

桑椹肥大型菌核病化学防治技术研究

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摘要:【目的】桑椹肥大型菌核病是由桑实杯盘菌(*Ciboria shiraiana*)引起的果桑毁灭性病害, 通过研究拟采取化学或生物防治措施安全有效控制该病害。【方法】测定了13种不同药剂对桑实杯盘菌菌丝生长的抑制作用, 选择抑菌效果较好的药剂进行了2年田间防治试验, 研究了不同药剂和不同防治时期对防治效果的影响, 并进行农药残留检测; 同时比较了哈茨木霉和枯草芽孢杆菌2种常用生防菌剂对病害的防治效果。【结果】50%咪鲜胺锰和42.4%唑咪·氟酰胺抑菌效果最好, EC_{50} 均为 $0.01\text{ }\mu\text{g}\cdot\text{mL}^{-1}$; 其次是50%多菌灵、50%异菌脲、30%戊唑·多菌灵、50%腐霉利; 72%霜脲·锰锌抑菌效果最差, EC_{50} 为 $15.10\text{ }\mu\text{g}\cdot\text{mL}^{-1}$ 。多菌灵、咪鲜胺锰盐和唑醚·氟酰胺2年田间校正防效较好, 均在95%以上, 腐霉利校正防效较差, 为88.11%。多菌灵农药残留超标, 咪鲜胺锰盐、唑醚·氟酰胺和腐霉利在安全范围内。鹊口期、开叶期和花穗形成期后开始喷药校正防效分别为96.98%、97.65%和96.39%, 初花期开始施药的校正防效为91.40%, 与前3个时期存在显著差异。哈茨木霉和枯草芽孢杆菌校正防效分别为61.74%和54.74%。【结论】为防止病菌产生抗药性, 在果桑花穗形成期开始可交替使用咪鲜胺锰盐和唑醚·氟酰胺, 7~10 d喷施1次, 采摘前25~30 d可停止用药, 该方法可安全有效控制病害, 并满足食品安全需求。生物防治效果不理想, 还需进一步探索和优化。

关键词:桑椹; 肥大型菌核病; 化学防治; 防治时期; 生物防治

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Study on the chemical control of hypertrophic sorosis scleroteniosis disease in mulberry

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Abstract:【Objective】The hypertrophic sorosis scleroteniosis caused by *Ciboria shiraiana* is a destructive disease in mulberry production. Carbendazim and thiophanate-methyl are currently being used as the main fungicides to control the disease, which have caused severe impacts on environmental pollution and food safety. To safely and effectively control the disease, high-efficiency fungicides were selected by mycelium growth rate method and used for field trial in 2019 and 2021. The high efficiency and safe fungicide screened from 2019 field experiment was used for study on the efficacy of controlling the disease at different stages, and the two common biological fungicides *Trichoderma harzianum* and *Bacillus subtilis* were also compared in 2021. The fungicide residues of each treatment were detected. 【Methods】The inhibitive effects of 13 different fungicides on the mycelia growth of *C. shiraiana* were determined. There were four replicates for each treatment, and the untreated PDA medium was served as the control. Those with better inhibitive effects were used in field trials. Four treatments were set up in Wuhan city, Hubei province in 2019. Carbendazim, prochloraz-manganese, pyraclostrobin·fluxapyroxad, and water as the control were used to evenly spray the whole mulberry tree canopy and

