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氟唑菌酰羟胺对水稻纹枯病的室内毒力测定与田间防效

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摘要:【目的】近年来,水稻纹枯病菌 *Rhizoctonia solani* Kühn 成为中国水稻产区危害最重的真菌病害之一,不仅给水稻产量造成了严重的损失,也降低了水稻的品质。为提高防治水稻纹枯病的效果,降低水稻纹枯病对常用药剂的抗药性,开发与使用新型药剂成为当前的热门话题。氟唑菌酰羟胺是一种新型广谱性杀菌剂,其作用机理是通过干扰呼吸链复合体Ⅱ,来阻碍能量的合成,从而抑制病菌的生长。为明确氟唑菌酰羟胺对水稻纹枯病菌的抑制效果,评价其对水稻生产的安全性,为防治水稻纹枯病菌提供轮换药剂。【方法】在室内采用菌丝生长速率法对氟唑菌酰羟胺进行了毒力测定,并于2019年和2020年在江西省宜春市泗溪镇曾家村对其进行了为期2年的田间防效试验,且在收获后分别进行了水稻产量性状分析。【结果】室内毒力:氟唑菌酰羟胺对水稻纹枯病菌菌丝生长抑制的毒力回归方程为 Y=0.923 7X+5.340 7,r=0.984 7,EC_{50} 和 EC_{95} 值分别为 0.427 7 mg/L 和 25.832 1 mg/L,与戊唑醇相近且优于咪鲜胺及多菌灵。田间药效:2019年晚稻氟唑菌酰羟胺施用量为160~200 g/hm^{2}时7 d、14 d的防效分别为62.7%~69.5%和79%~82%;2020年早稻氟唑菌酰羟胺施用量为160~200 g/hm^{2}时7 d、14 d的防效分别为50.7%~51.4%和72.6%~74.6%;均优于当季戊唑醇推荐用量为80 g/hm^{2}时的防效。与空白处理小区相比,单季最高增产可达98.17%。【结论】氟唑菌酰羟胺对水稻纹枯病菌具有良好的抑制作用,可用于水稻纹枯病的防治,施用量为160~200 g/hm^{2}时效果最好。对水稻生长安全,且在一定程度上能够提高水稻的产量,提升其品质。

关键词:氟唑菌酰羟胺;水稻纹枯病;室内毒力测定;田间防效;产量
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Toxicity and Field Control Efficacy of Pydiflumetofen against Rice Sheath Blight

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Abstract:[**Objective**]In recent years, rice sheath blight(*Rhizoctonia solani* Kühn)has become one of the

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most harmful fungal diseases in rice producing areas in China, not only causing serious losses in rice yield, but also reducing the quality of rice. In order to improve the effect of controlling rice sheath blight and reduce the resistance of rice sheath blight to commonly used fungicides, the development and use of new fungicides have become a current hot topic. Pydiflumetofen is a new broad-spectrum fungicide. Its mechanism of action is to hinder the synthesis of energy by interfering with the respiratory chain complex II, thereby inhibiting the growth of germs. This study was to clarify the inhibitory effect of pydiflumetofen on rice sheath blight, evaluate its safety in rice production, and provide a rotation agent for the control of rice sheath blight. [**Method**] The virulence of pydiflumetofen was tested indoors using the mycelial growth rate method, and a two-year field control test was carried out in Zengjia Village, Sixi Town, Yichun City, Jiangxi Province in 2019 and 2020, and after harvest, the rice yield and its traits were analyzed respectively. [**Result**] The toxicity test results: the regression equation of the virulence of pydiflumetofen on the mycelial growth inhibition of rice sheath blight was Y=0.923 7X+5.340 7, r=0.984 7, the EC_{50} and EC_{95} of pydiflumetofen on the growth inhibition of rhizoctonia solani were 0.427 7 mg/L and 25.832 1 mg/L, respectively. It was similar to tebuconazole and superior to prochloraz and carbendazim. Field efficacy test results: in 2019, when the application rate of pydiflumetofen for late rice was 160-200 g/hm^2, the control effects for 7 days and 14 days were 62.7% to 69.5% and 79% to 82%, respectively. The control effects for early rice in 2020 were 50.7% to 51.4% and 72.6% to 74.6%, respectively. Better than the recommended dosage of tebuconazole at 80 g/hm^2. Compared with the blank processing area, the highest yield increase could reach 98.17%. [**Conclusion**] The results showed that pydiflumetofen has a good inhibitory effect on rice sheath blight and can be used for the control of rice sheath blight, and the effect is the best when the application rate is 160-200 g/hm^2. It is safe for the growth of rice, and can increase the yield and quality of rice to a certain extent.

