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# 麦田多花黑麦草种群对 ACCase 及 ALS 类抑制剂的抗性 及土壤处理药剂筛选

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**摘要:**为明确多花黑麦草(*Lolium multiflorum*)对乙酰辅酶 A 羧化酶(ACCCase)及乙酰乳酸合成酶(ALS)类除草剂的抗性现状,在河南省驻马店市麦田多花黑麦草发生严重区域采集了 50 个种群,采用整株生物测定法分别测定了其对于唑啶草酯、炔草酯、啶磺草胺的抗性水平;另选择异丙隆、吡氟酰草胺、氟噻草胺、砒吡草唑、吡酰·异丙隆、啶磺草胺对其进行生物活性测定;并将砒吡草唑、氟噻草胺、啶磺草胺与吡酰·异丙隆混配开展田间药效评价。结果表明,供试多花黑麦草种群中,8 个种群对唑啶草酯表现高水平抗性,GR<sub>50</sub> 值(抑制杂草地上部分鲜重 50% 时所使用的除草剂剂量)在 146.67~456.15 g(a.i.)·hm<sup>-2</sup> 之间,抗性指数(RI)在 10.68~33.20 之间,占供试种群的 16%;31 个种群对炔草酯表现高水平抗性,GR<sub>50</sub> 在 101.82~446.40 g(a.i.)·hm<sup>-2</sup> 之间,RI 在 10.36~45.41 之间;16 个种群对啶磺草胺表现高水平抗性,占总数的 32%。除吡氟酰草胺和啶磺草胺外,其余 4 种除草剂(异丙隆、氟噻草胺、砒吡草唑、吡酰·异丙隆)对 SC-3(最高水平抗性种群)的生物活性均较高,GR<sub>90</sub> 分别为 1 089.36、144.43、51.42、568.69 g(a.i.)·hm<sup>-2</sup>。从田间药效看,砒吡草唑与吡酰·异丙隆混配在供试剂量下对多花黑麦草的防效较好,鲜重防效可达 94.27%~100%,且对小麦安全。因此,对于多花黑麦草发生严重的麦田,可采用该配方进行防治。

**关键词:**多花黑麦草;抗药性;生物活性;药剂筛选;防除效果

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## Resistance Levels of *Lolium multiflorum* Populations to ACCase and ALS Inhibitors and the Screening of Pre-Emergence Herbicides in Wheat Fields

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**Abstract:** In order to clarify the current resistance status of *Lolium multiflorum* to the herbicides of acetyl CoA carboxylase(ACCCase) and acetolactate synthase(ALS), a total of 50 populations were collected in the severe area of *L. multiflorum* in Zhumadian City, Henan Province and the resistance levels to pinoxaden, clodinafop-propargyl and pyroxsulam were determined by the whole-plant bioassay method. In addition, isoproturon, diflufenican, flufenacet, pyroxsulfone, diflufenican+isoproturon, and pyroxsulam were selected for bioactivity determination, and field efficacy evaluation were conducted with pyroxsulfone, flufenacet, and pyroxsulam mixed with diflufenican+isoproturon. The results showed that eight populations of *L. multiflorum* had high resistance to pinoxaden. The GR<sub>50</sub> (herbicide dose causing growth reduction of fresh weight by 50%) values ranged from 146.67 g(a.i.)·hm<sup>-2</sup> to 456.15 g(a.i.)·hm<sup>-2</sup>, and the resistance index(RI) ranged from 10.68 to 33.20, accounting

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for 16% of the tested populations. Thirty-one populations showed high level resistance to clodinafop-propargyl, with  $GR_{50}$  ranging from 101.82 g(a. i.) · hm<sup>-2</sup> to 446.40 g(a. i.) · hm<sup>-2</sup>, and RI ranging from 10.36 to 45.41; sixteen populations had high level resistance to pyroxsulam, accounting for 32% of the total. In the bioactivity assays, except for diflufenican and pyroxsulam, the other herbicides (isoproturon, flufenacet, pyroxasulfone, diflufenican+isoproturon) showed high activity against the SC-3 population (the highest level of resistance population), with  $GR_{90}$  values of 1 089.36, 144.43, 51.42 and 568.69 g(a. i.) · hm<sup>-2</sup>, respectively. Field efficacy results indicated that the mixture of pyroxasulfone and diflufenican+isoproturon provided good control of *L. multiflorum* at the supplied dose, with fresh weight control efficacy ranging from 94.27% to 100%, and safe to wheat. Therefore, the mixture of pyroxasulfone and diflufenican+isoproturon can be used to control the serious occurrence of *L. multiflorum* in wheat fields.

**Keywords:** *Lolium multiflorum*; Resistance; Bioactivity; Herbicides screening; Control efficacy

小麦是河南省的主产粮食作物之一,保障小麦生产安全对促进农业提质增效、农民持续增收等均具有重要意义<sup>[1-2]</sup>。由于近年来气候条件的变化、种植方式及用药方式的改变,小麦田杂草群落发生变化,节节麦、野燕麦、多花黑麦草等恶性禾本科杂草蔓延迅速且防治困难。据报道,河南省驻马店多花黑麦草发生面积占当地冬小麦种植面积的 30% 以上,发生严重地区小麦产量损失可达 50% 以上<sup>[3-4]</sup>。

多花黑麦草原产于欧洲南部、非洲北部等地,因具有生长速度快、粗蛋白含量高等优点而被引进中国作饲草<sup>[5]</sup>。但其繁殖能力较强且极易随耕作机械进行传播,近年来在中国河南、江苏、安徽、湖南等地区逐渐蔓延<sup>[6]</sup>。目前生产实践中对多花黑麦草主要采用化学防除,多使用 ACCase 抑制剂类的精噁唑禾草灵、唑啉草酯或 ALS 抑制剂类的甲基二磺隆和啶磺草胺等进行茎叶喷雾<sup>[7-9]</sup>。由于长期大量使用同一作用机制的除草剂,多花黑麦草产生抗药性,生产中难以被有效防除<sup>[10-12]</sup>。徐洪乐等<sup>[13]</sup>研究表明,精噁唑禾草灵、啶磺草胺等 6 种茎叶处理药剂在推荐剂量下对采自河南省驻马店市多花黑麦草的活性较差;张佩等<sup>[14]</sup>测定了采自河南、江苏、陕西、山东省共 50 个多花黑麦草种群,发现驻马店市的多花黑麦草种群对精噁唑禾草灵抗性指数最高,达 99.39;贾增坡等<sup>[15]</sup>通过田间试验发现,唑啉草酯对驻马店市抗性多花黑麦草的防治效果极差。继续使用上述除草剂将导致多花黑麦草抗性进一步加强<sup>[16-18]</sup>。

基于此,本研究拟采用整株生物测定法,检测采自河南省驻马店市小麦田 50 个多花黑麦草种群对 ACCase、ALS 类抑制剂的抗性水平,并进行氟噻草胺、砒吡草唑、啶磺草胺与吡酰·异丙隆田

间混配试验,以期小麦田多花黑麦草的化学防除及其抗药性延缓等提供科学依据。

## 1 材料与方法

### 1.1 供试材料

#### 1.1.1 供试杂草

供试 50 个多花黑麦草种群均为安徽丰乐农化有限责任公司提供,于 2019 年采自驻马店市 ACCase 及 ALS 类除草剂使用年限较长、杂草发生严重的田块,具体信息见表 1。敏感种群(S)为本实验室保存的株系,采自安徽省滁州市明光市苏巷镇吉庄村未使用过除草剂的非耕地。种子采集晾干后贮存备用。

#### 1.1.2 供试除草剂

供试除草剂详细信息见表 2。

### 1.2 试验设计

#### 1.2.1 多花黑麦草种群对常用 ACCase 及 ALS 类除草剂的抗药性水平测定

将多花黑麦草种子经 75% 酒精消毒 3~4 次,去除杂质及瘪粒种子,用蒸馏水清洗干净;在无菌培养皿底部平铺两层浸湿的滤纸,均匀撒入约百粒种子,放入培养箱,于光照 12 h/12 h、温度 20 °C/15 °C、相对湿度 75%~80% 的条件下,催芽 3~5 d;将发芽后的种子均匀播入装有混合土(壤土:河沙=5:1,体积比)的塑料花盆(高 10 cm,直径 15 cm)内,每盆播种 25 粒,播后覆 0.5~1.0 cm 细土,自盆底吸水至饱和时放入可调控温室,在光照 12 h/12 h、温度 24±2 °C/18±2 °C、相对湿度 60%~75% 的条件下,培养至 1 叶 1 心期,间苗至每盆 20 株。根据预试验的结果,各除草剂的剂量设计如表 3 所示,每处理重复 4 次,试验重复 2 次。

