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两种微生物菌剂对工业大麻田中大麻螟的防治效果

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摘要:为有效防控大麻螟,减少工业大麻虫害损失,选用2种微生物菌剂绿僵菌和白僵菌,设置常规施用量,通过田间小区试验,筛选出安全、高效、防效长久的大麻螟防治药剂。结果表明,绿僵菌制剂和白僵菌制剂处理均在播种后喷施47和54 d后对大麻螟的平均防效最佳,分别为85.56%~88.89%和64.71%~64.81%;喷施后41,47和54 d绿僵菌的虫口减退率几乎持平,为83.72%~88.89%,喷施后47,54和61 d白僵菌的虫口减退率几乎持平,为63.16%~64.81%。快速生长期喷施,绿僵菌制剂与白僵菌制剂处理对大麻螟校正防效差异不显著,喷施9,12和15 d校正死亡率分别是43.83%~79.87%和47.14%~83.84%,绿僵菌和白僵菌在喷施后15 d达到了虫口减退率最佳,分别为82.03%和86.09%,两制剂之间差异不显著。对于连作工业大麻种植田建议播种后喷施绿僵菌制剂或白僵菌制剂防治大麻螟,快速生长期建议喷施微生物杀虫剂配合化学杀虫剂,以达到迅速减少虫口且延长防效的目的。

关键词:工业大麻;大麻螟;微生物菌剂;防效

工业大麻(*Cannabis sativa* L.)又称为汉麻,是大麻科(Cannabinaceae)、大麻属(*Cannabis*)、大麻种(*C. sativa*)一年生直立草本植物^[1],是中国古老的传统种植农作物之一,其茎秆的韧皮纤维可作为纺织原料。黑龙江省因其昼长夜短、温差大的气候特点,有利于韧皮纤维形成和积累,特别适宜种植工业大麻。大麻螟(*Grapholita deliniana*)又称亚洲大麻螟,是工业大麻生产中危害较重的害虫^[2],其幼虫可蛀食工业大麻芯秆,咬噬韧皮纤维,啃食叶片^[3-4],降低工业大麻干茎产量和纤维质量。其田间防治主要是在羽化后未钻入茎秆时,喷施化学杀虫剂防治第一代和第二代幼虫^[5]。氯氟氰菊酯是一种广谱、高效的拟除虫类杀虫剂,在生产中作为工业大麻广谱杀虫剂使用,可以有效防控大麻跳甲和螟虫^[6]。生物防治方法越来越多地被应用在田间害虫的防治工作中^[7]。昆虫病原体白僵菌(*Beauveria bassiana*)和绿僵菌(*Metarhizium anisopliae*)已经广泛应用于螨和螟的微生物控制^[7],作为微生物类真菌杀虫制剂具有无污染、无残留、药效时间长、无抗

药性、环境友好等特点^[8]。白僵菌寄生在昆虫身上可以水解膜蛋白释放白僵素(大环脂类毒素),引起昆虫中毒,扰乱其新陈代谢^[9]。白僵菌可以有效防治浆果象甲、麦蛾^[10-11]。绿僵菌感染昆虫后释放神经毒素,致使昆虫表现神经系统障碍,无法进食,最后死亡^[12]。Ryan等^[13]通过对绿僵菌防治肩星天牛室内毒力评估,确定致死浓度为 3.08×10^6 CFU·cm⁻²。绿僵菌对鞘翅目害虫也有一定的防控效果^[14]。因此,本研究拟采用白僵菌悬浮液和绿僵菌悬浮液对工业大麻品种汉麻5号进行不同时期的喷施处理,研究微生物菌剂对大麻螟的防效和影响,以期微生物菌剂防治大麻螟提供参考。

1 材料与方法

1.1 试验地概况

田间试验设在黑龙江省农业科学院齐齐哈尔分院科研试验田,试验于2021和2022年4月下旬至9月中旬进行。试验田地势平坦,肥力中等,为碳酸盐黑钙土。属于中温带大陆性季风气候,年降水量443 mm,年均温3.2℃,活动积温为2 900℃。

1.2 材料

试验品种为纤维工业大麻汉麻5号。两种微生物菌剂是白僵菌悬浮液(1×10^{10} CFU·mL⁻¹)和绿僵菌悬浮液(1×10^8 CFU·mL⁻¹),由黑龙江大学生命科学学院宋富强团队提供。化学杀虫剂为5%高效氯氟氰菊酯(国光功尔)。