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surrounding ground for four times. The above treatments were randomly arranged with each treatment having 3 replicates. The corrected control efficiencies of different fungicides were investigated, and the fungicide residues were detected 20 days after the last spray. For calculation of the corrected control efficiency, nine branches of each mulberry tree were randomly selected, and the number of total and diseased fruits on each branch was recorded, sampling one meter in length. The effects of different fungicides, different control stages and biological control method were evaluated in Xiaogan city, Hubei province in 2021. Carbendazim, prochloraz-manganese, pyraclostrobin·fluxapyroxad, procymidone, and water as the control were used for the assessment of different fungicides efficiency. Prochloraz-manganese, the best efficiency and safe fungicide screened from the field experiment in 2019, was then used for the study on the effect at different control stages. The fungicide was sprayed at four different stages, February 23 (magpie mouth stage), March 3 (leaf opened stage), March 11 (flower spike formation stage) and March 22 (initial blooming stage), and the application was stopped on March 28 (full flowering stage). The corrected control efficiency of biological fungicides, *T. harzianum* and *B. subtilis* was compared. The treatments in 2021 were arranged randomly with 3 replicates for each treatment. The corrected control efficiencies of different fungicides were investigated, and the fungicide residues were detected 22 days after the last spray. For calculation of the corrected control efficiency, three branches from each mulberry tree were randomly selected, and the number of total and diseased fruits from each branch were recorded, sampling one meter in length.【Results】50% prochloraz-manganese and 42.4% pyraclostrobin·fluxapyroxad had the best inhibitory activity, with both showing EC_{50} of 0.01 $\mu\text{g} \cdot \text{mL}^{-1}$, followed by 50% carbendazim, 50% iprodione, 30% pentazole·carbendazim and 50% procymidone, and 72% curzate had the lowest inhibitory activity, with EC_{50} of 15.10 $\mu\text{g} \cdot \text{mL}^{-1}$. In 2019, the corrected control efficiencies of 800 fold dilution of carbendazim, 1000 fold dilution of prochloraz-manganese and 2000 fold dilution of pyraclostrobin·fluxapyroxad were 100%, 100% and 96.04%, respectively. The residues of carbendazim and prochloraz-manganese were 5.67 and 0.68 $\text{mg} \cdot \text{kg}^{-1}$, respectively. In 2021, the corrected control efficiencies of 800 fold dilution of carbendazim, 1000 fold dilution of prochloraz-manganese, 2000 fold dilution of pyraclostrobin·fluxapyroxad, and 1000 fold dilution of procymidone were 98.21%, 99.58%, 95.95% and 88.11%, respectively. The residues of carbendazim, prochloraz-manganese, and procymidone were 5.86, 0.68, and 2.94 $\text{mg} \cdot \text{kg}^{-1}$, respectively, and the residues of pyraclostrobin·fluxapyroxad was under detection. The corrected control efficiency of prochloraz-manganese sprayed at the magpie mouth stage, leaf opened stage, flower spike formation stage, and initial blooming stage was 96.98%, 97.65%, 96.39% and 91.40%, respectively. The corrected control efficiency at the initial blooming stage was significantly different from the above three stages. The fungicide residues at the four stages were 0.54, 0.49, 0.52 and 0.50 $\text{mg} \cdot \text{kg}^{-1}$, respectively. The corrected control efficiencies of 300 fold dilution of *T. harzianum* and 300 fold dilution of *B. subtilis* were 54.74% and 61.74%, respectively.【Conclusion】Carbendazim, prochloraz-manganese and pyraclostrobin·fluxapyroxad had the best corrected control efficiencies (above 95%) in two years field trials. Procymidone had the lowest corrected control efficiency of 88.11%. The residues of carbendazim exceeded the standard, while prochloraz-manganese, pyraclostrobin·fluxapyroxad and procymidone were found in the safe range. To prevent resistance of the pathogen to the fungicide, prochloraz-manganese and pyraclostrobin·fluxapyroxad can be sprayed alternately from the flower spike formation stage to 25–30 days before picking with an interval of 7 to 10 days. The method can safely and effectively control the disease, which can meet the food safety requirements. The efficiency of biological control is unsatisfactory and needs to be further explored and optimized.

Key words: Mulberry; Hypertrophic sorosis scleroteniosis disease; Chemical control; Control stage; Biological control

桑树是一种多年生的经济型植物,在亚洲、欧洲、美洲和非洲广泛种植,过去的5000多年里被用于丝绸产业^[1],其果实桑椹花青素含量极高,抗氧化功效明显,具有促进造血细胞生长、降血糖、降血脂等药理作用,被原卫生部列为“既是食品又是药品”名单。桑椹除直接食用外,目前已开发出果汁饮品、桑果酒、桑果酱、桑椹膏及花青素等产品,市场前景广阔。初步估计全国果桑栽植面积已超过15 000 hm²,桑果产量近80万 t^[2]。果桑生产可促进传统蚕桑产业向多元化发展,又可显著提升种植农户收入,带动乡村采摘旅游产业发展。然而在产业发展过程中,桑椹菌核病来势猛、发病快,在种植区普遍发生,发病率为30%~90%^[2-3],有些地方成千亩桑园由病害导致桑果绝产,给果桑产业造成毁灭性危害。该病目前公认的有桑椹肥大型、桑椹缩小型和桑椹小粒型3种类型,病原菌分别为桑实杯盘菌(*Ciboria shiraiana*)^[4-5]、桑椹核地杖菌(*Scleromitrula shiraiana*)^[6]和肉阜状杯盘菌(*Ciboria carunculoides*)^[7-8]。由桑实杯盘菌引起的桑椹肥大型菌核病被报道在亚洲分布最广泛^[9-10],在我国大部分桑树栽培地区也均有发生,危害十分严重。3种类型的病害的发病时间基本一致,均于桑树开花15~20 d后开始发病,但其病果形态特征与发病症状各不相同。桑椹肥大型菌核病表现为病果膨大,花被肿厚,呈乳白色或灰白色,果实中心黑色的菌核,弄破后散发出臭气;桑椹缩小型菌核病表现为病果显著缩小,质地坚硬,呈灰褐色,表面布有暗褐色细斑点,在病果内部形成黑色坚硬的菌核;桑椹小粒型菌核病表现为桑椹各小果染病后,病小果显著膨大而突出,整个病果呈灰黑色,容易脱落而残留果柄,病小果的花被不肥大,仅子房特别大,其内生小型菌核^[11]。