表 1 供试多花黑麦草种群信息  
Table 1 Information of *L. multiflorum* populations tested

编号 No.	采集地区(驻马店市) Collection area(Zhumadian city)	经纬度 Longitude & latitude	编号 No.	采集地区(驻马店市) Collection area(Zhumadian city)	经纬度 Longitude & latitude
YC-1	驿城区沙河镇大李庄村 Daizhuang Village, Shahe Town, Yicheng District	113.712° E; 32.978° N	QS-1	确山县留庄镇张里山村 Zhanglishan Village, Liuzhuang Town, Queshan County	114.199° E; 32.673° N
YC-2	驿城区沙河镇杨庄村 Yangzhuang Village, Shahe Town, Yicheng District	113.708° E; 32.993° N	QS-2	确山县留庄镇代庄村 Daizhuang Village, Liuzhuang Town, Queshan County	114.202° E; 32.628° N
YC-3	驿城区板桥镇任张楼村 RenzhangLou Village, Banqiao Town, Yicheng District	113.678° E; 33.004° N	QS-3	确山县双河镇大戴庄村 Dadaizhuang Village, Shuanghe Town, Queshan County	114.171° E; 32.541° N
YC-4	驿城区老河乡东赵岗村 Dongzhaogang Village, Laohe Town, Yicheng District	113.784° E; 32.977° N	QS-4	确山县双河镇陈店村 Chendian Village, Shuanghe Town, Queshan County	114.148° E; 32.538° N
YC-5	驿城区水屯镇陈楼村 Chenlou Village, Shuitun Town, Yicheng District	114.155° E; 32.993° N	QS-5	确山县石滚河镇陈冲村 Chenchong Village, Shigunhe Town, Queshan County	113.815° E; 32.692° N
SP-1	遂平县文城乡前李村 Qianli Village, Wencheng Town, Suiping County	113.765° E; 33.059° N	BY-1	泌阳县高邑镇史洼村 Shiwa Village, Gaoyi Town, Biyang County	113.480° E; 32.732° N
SP-2	遂平县玉山镇吴庄村 Wuzhuang Village, Yushan Town, Suiping County	113.819° E; 33.196° N	BY-2	泌阳县高邑镇党庄村 Dangzhuang Village, Gaoyi Town, Biyang County	113.423° E; 32.718° N
SP-3	遂平县和兴镇张店村 Zhangdian Village, Hexing Town, Suiping County	114.0498° E; 33.227° N	BY-3	泌阳县杨家集镇晁庄村 Chaozhuang Village, Yangjiatou Town, Biyang County	113.323° E; 32.811° N
SP-4	遂平县常庄镇徐楼村 Xulou Village, Changzhuang Town, Suiping County	114.175° E; 33.181° N	BY-4	泌阳县贾楼乡凤凰台村 Fenghuangtai Village, Jialou Town, Biyang County	113.362° E; 32.905° N
SP-5	遂平县花庄镇赵庄村 Zhaozhuang Village, Huazhuang Town, Suiping County	113.816° E; 33.094° N	BY-5	泌阳县羊册镇荒庄村 Huangzhuang Village, Yangce Town, Biyang County	113.308° E; 32.965° N
XP-1	西平县盆尧镇叶李村 Yeli Village, Penyao Town, Xiping County	114.137° E; 33.358° N	RN-1	汝南县老君庙镇余子河村 Yuzihe Village, Laojunmiao Town, Ruman County	114.274° E; 32.872° N
XP-2	西平县盆尧镇徐杨村 Xuyang Village, Penyao Town, Xiping County	114.129° E; 33.399° N	RN-2	汝南县老君庙镇白腰村 Baiyan Village, Laojunmiao Town, Ruman County	114.287° E; 32.888° N
XP-3	西平县盆尧镇于营村 Yuying Village, Penyao Town, Xiping County	114.103° E; 33.387° N	RN-3	汝南县东官庄镇李塘村 Litang Village, Dongguanhuang Town, Ruman County	114.293° E; 32.809° N
XP-4	西平县出山镇罗岗庄 Luogangzhuang, Chushan Town, Xiping County	113.635° E; 33.297° N	RN-4	汝南县东官庄镇大湾村 Dawan Village, Dongguanhuang Town, Ruman County	114.248° E; 32.849° N
XP-5	西平县出山镇翟老庄 Zhailaozhuang, Chushan Town, Xiping County	113.649° E; 33.333° N	RN-5	汝南县张楼镇庙东村 Miaodong Village, Zhanglou Town, Ruman County	114.210° E; 33.136° N
SC-1	上蔡县黄埠镇新庄村 Xinzhuang Village, Huangbu Town, Shangcai County	114.155° E; 32.993° N	XC-1	新蔡县韩集镇熊楼村 Xiongrou Village, Hanji Town, Xincai County	114.982° E; 32.924° N
SC-2	上蔡县黄埠镇汝河村 Ruhe Village, Huangbu Town, Shangcai County	114.229° E; 33.186° N	XC-2	新蔡县韩集镇袁庄村 Yuanzhuang Village, Hanji Town, Xincai County	114.975° E; 32.861° N
SC-3	上蔡县黄埠镇后张村 Houzhang Village, Huangbu Town, Shangcai County	114.184° E; 33.205° N	XC-3	新蔡县黄楼镇黄楼村 Huanglou Village, Huanglou Town, Xincai County	114.750° E; 32.845° N
SC-4	上蔡县黄埠镇新庄村 Xinzhuang Village, Huangbu Town, Shangcai County	114.184° E; 33.135° N	XC-4	新蔡县黄楼镇黄寨村 Huangzhai Village, Huanglou Town, Xincai County	114.755° E; 32.819° N
SC-5	上蔡县黄埠镇蔡寨口村 Caibukou Village, Huangbu Town, Shangcai County	114.231° E; 33.205° N	XC-5	新蔡县黄楼镇秦桥村 Qinqiao Village, Huanglou Town, Xincai County	114.754° E; 32.829° N
PY-1	平舆县庙湾镇大杨村 Dayang Village, Miaowan Town, Pingyu County	114.699° E; 33.035° N	ZY-1	正阳县汝南埠镇洪山村 Hongshan Village, Rumanbu Town, Zhengyang County	114.759° E; 32.605° N
PY-2	平舆县庙湾镇汪庄村 Wazhang Village, Miaoyangbu Town, Pingyu County	114.804° E; 32.950° N	ZY-2	正阳县汝南埠镇余楼村 Yulou Village, Rumanbu Town, Zhengyang County	114.807° E; 32.631° N
PY-3	平舆县阳城镇西张营村 Xizhangying Village, Yangcheng Town, Pingyu County	114.485° E; 33.106° N	ZY-3	正阳县吕河乡夏庄村 Xiazhuang Village, Lyhe Town, Zhengyang County	114.474° E; 32.518° N
PY-4	平舆县阳城镇岭王村 Lingwang Village, Yangcheng Town, Pingyu County	114.471° E; 33.122° N	ZY-4	正阳县彭桥乡大张村 Dazhang Village, Pengqiao Town, Zhengyang County	114.395° E; 32.459° N
PY-5	平舆县万冢镇张刘村 Zhangliu Village, Wanzhong Town, Pingyu County	114.500° E; 33.022° N	ZY-5	正阳县横水乡洪庙村 Hongmiao Village, Shenshui Town, Zhengyang County	114.407° E; 32.566° N

表 2 供试药剂信息

Table 2 Tested herbicides information

供试药剂 Tested herbicide	生产厂家 Manufacturer	作用机制 Mechanism
95%唑啉草酯原药 Pinoxaden 95% TC	瑞士先正达作物保护有限公司 Syngenta Crop Protection AG	乙酰辅酶 A 羧化酶抑制剂 Acetyl-CoA carboxylase inhibitor
95%炔草酯原药 Clodinafop-propargyl 95% TC	瑞士先正达作物保护有限公司 Syngenta Crop Protection AG	乙酰辅酶 A 羧化酶抑制剂 Acetyl-CoA carboxylase inhibitor
96.5%啶磺草胺原药 Pyroxulam 96.5% TC	科迪华农业科技有限责任公司 Corteva Agriscience Technology Co. Ltd.	乙酰乳酸合成酶抑制剂 Acetolactate synthase inhibitor
95%异丙隆原药 Isoproturon 95% TC	安徽华星化工有限公司 Anhui Huaxing Chemical Co. Ltd.	光合作用光系统II抑制剂 Photosynthesis PS II inhibitor
97%吡氟酰草胺原药 Diflufenican 97% TC	拜耳股份公司 Bayer Crop Science (China) Co. Ltd.	八氢番茄红素合酶抑制剂 Phytoene desaturase inhibitor
98%氟噻草胺原药 Flufenacet 98% TC	江西众和生物科技有限公司 Jiangxi Zhonghe Biotechnology Co. Ltd.	极长链脂肪酸合成抑制剂 Very long-chain fatty acid synthesis inhibitor
98%砜吡草唑原药 Pyroxasulfone 98% TC	上海群力化工有限公司 Shanghai Qunli Chemical Co. Ltd.	极长链脂肪酸合成抑制剂 Very long-chain fatty acid synthesis inhibitor
55%吡酰·异丙隆悬浮剂 Diflufenican+isoproturon 55% SC	安徽丰乐农化有限责任公司 Anhui Fengle Agrochemical Co. Ltd.	—