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1.3 方法

1.3.1 试验设计 田间试验设置4个处理,分别是白僵菌制剂、绿僵菌制剂、氯氟氰菊酯制剂、蒸馏水(CK),每个处理6.5 m²,3次重复。设置2个喷施时间,分别是播后和快速生长中期,日落后喷施,喷施药剂后罩网观察虫情。播种密度为250株·m⁻²。出苗前,人工除草1次。

田间试验使用药剂的终浓度分别为白僵菌制剂1×10¹⁰ CFU·L⁻¹,绿僵菌制剂1×10⁸ CFU·L⁻¹,5%高效氯氟氰菊酯1 mL·L⁻¹。

1.3.2 测定项目及方法 喷施杀虫制剂前,调查每个处理小区内大麻蝇的幼虫基数。播后喷施杀虫制剂处理,喷施后40 d开始调查,每7 d调查1次,共调查5次。快速生长中期喷施处理,喷施后,每3 d调查1次,共调查5次。

采用Abbott公式对死亡率进行校正。

校正死亡率(%)=(处理死亡率-对照死亡率)/(1-对照死亡率)×100

虫口减退率(%)=(防治前虫口密度-防治后虫口密度)/防治前虫口密度×100

1.3.3 数据分析 采用Excel 2010和DPS 7.05

软件进行数据分析和处理。

2 结果与分析

2.1 播种后不同杀虫制剂对大麻蝇幼虫的预防效果

2.1.1 虫口数变化 播种后喷施封闭杀虫剂是一种防治土壤越冬害虫的方法。从图1可以看出,喷施制剂后41 d陆续开始出现大麻蝇幼虫,并且随着喷施后天数的增加,虫口数逐渐增加。白僵菌制剂、绿僵菌制剂、氯氟氰菊酯制剂和CK处理的虫口数分别由喷施后41 d的7.33,2.33,13.67和14.33头增加至68 d的37.00,23.67,83.33和90.67头。白僵菌和绿僵菌处理虫口数从41 d开始显著少于氯氟氰菊酯和CK处理。随着喷施天数的增加,喷施后47~68 d绿僵菌显著低于白僵菌处理,化学制剂氯氟氰菊酯处理的虫口数与CK一直差异不显著。说明播种后喷施氯氟氰菊酯制剂对控制虫口数效果不佳,白僵菌和绿僵菌对控制虫口数均有显著效果,且两制剂之间差异显著。绿僵菌虫口数控制效果最佳,白僵菌次之,氯氟氰菊酯效果最小。

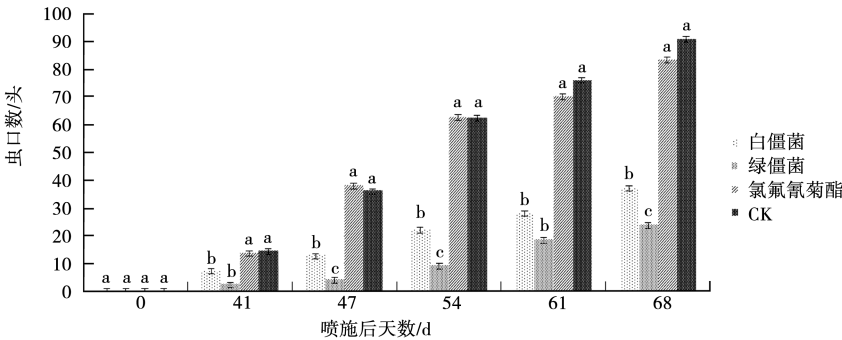


图1 播种后喷施不同杀虫制剂对大麻蝇虫口数的影响

注:不同小写字母表示处理间在P<0.05水平差异显著。下同。

2.1.2 虫口减退率 从图2可以看出,绿僵菌和白僵菌的虫口减退率远远高于氯氟氰菊酯。喷施后41,47和54 d绿僵菌的虫口减退率几乎持平,为83.72%~88.89%。喷施后47,54和61 d白僵菌的虫口减退率几乎持平,为63.16%~64.81%。两微生物菌剂之间虫口减退率均差异显著,绿僵

菌在播后喷施的虫口减退效果高于白僵菌,但白僵菌在起效之后能够很好的控制虫口减退率,绿僵菌的虫口减退率下降趋势高于白僵菌,推测白僵菌在本次试验中虫体传播好于绿僵菌。氯氟氰菊酯制剂喷施后41~68 d的虫口减退率为-5.56%~8.09%,虫口减退率不佳。