目前生产上对其的防治主要依赖70%甲基托布津和50%多菌灵2种药剂,长期使用单一药剂,易导致病菌产生抗药性^[12],随着用药浓度不断递增,农药残留量也随之增加,桑椹品质及其食用安全性得不到保证。一些农业措施如清除病枝和病果、合理栽植、深翻土壤、合理施肥、覆盖地膜等,可一定程度减轻病害发生,但不能从根本上控制病害。已经发现一些对桑椹菌核病菌具有拮抗作用的微生物,如苏云金杆菌(*Bacillus thuringiensis*)、肠杆菌(*Enterobacter* sp.)、哈茨木霉(*Trichoderma harzianum*)、棘孢木霉(*Trichoderma asperellum*)等^[9,13-14],但大田防

治效果不理想。化学防治方面,目前报道甲基托布津和多菌灵仍然是防治桑椹菌核病的有效药剂^[15-17]。虽然有报道,20%烯肟·戊唑醇水悬浮剂2000倍液与70%甲基托布津1000倍液交替使用,校正防效在98.5%以上^[18];430 g·L⁻¹戊唑醇悬浮剂3000倍稀释药液的,校正防效达95.74%^[19];430 g·L⁻¹戊唑醇悬浮剂与30%吡唑醚菌酯悬浮剂混合剂防治,校正防效达100%^[20];但其是否存在农药残留超标问题还需检测。正确防治时期的选择对防治桑椹菌核病非常关键,湖北地区春季气候变化大,导致果桑发芽、开花等物候期差异较大,给病害的防治带来了挑战。很多果桑种植户会忽略物候期的差异,选择2月底进行病害防治,一些种植户由于连续几年颗粒无收,会选择更早的时间进行防治,导致用药频繁,防治效果不稳定,农药残留风险增大,且易使病原菌产生抗药性。

本研究中,笔者拟在室内药剂筛选的基础上,研究不同药剂、不同喷药时期及生防菌对桑椹肥大型菌核病防治的影响,同时进行农药残留检测分析,总结一套桑椹肥大型菌核病防控技术,为有效控制该病害及保障桑椹食用安全提供参考依据。

1 材料和方法

1.1 材料

供试药剂:50%咪鲜胺锰盐可湿性粉剂(prochloraz-manganese)、50%异菌脲悬浮剂(iprodione),苏州富美实植物保护剂有限公司;42.4%唑醚·氟酰胺悬浮剂(pyraclostrobin · fluxapyroxad),巴斯夫植物保护(江苏)有限公司;50%多菌灵可湿性粉剂(carbendazim),江苏蓝丰生物化工股份有限公司;30%戊唑·多菌灵悬浮剂(pentazole · carbendazim),江苏龙灯化学有限公司;50%腐霉利可湿性粉剂(procymidone),陕西亿农高科药业有限公司;70%甲基托布津可湿性粉剂(thiophanate-methyl)日本曹达株氏会社;40%菌核净可湿性粉剂(dimethachlon),江西禾益化工股份有限公司;30%苯醚甲环唑水分散粒剂(difenoconazole),山东亿嘉农化有限公司;12.5%四氟醚唑水乳剂(tetraconazole),意大利赛格公司;60%唑醚·代森联水份散粒剂(pyraclostrobin · metiram),巴斯夫欧洲公司;40%氟硅唑乳油(flusilazole)、72%霜脲·锰锌可湿性粉剂(curzate),美国杜邦公司;枯草芽孢杆菌(*Bacillus subtilis*)可湿

性粉 2×10^{10} CFU·g⁻¹,山东绿陇生物科技有限公司;哈茨木霉(*Trichoderma harzianum*)可湿性粉剂 1×10^8 CFU·g⁻¹,山东绿陇生物科技有限公司。

供试菌株:桑实杯盘菌(CCTCC AF 2014019)购自中国典型培养物保藏中心。

培养基:马铃薯葡萄糖琼脂(potato dextrose agar,PDA)培养基成分为马铃薯200 g、葡萄糖20 g、琼脂16 g,蒸馏水定容至1 L,121 °C下灭菌30 min。