表 3 抗性水平测定所用药剂及剂量

Table 3 Herbicides and doses for resistance level determination

供试药剂 Tested herbicide	种群 Population	剂量 Dose/[g (a. i.) · hm <sup>-2</sup> ]
95%唑啉草酯原药 Pinoxaden 95% TC	敏感种群 Sensitive population	0, 1.97, 3.95, 7.9, 15.79, 31.58, <u>63.16</u>
	供试种群 Test population	0, 31.58, <u>63.16</u> , 126.32, 252.64, 505.28, 1 010.56
95%炔草酯原药 Clodinafop-propargyl 95% TC	敏感种群 Sensitive population	0, 2.59, 5.18, 10.36, 20.72, 41.45, <u>82.89</u>
	供试种群 Test population	0, 41.45, <u>82.89</u> , 165.78, 331.56, 663.12, 1 326.24
96.5%啶磺草胺原药 Pyroxulam 96.5% TC	敏感种群 Sensitive population	0, 0.46, 0.91, 1.82, 3.64, 7.28, <u>14.57</u>
	供试种群 Test population	0, 7.28, <u>14.57</u> , 29.14, 58.28, 116.56, 233.12

加下划线的数字表示该药剂的田间推荐剂量。下同。

The recommended dose is indicated by an underline. The same in table 4.

待供试杂草长至 3 叶 1 心期时,使用 JY-3WP-2000 行走式喷雾塔精准喷雾施药,扇形喷头,喷液压力 275 kPa,喷头距杂草顶端 50 cm,喷液量 450 L · hm<sup>-2</sup>;喷药后培养 21 d,称量杂草地上部分鲜重,按照公式(1)计算鲜重抑制率(E);以各供试剂量对数值(x)和不同剂量下杂草鲜重抑制率几率值(y)拟合毒力回归方程(y = a + bx)、GR<sub>50</sub> 值及 95%置信区间;按照公式(2)计算抗性指数(resistance index, RI),按照 RI 划分抗性等级,划分标准:RI < 2.0 为敏感,2.0 ≤ RI < 5.0 为低抗,5.0 ≤ RI < 10.0 为中抗,RI ≥ 10.0 为高抗<sup>[19]</sup>。

$$E = [(M_0 - M) / M_0] \times 100\% \quad (1)$$

$$RI = \text{抗性种群 GR}_{50} / \text{敏感种群 GR}_{50} \quad (2)$$

式中, M<sub>0</sub> 为空白对照组鲜重, M 为药剂处理

组鲜重。

### 1.2.2 高抗多花黑麦草种群对其他除草剂室内生物活性测定

选择已登记的 5 种土壤处理和 1 种茎叶处理除草剂,对 1.2.1 中表现为高抗的种群进行抗性检测,具体供试药剂及剂量见表 4;土壤处理和茎叶处理方法分别参照 GB NY/T 1155.3—2006 和 GB NY/T 1155.4—2006 进行。

### 1.2.3 不同除草剂与吡酰·异丙隆混配对多花黑麦草的田间药效测定

参照 GB/T 17980.41—2000,在河南省驻马店市上蔡县黄埠镇新庄村董庄(114.300°E; 32.223°N)进行。小麦品种为百农 607,播种量为 250 kg · hm<sup>-2</sup>,播前底肥施用复合肥 1 800 kg · hm<sup>-2</sup>;耕地

方式为深翻加旋耕,土质偏砂质,于2022年10月24日机条播。施药前田块地势平整,前期调查多花黑麦草发生量为 $100\sim 300$ 株 $\cdot$   $m^{-2}$ ;前茬作物为花生。单剂剂量设定均为该药剂所登记的推荐最高剂量,混剂剂量设定均为每个单剂的推荐剂量中量与吡酰·异丙隆推荐量低量、中量、高量混配,采用二次稀释法配制药剂,充分混匀后进行喷施。具体处理剂量见表5。每个处理4次重复,共56个小区,小区面积为 $20$   $m^2$  ( $4$   $m\times 5$   $m$ ),采用完全随机区组排列,于播种当天施药,施药当天天气阴,最高温度 $24$   $^{\circ}C$ ,最低温度 $12$   $^{\circ}C$ ,施药时温度 $20$   $^{\circ}C$ ,西风 $1.0$   $m\cdot s^{-1}$ ,相对湿度 $62\%$ 。试验期间无大

幅度升、降温天气。采用3WBD-10B背负式电动喷雾器施药,喷雾器流速 $1\ 200$   $mL\cdot min^{-1}$ ,扇形喷头,各区组间均留 $0.5$   $m$ 隔离带;喷液量 $450$   $L\cdot hm^{-2}$ 。分别于药后 $7$   $d$ 、 $30$   $d$ 及 $45$   $d$ 观察不同小区内小麦有无药害症状、受害程度、生长状况及杂草变化。采用绝对值法调查株防效与鲜重防效:每小区沿对角线随机取 $3$ 点,每点 $0.25$   $m^2$ ,调查各取样点内多花黑麦草的存活株数(以茎秆计数);于药后 $60$   $d$ 调查时,剪取样框内杂草的地上部分并称重,计算各小区杂草的株数及鲜重总值,按公式(3)计算株防效( $P_e$ ),鲜重防效( $W$ )计算方法同公式(1)。

表4 室内生物活性测定药剂及剂量

Table 4 Herbicides and doses for laboratory biological activity determination

供试药剂 Tested herbicide	剂量 Dose/[g(a. i.) $\cdot$ $hm^{-2}$ ]
95%异丙隆原药 Isoproturon 95% TC	0,493.42,986.84,1973.68,3947.36,7894.72,15789.44
97%吡氟酰草胺原药 Diflufenican 97% TC	0,77.32,154.64,309.28,618.56,1237.12,2474.24
98%氟噻草胺原药 Flufenacet 98% TC	0,65.90,131.79,263.58,527.16,1054.32,2108.64
98%砒吡草唑原药 Pyroxasulfone 98% TC	0,21.05,42.09,84.19,168.37,336.74,673.48
55%吡酰·异丙隆 SC Diflufenican+Isoproturon 55% SC	0,154.69,309.38,618.75,1237.5,2475.4950
96.5%啶磺草胺原药 Pyroxsulam 96.5% TC	0,6.22,12.44,24.88,49.76,99.52,199.04

表5 田间药效试验所用药剂及剂量

Table 5 Herbicides and doses for field efficacy determination

编号 NO.	处理 Treatment	剂量 Dose/[g(a. i.) $\cdot$ $hm^{-2}$ ]
1	40%砒吡草唑 SC Pyroxasulfone 40% SC	180
2	41%氟噻草胺 SC Flufenacet 41% SC	147.6
3	4%啶磺草胺 OD Pyroxsulam 4% OD	15
4	55%吡酰·异丙隆 SC Diflufenican+Isoproturon 55% SC	1402.5
5	40%砒吡草唑 SC+55%吡酰·异丙隆 SC Pyroxasulfone 40% SC+(Diflufenican+Isoproturon 55% SC)	165+1072.5
6	40%砒吡草唑 SC+55%吡酰·异丙隆 SC Pyroxasulfone 40% SC+(Diflufenican+Isoproturon 55% SC)	165+1237.5
7	40%砒吡草唑 SC+55%吡酰·异丙隆 SC Pyroxasulfone 40% SC+(Diflufenican+Isoproturon 55% SC)	165+1402.5
8	41%氟噻草胺 SC+55%吡酰·异丙隆 SC Flufenacet 41% SC+(Diflufenican+Isoproturon 55% SC)	129.15+1072.5
9	41%氟噻草胺 SC+55%吡酰·异丙隆 SC Flufenacet 41% SC+(Diflufenican+Isoproturon 55% SC)	129.15+1237.5
10	41%氟噻草胺 SC+55%吡酰·异丙隆 SC Flufenacet 41% SC+(Diflufenican+Isoproturon 55% SC)	129.15+1402.5
11	4%啶磺草胺 OD+55%吡酰·异丙隆 SC Pyroxsulam 4% OD+(Diflufenican+Isoproturon 55% SC)	12+1072.5
12	4%啶磺草胺 OD+55%吡酰·异丙隆 SC Pyroxsulam 4% OD+(Diflufenican+Isoproturon 55% SC)	12+1237.5
13	4%啶磺草胺 OD+55%吡酰·异丙隆 SC Pyroxsulam 4% OD+(Diflufenican+Isoproturon 55% SC)	12+1402.5
14	空白对照 CK	—

