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Herbicide resistance of weeds

Research on the Resistance of *Amaranthus retroflexus* L. to Nicosulfuron in Corn Fields in North China

Abstract:

To investigate the resistance level of the Amaranthus retroflexux L. population to the commonly used herbicide Nicosulfuron in corn fields in North China, the whole plant bioassay method was used to measure 52 Amaranthus retroflexux L. populations collected in North China. The results showed that the Amaranthus retroflexux L. in corn fields in North China showed varying levels of resistance to Nicosulfuron, and the vast majority of Amaranthus retroflexux L. populations in the corn fields in this collection area had developed medium to high levels of resistance to Nicosulfuron. This study clarified the resistance level and field distribution status of the Amaranthus retroflexux L. population in corn fields in North China, providing guidance for the rational application of Nicosulfuron in production to prevent and control Amaranthus retroflexux L..

Key words: Maize fields; *Amaranthus retroflexus* L.; Nicosulfuron; Herbicide-resistant weeds

1、 Introduction

Amaranthus retroflexus L, the Amaranth genus in the Amaranthaceae family is an annual dicotyledonous weed, ranking first in the third batch of invasive species list in China [1].Since its introduction to China in 1905, it has shown rapid and large-scale expansion in the central and western regions. Amaranthus retroflexux L. has strong reproductive ability, wide germination habitat, strong stress tolerance, and strong phenotypic plasticity.[2] As a typical C4 plant, its CO2 compensation point is low, transpiration efficiency is high, and it highly competes with the light, nutrients, and water required for crop growth,causing severe damage to crop productivity in the agricultural system, in turn resulting in economic losses [3] [4].

The prevention and control measures for Amaranthus retroflexux L. in field production mainly rely on chemical control. Nicosulfuron [2- (4,6-dimethoxypyrimidin-2-ylcarbamoyl) - N, N-dimethylnicotinamide] belongs to the sulfonylurea herbicide class. As an inhibitor of acetyllactate synthase (ALS), its main mode of action is to interfere with the activity of ALS enzyme, inhibit the synthesis of branched chain amino acids valine, leucine, and isoleucine, thereby achieving weed control effects. Nicosulfuron methyl has the characteristics of strong internal absorption conductivity, wide herbicide spectrum, high efficiency, low toxicity and low residue , and is the most widely used herbicide component in corn fields.

Nicosulfuron has single action site and long drug use history. In recent years, there have been frequent reports on weeds that have evolved resistance to Nicosulfuron . The North China region belongs to the important corn production areas of the Yellow River, Huai River, and Hai River in China. Nicosulfuron is the main drug used for weed control after corn seedlings in these areas. To clarify the current situation of the resistance of Amaranthus retroflexux L. to Nicosulfuron in the North China region, resistance monitoring of Amaranthus retroflexux L. was carried out through two consecutive years of field population collection. Through the following article, we hope to provide scientific data for efficient prevention and control of dominant weeds in the field, rational and effective application of pesticides, and feasible guidance for the development of crops resistant to Nicosulfuron.

2、 Materials and Methods

2.1 Test materials

2.1.1 Test seeds

The field population of Amaranthus retroflexus L. was collected in North China in 2021 and 2022 with the majority distributed in six cities in central and southern Hebei, including Langfang, Baoding, Shijiazhuang, Hengshui, Xingtai, and Handan, including 52 populations, as shown in Table 1. The sensitive population PB-1 was collected in Pingshan County, which is a protected area for non-drug history. All seeds are collected after maturity and stored in a 4 ℃ seed storage cabinet for future use.

