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Biological Characteristics of Persimmon Anthracnose Pathogen *Colletotrichum horii* and Screening of Inhibitory Fungicides

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Abstract This experiment studied the biological characteristics of *Colletotrichum horii* causing persimmon anthracnose using the crossing method and blood cell counting plate method, and screened inhibitory fungicides via assessing the effects of 16 common fungicides on the mycelial growth and spore germination. The results showed that the most suitable temperature for mycelial growth of *C. horri* is 25℃, the most suitable temperature for spore germination is 28℃; the suitable pH for mycelial growth of *C. horri* is 4.0 -6.0, the most suitable pH for spore germination is 4.0; the optimal carbon source is glucose and maltose, and the optimal source of nitrogen is beef extract. Among the 16 common fungicides, 33.5% copper quinolate SC, 25% bromothalonil EC and 70% Mancozeb WP have the optimal inhibitory effects on the mycelial growth and spore germination of *C. horri*, and can be used as preferred agent for prevention and control of persimmon anthracnose, followed by 70% Polyram WG, 400 g/L Flusilazole EC and 50% Thiram WP, which can be used as alternative agents. The results are expected to provide experimental basis for effective control of persimmon anthracnose.

Key words Persimmon anthracnose, *Colletotrichum horii*, Biological characteristics, Inhibitory fungicide, Indoor fungicide screening

1 Introduction

Persimmon anthracnose caused by *Colletotrichum horii* is a destructive disease in the persimmon production, and is distributed in nearly all cultivation areas of persimmon trees in China. Persimmon anthracnose lives through the winter mainly in the form of mycelium in the diseased branches, and under the appropriate conditions, conidia are germinated as the primary invasive source of the disease of the next year, which seriously endangers the growth of the persimmon trees and can cause serious fruit drop or early defoliation, leading to weak growth or even death of the whole plant, consequently leading to destructive disaster[1-4]. Persimmon anthracnose annually inflicts direct economic losses of tens of millions, and seriously restricts the sustainable development of persimmon industry in China. Understanding and studying the biological characteristics of the anthracnose pathogen *C. horii* is the premise and basis for effective prevention and control of the disease. On this basis, further study and screening of high effective fungicides can improve the quality and increase the yield of persimmon, and promote the development of persimmon industry.

However, there are few studies about the biological characteristics of persimmon anthracnose. Xie *et al.*[5] summarized the advances in studies of *C. horii*, including the symptoms, morphological characteristics, host specificity, pathogen detection, infection process and the effects of environmental factors on anthracnose, but not involving pathogen. Qu Jianlu *et al.*[6] studied the biological characteristics of the anthracnose pathogen *C. gloeosporioides* using the crossing method and blood cell counting method, and explored the optimal temperature and medium pH for the growth of mycelium and spore germination, as well as the optimal carbon source and nitrogen source. For the prevention and control of persimmon anthracnose, based on strengthening cultivation management measures and improving the disease resistance of plants, chemical fungicides are still the main means. Common fungicides are prochloraz, difenoconazole, tebuconazole, Mancozeb, thiophanate-methyl, chlorothalonil, carbendazim, iprodione, anilazine, paclobutrazol, *etc.*[6-11].

Studies about the biological characteristics of the persimmon anthracnose pathogen are limited to *C. gloeosporioides*[6], and the different strains of the same pathogen have different sensitivity to environmental conditions. Therefore, for the different strains of the pathogens obtained, it is necessary to study its biological characteristics and lay the foundation for the prevention and control of persimmon anthracnose. However, the continuous and improper use of chemical pesticides not only causes pesticide residues and environmental pollution, but also causes fungicide resistance of pathogen and reduces the effect of prevention and control of persimmon anthracnose[12-13]. Therefore, it is necessary to screen more effective fungicides for proper mixing and rotation to delay or reduce the occurrence of fungicide resistance, and prolong the service life of the fungicide, ultimately achieve effective prevention and control of persimmon diseases. In view of these, we studied the biological characteristics of the anthracnose pathogen

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C. horii and analyzed the inhibitory effects of 16 common fungicides, to screen the effective inhibitory fungicides and provide a scientific basis for effective prevention and control of persimmon anthracnose.