仪器:HP250GS-C型智能人工气候箱,武汉瑞华仪器设备有限责任公司;超净工作台 SW-CJ-2FD,苏州苏洁净化设备公司。

1.2 供试药剂对桑实杯盘菌菌丝生长的抑制作用

采用菌丝生长速率法进行测定^[21],用无菌水将13种供试药剂配制成5个不同质量浓度的含药PDA平板,即含多菌灵、甲基托布津100.0、50.0、10.0、1.0、0.1 μg·mL⁻¹,霜脲·锰锌10.0、5.0、1.0、0.5、0.1 μg·mL⁻¹,四氟醚唑2.00、0.80、0.40、0.10、0.01 μg·mL⁻¹,咪鲜胺锰盐、戊唑·多菌灵和唑醚·代森联1.00、0.80、0.40、0.10、0.01 μg·mL⁻¹,异菌脲、腐霉利、菌核净、苯醚甲环唑和氟硅唑0.800、0.400、0.100、0.010、0.001 μg·mL⁻¹,唑醚·氟酰胺0.400、0.200、0.100、0.010、0.001 μg·mL⁻¹。将活化5 d直径6 mm的桑实杯盘菌菌丝块接种到PDA平板中央,每个浓度4次重复,置25 °C恒温培养箱培养,1 d后用十字交叉法测量菌落直径,计算相对抑菌率。相对抑菌率(%)=[(对照菌落直径-处理菌落直径)]/(对照菌落直径-菌丝块直径)×100。取药剂浓度的对数值为x,菌丝生长相对抑制率的概率值为y,用DPS(version 7.05)软件求得各杀菌剂的毒力回归方程、相关系数(r)及半数有效浓度(50% effective concentration,EC₅₀)。

1.3 不同药剂对桑椹肥大型菌核病的防治效果

2019年选用室内药剂筛选对桑实杯盘菌抑菌效果好的50%多菌灵800倍液、50%咪鲜胺锰盐1000倍液、42.4%唑醚·氟酰胺2000倍液在武汉市果桑基地进行田间药剂防治试验,以清水为对照。该基地树龄为5 a,栽植株行距2 m×3 m,2018年未进行人工管理。通过对病果症状观察,构建实时荧光定量PCR方法检测^[22]及ITS高通量测序对不同时间点病果中病原菌种类进行分析(数据未显示),发现桑椹肥大型和小粒型菌核病均存在。每个药剂处理

3个小区,每个小区2株桑树,各处理小区采用随机区组排列。分别于3月6日、3月14日、3月25日、4月3日各喷药1次。最后1次施药20 d后进行调查,并将相同处理小区的桑椹样品混合,送往湖北省农业科学院农业质量标准与检测技术研究所进行药剂残留检测分析。每株桑树随机调查9根枝条,每根枝条调查1 m长度,记录1 m枝条的总果数和病果数,计算发病率和校正防效。发病率(%)=病果粒数/总果粒数×100;校正防效(%)=(对照区发病率-处理区发病率)/对照区发病率×100。

2021年,将50%多菌灵800倍液、50%腐霉利1000倍液、50%咪鲜胺锰盐1000倍液和42.4%唑醚·氟酰胺1000倍液4种药剂和1个清水对照,在孝感市果桑基地进行田间药剂防治试验。该基地树龄为3 a,栽植株行距2 m×3 m,2020年5月初摘除了病果并深埋,5月底进行夏伐式修剪,冬季未清园,其他田间管理按常规进行。通过对病果症状观察及构建的实时荧光定量PCR方法检测,发现桑椹肥大型和小粒型菌核病均存在。每个药剂处理3个小区,每个小区3株桑树,共15个处理区,各处理小区采用随机区组排列,小区间留1行桑树作为隔离行,分别于2月23日(鹊口期)、3月3日(开叶期)、3月11日(花穗形成期)、3月22日(初花期)、3月28日(盛花期)喷药1次,共用药5次。统一于4月19日调查,每株桑树随机调查3根枝条,每根枝条调查1 m长度,记录1 m枝条的总果数和病果数,计算发病率和校正防效。同时采集不同处理小区桑椹,将相同处理的小区样品混合,送往湖北省农业科学院农业质量标准与检测技术研究所和浙江华才检测技术有限公司进行药剂残留检测分析。