Table 1 Sampling information of *Amaranthus retroflexus* L. collected from fields

Code	Collection site	Geographcial coordinates	Code	Collection site	Geographcial coordinates
1	Yujinwa Village, Bazhou Town, Bazhou City, Langfang City, Hebei Province	E116°42′ N39°05′	2	Shanlaiying Village, Bazhou Town, Bazhou City, Langfang City, Hebei Province	E116°37′ N39°06′
3	Niuzhuanghuo Village, Bazhou Town,Bazhou City, Langfang City, Hebei Province	E116°45′ N39°06′	4	Anjiaying Village, Nanmeng Town, Bazhou City, Langfang City, Hebei Province	E116°40′ N39°17′

5	Lijiaying Village, Nanmeng Town, Bazhou City, Langfang City, Hebei Province	E116°41′ N39°17′	6	Cuigezhuang Village, Bazhou Town, Langfang City, Hebei Province	E116°41′ N39°17′
7	Xindianyi Village, Kangxianzhuang Town, Bazhou City, Langfang City, Hebei Province	E116°46′ N39°16′	8	Shichenger Village, Kangxianzhuang Town, Langfang City, Hebei Province	E116°49′ N39°14′
9	Xiaoanzhuang Village, Kangxianzhuang Town, Bazhou City, Langfang City, Hebei Province	E116°46′ N39°17′	10	Hongshanbao Village, Nanzhuang Town, Li County, Baoding City, Hebei Province	E115°64′ N38°37′
11	Zhengding County, Shijiazhuang City, Hebei Province	E114°57′ N38°14′	12	Xiaoliu Village, Jingzhou Town, Jing County, Hengshui City, Hebei Province	E116°24′ N37°67′
13	Mazhuang Village, Jingzhou Town, Jing County, Hengshui City, Hebei Province	E116°25′ N37°64′	14	Fangliji Village, Taitou Town, Wei County, Handan City, Hebei Province	E114°86′ N36°24′
15	Changjiazhuang Village, Dalu Town, Ningjin County, Xingtai City, Hebei Province	E115°09′ N31°66′	16	Nanliang Village, Dalu Town, Ningjin County, Xingtai City, Hebei Province	E115°03′ N37°62′
17	Tangqiu Village, Tangqiu Town, Ningjin County, Xingtai City, Hebei Province	E114°99′ N37°69′	18	Shuangjing Village, Tangqiu Town, Ningjin County, Xingtai City, Hebei Province	E114°95′ N37°70′
23	Dalier Village, Dalu Town, Ningjin County, Xingtai City, Hebei Province	E115°05′ N37°66′	24	Lichengdao Village, Lichengdao Town, Wuji County, Shijiazhuang City, Hebei Province	E114°93′ N38°24′
25	Liguizi Village, Lichengdao Town, Wuji County, Shijiazhuang City, Hebei Province	E114°94′ N38°22′	26	Zhoujiazhuang Village, Lichengdao Town, Wuji County, Shijiazhuang City, Hebei Province	E114°95′ N38°21′
27	Dishang Village, Qiutou Town, Shijiazhuang City, Hebei Province	E114°71 N37°94′	28	Lijiaying Village, Nanmeng Town, Bazhou City, Langfang City, Hebei Province	E116°39′ N39°17′
29	Heping Village, Nanmeng Town, Bazhou City, Langfang City, Hebei Province	E116°38′ N39°19′	30	Beigaogezhuang Village, Kangxiangzhuang Town, Bazhou City, Langfang City, Hebei Province	E116°43′ N39°12′