$$P_e = [(L_{CK} - L) / L_{CK}] \times 100\% \quad (3)$$

式中,  $L_{CK}$  为空白对照区多花黑麦草株数,  $L$  为各药剂处理区多花黑麦草株数。

小麦收获期进行测产, 各小区去除边行后, 取 1 m 样点调查有效穗数; 选取 100 株, 测定穗粒数、千粒重; 每小区取 1 m<sup>2</sup> 实收测产, 计算理论产量, 并按公式(5)计算增产率( $Y$ )。

$$Y = [(B - D_{CK}) / D_{CK}] \times 100\% \quad (4)$$

式中,  $B$  为各药剂处理区小麦实收产量,  $D_{CK}$  为空白对照区小麦实收产量。

### 1.3 数据处理

试验数据使用 DPS 7.05 进行统计分析, 用 Duncan 新复极差法进行差异显著性分析, 用 Origin 2018 作图。

## 2 结果与分析

### 2.1 不同多花黑麦草种群对常用 ACCase 及 ALS 类除草剂的抗性

#### 2.1.1 对唑啉草酯的抗性

由表 6、图 1 可知, 不同种群的多花黑麦草对唑啉草酯的抗性程度不同, 其中 8 个种群对唑啉草酯表现高抗, 占供试种群的 16%; 抗性最高的为采自上蔡县黄埠镇后张村的种群 SC-3, RI 为 33.20, GR<sub>50</sub> 为 456.15 g(a. i.) · hm<sup>-2</sup>, 其次为种群 SC-2, RI 和 GR<sub>50</sub> 分别为 24.70、339.31 g(a. i.) · hm<sup>-2</sup>。对唑啉草酯中抗的种群有 17 个, 占总种群的 34%, GR<sub>50</sub> 在 69.95~131.92 g(a. i.) · hm<sup>-2</sup> 间; 对唑啉草酯表现低抗的种群有

表 6 不同多花黑麦草种群对唑啉草酯的抗性

Table 6 Resistance of different *L. multiflorum* populations to pinoxaden

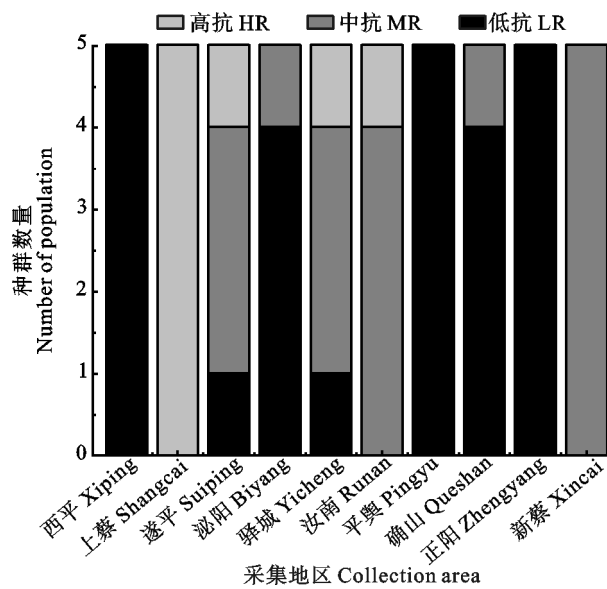
种群编号 Population No.	回归方程 Regression equation	相关系数 Correlation coefficient	GR <sub>50</sub> / [g (a. i.) · hm <sup>-2</sup> ]	95%置信区间 confidence interval/ [g(a. i.) · hm <sup>-2</sup> ]	抗性指数 Resistance index
S	$y = 2.2249 + 2.4389x$	0.956 3*	13.74	9.58~19.69	1.00
YC-1	$y = -1.3196 + 3.2680x$	0.877 1	85.86	40.68~181.22	6.25
YC-2	$y = 0.5571 + 2.0509x$	0.998 2*	146.67	136.54~157.55	10.68
YC-3	$y = -2.6489 + 4.2425x$	0.950 4*	63.52	38.37~105.17	4.62
YC-4	$y = 1.9244 + 1.4571x$	0.997 5*	129.06	118.42~140.67	9.39
YC-5	$y = -2.3635 + 3.6315x$	0.907 3	106.59	59.29~191.62	7.76
QS-1	$y = -2.6976 + 4.2423x$	0.943 1	65.24	38.13~111.62	4.75
QS-2	$y = -1.5930 + 3.4571x$	0.927 7	80.74	46.02~141.65	5.88
QS-3	$y = -1.8240 + 3.9250x$	0.929 5	54.78	28.58~105.00	3.99
QS-4	$y = -1.6720 + 3.9169x$	0.951 4*	50.51	29.17~87.47	3.68
QS-5	$y = -2.3935 + 4.1297x$	0.937 8	61.70	34.65~109.89	4.49
SP-1	$y = 0.6566 + 1.9765x$	0.996 6*	157.60	143.20~173.46	11.47
SP-2	$y = -1.5820 + 3.5384x$	0.954 5*	72.47	45.95~114.30	5.27
SP-3	$y = -2.0038 + 4.0370x$	0.955 1*	54.32	32.60~90.48	3.95
SP-4	$y = -0.7723 + 3.1290x$	0.892 3	69.95	33.09~147.86	5.09
SP-5	$y = 0.2715 + 2.3117x$	0.997 1*	111.04	100.90~122.20	8.08
BY-1	$y = -1.3497 + 3.3676x$	0.921 4	76.83	42.13~140.10	5.59
BY-2	$y = -1.7870 + 3.9546x$	0.950 9*	52.03	30.15~89.77	3.79
BY-3	$y = -2.1968 + 4.0754x$	0.943 1	58.33	33.22~102.43	4.25
BY-4	$y = -1.8574 + 4.0053x$	0.962 1*	51.53	32.00~82.99	4.25
BY-5	$y = -2.4996 + 4.1762x$	0.942 6	62.49	36.08~108.25	4.55
RN-1	$y = 1.1683 + 1.8071x$	0.995 3*	131.92	117.34~148.31	9.60
RN-2	$y = -1.9401 + 3.5107x$	0.909 6	94.81	51.98~172.92	6.90
RN-3	$y = -1.4853 + 3.3123x$	0.881 3	90.77	44.33~185.85	6.61
RN-4	$y = 1.3620 + 1.6585x$	0.992 6*	156.17	135.39~180.15	11.37
RN-5	$y = 1.4533 + 1.6990x$	0.988 5*	122.34	101.57~147.35	8.90
XP-1	$y = 2.4215 + 1.4373x$	0.978 8*	62.23	44.97~86.12	4.53

(续表 6 Continued table 6)

种群编号 Population No.	回归方程 Regression equation	相关系数 Correlation coefficient	GR <sub>50</sub> / [g (a. i.) • hm <sup>-2</sup> ]	95%置信区间 95% Confidence interval/ [g(a. i.) • hm <sup>-2</sup> ]	抗性指数 Resistance index
XP-2	$y = -0.5630 + 3.0606x$	0.887 3	65.71	29.83~144.71	4.78
XP-3	$y = -1.8679 + 3.9498x$	0.935 3	54.80	29.47~101.91	3.99
XP-4	$y = -1.7528 + 3.8971x$	0.926 4	54.05	27.65~105.64	3.93
XP-5	$y = -2.3594 + 4.1432x$	0.947 5	59.74	35.03~101.86	4.35
SC-1	$y = 0.5438 + 2.0167x$	0.991 5*	162.07	139.10~188.83	11.80
SC-2	$y = 0.3260 + 1.8470x$	0.993 5*	339.31	291.59~394.83	24.70
SC-3	$y = 0.1655 + 1.8181x$	0.993 1*	456.15	383.07~543.17	33.20
SC-4	$y = 2.3901 + 1.0753x$	0.989 4*	267.36	223.33~320.07	19.46
SC-5	$y = 0.7680 + 1.7306x$	0.984 5*	278.90	223.68~347.74	20.30
XC-1	$y = -1.2603 + 3.2944x$	0.902 7	79.49	40.67~155.34	5.79
XC-2	$y = -1.2563 + 3.2653x$	0.890 9	82.42	40.67~167.03	6.00
XC-3	$y = 1.3357 + 1.7588x$	0.995 4*	121.19	107.76~136.31	8.82
XC-4	$y = 1.4681 + 1.7009x$	0.993 1*	119.25	103.19~137.82	8.68
XC-5	$y = -1.4856 + 3.3684x$	0.905 8	84.23	44.28~160.22	6.13
ZY-1	$y = -2.8443 + 4.3370x$	0.961 4*	64.37	41.53~99.77	4.69
ZY-2	$y = -1.4363 + 4.1248x$	0.939 5	36.34	17.88~73.85	2.65
ZY-3	$y = -1.7981 + 3.9463x$	0.944 9	52.80	29.66~93.99	3.84
ZY-4	$y = -1.4240 + 3.7912x$	0.928 6	49.48	24.97~98.04	3.60
ZY-5	$y = -2.0284 + 4.0735x$	0.963 1*	53.14	33.41~84.52	3.87
PY-1	$y = -1.3486 + 4.0640x$	0.929 8	36.49	16.92~78.71	2.67
PY-2	$y = -1.9721 + 4.0436x$	0.960 7*	52.99	32.78~85.68	3.86
PY-3	$y = -1.6275 + 3.8850x$	0.941 6	50.80	27.74~93.05	3.70
PY-4	$y = -1.0219 + 3.6505x$	0.924 3	44.63	21.34~93.36	3.25
PY-5	$y = -0.7409 + 3.8472x$	0.930 0	31.06	13.71~70.38	2.26

\* :  $P < 0.05$ 。下同。

\* :  $P < 0.05$ 。The same in tables 7 and 8.