1.4 不同喷药时期对桑椹肥大型菌核病防治效果的影响

2021年在孝感市同一基地,选用50%咪鲜胺锰盐1000倍液分别于果桑2月23日(鹊口期)、3月3日(开叶期)、3月11日(花穗形成期)、3月22日(初花期)开始喷施,到3月28日(盛花期)停止施药,每个处理3株桑树,3次重复,对照处理同前,调查和处理方法同前。

1.5 生防菌对桑椹菌核病的防治效果

2021年在孝感市同一基地,将枯草芽孢杆菌300倍液和哈茨木霉菌300倍液,在果桑3月3日(开叶期)、3月11日(花穗形成期)、3月22日(初花期)、

3月28日(盛花期)喷施,每个处理3株桑树,3次重复,对照处理和调查方法同前。

1.6 数据处理和分析

采用DPS(version 7.05)软件对数据进行方差分析,并用LSD法比较不同处理间的差异显著性。

2 结果与分析

2.1 供试药剂对桑实杯盘菌菌丝生长的抑制作用

采用菌丝生长速率法测定不同药剂对桑实杯盘菌菌丝的抑制作用,结果表明,13种杀菌剂对病菌均有不同程度的抑制作用,杀菌剂的相对抑制率与其浓度对数之间呈极显著正相关($p < 0.01$)。50%咪鲜胺锰可湿性粉剂和42.4%唑醚·氟酰胺悬浮剂效果最好, EC_{50} 均为 $0.01 \mu\text{g} \cdot \text{mL}^{-1}$,其次是50%多菌灵可湿性粉剂、50%异菌脲悬浮剂、30%戊唑·多菌灵悬浮剂、50%腐霉利可湿性粉剂, EC_{50} 分别0.06、0.11、0.25和 $0.28 \mu\text{g} \cdot \text{mL}^{-1}$,72%霜脲·锰锌可湿性粉剂抑菌效果最差, EC_{50} 为 $15.10 \mu\text{g} \cdot \text{mL}^{-1}$ (表1)。

2.2 不同药剂对桑椹肥大型菌核病的防治效果

2019年武汉市果桑基地田间防治试验分别于3月6日、3月14日、3月25日、4月3日选择室内药剂筛选效果较好的药剂各喷药1次,结果表明,多菌灵800倍液、咪鲜胺锰盐1000倍液、唑醚·氟酰胺2000倍液可有效降低发病率,其中多菌灵和咪鲜胺锰盐的校正防效可达100%,唑醚·氟酰胺的校正防效为

表2 2019年不同药剂对桑椹肥大型菌核病的田间防治效果

Table 2 Field trials of different fungicide treatments on mulberry fruit sclerotiniosis disease in 2019

药剂 Fungicide	发病率 Disease incidence/%	校正防效 Corrected control efficiency/%	农药残留 Pesticide residue/ (mg·kg ⁻¹)
多菌灵800倍液 800 fold dilution of carbendazim	0 b	100 a	5.67
咪鲜胺锰盐1000倍液 1000 fold dilution of prochloraz-manganese	0 b	100 a	0.68
唑醚·氟酰胺2000倍液 2000 fold dilution of pyraclostrobin·fluxapyroxad	2.17±1.24 b	96.04±3.96 a	—
清水对照 Control	54.91±20.54 a		

注:表中数据为(平均数±标准误差)。同列数据后不同小写字母表示经LSD法检验在 $p < 0.05$ 差异显著。“—”表示未检测。下同。

Note: The data shown in the table are (mean ± standard error). Different small letters in the same column indicate significant difference at $p < 0.05$ by LSD test. “—” indicates not tested. The same below.

口期)、3月3日(开叶期)、3月11日(花穗形成期)、3月22日(初花期)、3月28(盛花期)进行田间药剂防治试验,结果(图1)表明,咪鲜胺锰盐、多菌灵和唑醚·氟酰胺的校正防效分别为99.58%、98.21%和95.95%,且差异不显著,腐霉利校正防效为88.11%,与其他3种药剂防治效果存在显著差异。最后一次喷药22 d后采样检测,咪鲜胺锰盐的残留量为0.68

表1 不同供试药剂对桑实杯盘菌菌丝的抑制作用

Table 1 Comparative the inhibition of 13 different fungicides to *Ciboria shiraiana*