31	Gao Village, Jianchapu Town, Bazhou City, Langfang City, Hebei Province	E116°51′ N39°13′	32	Dongsanjie Village, Jianchapu Town, Bazhou City, Langfang City, Hebei Province	E116°52′ N39°11′
33	Nanzhuangtou Village, Jianchapu Town, Bazhou City, Langfang City, Hebei Province	E116°49′ N39°13′	34	Xiaoanzhuang Village, Jianchapu Town, Bazhou City, Langfang City, Hebei Province	E116°44′ N39°16′
35	Xinyi Village, Kangxianzhuang Town, Bazhou City, Langfang City, Hebei Province	E116°44′ N39°14′	36	Dongsanjie Village, Nanmeng Town, Bazhou City, Langfang City, Hebei Province	E116°41′ N39°17′
37	Yangduo Village, Longhua Town, Jing County, Hengshui City, Hebei Province	E115°97′ N37°60′	38	Nanqiao Village, Longhua Town, Jing County, Hengshui City, Hebei Province	E115°99′ N37°61′
41	Huajiakoou Village, Anling Town, Jing County, Hengshui City, Hebei Province	E116°36′ N37°65′	42	Qian Village, Anling Town, Jing County, Hengshui City, Hebei Province	E116°33′ N37°67′
43	Xilu Village, Liufu Town, Jing County, Hengshui City, Hebei Province	E116°04′ N37°66′	44	Yingpu Village, Liufu Town, Jing County, Hengshui City, Hebei Province	E116°07′ N37°72′
45	Kushuiying Village, Liufu Town, Jing County, Hengshui City, Hebei Province	E116°07′ N37°71′	46	Nanxiaowang Village, Nanxiaowang Town, Boye County, Baoding City, Hebei Province	E115°52′ N38°41′
47	Nanxiaowang Village, Nanxiaowang Town, Boye County, Baoding City, Hebei Province	E115°52′ N38°41′	48	Daxu Village,Dongxu Town,Boye County,Baoding City,Hebei Province	E115°49′ N38°51′
49	Daxu Village, Dongxu Town, Boye County, Baoding City, Hebei Province	E115°49′ N38°51′	50	Nanyi Village, Beiyang Town, Boye County, Baoding City, Hebei Province	E115°45′ N38°50′
51	Beifengti Village, Bianma Town, Wei County, Handan City, Hebei Province	E115°03′ N36°13′	52	Nanfengti Village, Bianma Town, Wei County, Handan City, Hebei Province	E115°03′ N36°13′

2.1.2 Experimental medication

40g/L Nicosulfuron methyl dispersible oil suspension (Ishihara Industries, Ltd., Japan).

2.1.3 Testing instruments

Model 3WP-2000 walking spray tower (Nanjing Agricultural Mechanization Research Institute, Ministry of Agriculture and Rural Affairs).

2.2 Test method

2.2.1 Indoor weed cultivation

Mix the nutrient soil and vermiculite in a 3:1 ratio and place them in a seedling tray with a width of 15cm and a length of 30cm. Select round and plump amaranth seeds and evenly spread them on the soil surface and cover them with soil. Let them absorb water through the holes at the bottom of the tray and cultivate them in a greenhouse with a temperature of 25 ℃, humidity of 60%~80%, and a light cycle of 12L: 12D. After the cotyledons grow out, transfer the seedlings to a seedling pot with a height of 10cm and a diameter of 11cm, and continue cultivation under the same greenhouse conditions.

2.2.2 Whole plant bioassay

The seedlings of Amaranthus retroflexus L. were cultured to the 3~4 leaf stage,and the 3WP-2000 walking spray tower (Nanjing Institute of Agricultural Mechanization, Ministry of Agriculture and Rural Affairs) was used for stem and leaf spray treatment. The spray pressure was 0.3Mpa, and the spray volume was 450L/hm^2. The medication was administered at doses of 0 (CK), 15, 30, 60, 120, and 240g/hm^2 for the effective ingredient of 40g/L Nicosulfuron dispersible oil suspension. According to the results of this preliminary experiment, the sensitive population of Amaranthus retroflexus L. was treated with a dosage of 40g/L Nicosulfuron methyl dispersible oil suspension at 0 (CK), 1.875, 3.75, 7.5, 15, and 30g/hm^2. Each treatment is repeated three times, and the solution is allowed to air dry naturally before continuing to be cultured in a greenhouse. On the 1st, 3rd, 7th, and 14th day after medication, record in detail the efficacy of the medicine. On the 14th day, cut off the aboveground part of Amaranthus retroflexus L., weigh it, and record the fresh weight data. Calculate the preventive effect according to formula (1):

$$E/\% = [(N_{CK} - N_{PT}) / N_{CK}] \times 100 \quad (1)$$

In the formula, NCK represents the fresh weight of amaranth in the blank control treatment, and NPT represents the fresh weight of amaranth in the medication treatment area.