HR: High resistance; MR: Middle resistance; LR: Low resistance. 下同。The same below.

图 1 不同县区多花黑麦草种群对啶啉草酯的抗性

Fig. 1 Resistance levels of *L. multiflorum* to pinoxaden from different counties

25个,占比50%,RI最高为4.78。值得重视的是,采自上蔡县的5个多花黑麦草种群对唑啉草酯均表现高抗。

2.1.2 对炔草酯的抗性

供试多花黑麦草种群施用炔草酯后表现叶

片发黄、株高受抑制等症状,药后21d左右部分植株受害区域返青。由表7、图2可知,对炔草酯表现为高抗的多花黑麦草种群有31个,占比62%,GR<sub>50</sub>在101.82~446.40 g(a.i.)·hm<sup>-2</sup>之间,RI在10.36~45.41之间,其中抗性水平最

表7 不同多花黑麦草种群对炔草酯的抗性

Table 7 Resistance of different *L. multiflorum* populations to clodinafop-propargyl

种群编号 Population No.	回归方程 Regression equation	相关系数 Correlation coefficient	GR <sub>50</sub> / [g (a. i.) · hm <sup>-2</sup> ]	95%置信区间 95% Confidence interval/ [g(a. i.) · hm <sup>-2</sup> ]	抗性指数 Resistance index
S	y=1.1714+3.8580x	0.919 6	9.83	5.82~16.58	1.00
YC-1	y=-1.7857+3.2830x	0.876 0	116.66	55.59~244.84	11.87
YC-2	y=0.7398+1.8777x	0.996 8*	185.69	168.79~204.29	18.89
YC-3	y=-2.9417+4.1545x	0.940 5	81.58	46.53~143.03	8.30
YC-4	y=1.7431+1.4705x	0.998 5*	163.99	153.42~175.30	16.68
YC-5	y=-2.6552+3.5821x	0.903 8	137.10	75.01~250.58	13.95
QS-1	y=-3.1690+4.2132x	0.933 1	86.87	48.48~155.69	8.84
QS-2	y=-1.6449+3.2737x	0.894 2	107.10	53.38~214.87	10.90
QS-3	y=-2.4209+3.9728x	0.932 6	73.77	39.38~138.20	7.50
QS-4	y=-2.1671+3.8924x	0.933 0	69.39	36.52~131.83	7.06
QS-5	y=-2.7621+4.0797x	0.931 4	79.92	43.30~147.50	8.13
SP-1	y=0.8987+1.7208x	0.998 0*	241.76	224.52~260.33	24.59
SP-2	y=-1.6083+3.3870x	0.942 4	89.35	52.54~151.95	9.09
SP-3	y=-1.4745+3.2246x	0.893 7	101.82	49.93~207.64	10.36
SP-4	y=0.9686+1.6960x	0.998 9*	238.24	225.47~251.74	24.24
SP-5	y=0.3998+2.1463x	0.996 9*	139.11	125.88~153.74	14.15
BY-1	y=-1.5797+3.2545x	0.893 6	105.13	52.00~212.55	10.70
BY-2	y=-2.7852+4.1045x	0.940 7	78.84	44.64~139.24	8.02
BY-3	y=-2.4469+3.9799x	0.931 7	74.33	39.57~139.62	7.56
BY-4	y=-2.6139+4.0361x	0.933 3	76.99	41.72~142.07	7.83
BY-5	y=-2.8739+4.1268x	0.937 1	80.91	45.27~144.62	8.23
RN-1	y=1.3617+1.5881x	0.998 4*	195.42	182.82~208.89	19.88
RN-2	y=-1.9640+3.3452x	0.885 9	120.72	60.17~242.22	12.28
RN-3	y=-1.4519+3.1926x	0.881 8	104.93	49.55~222.18	10.67
RN-4	y=1.6963+1.5239x	0.994 3*	147.23	128.79~168.31	14.98
RN-5	y=1.9446+1.4150x	0.992 8*	144.31	124.10~167.82	14.68
XP-1	y=1.5747+1.6644x	0.993 4*	114.29	97.70~133.70	14.15
XP-2	y=-1.6783+3.2785x	0.892 0	108.90	54.05~219.42	11.08
XP-3	y=-1.9346+3.3568x	0.894 6	116.37	59.35~228.10	12.29
XP-4	y=-2.1616+3.4396x	0.902 2	120.80	63.97~228.10	12.29
XP-5	y=-2.9991+4.1977x	0.952 1*	80.47	48.71~132.93	8.19
SC-1	y=0.8112+1.8141x	0.995 7*	203.75	182.99~226.86	20.73
SC-2	y=0.4088+1.9550x	0.998 8*	223.07	210.56~236.32	22.69
SC-3	y=0.3990+1.7364x	0.997 3*	446.40	405.09~491.94	45.41
SC-4	y=2.1487+1.1215x	0.986 5*	348.63	284.61~427.04	35.47
SC-5	y=1.0077+1.5668x	0.996 0*	353.25	316.25~394.58	35.94
XC-1	y=-1.6370+3.2636x	0.889 8	108.05	53.07~220.00	10.99
XC-2	y=-1.5018+3.2057x	0.881 2	106.71	50.54~225.29	10.86
XC-3	y=1.2401+1.7404x	0.994 9*	144.65	127.35~164.29	14.72
XC-4	y=1.2904+1.7280x	0.997 4*	140.18	128.03~153.48	14.26
XC-5	y=-1.8521+3.3425x	0.899 0	112.20	57.65~218.35	11.41
ZY-1	y=-3.1794+4.2502x	0.949 6	84.03	50.63~139.47	8.55
ZY-2	y=-1.5813+3.3407x	0.929 6	93.33	52.11~167.15	9.49
ZY-3	y=-1.6344+3.2848x	0.900 6	104.66	53.15~206.09	10.65
ZY-4	y=-2.0911+3.4260x	0.904 9	117.44	62.43~220.91	11.95
ZY-5	y=-0.8431+3.0780x	0.907 5	79.13	38.18~163.99	8.05
PY-1	y=-3.5512+4.3661x	0.947 6	90.89	55.08~149.99	9.25
PY-2	y=-3.3764+4.3046x	0.945 1	88.29	52.51~148.48	8.98
PY-3	y=-2.7677+4.0984x	0.940 3	78.58	44.37~139.18	7.99
PY-4	y=-2.8228+4.1186x	0.941 6	79.32	45.20~139.20	8.07
PY-5	y=-3.7235+4.4234x	0.948 4	93.78	57.44~153.12	9.54

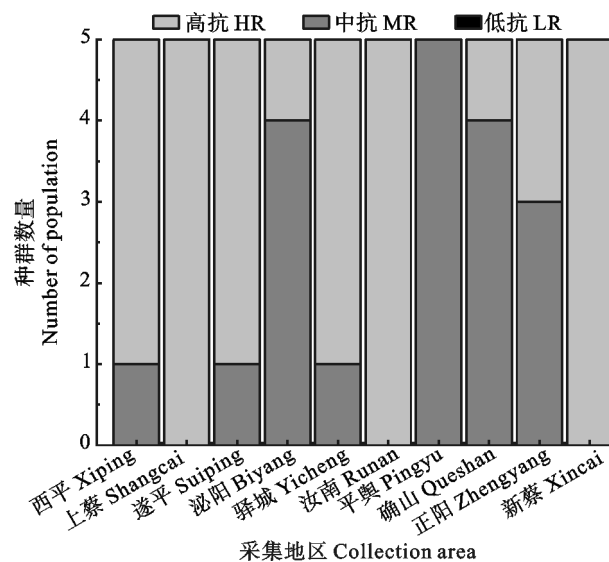


图 2 不同县区多花黑麦草种群对炔草酯的抗性水平

Fig. 2 Resistance levels of different counties of *L. multiflorum* to clodinafop-propargyl