2 Materials and methods

2.1 Materials The anthracnose pathogen *C. horii* was isolated by our team. The 16 common fungicides used for screening and their manufacturers were listed in Table 1.

2.2 Biological characteristics of *C. horri*

2.2.1 Effects of temperature on colony diameter and spore production. The 5 mm-in-diameter mycelium disk of *C. horri* was inoculated into the center of the PDA medium plate, and cultured in a 5, 10, 15, 20, 25, 28, 30, 35℃ thermostat incubator. The colony diameter was measured by the crossing method on the 5th day, and the spore production was measured by the blood cell counting method[14] on the 10th day, and each treatment was repeated 3 times, the same below.

2.2.2 Effects of pH on colony diameter and spore production. The 5 mm-in-diameter mycelium disk of *C. horri* was inoculated into the center of the PDA medium plate with pH of 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, 10.0, 11.0, and 12.0, and incubated at 27℃. The colony diameter was measured on the 5th day, and the spore production was measured on the 10th day.

Table 1 The 16 common fungicides and their manufacturers

Fungicide	Manufacturer	Dilution times
Clear water control	–	0
50% Carbendazim WP	Weihai Hanfu Biochemical Pharmaceutical Co., Ltd.	800
1.5% Polyoxin DP	Yanbian Chunlei Biological Pharmaceutical Co., Ltd.	600
77% Copper calcium sulphate WP	Industrias Quimicas Del Valles S. A., Spain	400
95% Posetyl-aluminium WP	Zhejiang Jiahua Pharmchemical Co., Ltd.	100
70% Polyram WG	German BASF SE	500
22% Carbendazim + 8% Tebuconazole (Fulian)	Jiangsu Rotam Chemistry Co., Ltd.	1 200
10% Difenoconazole WG	Syngenta Crop Protection LLC	7 000
33.5% Copper quinolate SC	Zhejiang Hisun Chemical Co., Ltd.	2 000
25% Bromothalonil EC	Jiangsu Tuoqiu Agricultural Chemical Co., Ltd.	3 000
70% Mancozeb WP	Xi'an MPC Stock Co., Ltd.	1 200
430 g/L Tebuconazole SC	Bayer CropScience China Co., Ltd.	4 000
250 g/L Hexaconazole SC	Taiwan Jiatai Enterprise Co., Ltd.	5 000
50% Chlorobromoisocyanuric acid AF	Nanjing Nannong Pesticide Technology Development Co., Ltd.	800
50% Prochloraz-manganese chloride complex WP	Nanjing Red Sun Co., Ltd.	1 200
400 g/L Flusilazole EC	DuPont USA	10 000
50% Thiram WP	Hebei Zanfeng Bioengineering Co., Ltd.	1 600

2.2.3 Effects of carbon and nitrogen source on colony diameter and spore production. Taking the potassium nitrate as a nitrogen source and the medium without additional carbon source as the control, the effects of different carbon sources (glucose, sucrose, fructose, maltose, starch, glycerol and mannitol) on the colony diameter and the spore production of *C. horri* were determined. Taking glucose as the carbon source and the medium without additional nitrogen source as the control, the effects of different nitrogen sources (beef extract, peptone, yeast extract, ammonium sulfate, ammonium chloride, potassium nitrate, sodium nitrate and urea) on the colony diameter and spore production of *C. horri* were determined.

The 5 mm-in-diameter mycelium disk of *C. horri* was inoculated into the center of the PDA medium plate with different carbon and nitrogen sources, and incubated at 27℃. The colony diameter was measured on the 5th day, and the spore production was measured on the 10th day.