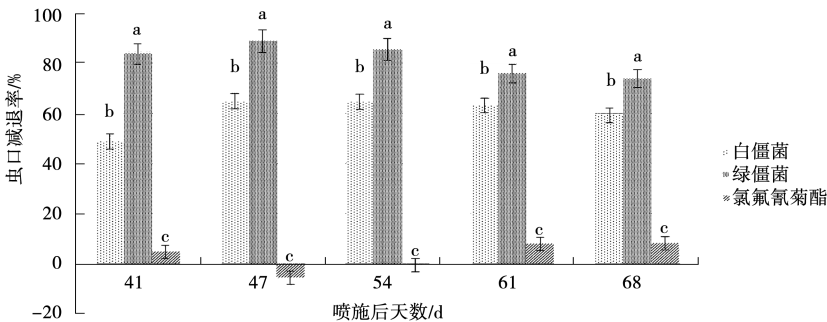


图2 播种后喷施不同杀虫制剂对大麻蝇虫口减退率的影响

2.1.3 防治效果 从图 3 可以看出,从喷施后 41 d 开始,白僵菌和绿僵菌与氯氟氰菊酯和 CK 的校正防效达到差异显著。从喷施后 47 d 开始,绿僵菌和白僵菌的校正防效之间差异显著。绿僵菌制剂校正防效呈现先升后降的趋势,在喷施后 47 d 绿僵菌校正防效达到最大,为 88.89%,随后

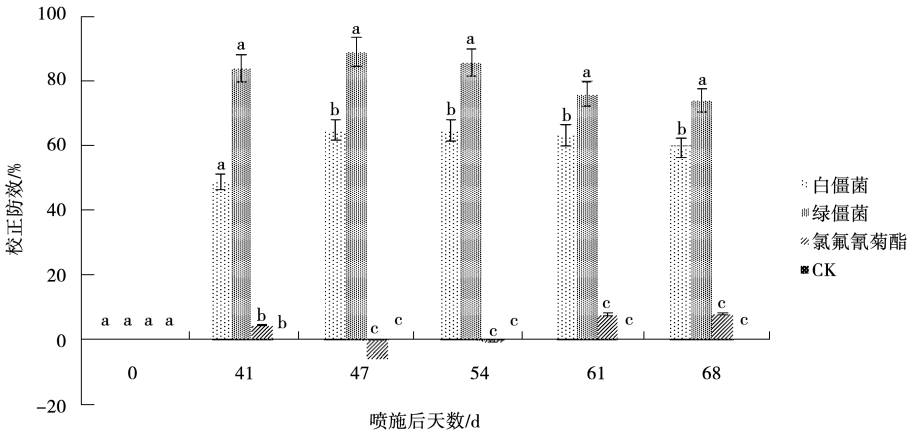


图 3 播种后喷施不同杀虫制剂对大麻螟的平均防效

2.2 快速生长期不同杀虫制剂对大麻螟幼虫的防治效果

2.2.1 虫口数 从图 4 可以看出,从快速生长期喷施制剂开始,绿僵菌和白僵菌在喷施后对虫口数的控制一直呈逐渐下降趋势,氯氟氰菊酯处理的虫口数呈现先大幅下降后稍微上升的趋势。喷施后 3 d 白僵菌和氯氟氰菊酯处理虫口数均显著低于 CK,但绿僵菌与 CK 差异不显著。喷施后的 6~15 d 各药剂处理虫口数均显著低于 CK,其中氯氟氰菊酯处理虫口数最低,整体上低于绿僵菌

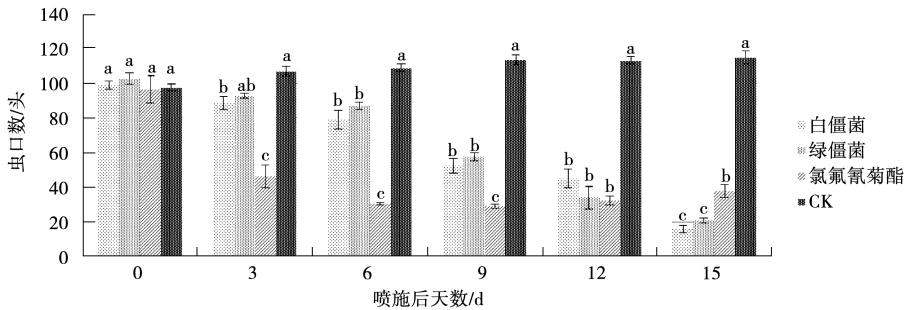


图 4 快速生长期喷施不同杀虫制剂对大麻螟虫口数的影响

2.2.2 虫口减退率 从图 5 可以看出,绿僵菌和白僵菌在喷施后 3,6 和 9 d 的虫口减退率都低于氯氟氰菊酯制剂,分别 13.40%~49.27%和 17.13%~53.96%,与氯氟氰菊酯差异显著。绿僵菌在喷施后 12 d 与氯氟氰菊酯虫口减退率几