高的为采自上蔡县黄埠镇后张村的 SC-3,其次为采自上蔡县黄埠镇蔡埠口村的 SC-5; 剩余 19 个种群均表现为中抗, 占供试总数的 38%,  $GR_{50}$  在  $69.39 \sim 93.78 \text{ g(a.i.)} \cdot \text{hm}^{-2}$  之间。

### 2.1.3 对啶磺草胺的抗性

供试多花黑麦草种群对啶磺草胺的抗性结果如表 8、图 3, 表现高抗的共有 16 个种群, 占总数的 32%, 其中抗性最高的为采自汝南县老君庙镇白堰村的 RN-4 种群,  $GR_{50}$  为  $121.48 \text{ g(a.i.)} \cdot \text{hm}^{-2}$ , RI 为 53.41; 中抗的种群有 11 个, 占总数的 22%,  $GR_{50}$  在  $11.46 \sim 19.66 \text{ g(a.i.)} \cdot \text{hm}^{-2}$  之间, RI 为  $5.03 \sim 8.62$ ; 低抗种群有 23 个, 占总数的 46%。

## 2.2 不同药剂对多花黑麦草种群 SC-3 的室内生物活性

如表 9 所示, 多花黑麦草种群 SC-3 在喷施  $493.42 \text{ g(a.i.)} \cdot \text{hm}^{-2}$  的异丙隆后, 出现叶尖或叶缘褪绿、叶片泛黄现象, 在  $1973.68 \text{ g(a.i.)} \cdot \text{hm}^{-2}$  剂量下, 植株首先叶片变黄, 最后枯死; 在喷施吡氟酰草胺  $309.28 \text{ g(a.i.)} \cdot \text{hm}^{-2}$  的剂量下, 幼芽发生白化现象, 药后 15~25 d 整个植株萎蔫死亡; 在氟噻草胺  $131.79 \text{ g(a.i.)} \cdot \text{hm}^{-2}$  的剂量下, 株高受到抑制, 用药后 20~25 d 植株逐渐死亡; 喷施  $42.09 \text{ g(a.i.)} \cdot \text{hm}^{-2}$  的砒吡草唑后, SC-3 种群只露出小芽便逐渐死亡; 砒吡草唑在  $168.37 \text{ g(a.i.)} \cdot \text{hm}^{-2}$  剂量下, 该种群不能出芽。在喷施混剂吡酰·异丙隆  $1237.5 \text{ g(a.i.)} \cdot \text{hm}^{-2}$  后 7~15 d, SC-3 植株心叶呈水浸状, 茎叶

萎蔫似软腐病状, 药后 20~30 d 开始自老叶逐渐枯死。通过比较各药剂的  $GR_{90}$  值与其田间推荐剂量可知, 除吡氟酰草胺与啶磺草胺外, 其他几种除草剂对多花黑麦草的活性均较高,  $GR_{90}$  值均低于其田间推荐剂量的高量。

## 2.3 不同除草剂与吡酰·异丙隆混配对多花黑麦草的田间药效

安全性结果表明, 药后 45 d, 各药剂单独使用均对小麦安全; 砒吡草唑+吡酰·异丙隆、啶磺草胺+吡酰·异丙隆各混配剂量下, 小麦均未出现明显药害症状; 氟噻草胺+吡酰·异丙隆在  $129.15 + 1072.5 \text{ g(a.i.)} \cdot \text{hm}^{-2}$ 、 $129.15 + 1237.5 \text{ g(a.i.)} \cdot \text{hm}^{-2}$ 、 $129.15 + 1402.5 \text{ g(a.i.)} \cdot \text{hm}^{-2}$  的剂量下, 小麦株高有所降低, 整体偏黄。药后 60 d, 前期小麦出现的药害均恢复正常, 与空白对照相比无明显差异。

田间药效结果(表 10)表明, 药后 7 d, 各药剂对多花黑麦草的株防效均小于 70%; 药后 30 d, 各处理对多花黑麦草株防效较 7 d 有所提高, 增幅在 6.75%~44.25%之间; 药后 45 d, 各处理对多花黑麦草的株防效显著增加 ( $P < 0.05$ ), 砒吡草唑+吡酰·异丙隆在  $165 + 1072.5 \text{ g(a.i.)} \cdot \text{hm}^{-2}$ 、 $165 + 1237.5 \text{ g(a.i.)} \cdot \text{hm}^{-2}$ 、 $165 + 1402.5 \text{ g(a.i.)} \cdot \text{hm}^{-2}$  剂量下的株防效达 87.17%~100%, 处理区组内杂草出苗后叶片枯萎死亡; 吡酰·异丙隆单剂对多花黑麦草的株防效为 73.9%; 啶磺草胺单剂的株防效最低, 仅 29.43%。药后 60 d, 各处理株防效较前期提升较小; 砒吡草唑+吡

表8 不同多花黑麦草种群对啶磺草胺的抗性

Table 8 Resistance of different *L. multiflorum* populations to pyroxsulam

种群编号 Population No.	回归方程 Regression equation	相关系数 Correlation coefficient	GR <sub>50</sub> / [g (a. i.) • hm <sup>-2</sup> ]	95%置信区间 95% Confidence interval/ [g(a. i.) • hm <sup>-2</sup> ]	抗性指数 Resistance index
S	y=4.1377+2.4141x	0.996 3*	2.28	2.06~2.52	1.00
YC-1	y=0.5409+2.5701x	0.990 1*	66.00	55.30~78.78	28.95
YC-2	y=0.4317+2.5107x	0.875 6	57.30	29.48~111.35	25.13
YC-3	y=-1.3976+3.6388x	0.994 2*	23.95	20.87~27.50	10.50
YC-4	y=2.2595+1.9868x	0.994 2*	23.95	20.87~27.50	10.50
YC-5	y=1.0682+3.1714x	0.888 3	17.37	8.27~36.49	7.61
QS-1	y=1.4750+3.9415x	0.923 9	7.84	3.43~17.93	3.44
QS-2	y=1.3593+3.6578x	0.939 0	9.89	5.09~19.25	4.34
QS-3	y=1.6117+3.8837x	0.926 3	7.45	3.26~17.07	3.27
QS-4	y=1.8182+3.8027x	0.932 4	6.87	3.04~15.52	3.01
QS-5	y=1.5167+3.9182x	0.921 9	7.74	3.33~18.00	3.34
SP-1	y=2.6902+1.6713x	0.998 3*	24.10	22.38~25.96	10.57
SP-2	y=0.3123+4.1330x	0.950 7*	13.62	8.12~22.86	5.97
SP-3	y=0.8451+3.8891x	0.944 3	11.70	6.49~21.11	5.13
SP-4	y=0.5555+3.4356x	0.914 5	19.66	10.74~36.01	8.62
SP-5	y=2.1479+1.9899x	0.997 4*	27.12	24.83~29.62	11.89
BY-1	y=1.4710+3.5977x	0.933 2	9.57	4.71~19.45	4.20
BY-2	y=0.9036+3.8136x	0.922 2	11.86	5.85~24.04	5.20
BY-3	y=1.1663+3.7204x	0.930 2	10.73	5.37~21.23	4.71
BY-4	y=1.2698+3.6724x	0.927 8	10.37	5.06~21.23	4.55
BY-5	y=1.2802+3.6619x	0.937 6	10.37	5.32~20.22	4.55
RN-1	y=1.8097+2.2492x	0.992 5*	26.21	22.49~30.55	11.50
RN-2	y=1.6014+1.8539x	0.986 6*	68.11	55.31~83.87	29.87
RN-3	y=1.6950+1.8474x	0.998 3*	61.52	57.29~66.06	26.98
RN-4	y=0.5159+2.1512x	0.988 4*	121.48	95.40~154.68	53.41
RN-5	y=1.5705+2.0200x	0.990 9*	49.86	42.51~58.47	21.86
XP-1	y=0.7578+4.0054x	0.969 4*	11.46	7.43~17.67	5.03
XP-2	y=1.3862+3.9828x	0.923 2	8.08	3.55~18.37	3.54
XP-3	y=1.4755+3.6333x	0.948 9	9.33	5.03~17.33	4.09
XP-4	y=1.0787+3.8448x	0.962 7*	10.47	6.36~17.24	4.59
XP-5	y=1.3682+3.9875x	0.922 0	8.14	3.57~18.60	3.57
SC-1	y=1.9918+1.6840x	0.982 4*	61.14	48.45~77.17	26.82
SC-2	y=2.3254+1.8636x	0.996 9*	27.24	24.74~29.99	11.94
SC-3	y=2.5359+1.6040x	0.997 1*	34.37	31.44~37.58	15.07
SC-4	y=2.0354+1.8179x	0.994 9*	42.73	37.98~48.07	18.74
SC-5	y=2.4184+1.7088x	0.997 4*	32.42	29.77~35.30	14.22
XC-1	y=0.8003+3.3118x	0.902 9	18.54	9.52~36.10	8.13
XC-2	y=0.6854+3.4297x	0.928 1	18.11	10.28~31.93	7.95
XC-3	y=0.1590+4.1791x	0.944 0	14.40	8.37~24.77	6.32
XC-4	y=1.5114+3.0051x	0.885 0	14.48	6.42~32.70	6.35
XC-5	y=1.4542+3.1131x	0.916 6	13.77	6.91~27.44	6.04
ZY-1	y=1.1181+3.7328x	0.925 5	10.96	5.38~22.35	4.81
ZY-2	y=1.6392+3.8633x	0.922 3	7.41	3.15~17.44	3.25
ZY-3	y=1.5097+3.9238x	0.922 3	7.75	3.34~17.98	3.34
ZY-4	y=1.4873+3.5626x	0.918 8	9.68	4.40~21.29	4.25
ZY-5	y=1.4072+3.6318x	0.936 2	9.76	4.91~19.37	4.28
PY-1	y=1.3167+4.0357x	0.932 5	8.18	3.82~17.51	3.59
PY-2	y=1.6265+3.9075x	0.937 1	7.30	3.39~15.70	3.20
PY-3	y=1.5418+3.9302x	0.932 1	7.58	3.45~16.65	3.33
PY-4	y=1.5702+3.9147x	0.931 0	7.52	3.39~16.67	3.30
PY-5	y=1.2777+3.6695x	0.928 4	10.34	5.06~21.12	4.54