Keywords: pydiflumetofen; rice sheath blight; indoor virulence test; field control efficacy; yield

【研究意义】水稻是我国最重要的粮食作物之一,其栽培面积占我国粮食种植总面积的30%左右[1],随着社会经济发展以及人民生活水平的提高,人们对稻米已不再仅限于“量”的需求,而更加注重口感及食味品质的提升[2-4]。由立枯丝核菌*Rhizoctonia solani*引起的水稻纹枯病是水稻三大病害之一[5-6],水稻纹枯病菌的存活能力强,能够以菌核在土壤中越冬,也能够以菌丝体形式在稻茬、病残体、田间其他杂草寄主上越冬[7]。水稻纹枯病菌能借助田间灌溉水在田间传播,发生部位较为隐蔽,不易被及时发现,当一株水稻发病时,田间其他水稻很快也会染病,因此危害十分严重,严重威胁水稻生长发育和产量,给农业造成极大的经济损失[8-9]。据统计我国水稻纹枯病年发病面积达1 300万hm^2,一般减产在10%~20%,严重时达到50%,成为水稻主要病害之一[10]。化学防治是当前主要的防治措施,也是最为省时省力且效果显著的一种方式,但由于长期使用一种或同一类型的药剂,易造成抗药性的产生,如井冈霉素防治水稻效果就严重下降[11-12],因此,必须制定综合有效的防治策略,延缓该病抗药性的产生,同时也需要开发、引进与推广新药剂[13]。【前人研究进展】氟唑菌酰羟胺(pydiflumetofen)是由瑞士先正达作物保护有限公司开发的新一代琥珀酸脱氢酶抑制剂(SDHI)类杀菌剂,其特点是广谱高效,适用于多种作物防治多种病害,且对作物生长较安全,可以在抗击真菌病害中发挥关键作用[14-16]。目前已有报道这种杀菌剂既可以单独使用,用于小麦赤霉病[17]、桑椹菌核病[18]、黄瓜霜霉病[19]等病害的防治,也可以与其他优良杀菌剂混合使用,用于柑橘疮痂病[20]、草莓白粉病[21]等病害的防治,并且不易产生交互抗性[22]。【本研究切入点】有关该药剂对水稻纹枯病的田间防效,国内外还未有报道。【拟解决的关键问题】本研究旨在通过氟唑菌酰羟胺对水稻纹枯病的室内毒力与大田防效试验,探讨氟唑菌酰羟胺对水稻纹枯病的抑制效果,并通过产量结果明确其田间实际应用的最佳剂量,为氟唑菌酰羟胺在水稻上的应用提供新依据。

1 材料与方法

1.1 供试菌种

水稻纹枯病菌:江西农业大学农学院实验室分离并保存。

1.2 供试药剂

200 g/L氟唑菌酰羟胺悬浮剂、氟唑菌酰羟胺原药,瑞士先正达生物科技有限公司;430 g/L戊唑醇悬浮剂,戊唑醇原药,拜耳股份有限公司;咪鲜胺原药,江苏辉丰生物农业股份有限公司;多菌灵原药,山东潍坊润丰化工股份有限公司。

1.3 试验方法

1.3.1 室内毒力测定 采用菌丝生长速率法,应用PDA培养基,在预备性试验的基础上,用无菌水将供试药剂稀释成适当浓度的母液,与灭菌的PDA培养基均匀混合,配成药剂浓度呈等比梯度的含药培养基,分别倒入直径9 cm的培养皿中10~12 mL待冷却。将活化后筛选出来的水稻纹枯病菌取出放置在超净工作台中,用6 mm直径的打孔器(沾酒精后在火焰上灼烧后冷却)在菌落外缘1/3处打取若干个菌碟,用接种针挑取菌碟至含药培养基平板的中部位置,菌丝面朝下,每个平板一个菌碟,密封好,并做好标记,培养皿倒扣放置。并设置不加药剂的培养皿为空白对照组,每组处理重复3次,接种完毕后将所有培养皿放入28 ℃恒温箱中培养。待接种24 h后每天观察生长情况,待对照组长满培养皿时为止,用十字交叉法测量每个处理的菌落直径,取2次直径的平均值为该菌落的直径大小。

根据测量的数据求出不同药剂对水稻纹枯病菌的抑制率,为便于计算,需要将药剂浓度转变为对数值,生长抑制率转变为机率值,最后用Excel和SPSS软件对药剂浓度对数与机率值之间进行数据分析,从而计算得到线性回归方程$Y=aX+b$,再求得EC_{50}和EC_{95}值及相关系数r。菌丝生长抑制率的公式如下:

抑制率=(对照组菌落直径-处理组菌落直径)/(对照组菌落直径-菌碟直径)×100% (1)

1.3.2 田间药效试验 根据室内毒力测定结果,选择与氟唑菌酰羟胺毒力相近的戊唑醇作为对照药剂。采用浙江市下SX-MD16E-2背负式电动喷雾器,每次用水量为600 L/hm²,在水稻分蘖期通过二次施药进行试验。具体施药时间及品种选择:晚稻:2019年9月17日第1次施药,9月24日第2次施药,供试水稻品种为“甬优538”;早稻:2020年5月22日第1次施药,5月29日第2次施药,供试水稻品种为“陵两优179”。试验地选择在江西省宜春市泗溪镇曾家村,28°9′36″N,115°3′36″E;土壤类型:潴育型麻砂泥田;pH值约5.22;有机质含量3.59%。试验设置7个处理(表1)。每处理设3个重复小区,每个小区面积30 m²,随机区组排列,并筑起田埂以防药剂干扰邻近小区。

表1 试验药剂剂量设计

Tab.1 Dosage design for pesticides in experiment

编号 Serial number	处理 Treatment	有效剂量/($g·hm^{-2}$) Effective dosage
A	200 g/L氟唑菌酰羟胺SC	40
B	200 g/L氟唑菌酰羟胺SC	80
C	200 g/L氟唑菌酰羟胺SC	120
D	200 g/L氟唑菌酰羟胺SC	160
E	200 g/L氟唑菌酰羟胺SC	200
F	430 g/L戊唑醇SC	80
CK	清水/空白	—

试验调查按农药田间药效试验准则(一):杀菌剂防治水稻纹枯病(GB/T 17980.20—2000)进行。于2次施药后7 d及14 d调查水稻纹枯病发病情况。采用对角线5点取样,每点调查附近5丛,共25丛,记录总株数、病株数和各病级数,计算病情指数、防效,及施药对水稻和其他生物的影响,计算各个处理小区的病情指数与相对应的防治效果。

病情分级标准:0级为全株无病;1级为第四叶片及其以下各叶鞘、叶片发病(以剑叶为第一片叶);3级为第三叶片及其以下各叶鞘、叶片发病;5级为第二叶片及其以下各叶鞘、叶片发病;7级为剑叶及其以下各叶鞘、叶片发病;9级为全株发病,提早枯死。其中病株率、病情指数和防治效果公式:

病株率=病株数/调查总株数×100% (2)

病情指数=100×∑(各级病穗数×相对级数值)/(调查总穗数×最高级数值) (3)

病指防效=(1-(空白组施药前病指×处理组施药后病指)/(空白组施药后病指×处理组施药前病指))×100% (4)

株防效=(对照区株数施-药区株数)/对照区株数×100% (5)

1.3.3 水稻测产 水稻成熟收割前,每个小区随机选取5穴水稻进行考种,包括单株有效穗数、株高、穗长、穗粒数、实粒数和千粒质量,由此计算理论产量和增产率。并采用SPSS 25.0对数据进行统计,采用Duncan新复极差法进行数据分析。

实粒率=样品实粒数/样品总粒数×100% (6)

理论产量=10 000 m^2×有效穗数×平均实粒数×千粒质量/(1-13.5%(含水量))/106 (7)

增产率(或抑制率)=(施药区产量-对照区产量)/对照区产量×100% (8)

1.3.4 安全性调查 在第2次施药后1,3,5,7,10,20,30 d,调查药剂处理对水稻生长发育的影响。

2 结果与分析

2.1 室内毒力测定结果

由表2可知:4种杀菌剂对水稻纹枯病的EC_{50}值由小到大依次是戊唑醇(0.321 2 mg/L)、氟唑菌酰羟胺(0.427 7 mg/L)、咪鲜胺(0.636 8 mg/L)、多菌灵(0.705 6 mg/L),而其EC_{95}值由小到大依次是戊唑醇(21.970 1 mg/L)、多菌灵(24.680 1 mg/L)、氟唑菌酰羟胺(25.832 1 mg/L)、咪鲜胺(40.960 3 mg/L),表明氟唑菌酰羟胺在很低的浓度下对水稻纹枯病具有良好的抑制效果。

表2 4种杀菌剂的毒力回归方程、EC_{50}、EC_{95}与相关系数

Tab.2 The virulence regression equation、EC_{50}、EC_{95} and correlation coefficient of 4 fungicides