2.3 Screening of inhibitory fungicides The mycelial growth rate method was used to determine the inhibition rate of 16 kinds of fungicides on the mycelial growth of *C. horri*. The spore germination method was used to determine the germination rate of conidia under the treatment of each agent. Chemical agents that can effectively inhibit the mycelial growth and conidial germination of *C. horri* were screened according to the inhibitory effects of each fungicide[15].

Mycelial inhibition test: under aseptic conditions, before the PDA medium was solidified, appropriate volume of the agent was added to mix well and prepare the drug-containing medium according to the recommended field concentration of each fungicide, and inverted the plate. After the medium was solidified, the 5 mm-in-diameter mycelium disk of *C. horri* was inoculated into the center of the drug containing medium plate, and the PDA medium containing no drug was taken as the control. Each treatment was repeated 3 times. After incubation at 25℃ for 5 day, the colony diameter was measured by the crossing method, the average diameter of each treated colony was calculated, and the inhibition rate on the mycelial growth by each fungicide was calculated according to the following formula.

Inhibition rate on the mycelial growth (%) = [(control colony diameter – treatment colony diameter)/(control colony diameter – disk diameter) ×100.

Spore germination test: separately absorbed 40 μL of suspension with the conidia concentration of about 1.0×10^6/mL and the

fungicide solution with two times of recommended concentration, mixed well, and dropped it on a clean single concave slide, incubated at 25℃ with sterile water as the control. After 8 h of culture, observation was carried out under a microscope and the growth rate of conidia of each treatment was counted.

3 Results and analysis

3.1 Effects of temperature on colony diameter and spore production of *C. horri* The results showed that at the temperature of 5 – 35℃, the mycelium of *C. horri* could growth; at the temperature of 20 – 30℃, the mycelium grew better, and the most suitable temperature was 25℃; below 5℃ or above 35℃, the mycelium could not grow well; below 0℃, the mycelium would stop growing; above 40℃ (the lethal temperature), the mycelium would die; at the temperature of 10 – 35℃, conidia could be generated; at 25 – 30℃, the spore generation was better, and the most suitable temperature for spore generation was 28℃.

Combining the optimal temperature of mycelial growth and spore generation and considering the need for mycelial growth and spore generation, the subsequent biological characteristics were studied by culture at constant temperature of 27℃.

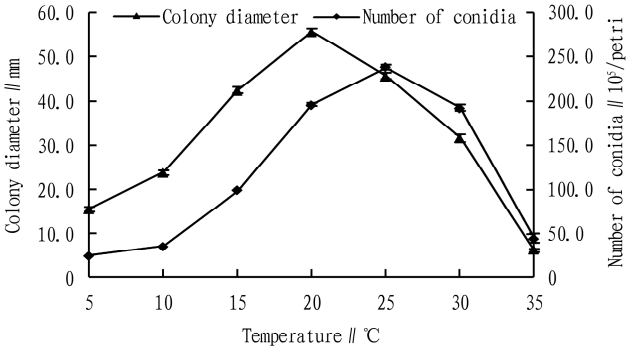

Fig. 1 Effects of temperature on colony diameter and spore production of *Colletotrichum horii*

3.2 Effects of medium pH on colony diameter and spore production of *C. horri* The persimmon anthracnose pathogen *C. horri* could grow and generate spore on PDA medium with pH 3.0 – 12.0. The mycelial growth was better at pH 4.0 – 10.0, and the optimal pH for mycelia growth was 5.0. The acidic condition was more favorable for spore generation. When the pH was 3.0, the maximum spore production was obtained. As the pH increases, the spore production decreases. Combining the mycelial growth and spore production, when the pH was 4.0, it was favorable for mycelial growth and spore production.