2.3 Data analysis

Using DPS (version 17.1) data statistical analysis software, regression analysis was conducted on the logarithmic values of the effective ingredient dosage of the drug and the probability values of the fresh weight control effect of Amaranthus retroflexus L.. The toxicity regression equation, ED_{50}, 95% confidence interval, correlation coefficient, and resistance index were calculated. Resistance index is graded as follow: sensitivity: RI<2; Low resistance: 2 ≤ RI ＜ 5; Intermediate resistance: 5 ≤ RI ＜ 10; High resistance: RI ≥ 10 [14].

3. Result

3.1 Symptoms of pesticide damage caused by the treatment of amaranth with Nicosulfuron methyl

After 1 day of treatment with medication, the sensitive population has developed drug damage, manifested as slight growth inhibition; After 3 days, typical symptoms of Nicosulfuron poisoning such as stem wilting and purple red leaf backs gradually appeared; After 7 days, the growth was severely inhibited and the symptoms of drug damage worsened; After 14 days, the stem wilted and showed symptoms of withering and death. However, the resistant population only showed symptoms of high concentration growth inhibition after 14 days of treatment.

a. Resistance populations; b. Susceptible populations.

Fig. 1 Symptoms of nicosulfuron with different concentrations against susceptible and resistance *Amaranthus retroflexus* L. populations (14 days after treatment)

3.2 The Resistance Level of Field Population of Amaranth to Nicosulfuron

The monitoring results of the resistance of the Amaranthus retroflexus L. population in North China to Nicosulfuron are shown in Table 2.

Table2 Resistance levels of the field populations of *Amaranthus retroflexus L.* to Nicosufuron

Populations	Regression equation	ED_{50}	95% Confidence interval/(g/hm^2)	Correlation coefficient	Resistance index (RI)	Resistance level
PB-1	y=5.1474+0.4538x	0.4734	0.2851~0.7861	0.9814	1.00	S
17	y=-0.047+1.187x	0.912	0.000-5.946	0.857	1.93	S
45	y=4.9341+0.8323x	1.2001	0.3242~4.4420	0.895	2.54	LR
28	y=4.9147+0.8419x	1.2628	0.4784~3.3330	0.9364	2.67	LR

36	y=4.9224+0.5250x	1.4055	0.2923~6.7587	0.9416	2.97	LR
32	y=4.7940+0.9841x	1.6193	0.5355~4.8963	0.9094	1.46	LR
46	y=4.7800+1.0015x	1.6583	0.5808~4.7349	0.9165	1.49	LR
38	y=4.8011+0.8070x	1.7637	0.7700~4.0400	0.9436	1.59	LR
42	y=4.8997+0.3969x	1.789	0.2122~15.0813	0.8885	1.61	LR
33	y=4.7872+0.7772x	1.8782	0.4925~7.1629	0.95	1.69	LR
35	y=4.8926+0.3902x	1.8844	0.7445~4.7696	0.9749	1.70	LR
43	y=4.7927+0.7209x	1.9392	0.9808~3.8338	0.9587	1.75	LR
6	y=-0.991+2.741x	2.299	0.000-10.130	1	2.07	LR
13	y=-0.659+1.464x	2.818	0.067-9.355	0.926	2.54	LR
30	y=4.7579+0.5220x	2.9096	1.0242~8.2656	0.9157	2.62	LR
12	y=-1.014+2.089x	3.058	0.053-9.622	0.745	2.75	LR
40	y=4.5309+0.9320x	3.1869	0.5887~17.2526	0.9007	2.87	LR
19	y=-0.893+1.575x	3.689	0.189-10.555	0.889	3.32	LR
21	y=-2.092+2.952x	5.112	0.207-12.431	1	4.60	LR
16	y=-2.154+2.966x	5.326	0.263-12.619	1	4.80	LR
23	y=-1.887+2.525x	5.587	0.584-12.557	0.936	5.03	MR
7	y=-2.225+2.935x	5.729	0.424-12.928	0.999	5.16	MR
20	y=-1.799+2.366x	5.758	0.722-12.710	0.927	5.18	MR
22	y=-2.353+2.973x	6.187	0.599-13.349	1	5.57	MR
18	y=-1.191+1.471x	6.447	0.882-14.773	0.993	5.80	MR
11	y=-1.375+1.681x	6.58	1.068-14.368	0.954	5.92	MR
3	y=-2.429+2.930x	6.745	0.916-13.817	0.998	6.07	MR
8	y=-2.521+2.858x	7.62	1.495-14.605	0.996	6.86	MR
10	y=-2.555+2.847x	7.894	1.683-14.865	0.99	7.11	MR
14	y=-2.546+2.828x	7.947	1.730-14.915	0.992	7.16	MR
39	y=4.1943+0.8465x	8.9504	1.6061~49.8798	0.8157	8.06	MR
15	y=-2.668+2.694x	9.774	3.113-16.772	0.924	8.80	MR
4	y=-2.463+2.355x	11.112	0.020-27.228	0.915	10.01	HR