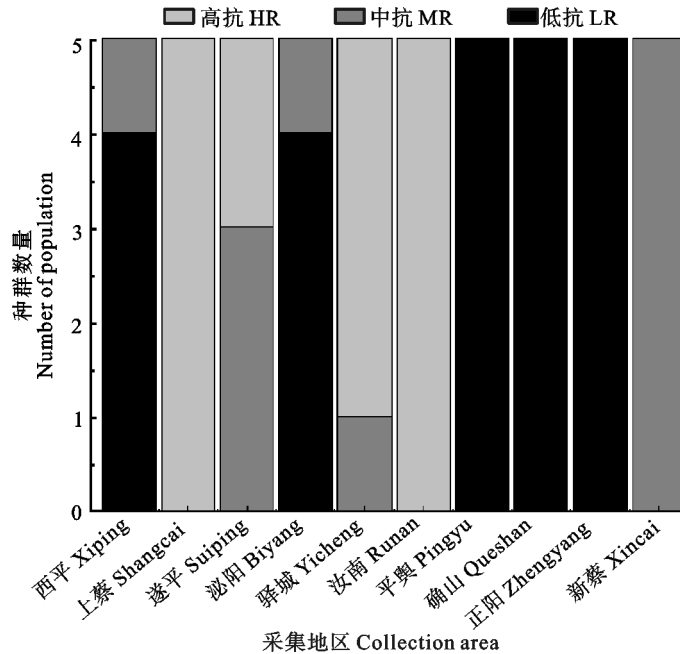


图 3 不同县区多花黑麦草种群对啶磺草胺的抗性水平

Fig. 3 Resistance levels of different counties of *L. multiflorum* to pyroxsulam

表 9 不同除草剂对多花黑麦草种群 SC-3 的生物活性

Table 9 Biological activity of different herbicides on *L. multiflorum* population SC-3

药剂 Herbicide	田间推荐剂量/ [g(a. i.) · hm <sup>-2</sup> ]	回归方程 Regression equation	相关系数 Correlation coefficient	GR <sub>50</sub> (95%CL)/ [g(a. i.) · hm <sup>-2</sup> ]	GR <sub>90</sub> (95%CL)/ [g(a. i.) · hm <sup>-2</sup> ]
95%异丙隆原药 Isoproturon 95% TC	789.47~1 184.21	y = -5.8194 + 3.9843x	0.938 2	519.42(247.09~1 091.93)	1 089.36(630.61~1 881.87)
97%吡氟酰草胺原药 Diflufenican 97% TC	123.71~185.57	y = -3.3512 + 4.0059x	0.968 6	121.54(78.39~188.43)	253.88(182.96~352.29)
98%氟噻草胺原药 Flufenacet 98% TC	112.96~150.61	y = -2.2630 + 3.9564x	0.936 7	68.51(32.14~146.05)	144.43(82.87~251.73)
98%砞吡草啶原药 Pyroxasulfone 98% TC	153.06~183.67	y = -0.7189 + 4.0912x	0.927 0	25.00(11.50~54.36)	51.42(28.91~91.43)
55%吡酰·异丙隆 SC Diflufenican+ isoproturon 55% SC	1 072.5~1 402.5	y = -5.0925 + 4.1287x	0.949 4	278.27(163.17~474.57)	568.69(378.09~855.36)
96.5%啶磺草胺原药 Pyroxsulam 96.5% TC	9.33~15.54	y = 0.6285 + 3.3566x	0.868 2	20.06(9.63~41.79)	48.33(24.33~96.00)

酰·异丙隆在 165+1 072.5 g(a. i.) · hm<sup>-2</sup>、165+1 237.5 g(a. i.) · hm<sup>-2</sup>、165+1 402.5 g(a. i.) · hm<sup>-2</sup> 剂量下对多花黑麦草鲜重防效最高,在 94.27%~100%之间;氟噻草胺+吡酰·异丙隆混配效果较啶磺草胺+吡酰·异丙隆高,鲜重防效分别在 65.24%~70.88%、57.69%~65.13%之间;啶磺草胺单剂对多花黑麦草防除效果最低,株防效及鲜重防效分别为 31.28%、31.57%;砞吡草啶与吡酰·异丙隆单剂对多花黑麦草的防效差异较小。产量结果(表

11)表明,砞吡草啶+吡酰·异丙隆在 165+1 072.5 g(a. i.) · hm<sup>-2</sup>、165+1 237.5 g(a. i.) · hm<sup>-2</sup>、165+1 402.5 g(a. i.) · hm<sup>-2</sup> 剂量下,小麦理论产量分别为 7 957.50、8 183.00、8 325.10 kg · hm<sup>-2</sup>,显著高于对照区小麦产量(7 163.00 kg · hm<sup>-2</sup>),增产率分别为 11.11%、14.26%、16.26%;其余各处理小麦均有不同程度的增产,增幅在 2.50%~8.43%之间,且各药剂处理对小麦有效穗数、穗粒数和千粒重均具有不同程度提高。

表 10 不同除草剂与吡嘧·异丙隆混配对多花黑麦草的田间药效  
Table 10 Field efficacy of different herbicides mixed with diflufenican + isoproturon on *L. multiflorum*

编号 No.	药剂 Herbicide	剂量 Dose/[g (a.i.)·hm <sup>-2</sup> ]	株防效 Plant control efficacy/%				鲜重防效 Fresh weight control efficacy/%
			7 d	30 d	45 d	60 d	
1	40% 氟吡草啶 SC pyroxasulfone 40% SC	180	55.50±2.38c	67.04±0.92c	69.07±0.68d	72.29±1.95d	75.84±0.56c
2	41% 氟噻草胺 SC flufenacet 41% SC	147.6	47.75±4.03ef	52.28±1.34f	53.67±1.23g	57.98±1.32fg	57.66±0.60h
3	4% 啶磺草胺 OD pyroxsulam 4% OD	15	18.25±4.57h	25.95±2.61h	29.43±2.41h	31.28±2.30h	31.57±0.81i
4	55% 吡嘧·异丙隆 SC diflufenican + isoproturon 55% SC	1 402.5	61.00±2.83ab	66.17±1.00c	73.90±1.65c	75.88±0.65c	74.91±0.45c
5	40% 氟吡草啶 SC+55% 吡嘧·异丙隆 SC pyroxasulfone 40% SC+(diflufenican + isoproturon 55% SC)	165+1 072.5	47.75±3.78ef	63.13±0.77d	87.17±0.88b	96.04±0.38b	94.27±0.45b
6	40% 氟吡草啶 SC+55% 吡嘧·异丙隆 SC pyroxasulfone 40% SC+(diflufenican + isoproturon 55% SC)	165+1 237.5	52.75±3.30cde	75.42±1.00b	100a	100a	100a
7	40% 氟吡草啶 SC+55% 吡嘧·异丙隆 SC pyroxasulfone 40% SC+(diflufenican + isoproturon 55% SC)	165+1 402.5	65.50±3.32a	81.21±0.82a	100a	100a	100a
8	41% 氟噻草胺 SC+55% 吡嘧·异丙隆 SC flufenacet 41% SC+(diflufenican + isoproturon 55% SC)	129.15+1 072.5	53.25±3.30cd	58.34±1.68e	63.92±1.67e	65.21±1.54e	65.24±0.76f
9	41% 氟噻草胺 SC+55% 吡嘧·异丙隆 SC flufenacet 41% SC+(diflufenican + isoproturon 55% SC)	129.15+1 237.5	55.50±3.32c	59.22±1.42e	65.49±1.32e	67.07±0.93e	66.90±0.49e
10	41% 氟噻草胺 SC+55% 吡嘧·异丙隆 SC flufenacet 41% SC+(diflufenican + isoproturon 55% SC)	129.15+1 402.5	58.00±1.41bc	62.92±0.92d	68.61±0.45d	70.84±1.17d	70.88±0.55d
11	4% 啶磺草胺 OD+55% 吡嘧·异丙隆 SC pyroxsulam 4% OD+(diflufenican + isoproturon 55% SC)	12+1 072.5	41.25±3.69g	47.52±1.22g	52.95±1.78g	57.68±2.05g	57.69±1.74h
12	4% 啶磺草胺 OD+55% 吡嘧·异丙隆 SC pyroxsulam 4% OD+(diflufenican + isoproturon 55% SC)	12+1 237.5	44.75±3.78fg	49.40±1.28g	53.95±1.55g	59.96±1.74f	59.87±1.53g
13	4% 啶磺草胺 OD+55% 吡嘧·异丙隆 SC pyroxsulam 4% OD+(diflufenican + isoproturon 55% SC)	12+1 402.5	48.50±3.32def	53.43±1.60f	59.50±1.85f	65.05±1.98e	65.13±1.50f