3.3 Effects of carbon source on colony diameter and spore production of *C. horri* There were significant differences in mycelial growth and spore production of *C. horri* on PDA medium containing different external carbon sources. Among the seven tested carbon sources, the colony diameter was the largest on the maltose medium, followed by the glucose medium, then were the fructose and sucrose medium. The colony diameter on the glycerol, mannitol and starch medium was smaller than that without the carbon source. The maltose medium had the largest spore production, followed by glucose, sucrose, glycerol, starch, fructose, and mannitol. On the medium without carbon source, the mycelium could grow, and the colony diameter and spore production were second only to the sucrose medium, but the colonies were sparse and nearly transparent. The results showed that the medium with maltose and glucose as carbon sources was favorable for the mycelial growth and spore production of *C. horri*. Glucose is a main component of PDA medium. In this experiment, when glucose was used as the carbon source, there was little difference with the maltose in the mycelial growth and spore production of *C. horri*, indicating that the carbon source of the common PDA medium is sufficient for mycelial growth and spore production of C. horri. Therefore, in subsequent experiment, glucose was used as the carbon source to culture *C. horri*.

Table 2 Effects of medium pH on colony diameter and spore production of *Colletotrichum horii*

pH	Colony diameter // mm	Number of conidia // $\times 10^5$/petri
3.0	36.3 ±0.6 Ee	275.8 ±3.3 Aa
4.0	53.1 ±0.6 Cc	249.6 ±3.5 Bb
5.0	65.0 ±0.7 Aa	159.9 ±3.2 Dd
6.0	61.1 ±0.5 Bb	175.4 ±2.9 Cc
7.0	50.9 ±0.6 Cc	153.4 ±2.4 De
8.0	46.2 ±0.5 Dd	91.4 ±2.0 Ef
9.0	38.0 ±0.7 Ee	66.0 ±2.2 Fg
10.0	30.0 ±0.7 Ff	31.3 ±1.4 Gh
11.0	26.2 ±0.5 Gg	24.7 ±1.4 Ghi
12.0	22.8 ±0.5 Hh	22.7 ±1.0 Gi

Note: different capital letters in the same column data denoted extremely significant difference ($P<0.01$), and different small letters the same column data denoted significant difference ($P<0.05$).

Table 3 Effects of different carbon sources on colony diameter and spore production of *Colletotrichum horii*

Type of carbon source	Colony diameter // mm	Number of conidia // $\times 10^5$/petri
Sucrose	46.9 0.6 CDd	31.4 ±1.0 Bc
Glucose	51.0 ±0.4 Bb	33.7 ±0.8 Ab
Maltose	55.1 ±0.4 Aa	35.6 ±0.9 Aa
Mannitol	43.2 ±0.4 Ff	8.9 ±0.4 Fh
Starch	44.3 ±0.5 DEFe	16.8 ±0.4 Ef
Fructose	47.8 ±0.4 Cc	14.8 ±0.5 Eg
Glycerol	43.9 ±0.4 EFef	22.5 ±0.7 De
Control	45.3 ±0.5 DEde	25.8 ±0.6 Cd

3.4 Effects of nitrogen source on colony diameter and spore production of *C. horri* Effects of different carbon sources were great on colony diameter and spore production of *C. horri*. Among the 8 tested nitrogen sources, the colony diameter on the beef extract medium was the largest, followed by the yeast extract, and then the peptone, indicating that the beef extract, the yeast extract and the peptone could be used as the nitrogen sources and were favorable for the mycelial growth of *C. horri*. On the medium with ammonium chloride, urea, and ammonium sulfate as the nitrogen source, the mycelial growth was slow and the colony diameter was smaller than that of the control. As for the spore generation, when using the sodium nitrate as the nitrogen source, the spore production was the largest, followed by the beef extract and yeast extract,

and other nitrogen sources were not favorable for the spore generation. On the medium without external nitrogen source, *C. horri* could grow and the colony diameter was second only to peptone, but the colony was very light, nearly transparent, and the spore production was only slightly higher than using ammonium chloride as nitrogen source. Combining the mycelial growth and spore production, using beef extract and yeast extract as nitrogen source were favorable for the mycelial growth and spore production of *C. horri*.

In summary, taking glucose as carbon source and beef extract as nitrogen source, at pH 4.0 and temperature of 27℃ are favorable for the mycelial growth and spore production of *C. horri*.