绿僵菌的防效逐渐降低。白僵菌制剂校正防效也呈现先升后降的趋势,但 47,54 和 61 d 校正防效几乎持平,为 63.16%~64.81%,喷施 68 d 后校正防效最低,为 59.19%,但对比绿僵菌制剂,白僵菌制剂的校正防效下降趋势缓慢。喷施氯氟氰菊酯制剂的校正防效与 CK 差异不显著。

和白僵菌处理,绿僵菌和白僵菌处理间差异不显著。喷施后 9 d,氯氟氰菊酯的虫口数控制达到最佳,为 29 头。与喷施后 6 和 12 d 几乎持平,绿僵菌和白僵菌的虫口数降为 60 头左右。喷施后 12 d,3 种制剂处理的虫口数都在 40 头左右,且处理间差异不显著。到 15 d 时,绿僵菌制剂和白僵菌制剂处理的虫口数均最低,分别为 16.00 头和 20.67 头,但氯氟氰菊酯制剂处理的虫口数有轻微的上升,并且显著高于绿僵菌和白僵菌。

乎持平,为 70.00%。绿僵菌和白僵菌在喷施后 15 d 达到了虫口减退率最佳,分别为 82.03%和 86.09%,两制剂之间差异不显著。可以看出氯氟氰菊酯促杀作用明显,绿僵菌和白僵菌杀虫效果需要 10 d 左右才能明显提升。

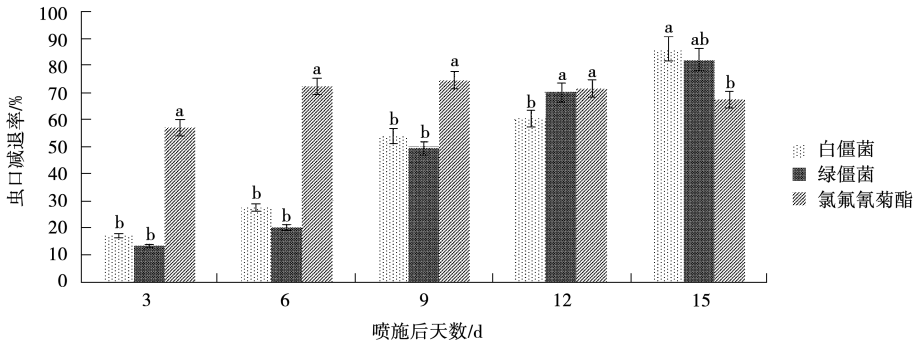


图5 快速生长期喷施不同杀虫制剂对大麻蝇虫口减退率的影响

2.2.3 校正防效 从图6可以看出,氯氟氰菊酯的校正防效呈现先升后降的趋势,其中快速生长期喷施后9 d达到最大校正死亡率,为70.00%,喷施后6和12 d的校正死亡率略低于喷施后9 d。绿僵菌和白僵菌制剂的校正死亡率呈现一直上升的趋势,但前6 d上升趋势较缓,绿僵菌和白

僵菌处理在喷施后3~9 d的校正死亡率均低于氯氟氰菊酯,且差异显著。喷施后12 d,各药剂处理的校正死亡率差异不显著,喷施后15 d,绿僵菌和白僵菌处理的校正死亡率最高,分别达到79.87%和83.84%,且显著高于氯氟氰菊酯处理。