杀菌剂 Fungicide	毒力回归方程 Regression equation	EC_{50}/($mg\cdot L^{-1}$)	EC_{95}/($mg\cdot L^{-1}$)	相关系数r Correlation coefficient
戊唑醇 Tebuconazole	Y=0.896 4X+5.442 1	0.321 2	21.970 1	0.991 5
氟唑菌酰羟胺 Pydiflumetofen	Y=0.923 7X+5.340 7	0.427 7	25.832 1	0.984 7
咪鲜胺 Prochloraz	Y=0.909 6X+5.178 3	0.636 8	40.960 3	0.989 1
多菌灵 Carbendazim	Y=1.065 5X+5.161 4	0.705 6	24.680 1	0.982 9

2.2 田间药效试验结果

2019年晚稻田间试验结果(表3)显示:在第2次施药后7 d,氟唑菌酰羟胺施药量为40~200 g/hm^2时对水稻纹枯病的防效为60.92%~69.51%,与对照药剂戊唑醇施药量为80 g/hm^2防效相当,且没有显著性差异;在第2次施药后14 d,氟唑菌酰羟胺施药量为120~200 g/hm^2时的防效均有所提高,最高达到了82.12%,与戊唑醇推荐剂量没有显著差异。在供试的氟唑菌酰羟胺5个剂量中,以施药量为200 g/hm^2时的防效最好,极显著高于施药量为40~120 g/hm^2的防效。

2020年早稻田间试验结果(表3)显示:在第2次施药后7 d,氟唑菌酰羟胺施药量为40~200 g/hm^2时对水稻纹枯病的防效为43.94%~51.39%,与对照药剂戊唑醇施药量为80 g/hm^2防效相当,没有显著性差异;在第2次施药后14 d,氟唑菌酰羟胺各剂量的防效均有所提高,最高达到了74.56%。在供试的氟唑菌酰羟胺5个剂量中,以施药量为160 g/hm^2时的防效最好,极显著高于施药量为40~80 g/hm^2的防效,与戊唑醇推荐施药量的防效相当。

两季试验结果表明:氟唑菌酰羟胺施药量为160~200 g/hm^2时,通过2次茎叶喷雾的方式施药对水稻纹枯病的防治效果最理想。

2.3 田间产量结果

两季产量结果(表4)显示:氟唑菌酰羟胺施药量对株高、穗长、千粒质量及有效穗数影响较小,但对单穗实粒数与产量结果影响较大。施药量为120~200 g/hm^2时:与不施药小区对比,2019年水稻增产率为11.77%~19.01%,2020年水稻增产率为76.74%~98.17%,其产量均高于同年对照药剂戊唑醇推荐剂量下的产量,说明其具有明显的增产作用。

表3 各药剂对水稻纹枯病的田间防治效果

Tab.3 Field control effect of various pesticides on rice sheath blight

时间 Time	编号 No.	病指基数 Cardinal number	第2次药后7 d 7 d after the second application			第2次药后14 d 14 d after the second application		
			病株率/% Rate of diseased plant	病指 Disease index	防效/% Control effect	病株率/% Rate of diseased plant	病指 Disease index	防效/% Control effect
2019年晚稻 Late rice	A	0.48	12.67	1.93	61.74aA	30.67	6.30	62.66cC
	B	0.40	10.67	1.63	60.92aA	21.00	4.70	65.22cC
	C	0.41	10.00	1.63	61.74aA	18.33	3.48	74.70bB
	D	0.37	10.33	1.44	62.70aA	17.67	2.63	79.06abAB
	E	0.59	17.00	1.89	69.51aA	23.00	3.59	82.12aA
	F	0.56	14.67	1.85	68.12aA	24.33	3.74	80.14abAB
	CK	0.41	21.70	4.26		64.33	13.81	
2020年早稻 Early rice	A	1.77	30.67	11.50	43.94bB	32.33	19.64	52.26cC
	B	1.49	21.33	9.49	45.02abAB	28.00	15.55	55.13cC
	C	1.16	18.00	7.17	46.87abAB	27.67	8.84	67.33bB
	D	1.68	17.67	9.59	50.65aA	29.33	9.91	74.56aA
	E	1.54	23.33	8.66	51.39aA	32.00	9.77	72.64abAB
	F	1.68	24.33	9.77	49.69abAB	40.67	11.82	69.67abAB
	CK	1.95	47.67	22.67	–	64.47	45.47	–

同列数据后标有不同小写字母者表示数据间差异显著(P<0.05),标有不同大写字母者表示数据间差异极显著(P<0.01)。

The lowercase letters after the same column indicate significant difference at 0.05 level, lowercase letters at the end of the same column indicate a very significant difference at the 0.01 level.