Table 4 Effects of different nitrogen sources on colony diameter and spore production of *Colletotrichum horii*

Type of nitrogen source	Colony diameter//mm	Number of conidia// $\times 10^5$/petri
Potassium nitrate	45.3 ±0.4 Dd	15.4 ±0.6 Dd
Ammonium chloride	35.0 ±0.4 Gg	4.4 ±0.4 Fg
Urea	32.3 ±0.5 Hh	9.9 ±0.3 Ef
Yeast extract	60.5 ±0.6 Bb	27.7 ±0.7 Cc
Beef extract	62.9 ±0.4 Aa	32.4 ±0.8 Bb
Sodium nitrate	41.7 ±0.4 Ee	35.9 ±0.9 Aa
Ammonium sulfate	32.2 ±0.5 Hh	15.0 ±0.6 Dde
Peptone	54.3 ±0.5 Cc	14.2 ±0.5 De
Control	36.6 ±0.4 Ff	4.7 ±0.4 Fg

3.5 Inhibition of common fungicides on *C. horri* A comparative experiment was carried out for the inhibition of 16 common fungicides on the mycelial growth of *C. horri*. The results showed that compared with the clear water control, 250 g/L Hexaconazole SC, 70% Polyram WG, 22% Carbendazim + 8% Tebuconazole (Fulian), 50% Thiram WP, 10% Difenoconazole WG, 33.5% Copper quinolate SC, 25% Bromothalonil EC, 70% Mancozeb WP, 430 g/L Tebuconazole SC, 50% Prochloraz-manganese chloride WP, and 400 g/L Flusilazole EC had the optimal inhibition effect, and the mycelial growth inhibition rate was 95.54% – 100%. Followed by 1.5% Polyoxin DP, 95% Posetyl-aluminium WP, and 50% Chlorobromoisocyanuric acid AF, the mycelial growth inhibition rate was 62.73%, 63.26% and 62.35%, respectively; 77% Copper calcium sulphate WP and 50% Carbendazim WP had weaker inhibition effect, the mycelial growth inhibition rate was lower than 50% (Table 2).

Through treatment of conidia of *C. horri* with 16 common fungicides, it found that the spore germination rate had large differences (Table 2). Specifically, after treatment with 70% Polyram WG, 33.5% Copper quinolate SC, 25% Bromothalonil EC, 70% Mancozeb WP, and 50% Thiram WP, the spore germination rate was 0, indicating that these six fungicides had the optimal inhibitory effects on the conidia germination of *C. horri*. Followed by 1.5% Polyoxin DP, 77% Copper calcium sulphate WP, and 400 g/L Flusilazole EC, the spore germination rate was 5.53%, 7.11% and 3.08%, respectively, indicating that these three fungicides had strong inhibitory effects on the conidia germination of *C. horri*. 50% Carbendazim WP, 95% Posetyl-aluminium WP, 10% Difenoconazole WG, and 250 g/L Hexaconazole SC had the weakest inhibitory effects, their conidia germination rate was close to or higher than that of the clear water control.

Table 5 Effects of 16 common fungicides on the mycelial growth and conidia germination of *Colletotrichum horii*

Fungicide	Inhibition rate of mycelial growth//%	Conidia germination rate//%
Clear water control	–	62.33 ±0.58 Cc
50% Carbendazim WP	11.61 d	57.67 ±0.58 Dd
1.5% Polyoxin DP	61.94 b	5.67 ±0.58 Ii
77% Copper calcium sulphate WP	40.71 c	7.33 ±0.58 Hh
95% Posetyl-aluminium WP	63.11 b	69.33 ±1.15 Bb
70% Polyram WG	97.27 a	0.00 Jj
22% Carbendazim + 8% Tebuconazole (Fulian)	98.09 a	32.67 ±0.58 Ff
10% Difenoconazole WG	100.00 a	66.67 ±1.00 Bb
33.5% Copper quinolate SC	100.00 a	0.00 Jj
25% Bromothalonil EC	100.00 a	0.00 Jj
70% Mancozeb WP	100.00 a	0.00 Jj
430 g/L Tebuconazole SC	100.00 a	20.33 ±0.58 Gg
250 g/L Hexaconazole SC	95.63 a	75.33 ±1.53 Aa
50% Chlorobromoisocyanuric acid AF	62.70 b	0.00 Jj
50% Prochloraz-manganese chloride WP	100.00 a	47.33 ±0.58 Ee
400 g/L Flusilazole EC	100.00 a	3.33 ±0.58 Jj
50% Thiram WP	99.18 a	0.00 Jj