供试药剂 Fungicide	毒力回归方程 Toxic regres- sionequations	相关系数 Correlation coefficient, r	$EC_{50}/$ ($\mu\text{g} \cdot \text{mL}^{-1}$)
50%咪鲜胺锰	$y=6.50+0.69x$ 0.94	0.01	
50% Prochloraz-manganese			
42.4%唑醚·氟酰胺	$y=6.70+0.89x$ 0.96	0.01	
42.4% Pyraclostrobin·fluxapyroxad			
50%多菌灵 50% Carbendazim	$y=5.62+0.50x$ 0.92	0.06	
50%异菌脲 50% Iprodione	$y=5.88+0.92x$ 0.94	0.11	
30%戊唑·多菌灵	$y=6.32+2.21x$ 0.98	0.25	
30% Pentazole-carbendazim			
50%腐霉利 50% Procymidone	$y=6.67+3.00x$ 0.98	0.28	
70%甲基托布津	$y=5.24+0.59x$ 0.98	0.39	
70% Thiophanate-methyl			
40%菌核净 40% Dimethachlon	$y=6.44+3.71x$ 0.98	0.41	
30%苯醚甲环唑	$y=5.04+0.64x$ 0.94	0.87	
30% Difenoconazole			
60%唑醚·代森联	$y=4.98+0.60x$ 0.93	1.08	
60% Pyraclostrobin·metiram			
40%氟硅唑 40% Flusilazole	$y=4.92+1.26x$ 0.99	1.16	
12.5%四氟醚唑	$y=4.74+1.00x$ 0.97	1.81	
12.5% Tetraconazole			
72%霜脲·锰锌 72% Curzate	$y=3.71+1.09x$ 0.95	15.10	

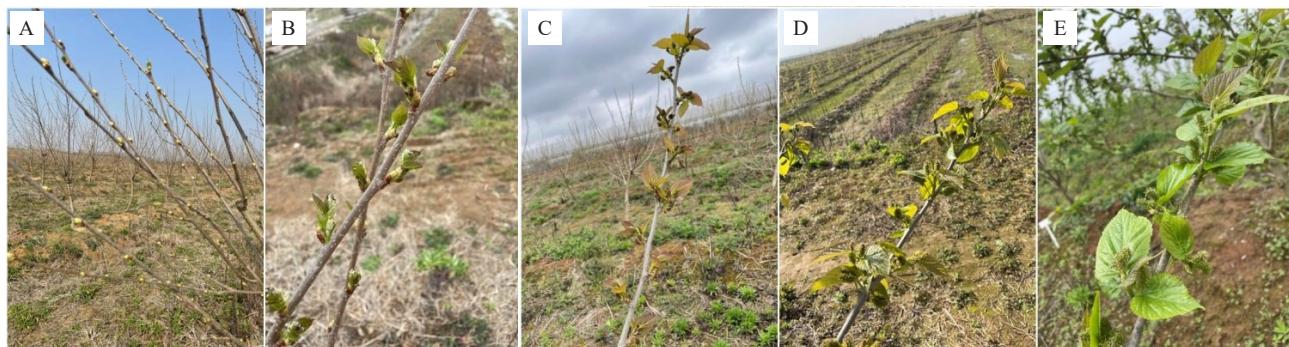
96.04%。最后1次喷药20 d后采样检测,多菌灵的残留量为 $5.67 \text{ mg} \cdot \text{kg}^{-1}$,咪鲜胺锰盐的残留量为 $0.68 \text{ mg} \cdot \text{kg}^{-1}$ (表2)。

2021年在孝感市果桑基地分别于2月23日(鹊

mg·kg⁻¹,多菌灵的残留量为 $5.86 \text{ mg} \cdot \text{kg}^{-1}$,唑醚·氟酰胺的残留量低于检测下限,腐霉利的残留量为 $2.94 \text{ mg} \cdot \text{kg}^{-1}$ (表3)。

2.3 不同喷药时期对桑椹肥大型菌核病的防治效果影响

选用50%咪鲜胺锰盐分别于果桑2月23日(鹊口期)、3月3日(开叶期)、3月11日(花穗形成期)、3



A. 鹊口期;B. 开叶期;C. 花穗形成期;D. 初花期;E. 盛花期。

A. Magpie mouth stage; B. Leaf opened stage; C. Flower spike formation stage; D. Initial blooming stage; E. Full blooming stage.