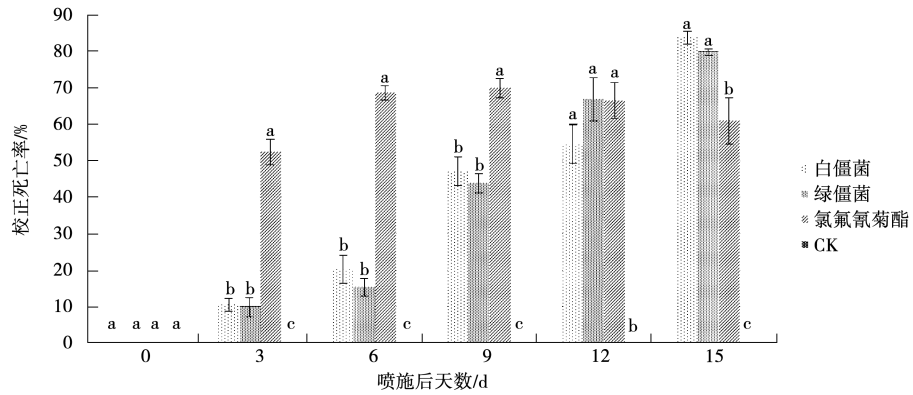


图6 快速生长期喷施不同杀虫制剂对大麻蝇校正防效的影响

3 讨论

为了防治虫害和减少作物损失,农民长期以来以使用化学杀虫剂为主。化学杀虫剂具有广谱、高效、速效等特点,但其长残留、虫体的耐药性、土壤和水体的毒性积聚也受重视^[15-19]。因此,迫切需要选择针对性强、高效、无残留且环境友好的杀虫剂。微生物杀虫剂中的微生物主要是自然界存在的微生物或其次级代谢物,它们通过接触的方式进入虫体,以对人体无毒的形式影响虫体代谢来防控害虫,不会对生态系统和农业环境造成损害。随着绿色、安全、可持续农业的发展以及对农业环境安全的日益重视,对环境和作物影响小的微生物杀虫剂也被广泛应用在多种作物上,这对微生物多重用途的发展具有重要意义。虽然已经发现的昆虫病原真菌有很多,寄生范围很广,但开

发生产成杀虫剂的不多。其中白僵菌和绿僵菌是应用比较广泛的真菌杀虫剂^[20-23]。Gurulingappa^[24]等的研究表明白僵菌分生孢子和代谢产物可以降低棉蚜的繁殖率。白僵菌还可以破坏昆虫的免疫系统,其分泌的含半胱氨酸的蛋白质疏水蛋白可以帮助真菌附着在昆虫的体表^[25-26]。还有研究表明白僵菌的次级代谢物可以对昆虫的生长和免疫系统起到抑制作用^[27]。绿僵菌是土壤和昆虫中存在的一种重要的孢子病原真菌,在世界各地不同地理区域都有发现^[28-29],因其安全、针对性强被归为生态友好型生物防治制剂^[30]。绿僵菌可以通过附着、渗透虫体表面的角质层来广泛防治虫害,其分生孢子释放几丁质酶,降解多糖,增加渗透压,改变昆虫细胞的脂质组成,使其很容易在虫体内生长^[16,31-32]。

大麻螟(*Grapholita delineana*)发源于东亚,现已蔓延至欧洲、南高加索地区和北美洲,在乌克兰,受大麻螟影响大麻种子产量损失约 30%~40%,纤维产量降低 18%~50%^[33]。Fedorenko^[34]等的研究建议可在 4~6 对真叶时期通过喷施菊酯类化学杀虫剂防控第一代幼虫。但使用化学杀虫剂却带来了严重的农药残留问题^[35]。目前绿僵菌和白僵菌在大麻螟防控效果方面尚无明确报道,本研究首次将绿僵菌、白僵菌微生物制剂应用于工业大麻害虫防控工作,设置了不同喷施时期,调查喷施后不同天数的虫口数和平均防效,为微生物制剂绿色防控做出了探索性研究。本研究结果表明,播种后喷施氯氟氰菊酯这类触杀型菊酯杀虫剂对大麻螟几乎没有防效,喷施绿僵菌和白僵菌这类通过体表侵染,进而侵入虫体的微生物杀虫剂,有比较显著的平均防效。同时绿僵菌制剂的持续防效好于白僵菌制剂,平均防效最高可达 88.89%,略高于于健等^[36]利用白僵菌和绿僵菌对棉铃虫的试验结果。在工业大麻快速生长期喷施杀虫剂 3~9 d,氯氟氰菊酯制剂处理的校正死亡率是最高的,绿僵菌制剂和白僵菌制剂虽然也有防效,但虫口的校正死亡率相对较低且上升速度较为缓慢,不利于田间已经出现虫害的农田。绿僵菌制剂和白僵菌制剂在工业大麻快速生长期喷施 15 d 后的校正死亡率分别达到 79.87%和 83.84%,略低于钱瑞等^[37]喷施绿僵菌和白僵菌防治毛股沟臀叶甲的田间防效。大麻螟对工业大麻危害时间长,并且其成虫具有迁飞性,防治时需集中连片施药,保证防治效果。在生产实践中,大多选择在虫口出现的初期喷洒杀虫剂,化学杀虫剂相对微生物杀虫剂防效时间短,绿僵菌和白僵菌可以通过虫体间传播,因而防效期增加。因微生物在虫体外表和体内繁殖需要时间,所以后续试验中应配合天气提前喷洒微生物杀虫剂。对于连作工业大麻种植田建议播后喷施微生物杀虫剂,可以有效降低虫口数,快速生长期建议微生物杀虫剂配合化学杀虫剂达到迅速减少虫口且延长防效的目的。此外,对于微生物制剂混用增效剂或苏云金芽孢杆菌杀虫剂等以增强杀虫剂防治效果,本试验并未涉及,相关研究会在今后研究中展开。