4 Conclusions and discussions

The occurrence of plant diseases is closely related to the species and biological characteristics of pathogens. The study of the biological characteristics of pathogens is the basis and precondition for the prevention and control of pathogen induced diseases. Through studying the biological characteristics of the persimmon anthracnose pathogen, it is able to make clear the requirements of anthracnose pathogen for environmental conditions, so it is helpful for strengthening cultivation management measures, properly prevent and control the diseases, effectively control the occurrence of persimmon anthracnose and prevent its spread in large area. Temperature and pH of the medium are factors that have a greater impact

on the mycelial growth and spore production of pathogens. The results of this experiment showed that the mycelium of *C. horii* grew better at 20 – 30℃, and the optimal growth temperature was 25℃; the spore production was better at 25 – 30℃, and the optimal temperature was 28℃; at pH 4.0 – 10.0, the mycelial growth was better, and the optimal pH was 5.0; at pH 3.0, the spore production was the largest, as the pH increases, the spore production decreases in a wave form. Combining the results of mycelial growth and spore production, when the pH was 4.0, it was favorable for mycelial growth and spore production of *C. horri*. This is consistent with the results of Ren Guolan *et al.* [16], Liu Aiyuan *et al.* [17], Xie Changping and Niu Lixia[18], Zhang Haishan *et al.* [19], and Qu Jianlu *et al.* [6].

The carbon and nitrogen sources in the medium are the two most fundamental and important nutrients in the growth of pathogens[20]. Through this experiment, it is found that the mycelial growth rate and spore production of *C. horri* were different in the medium containing different carbon sources and nitrogen sources. Among them, glucose and maltose were suitable carbon sources for the persimmon anthracnose; beef extract was the most suitable nitrogen source, followed by yeast extract.

Nowadays, chemical agent is still the main means of disease prevention and control. There have been some reports on the screening of inhibitory fungicides for anthracnose pathogens. From 22 fungicides, Wu Liangqing *et al.* [15] screened 250 g/L Propiconazole EC, 33.5% Copper quinolate SC, 25% Bromothalonil EC, 70% Mancozeb WP, and *etc.* that have strong inhibitory effects on pear anthracnose. Zeng Xueying[21] found that 70% Mancozeb had the best inhibitory effect on the pathogen of Eucalyptus grandis, followed by 80% Thiram. Luo Guangming *et al.* [22] found that carbendazim had the best inhibitory effects on the pathogen of *Gardenia jasminoides* anthracnose. Through virulence test and in vivo inoculation test, Gao Yangyang *et al.* [23] found that pyraclostrobine, fludioxonil, and pyridazole had high virulence and in vivo control effects on pepper anthracnose and had great potential of application in the field prevention and control of pepper anthracnose.

In recent years, there have been some reports about the screening of pesticides for persimmon anthracnose. Xi Hui[24] found that thiabendazole and carbendazim had the best inhibitory effect on persimmon anthracnose, and the inhibition rate was above 90%, followed by tebuconazole and difenoconazole, while in the field, 80% thiram + ziram (500 × solution) had the best prevention and control effects, the prevention and control rate was 74.89%; 70% thiophanate-methyl, 50% carbendazim, and 80% Mancozeb had weaker prevention and control effect, and the prevention and control rate was less than 50%. Through the indoor virulence determination and field control effect, Deng Quanen *et al.* [25] screened out fludioxonil and prochloraz that had better inhibitory effects on persimmon anthracnose, and 25% prochloraz EC 2 000 × solution and 25 g/L fludioxonil SC 1 000 × solution had prevention and control rate of 49.10% and 47.76%, respectively.

