20%, the black fruit rates of infected plants are 11.6%, 10.5%, 8.0%, 9.7% and 6.2%, respectively. With *Hevea brasiliensis* as the shading tree of coffee, the black fruit rate is only 3.7% when the light intensity is 60% – 70%.

3.5 Insect pests The insect pests, including *Z. coffeae*, *X. quadripes* and *A. cenaruinus*, can induce black fruit disease of coffee. *A. cenaruinus* larvae mainly bore bark and branches of coffee plants, and cut off phloem and cambium, which affects the nutrient absorption and transport of fruits. *X. quadripes* usually goes through 4 stages of egg (3 – 16 d), larva (3 – 10 month), pupa (10 – 15 d) and adult. The first instar larvae mainly parasite on the epidermis, and the second instar and elder larvae eat into pupa chamber under the epidermis for pupation. *Z. coffeae* larvae bore upward in the branches and cause hollow branches, which will harm plant growth and easily induce black fruit disease.

4 Disease control

4.1 Selection of resistant cultivars Catimor series of coffee cultivars that have been promoted should be selected, and plant nutrient supply should be ensured when planting.

4.2 Perfecting program of coffee garden According to the growth habits of coffee and pathogen, a relatively suitable planting terrain with good drainage should be selected.

4.3 Strengthening cultivation management Reasonable close planting should be ensured, especially reasonable fertilization. For every 250 kg of fresh coffee fruits, 5, 2.5 and 6.25 kg of N, P and K fertilizer should be applied to ensure that the K content of coffee leaves is 1.75% – 1.90%. Meanwhile, the overall K nutrient level is not lower than the critical value.

4.4 Maintaining proper shading degree Young coffee fruits are easily burned by direct sunlight. Generally, the shading degree at seedling stage should be maintained at 60% – 70% to prevent seedlings from being burned. The shading degree of the garden should be maintained at 40% – 50% from transplanting to fruiting period. During the full blooming period, the appropriate shading degree of the garden is 20% – 40%.

4.5 Reasonable load The K content of leaves, number of branches and leaves, and number of fruiting branches are significantly correlated with the yield per unit area. Due to its special physiological structure, it is necessary to strictly control the amount of fruits according to the growth and nutrition of the plant, otherwise it is easy to cause the imbalance between nutrition and reproductive growth, and increase the incidence of black fruit disease. The yield of 500 fruit/km^2 is ideal, which can ensure good growth and quality of coffee plants.

4.6 Prevention and control of insect pests The eggs or larvae of *A. cenaruinus* should be captured to fundamentally reduce the pest. The adults can be controlled by spraying a mixture of 50% cartap WP 500 – 700 times dilution and 50% phoxim EC 1 000 – 1 500 times dilution. The infected branches should be pruned and burned, and wire or other sharp objects can be inserted into the insect channel to kill eggs or larvae during egg or larval stage. The larvae of *X. quadripes* mainly live in the bark of the tree. 1.8% Avermectin · imidacloprid EC, 20% imidacloprid AS or 1.3% matrine AS can be sprayed to control *X. quadripes* larvae. All agents should be used in strict accordance with instructions to prevent pollution. When the damage of *Zeuzera coffeae* is found, 10% dichlorvos AS can be injected into the worm channel, and then the hole is plugged with cotton dipped in agents. Spraying 20% bisultap AS 500 times dilution and 50% cartap WP 500 – 700 times dilution on the trunk also receives good control effect[5].

4.7 Chemical control of pathogens In the onset season, 1% Bordeaux solution, 40% copper oxide 100 times dilution, and 70% chlorothalonil 250 times dilution can be sprayed 2 – 3 times. Generally, agents are sprayed less than 2 times from April to September every year, and sprayed once from June to July when the temperature is higher. The plants infected by *F. solani* can be sprayed with thiophanate methyl 800 – 1 000 times dilution or carbendazim 400 times dilution, so as to effectively control the spread of black fruit disease. The latest study found that the growth of CPE5 strain was significantly inhibited by prochloraz-manganese (EC_{50} 1.835 2 mg/mL) or tebuconazole (EC_{50} 1.482 6 mg/mL), and propiconazole (EC_{50} 9.037 7 μg/mL) and epoxiconazole (EC_{50} 6.999 8 μg/mL) also showed strong inhibitory effects. At the same time, the infected branches, leaves and fruits should be cut and burned. Before landing of monsoon, it is better to spray 1% Bordeaux solution or 0.03% carbendazim once.

4.8 Prevention and treatment of physiological disorders Simultaneous sterilization and K supplement can effectively inhibit the occurrence of black fruit disease. Therefore, 0.2% KCl or K_2SO_4 solution can be sprayed 2 or 3 times during coffee fruiting period, and the control effect will be better if combined with the spray of rapid fertilizer such as growth promoter (Yemianbao), 50% carbendazm WP 1 500 times dilution or 1% Bordeaux solution.

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combination of history and geography is particularly important, which requires the combination of text and map. Multimedia teaching can show students a large number of historical documents and complete map pictures, and visualize the knowledge in front of students. Not only these, in the process of learning history, after a large number of boring text descriptions in the documentary, the presentation of video materials can refresh the students and deepen their impression of knowledge. Too simple explanation methods no longer meet the needs of all-round learning. Multimedia, multi-dimensional, and combined audio-visual teaching methods will improve teachers' teaching efficiency, deepen their learning impressions, and further optimize the overall quality of the classroom.

4.4 Positioning of teachers' functions In the professional field, teachers need to make an accurate positioning of their functions. For one thing, in the traditional teaching mode, the dominant position of teachers is particularly obvious, while the dominant position of students is relatively ignored. However, as a matter of fact, in the teaching process, the relationship between teachers and students should be equal. The traditional "teacher > student" relationship should gradually give way to "teacher-student mutual teaching and mutual learning" to form a real learning organization. Through the dynamic interaction between teachers and students, the value of the classroom can be maximized, and the value of education and teaching can be truly brought into play. For another thing, at the same time as the demand for students' comprehensive ability cultivation increases, teachers' cross-disciplinary teaching ability also needs to increase. Teachers of various subjects must break the current status of being isolated and closed to each other, gradually cooperate closely with each other, conduct joint research, and strive to become comprehensive teachers.

The references in this study are concentrated on the research on teaching innovation in world history education after the 20th century. Judging from the current situation, the teaching of world history has received certain attention and concern. With the release of the new curriculum standards, many scholars have started to bring new educational concepts into traditional teaching, check deficiencies and fill gaps, and constantly improve and balance the teaching of various disciplines. In the teaching of world history, some scholars have proposed the neglect of medieval history, and some scholars compared the history teaching of junior and high middle schools in China and the United States, and proposed that "developing what is useful or healthy and discarding what is not" is the essence of innovation. Such studies [9-10] are all new explorations of history teaching under the concept of innovative education. It can be seen that the theoretical conditions have been relatively perfect, but the practice is not sufficient. There are many theoretical studies presented in many literatures, and the future development of world history teaching under the concept of innovative education is discussed from various aspects. They continue to explain the importance of world medieval history, and provide theoretical basis. It is true that the lack of practice still makes the research in this direction has limitation, but there are few practical methods proposed. In view of such situation, we started from the existing theories and made effort to practice and strive to come up with more appropriate practice methods.

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