数据为平均值±标准差。同列数据后不同小写字母表示不同处理间差异显著(P<0.05)。下同。

Data are mean ± SD. Different lowercase letters following data in the same column indicate significant difference at 0.05 level. The same below.

表 11 不同除草剂与吡酰·异丙隆混配对小麦产量性状的影响

Table 11 Effects of different herbicides mixed with diflufenican+isoproturon on yield traits of wheat

编号 No.	有效穗数 Spike number/ ( $\times 10^4$ ) $\cdot \text{hm}^{-2}$	穗粒数 Grain number per spike	千粒重 1 000-kernel weight/g	理论产量 Theoretical yield/ ( $\text{kg} \cdot \text{hm}^{-2}$ )	增产率 Yield increasing rate/%
CK	470.75 $\pm$ 8.62h	32.50 $\pm$ 1.29f	43.25 $\pm$ 0.03f	7 163.00 $\pm$ 128.35g	—
1	491.50 $\pm$ 1.29c	36.00 $\pm$ 0.82c	44.13 $\pm$ 0.09d	7 764.75 $\pm$ 80.56bc	8.43
2	483.00 $\pm$ 2.94f	33.00 $\pm$ 0.82de	44.13 $\pm$ 0.03e	7 588.50 $\pm$ 116.55cde	5.95
3	473.25 $\pm$ 2.63g	31.50 $\pm$ 1.29e	43.87 $\pm$ 0.10e	7 340.50 $\pm$ 77.86f	2.50
4	493.00 $\pm$ 0.82c	36.75 $\pm$ 0.96c	44.18 $\pm$ 0.03d	7 724.75 $\pm$ 80.49c	5.28
5	529.00 $\pm$ 1.83b	47.50 $\pm$ 0.58b	44.51 $\pm$ 0.07c	7 957.50 $\pm$ 118.13b	11.11
6	541.50 $\pm$ 1.29a	49.25 $\pm$ 1.26a	45.15 $\pm$ 0.02a	8 183.00 $\pm$ 154.32a	14.26
7	541.00 $\pm$ 0.82a	47.75 $\pm$ 1.26ab	45.09 $\pm$ 0.05a	8 325.10 $\pm$ 93.29a	16.26
8	483.00 $\pm$ 0.82f	32.75 $\pm$ 0.96de	44.07 $\pm$ 0.47de	7 630.25 $\pm$ 86.03cde	6.49
9	482.75 $\pm$ 1.50f	33.50 $\pm$ 1.29d	44.22 $\pm$ 0.02d	7 645.75 $\pm$ 139.39cd	6.78
10	486.25 $\pm$ 0.96e	37.00 $\pm$ 1.41c	44.77 $\pm$ 0.07b	7 713.00 $\pm$ 166.98c	7.72
11	483.25 $\pm$ 0.96f	33.75 $\pm$ 1.26d	44.19 $\pm$ 0.04d	7 443.50 $\pm$ 80.06ef	3.95
12	483.00 $\pm$ 0.82f	32.50 $\pm$ 1.29de	44.18 $\pm$ 0.03d	7 494.25 $\pm$ 127.95def	4.63
13	488.50 $\pm$ 1.29d	37.50 $\pm$ 0.58c	44.29 $\pm$ 0.03d	7 512.25 $\pm$ 120.75def	4.92

编号与表 10 对应。

The numbers are as same as the ones in table 10.

### 3 讨论

本研究发现,河南省驻马店市不同区域多花黑麦草种群对 ACCase 类除草剂啶啉草酯、炔草酯及 ALS 类除草剂啶磺草胺均表现不同程度的抗性,高、中抗性种群占比较大。驻马店市多花黑麦草抗性发展迅速,可能与当地农民用药习惯、耕作习惯、杂草发生量及经济发展水平等相关<sup>[20-21]</sup>。采自上蔡县黄埠镇后张村的 SC-3 种群对炔草酯和啶啉草酯均产生了较高抗性,抗性指数分别达 45.41、33.20。可根据当地抗性发生情况改善用药习惯、合理用药,以降低杂草抗性发生速度。而啶啉草酯对上蔡县部分地区多花黑麦草的防效较低,可将啶啉草酯与其他类型药剂轮换使用或混配使用。已有研究表明,汝南县部分地区多花黑麦草对啶磺草胺的抗性呈上升趋势<sup>[10]</sup>,抗啶磺草胺的多花黑麦草种群对精噁唑禾草灵具有高抗性<sup>[22]</sup>。应加强对抗性种群的监测,并制订相应的科学防控措施。

随着茎叶处理除草剂对多花黑麦草的选择压不断增强,其抗性水平日益严重,土壤处理或将成为防治抗性多花黑麦草的新方向<sup>[23-25]</sup>。本研究中,高抗性多花黑麦草种群 SC-3 施用 5 种土壤处理除草剂后均表现不同程度的受害症状,除吡氟

酰草胺外,其他 4 种除草剂(异丙隆、氟噻草胺、砒吡草唑、吡酰·异丙隆)对其活性均较高,其中砒吡草唑与吡酰·异丙隆对多花黑麦草的 GR<sub>90</sub> 为 51.42、568.69 g(a. i.)  $\cdot \text{hm}^{-2}$ 。

目前用于防除小麦田禾本科类杂草的除草剂种类多而繁杂,且不同药剂间防效差异性较大,因此寻找适宜的除草剂进行混配,是提高田间杂草防效、减缓抗性的有效途径<sup>[26-27]</sup>。本研究结果表明,供试除草剂与吡酰·异丙隆混配后具有增效作用,其中砒吡草唑与吡酰·异丙隆混配对多花黑麦草的防效最高,在供试剂量 165+1 237.5 g(a. i.)  $\cdot \text{hm}^{-2}$  下对多花黑麦草的株防效及鲜重防效均可达 100%,且增产效果明显;其次为氟噻草胺与吡酰·异丙隆 129.15+1 402.5 g(a. i.)  $\cdot \text{hm}^{-2}$  混配。该结果与徐洪乐等<sup>[13]</sup>对多花黑麦草抗药性研究结果一致,这为延缓杂草抗药性的发生和多花黑麦草的防除提供了理论依据和实践指导。各药剂处理后小麦各产量性状均有不同程度的提高。因此建议以多花黑麦草为主要杂草的小麦种植区,可参考本试验结果进行合理施药,以提高对杂草的防除效果。尽管砒吡草唑与吡酰·异丙隆混配对杂草防除效果较高、且增产明显,但吡酰·异丙隆中的成分异丙隆易受低温影响,在低温环境下施药易造成小麦出现药害,且水稻对吡

氟酰草胺敏感,在实际应用中,应当谨慎选择,以确保农业生产的连续性和安全性<sup>[28]</sup>。此外,为促进多花黑麦草的综合治理,还应根据多花黑麦草的生物学特性来调整合适的耕作模式、施药方式等,再结合后期深耕、错期播种、化学防除等多种农业措施,以延缓杂草抗性发展,保障冬小麦高质量生产<sup>[29]</sup>。

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