This experiment explored the inhibitory effects of 16 common fungicides on *C. horri*, and found that there were large differences in the inhibitory effects on the mycelial growth and conidial germination of *C. horri* between different fungicides; 11 fungicides had strong inhibitory effects on the mycelial growth of *C. horri*, while 6 fungicides had strong inhibitory effects on the conidial germination of *C. horri* (Table 1). However, some fungicides had strong inhibitory effects on the mycelial growth of *C. horri*, but had weak inhibitory effects on the conidial germination. For example, 250 g/L Hexaconazole SC, 22% Carbendazim + 8% tebuconazole (Fulian), 10% Difenoconazole WG, 430 g/L Tebuconazole SC, and 50% Prochloraz-manganese chloride WP, while other fungicides could effectively inhibit the spore germination, but had weak inhibitory effects on the mycelial growth, 50% Chlorobromoisocyanuric acid AF, for instance.

On the basis of the biological characteristics of the pathogen, comprehensively considering the inhibitory effect of the fungicides on the mycelial growth and conidial germination, it can be concluded that among 16 common fungicides, 33.5% Copper quinolate SC, 25% Bromothalonil EC, and 70% Mancozeb WP can be used as optimal fungicides, followed by 70% Polyram WG, 400 g/L Flusilazole EC, and 50% Thiram WP, and the latter three can be used as alternative fungicides.

Since this study was carried out under indoor controllable conditions, and the influencing factors are single, the future experiment should consider the field experiment and the influences of climate factors, field crops, and abiotic factors, so as to screen the economical and practical, high effective and low toxic fungicides for prevention and control of persimmon anthracnose. Furthermore, to prevent the resistance of persimmon anthracnose, in the extension and application, it is recommended to screen several fungicides with better control effects to mix and rotate, so as to slow down or alleviate the fungicide resistance of pathogen and extend the service life of fungicides.

References

[1] LIU KQ, MOU HF, LIU FY. Research on anthracnose of persimmon[J]. Journal of Shandong Agricultural University, 1988, 19(4): 69 – 71. (in Chinese).

[2] LEE JH, HAN KS, LEE SC, *et al.* Early detection of epiphytic anthracnose inoculum on phyllosphere of *Disopyros kaki* var. *domestica*[J]. The Plant Pathology Journal, 2004, 20(4): 247 – 251.

[3] ZHANG JZ, XU T, HE LP. Anthracnose pathogen on *Diospyros kaki* cv. Wuheshi and its nuclear behavior in process of appressorium formation [J]. Mycosystema, 2005, 24(3): 446 – 456. (in Chinese).

[4] ZHANG JZ. Anthracnose of persimmon caused by *Colletotrichum gloeosporioides* in China[J]. Asian and Australasian Journal of Plant Science and Biotechnology, 2008, 2(2): 50 – 54.

[5] XIE L, ZHANG JZ, CAI L, *et al.* Biology of *Colletotrichum horii*, the causal agent of persimmon anthracnose[J]. Mycology: An International Journal on Fungal Biology, 2010, 1(4): 242 – 253.

[6] QU JL, WU HB, FAN K, *et al.* Biological characteristics of *Collelotrichum gloeosporioides* and inhibitory effects of several fungicides[J]. Chinese Journal of Pesticide Science, 2012, 14(5): 503 – 509. (in Chinese).

[7] LIU J, LIU HT, WANG SF. Control measures against anthrax in persimmon trees[J]. Journal of Shandong Forestry Science and Technology, 2004, 34(6): 78. (in Chinese).

[8] LI XM, DING XY. Effect of polyoxazole on the growth of *Diospyros nitida* Merr[J]. China Forestry Science and Technology, 2008, 22(5): 101 – 103. (in Chinese).