表4 不同药剂及处理对水稻产量性状的影响

Tab.4 Effects of different chemicals and treatments on rice yield and characters

时间 Time	编号 No.	株高/cm Plant height	穗长/cm Panicle length	有效穗/(万·hm^{-2}) Effective panicles	单穗实粒数 Filled spikelets per panicle	千粒质量/g 1 000-grain weight	理论产量/(kg·hm^{-2}) Theoretical yield	增产率/% Yield increase
2019年晚稻 Late rice	A	93.47aA	21.05aA	247.92aA	111.52cC	22.25aA	6 148.44cdCD	4.24cC
	B	95.40aA	21.43aA	245.83aA	113.7bcBC	22.47aA	6 267.90cdCD	6.26cC
	C	93.93aA	21.86aA	256.25aA	114.37abcABC	22.50aA	6 592.75abcABC	11.77abcABC
	D	93.10aA	21.87aA	251.10aA	119.75aA	22.90aA	6 883.05abAB	16.69abAB
	E	93.07aA	21.77aA	260.42aA	118.68abAB	22.70aA	7 019.51aA	19.01bcBC
	F	95.17aA	21.30aA	247.08aA	114.28abcABC	22.59aA	6 378.15bcdBCD	8.13bcBC
	CK	94.27aA	21.53aA	250.20aA	105.93dD	22.26aA	5 898.38dD	–
2020年早稻 Early rice	A	82.45aA	16.75aA	198.35aA	71.43bB	23.76aA	3 367.40dD	46.43aA
	B	80.92aA	16.00aA	196.67aA	73.2bB	23.47aA	3 378.19dD	46.90aA
	C	83.58aA	16.58aA	205.00aA	74.32bB	23.82aA	3 628.84cC	57.80cC
	D	80.75aA	16.45aA	200.25aA	86.23aA	23.57aA	4 064.28bB	76.74bB
	E	81.58aA	15.63aA	208.33aA	91.38aA	23.98aA	4 557.09aA	98.17aA
	F	82.58aA	16.08aA	195.00aA	88.41aA	23.81aA	4 103.92bB	78.46bB
	CK	81.58aA	15.92aA	200.00aA	50.28cC	22.84aA	2 299.66eE	–

同列数据后标有不同小写字母者表示数据间差异显著(P<0.05),标有不同大写字母者表示数据间差异极显著(P<0.01)。

The lowercase letters after the same column indicate significant difference at 0.05 level, lowercase letters at the end of the same column indicate a very significant difference at the 0.01 level.

2.4 安全性调查结果

施药后不定期目测观察,各处理小区的水稻在叶形、色泽、扬花、抽穗以及成熟时均正常,未见矮化、畸形或者褪色等药害症状,水稻生长正常。这表明,供试药剂在试验剂量范围内对水稻生长发育安全。

3 结论与讨论

由于水稻在生产种植中缺乏纹枯病高抗品种,化学防治仍然是其主要的防治措施[23-24]。而咪鲜胺、多菌灵、井冈霉素等药剂的长期使用,使得纹枯病菌株的抗药性越来越高,常规推荐剂量下的防效正逐年下降,通过试验筛选新药剂成为重中之重[25-26]。氟唑菌酰羟胺作为先正达开发的吡唑酰胺类杀菌剂,已有报道其对多种真菌病害具有良好的防治效果,并且被多国登记和上市。

通过室内毒力测定得知,在马铃薯葡萄糖琼脂培养基上,氟唑菌酰羟胺对水稻纹枯病菌的EC_{50}和EC_{95}分别为0.427 7 mg/L和25.832 1 mg/L;接近戊唑醇的EC_{50}(0.321 2 mg/L)和EC_{95}(21.970 1 mg/L),说明氟唑菌酰羟胺作为新型药剂,能够有效抑制水稻纹枯病菌。田间药效试验表明:在2019年晚稻氟唑菌酰羟胺施用量为160~200 g/hm^{2}时7 d、14 d的防效分别为62.7%~69.5%和79%~82%;2020年早稻的防效分别为50.7%~51.4%和72.6%~74.6%;均优于当季戊唑醇推荐用量为80 g/hm^{2}时的防效。与空白处理小区相比,单季最高增产可达98.17%。由此结果对比得出,氟唑菌酰羟胺施药量为160~200 g/hm^{2}时,并且经2次茎叶喷雾后对水稻纹枯病菌具有良好的防治效果,可有效降低病株率及病情指数,延缓病菌抗药性,并能够有效避免纹枯病的大规模发生,增加其产量,增加农民收入,且对水稻生长安全,为后续氟唑菌酰羟胺在水稻上的应用提供科学依据。

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