4 结论

绿僵菌制剂和白僵菌制剂处理均在播种后喷施后 47 和 54 d 对工业大麻田中大麻螟的平均防效最佳,分别为 85.56%~88.89%和 64.71%~64.81%,喷施后 41,47 和 54 d 绿僵菌的虫口减退率几乎持平,为 83.72%~88.89%,喷施后 47,54 和 61 d 白僵菌的虫口减退率几乎持平,为 63.16%~64.81%。快速生长期喷施绿僵菌制剂和白僵菌制剂,在喷施后 15 d 达到最佳防效,绿僵菌制剂与白僵菌制剂处理的大麻螟校正死亡率差异不显著,分别为 43.83%~79.87%和 47.14%~83.84%,绿僵菌和白僵菌在喷施后 15 d 虫口减退率最佳,分别为 82.03%和 86.09%,两制剂之间差异不显著。

参考文献:

- [1] 张晓艳,孙宇峰,曹焜,等. 纤用工业大麻新品种工业大麻 5 号生长发育及产量特的初步研究[J]. 种子, 2020, 39(1): 136-139, 141.
- [2] PERER A E. Field crop arthropod pests of economic importance[M]. America New York: Academic Press, 2022 (5): 317-357.
- [3] CRANSHA W W, SCHREINER M, BEITT K, et al. Developing insect pest management systems for hemp in the United States; a work in progress[J]. Journal of Integrated Pest Management, 2019, 26: 1-10.
- [4] MCPARTLAND J M. Epidemiology of the hemp borer, *Grapholita delineana* walker (Lepidoptera: Olethreutidae), a pest of *Cannabis sativa* L. [J]. Journal of Industrial Hemp, 2002, 7(1): 25-42.
- [5] EUFENIA M, RICCARDO P, JACOPO T, et al. Current applications, approaches, and potential perspectives for hemp[M]. New York: Academic Press, 2016.
- [6] LEAH N S, JANNA L B, FRED W, et al. *Cannabis* as conundrum[J]. Crop Protection, 2019, 117: 37-44.
- [7] FERNANDO E V, PATRICK F D, LAWRENCE A L, et al. Dissemination of beneficial microbial agents by insects[M]. Berlin: Springer, 2007.
- [8] STEFAN T J. Mass production of entomopathogenic fungi-state of the art-Chapter 11[M]. Canada: Academic Press, 2023: 317-357.
- [9] PETER A F, ANDREA K, ROBERT N, et al. Predation by flat bark beetles (Coleoptera: Silvanidae and Laemophloeidae) on coffee berry borer (Coleoptera: Curculionidae) in Hawaii coffee[J]. Biological Control, 2016, 101(10): 152-158.
- [10] ASSINAPOL N, SAMUEL N, SVETLANA G, et al. Field efficacy of entomopathogens and plant extracts on