37	y=3.7187+1.1147x	14.1098	7.9926~24.9087	0.9611	12.70	HR
44	y=3.7836+1.0405x	14.759	5.8748~37.0784	0.903	13.29	HR
34	y=3.8207+0.9622x	16.8151	10.4408~27.0811	0.9673	15.14	HR
1	y=-4.906+3.870x	18.518	11.524-24.430	0.979	16.67	HR
5	y=-5.218+4.097x	18.773	11.863-24.501	0.944	16.90	HR
2	y=-4.542+3.525x	20.736	1.303-36.298	0.935	18.67	HR
29	y=3.8068+0.8038x	30.517	16.6177~56.0418	0.9116	27.48	HR
31	y=0.8809+2.4400x	48.7717	38.1023~62.4287	0.9771	43.91	HR
41	y=4.0988+0.5232x	52.7665	35.6004~78.2099	0.9433	47.51	HR
52	y=3.6091+0.7459x	73.231	47.7482~112.3138	0.9355	65.94	HR
25	y=-5.288+2.582x	111.793	93.081-133.811	0.983	100.66	HR
27	y=-7.913+3.616x	154.221	134.133-178.307	0.989	138.86	HR
47	y=2.1608+1.2856x	161.5958	121.7751~214.4379	0.9843	145.50	HR
49	y=3.0898+0.8619x	164.5768	141.9466~190.8148	0.9957	148.19	HR
24	y=-6.642+2.941x	181.328	125.771-285.706	0.963	163.27	HR
9	y=-5.237+2.279x	198.651	162.414-251.337	0.957	178.87	HR
26	y=-5.107+2.184x	217.683	176.067-281.438	0.978	196.00	HR
48	y=2.0357+1.2433x	242.2459	206.5077~284.1690	0.9966	218.12	HR
51	y=2.3217+1.1149x	252.5065	195.6528~325.8811	0.9917	227.36	HR
50	y=1.0036+1.5797x	338.7321	170.0619~674.6924	0.9562	305.00	HR

Note: S represents the susceptible population. LR represents the low resistance. MR represents the moderate resistance. HR represents the high resistance.

The whole plant bioassay method was used to determine the ED_{50} of Nicosulfuron against 52 Amaranthus retroflexux L. populations, and resistance multiples were calculated.The results (Table 2) showed that the Amaranthus retroflexux L. population in North China showed varying degrees of resistance to Nicosulfuron: 1 sensitive population was collected and showed a resistance index of 1.93; 18 populations showed low resistance levels, with resistance indices ranging from 2.54 to 4.80; 12 populations had moderate resistance levels, with resistance indices ranging from 5.03 to 8.8,; 21 highly resistant populations were collected, with resistance levels ranging from 10.01 to 305.According to

Table 1, it can be seen that the Amaranthus retroflexux L. populations collected from Daxu Village in Dongxu Township, Boye County, Baoding City, Nanyi Village in Beiyang Township, and Beifengti Village in Bianma Township, Wei County, Handan City, have the highest resistance index to Nicosulfuron, reaching 218.12, 227.36, and 305 times, respectively.

The resistance population in urban areas collected in the North China region is over 80%. Sensitive populations account for 1.9% in each collection area, low resistance populations account for 34.6%, medium resistance populations 23.1%, and high resistance populations 40.4%. The ED_{50} value range is between 0.912 and 338.7321.