[9] WANG LM, GENG QC, ZUO ZS. Characteristics of varieties and key

cultivation techniques of *Diopyros kaki* cv. Dahongpao[J]. Northern Horticulture, 2011, 35(14): 58 – 59. (in Chinese).
[10] GENG QQ. Characteristics and control methods of anthracnose of persimmon tree[J]. Hebei Fruits, 2012, 24(5): 53. (in Chinese).
[11] LIU SZ. On control technique of anthracnose of persimmon[J]. Shanxi Fruits, 2013, 34(4): 54. (in Chinese).
[12] HUA YG, JIANG LY, LIN FP, *et al.* Fungicides screening trial against persimmon anthracnose in lab[J]. Forest Pest and Disease, 2001, 20(6): 11 – 13. (in Chinese).
[13] XUE J, TIAN ZL, LIU DY, *et al.* Test on control and law of occurrence of anthracnose of persimmon[J]. Shanxi Fruits, 2003, 24(4): 5 – 7. (in Chinese).
[14] LAI CY, LAI CB, ZENG FK, *et al.* The biological properties of the *Fusarium solani*(Mart.) Sacc. on tea cutting seedlings[J]. Acta Phytopathologica Sinica, 2002, 32(1): 79 – 83. (in Chinese).
[15] WU LQ, ZHU LW, HENG W, *et al.* Identification of Dangshan pear anthracnose pathogen and screening fungicides against it[J]. Scientia Agricultura Sinica, 2010, 43(18): 3750 – 3758. (in Chinese).
[16] REN GL, SHI XY, GONG CW, *et al.* The *Anthracnose* fungus of *Ophiopogon japonicus* and its biological Characteristics[J]. Journal of Henan Agricultural University, 1995, 29(3): 228 – 233. (in Chinese).
[17] LIU QY, CHEN WX, LI XY. Biological characteristics of the pathogenic fungus causing anthracnose of litchi[J]. Acta Phytopathologica Sinica, 2003, 33(4): 313 – 316. (in Chinese).
[18] XIE CP, NIU LX. Identification and characteristics of anthracnose pathogen of *Ophiopogon intermedius* cv. *Argenteo – marginatus*[J]. Chinese Journal of Tropical Agriculture, 2005, 25(3): 18 – 22. (in Chinese).
[19] ZHANG HS, TAN GJ, CHEN L. Biological characteristics of 2 species of *Colletotrichum* causing *Ophiopogon japonicus* anthracnose[J]. Acta Prataculturae Sinica, 2008, 17(4): 118 – 123. (in Chinese).
[20] YE T, MA ZQ, WANG WQ, *et al.* Resistance induction of *Fusarium graminearum* to tebuconazole and bionomics of resistant – mutants[J]. Chinese Journal of Pesticide Science, 2011, 13(3): 261 – 266. (in Chinese).
[21] ZENG XY. Identification of the pathogen causing *Eucalyptus anthrax* and laboratory screening of fungicides[J]. China Forestry Science and Technology, 2015, 29(4): 121 – 125. (in Chinese).
[22] LUO GM, DONG YK, GONG YH, *et al.* Identification of *Gardenia jasminoides* anthracnose pathogen and screening of its antibiotics agents [J]. China Journal of Experimental Traditional Medical Formulae, 2016, 22(19): 32 – 36. (in Chinese).
[23] GAO YY, HE LF, LI BX, *et al.* Identification of the pathogen causing pepper anthracnose in Shandong Province and screening of highly effective fungicides[J]. Scientia Agricultura Sinica, 2017, 50(8): 1452 – 1464. (in Chinese).
[24] XI H. Study on the investigation, identification and prevention of anthracnose of persimmon trees in China[D]. Luoyang: Henan University of Science and Technology, 2015. (in Chinese).
[25] DENG QE, DING XY, XU JQ, *et al.* Screening of fungicides to pathogens of persimmon anthracnose[J]. Forest Research, 2017, 30(1): 160 – 165. (in Chinese).