- Tuta absoluta* Meyrick (Lepidoptera: Gelechiidae) infesting tomato in Rwanda[J]. Crop Protection, 2020(134): 105183.
- [11] UDAYASHANKAR C, ARAKWE S J, SOUMYA K, et al. Biopesticides[M]. London: Woodhead Publishing, 2021.
- [12] SEINICASAN R, SEVGAN S, EKESI S, et al. Biopesticide based sustainable pest management for safer production of vegetable legumes and brassicas in Asia and Africa[J]. Pest Management Science, 2019, 5(10): 1-25.
- [13] RYAN P S, MELODY K, MICHEAL M W, et al. Evaluating the virulence and longevity of non-woven fiber bands impregnated with *Metarhizium anisopliae* against the Asian longhorned beetle, *Anoplophora glabripennis* (Coleoptera: Cerambycidae) [J]. Biological Control, 2009 (8), 50: 94-102.
- [14] KAVALLIERATOS N G, ATHANASSIOU C G, MICHALAKI M P, et al. Effect of the combined use of *Metarhizium anisopliae* (Metschnikoff) Sorokin and diatomaceous earth for the control of three stored-product beetle species[J]. Crop Protection, 2006, 25(10): 1087-1094.
- [15] GERWICK B C, SPARKS T C. Natural products for pest control: an analysis of their role, value and future[J]. Pest Management Science, 2014, 11: 1169-1185.
- [16] HERNANDEZ C E M, GUERRERO I E P, HERNANDEZ G A G, et al. Catalase overexpression reduces the germination time and increases the pathogenicity of the fungus *Metarhizium anisopliae* [J] Applied Microbiology and Biotechnology, 2010, 87(3): 1033-1044.
- [17] MAHMOOD I, IMADI S R, SHAZADI K, et al. Effects of pesticides on environment [J]. Plant, Soil and Microbes, 2016, 1: 253-269.
- [18] KUMAR N, PATHERA A K, SAINI P, et al. Harmful effects of pesticides on human health [J]. Annals of Agri Bio Research, 2012, 17: 125-127.
- [19] MOSTAFALOU S, ABDOLLAHI M. Pesticides: an update of human exposure and toxicity [J]. Archives of Toxicology, 2017, 91: 549-599.
- [20] VINALE F, MARRA R, SCALA F, et al. Major secondary metabolites produced by two commercial *Trichoderma* strains active against different phytopathogens [J]. Letters in Applied Microbiology, 2006, 43: 143-148.
- [21] VINALE F, SIVASITHAMPARAM K, GHISALBERTI E L, et al. Trichoderma-plant-pathogen interactions [J]. Soil Biology and Biochemistry, 2008, 40(1): 1-10.
- [22] VINALE F, SIVASITHAMPARAM K, GHISALBERTI E L, et al. A novel role for *Trichoderma* secondary metabolites in the interactions with plants [J]. Physiological and Molecular Plant Pathology, 2008, 72: 80-86.
- [23] VINALE F, NICOLETTI R, LACATENA F, et al. Secondary metabolites from the endophytic fungus *Talaromyces pinophilus* [J]. Natural Product Research, 2017, 31: 1778-1785.
- [24] GURULINGAPPA P, MCGEE P A, SWORD G. Endophytic *Lecanicillium lecanii* and *Beauveria bassiana* reduce the survival and fecundity of *Aphis gossypii* following contact with conidia and secondary metabolites [J]. Crop Protection, 2011, 30: 349-353.
- [25] ORTIZ-URQUIZA A, KEYHANI N O. Action on the surface: entomopathogenic fungi *versus* the insect cuticle [J]. Insects, 2013, 4: 357-374.
- [26] ZHENG P, XIA Y, XIAO G, et al. Genome sequence of the insect pathogenic fungus *Cordyceps militaris*, a valued traditional Chinese medicine [J]. Genome Biology, 2011, 12: 1-21.
- [27] FENG P, SHANG Y, CEN K, et al. Fungal biosynthesis of the bibenzoquinone oosporein to evade insect immunity [J]. Proceedings of the National Academy of Sciences of the United States of America, 2015, 112(36): 11365-11370.
- [28] TULLOCH M. The genus *Metarhizium* [M]. Transaction of the British Mycological Society, 1976, 66: 407-411.
- [29] ROBERTS D W, LEGER R S J. *Metarhizium* spp., cosmopolitan insect-pathogenic fungi: mycological aspects [J]. Advances in Applied Microbiology, 2014, 54: 1-70.
- [30] BUTT T M, JACKSON C W, MAGAN N. Introduction-fungal biological control agents: problems and potential [J]. CAB International, Wallingford, 2001: 1-9.
- [31] WANG C, STLEGER R J. A collagenous protective coat enables *Metarhizium anisopliae* to evade insect immune responses [J]. Proceedings of the National Academy of Sciences of the United States of America, 2006, 103: 6647-6652.
- [32] ZHANG H, HU W, XIAO M, et al. Destruxin A induces and binds HSPs in *Bombyx mori* Bm12 cells [J]. Journal of Agricultural and Food Chemistry, 2017, 65: 9849-9853.
- [33] MILLER W E. *Grapholita delineaana* (Walker), a Eurasian hemp moth, discovered in North America [J]. Annals of the Entomological Society of America, 1982, 75(2): 184-186.
- [34] FEDORENKO V P, KABANETS V V, KABANETS V M. Pests of cultivated hemp [M]. Kiev: National Academy of Agricultural Sciences of Ukraine, Institute of Plant Protection, 2016.
- [35] NICOLÁS M, LEHOTAYA S J, LIGHTFIELD A R, et al. Validation of a high-throughput method for analysis of pesticide residues in hemp and hemp products [J]. Journal of Chromatography A, 2021, 1645: 462097.
- [36] 于健, 查萌, 郑梦君, 等. 白僵菌和绿僵菌对棉铃虫的室内防控效果评价 [J]. 新疆农业科学, 2020, 57(4): 608-615.
- [37] 钱瑞, 刘霞, 周开云, 等. 金龟子绿僵菌 CQMa4 及球孢白僵菌对茶叶毛股沟臀叶甲的田间防治效果 [J]. 农技服务, 2022, 39(2): 25-27.