图 1 2021 年喷药时果桑田间生长情况

Fig. 1 The growth situation of mulberry fruit during spraying fungicides in 2021

表 3 2021 年不同药剂对桑椹肥大型菌核病的田间防治效果

Table 3 Field trials of different fungicide treatments on mulberry hypertrophic sorosis scleroteniosis disease in 2021

药剂 Fungicide	发病率 Disease incidence/%	校正防效 Corrected control efficiency/%	农药残留 Pesticide residue/ (mg·kg ⁻¹)
咪鲜胺锰盐 1000 倍液 1000 fold dilution of prochloraz-manganese	0.19±0.28 b	99.58±0.60 a	0.68
多菌灵 800 倍液 800 fold dilution of carbendazim	0.82±0.41 b	98.21±0.89 a	5.86
唑醚·氟酰胺 2000 倍液 2000 fold dilution of pyraclostrobin·fluxapyroxad	1.87±1.04 b	95.95±1.30 a	—
腐霉利 1000 倍液 1000 fold dilution of procymidone	5.48±2.05 b	88.11±4.45 b	2.94
清水对照 Control	46.07±5.63 a		

月 22 日(初花期)开始喷施,结果表明,鹊口期、开叶期和花穗形成期后开始喷药校正防效分别为 96.98%、97.65% 和 96.39%,初花期开始施药校正防

效为 91.40%,与鹊口期、开叶期和花穗形成期开始喷药防治效果存在显著差异。喷药 2、3、4、5 次的农药残留量分别为 0.50、0.52、0.49、0.54 mg·kg⁻¹(表 4)。

表 4 2021 年不同喷药时期对桑椹肥大型菌核病的田间防治效果

Table 4 Field trials of different control stages on mulberry hypertrophic sorosis scleroteniosis disease in 2021

喷药时间 Spraying time	发病率 Disease incidence/%	校正防效 Corrected control efficiency/%	农药残留 Pesticide residue/ (mg·kg ⁻¹)
2 月 23 日(鹊口期) February 23 (Magpie mouth period)	1.39±0.15 b	96.98±0.33 a	0.54
3 月 3 日(开叶期) March 3 (leaf opened period)	1.08±0.31 b	97.65±0.67 a	0.49
3 月 11 日(花穗形成期) March 11 (Flower spike formation stage)	1.66±0.09 b	96.39±0.20 a	0.52
3 月 22 日(初花期) March 22 (Initial blooming stage)	3.96±1.17 b	91.40±4.40 b	0.50
清水对照 Control	46.07±5.63 a		

2.4 生防菌对桑椹肥大型菌核病的防治效果

用枯草芽孢杆菌 300 倍液和哈茨木霉菌 300 倍液,在果桑 3 月 3 日(开叶期)、3 月 11 日(花穗形成期)、3 月 22 日(初花期)、3 月 28 日(盛花期)喷施,枯草芽孢杆菌 300 倍液和哈茨木霉菌 300 倍液的校正防效分别为 61.74% 和 54.74%(表 5)。

3 讨 论

桑椹菌核病的防治主要有 4 种手段:一是使用

表 5 2021 年不同生防菌对桑椹肥大型菌核病的田间防治效果

Table 5 Field trials of different biocontrol strain treatments on mulberry hypertrophic sorosis scleroteniosis disease in 2021

生防菌处理 Biocontrol strain treatments	发病率 Disease incidence/%	校正防效 Corrected control efficiency/%
枯草芽孢杆菌 <i>Bacillus subtilis</i>	17.62±3.94 b	61.74±8.55 a
哈茨木霉菌 <i>Trichoderma harzianum</i>	20.85±3.83 b	54.74±8.31 a
清水对照 Control	46.07±5.63 a	

化学药物防治,控制发病;二是通过农业或物理防治措施,从桑树栽培田间管理上减少病源;三是生物防治,利用拮抗菌抑制病原菌生长;四是进行品种选育,在生产上推广既抗病又适宜当地气候的优良果桑品种。抗病品种是所有防治措施中最有效的、经济的手段,目前生产上推广面积最大的果桑品种是粤椹大10,该品种具有高产优质的特点,但对桑椹菌核病的抗性较差,目前尚无可生产上大面积推广应用的高产优质抗病替代果桑品种,因此,急需寻找防治该病的方法。