Field Control Effect of Two Microbial Inoculum Against *Grapholita delineana*

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Abstract: In order to prevent *Grapholita delineana* and reduce the loss of industrial hemp pests. Two microbial inoculums were applicated in the field experiment with usual dosage and block desighn, the test result in safe, efficient and long-lasting agent against hemp borer. The paper showed that the average control effect of *Metarhizium anisopliae* preparation and *Beauveria bassiana* preparation on industrial hemp moth was the best at 47 days and 54 days after spraying after sowing, which were 85.85%-88.89% and 64.71%-64.81%, respectively. The population decline rate of *Metarhizium anisopliae* was almost flat at 41 days, 47 days and 54 days after spraying, which was 83.72%-88.89%. The population decline rate of *Beauveria bassiana* was almost flat at 47 days, 54 days and 61 days after spraying, which was 63.16%-64.81%. there was not significant difference between corrected controlling effects of *Metarrhizium anisopliae* and *Beauveria bassiana*, which were 43.83%-79.87% and 47.14%-83.84% respectively, while spraying in the fast growing period, which the population decline rate of *M. anisopliae* and *B. bassiana* reached the best at 15 days after spraying, which were 82.03% and 86.09%, respectively. There was no significant difference between the two preparations. For continuous cropping industrial hemp cultivation fields, it is recommended to spray *Metarhizium anisopliae* or *Beauveria bassiana* preparation to control the hemp borer after sowing. During the rapid growth period, it is recommended to spray microbial insecticides combined with chemical insecticides to rapidly reduce the pest population and prolong the control effect.

Keywords: industrial hemp; *Grapholita delineana*; microbial inoculum; control effect

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Effects of Different Microbial Agents on Growth of Broomcorn Millet and Enzyme Activities of Soil

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Abstract: In order to verify the application effect of microbial agents in the production of broomcorn millet, using the method of field test, Qishu 3 was used as the test material, and six microbial agents including *Bacillus subtilis*, *Bacillus licheniformis*, *Trichoderma harziensis*, *Bacillus amyloliquefaciens*, composite microbial agent and photosynthetic bacteria were irrigated in the root of the 5th leaf stage, with no microbial agent as the control (CK). Agronomic traits, yield traits, photosynthetic characteristics and soil enzyme activities of broomcorn millet under different treatments were analyzed. The results showed that compared with CK, the activities of soil urease, sucrase and neutral phosphatase were significantly enhanced after the application of microbial agent. The six microbial agents could significantly improve the agronomic traits (panicle length, effective tiller number, plant height, stem diameter), yield traits (panicle weight, grain weight per panicle, yield) and photosynthetic characteristics (net photosynthetic rate, transpiration rate, intercellular CO₂ concentration) of Qishu 3, but had no significant effect on 1 000-grain weight. The results showed that the compound microbial agent and photosynthetic bacteria treatment had the best effect on improving soil enzyme activity and growth indexes of broomcorn millet, and the highest grain yield, respectively increasing by 14.90% and 13.45% compared with CK, which can be applied to the high-yield cultivation of broomcorn millet field in Heilongjiang Province.

Keywords: microbial agents; broomcorn millet; soil enzyme activity; agronomic traits