笔者在本研究中测定了13种杀菌剂对桑椹肥大型菌核病菌菌丝的抑制作用。一些药剂如 $250\text{ g}\cdot\text{L}^{-1}$ 吡唑醚菌酯乳油(江西正邦生物化工有限责任公司)注明了禁止在蚕室附近使用,未进行药剂筛选。2019年选择了室内抑菌效果最好的3种药剂,在武汉市果桑基地进行田间药剂防治试验,结果表明50%多菌灵可湿性粉剂800倍液、50%咪鲜胺锰盐可湿性粉剂1000倍液和42.4%唑醚·氟酰胺悬浮剂2000倍液校正防效可达100%、100%和96.04%。为进一步验证这3种药剂的防治效果,2021年在孝感市果桑基地进行田间药剂防治试验,同时与室内抑菌效果较好、被报道对桑椹菌核病有较好防治效果且无明显药害的腐霉利进行比较^[12,17,24],发现50%多菌灵可湿性粉剂800倍液、50%咪鲜胺锰盐可湿性粉剂1000倍液和42.4%唑醚·氟酰胺悬浮剂2000倍液校正防效分别为98.21%、99.58%、95.95%,3种药剂防治效果差异不显著,但50%腐霉利可湿性粉剂的校正防效只有88.11%,防效与其他3种药剂存在显著差异。2年农药残留检测均发现多菌灵800倍液防治后的农药残留量均高于GB 2763—2021《食品安全国家标准 食品中农药最大残留限量》水果中最高标准 $5\text{ mg}\cdot\text{kg}^{-1}$;咪鲜胺锰盐1000倍液的农药残留量低于水果中最高标准 $10\text{ mg}\cdot\text{kg}^{-1}$,低于葡萄(浆果和其他小型类水果:皮可食小型攀缘类水果)要求的 $2\text{ mg}\cdot\text{kg}^{-1}$ 。2021年试验结果表明,咪鲜胺锰盐1000倍液的农药残留量并未因施药次数的增加而发生显著改变;唑醚·氟酰胺2000倍液农残低于最低检测量 $0.01\text{ mg}\cdot\text{kg}^{-1}$;腐霉利1000倍液的农药残留量低于水果中草莓要求的 $10\text{ mg}\cdot\text{kg}^{-1}$ 标准。

正确防治时期的选择对防治桑椹菌核病非常关键,现有报道大多认为桑椹菌核病病原菌对桑树的侵染期是初花期^[23],且推荐该时期进行第1次药物

防治^[24],但笔者选用了2019年防治效果最好且农残安全的药剂咪鲜胺锰盐可湿性粉剂1000倍液,比较了不同防治时期对病害防治的影响,试验结果表明鹊口期、开叶期和花穗形成期后开始喷药校正防效分别为96.98%、97.65%和96.39%,这3个时期喷药防治效果差异不显著,但初花期开始施药校正防效为91.40%,与鹊口期、开叶期和花穗形成期开始喷药效果存在显著差异。另外,通过总结发现喷药时期的选择与2018—2021年观察到的田间菌核萌发过程时间点吻合,菌核一般于2月末开始萌动,3月中下旬形成成熟的子囊盘,4月上中旬子囊盘消失。因此,生产上为节省成本可推荐花穗形成期开始喷药,因为此时掉落在地面的菌核萌发形成成熟的子囊盘,大量子囊孢子会被释放到空中。

生物防治方面,张健等^[13]分离的哈茨木霉Tr16和棘孢木霉Tr50菌株发酵液10倍稀释后进行田间防治的防效达91.27%和82.53%。郑章云等^[14]采用泰诺木霉菌 $2\times 10^8\text{ CFU}\cdot\text{g}^{-1}$ 可湿性粉剂300~800倍液和哈茨木霉菌 $3\times 10^8\text{ CFU}\cdot\text{g}^{-1}$ 可湿性粉剂300~800倍液在桑树初花期、盛花期和谢花期分别喷施桑树,校正防效分别为69.76%~84.02%和35.42%~53.38%。Xu等^[25]从健康果桑茎秆筛选获得内生菌枯草芽孢杆菌,发现可以使发病率降到0.8%。本研究枯草芽孢杆菌 $2\times 10^{10}\text{ CFU}\cdot\text{g}^{-1}$ 可湿性粉剂300倍液和哈茨木霉菌 $1\times 10^8\text{ CFU}\cdot\text{g}^{-1}$ 可湿性粉剂300倍液对桑椹菌核病的校正防效分别为61.74%和54.74%与前人报道的最优防效有一定差距^[13-14,25]。同一种生防菌防治效果的不同,可能与病害发病率、生产工艺及活性成分等有关。因此,将枯草芽孢杆菌和哈茨木霉菌作为生防菌应用于田间防治,值得进一步探索和优化。在应用生物制剂防治方面,探索如何结合化学药剂防治,以减少化学药剂的使用,进一步减少桑果中的农药残留,是后续研究的内容之一。

4 结 论

通过室内药剂筛选,两年不同药剂田间防治试验,2021年不同喷药时期及不同生防菌对桑椹肥大型菌核病的防治试验,结果表明,果桑花穗形成期开始使用50%咪鲜胺锰盐可湿性粉剂1000倍液,7~10 d喷施1次,采摘前25~30 d可停止用药,校正防效可超过99%。另外,42.4%唑醚·氟酰胺悬浮剂2000倍液2年校正防效均在95%以上,且这两种药剂残留

在安全范围内。为防止病原菌产生抗药性,可交替使用这两种药剂进行防治。

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