3.3 The distribution of resistant amaranth populations in North China

Almost all of the Amaranthus retroflexux L. populations collected in the North China region showed resistance to Nicosulfuron, as shown in Figure 2: There were 5 collection points in Shijiazhuang, with 4 highly resistant populations, accounting for 80% of the collection population in the area; 1 low resistance population, accounting for 20%. A total of 18 populations were collected in the Langfang area, all of which were resistant populations, all from Bazhou, with 44.4% being highly resistant populations; three moderately resistant populations, accounting for 16.7%; a total of 7 low resistance populations, accounting for 38.9%. Six collection points were in Baoding area, with a high resistance population accounting for 66.7%; The population with moderate resistance accounts for 16.7%, while the population with low resistance accounts for 16.7%.

All 11 populations collected in Hengshui area were resistant populations. There are a total of 3 highly resistant populations, accounting for 27.3% of the whole population;1 population with moderate resistance; 7 low resistance populations, accounting for 63.7%. A total of 9 populations were collected from Ningjin County in the Xingtai area, but none of them reached a high level of resistance to Nicosulfuron. The sensitive population was collected from Tangqiu Village, Tangqiu Township, with an ED_{50} value of 0.912; 3 low resistance populations, accounting for 33.3%; 5 intermediate resistance populations were collected, accounting for 55.6%. Three populations were collected from Wei County in Handan area, with two showing high resistance and one showing low resistance.

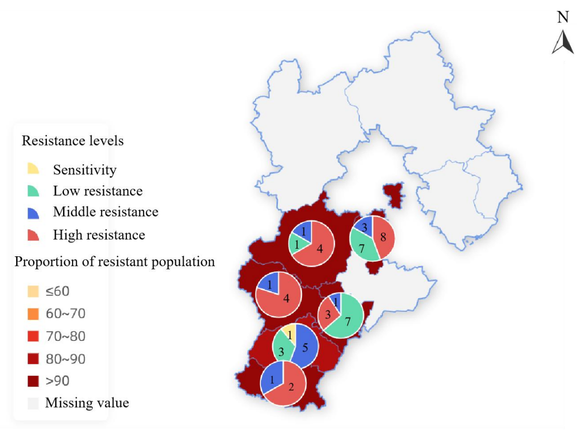

Fig.2 Distribution and resistance level of nicosulfuron-resistant *A. retroflexus* L.

4、 Conclusion

Plants are unable to actively evade the influence of aggressive environmental factors and have evolved very high phenotypic plasticity in the face of stress [5] [6]. The resistance of weeds to herbicides is widely regarded as the result of their adaptive evolution under strong selection pressure, and the differences in dosage and frequency of herbicides in different regions are related to the hierarchical development of weed resistance [7]. This experiment found through the collection and resistance monitoring of field populations of Amaranthus retroflexux L. in 6 urban areas and 20 townships in North China that the Amaranthus retroflexux L. population in North China has developed varying degrees of resistance to Nicosulfuron. Only 1.9% of the whole were the sensitive population. Except for Xingtai, no sensitive population was collected in the other 5 cities, and the proportion of higher resistant populations in other areas was over 25%, especially in Shijiazhuang and Handan, where the proportion was over 65%. The research results indicated that the vast majority of Amaranthus retroflexux L. populations in the corn fields within the collection area have developed moderate to high levels of resistance to Nicosulfuron. Therefore, it is necessary to strengthen the management of herbicide application after maize seedlings. It is recommended to stop using Nicosulfuron in areas with high levels of Amaranthus retroflexux L. resistance, and to rotate the use of herbicides with different mechanisms of action in areas with medium to low levels of resistance to delay the malignant development of Amaranthus retroflexux L. resistance in North China. In addition, in the research results, it was found that the Amaranthus retroflexux L. populations collected from two plots in Nanxiaowang Village, Nanxiaowang Township, Boye County showed low and high resistance levels to Nicosulfuron, respectively. This indicates that there is a phenomenon of diverse application habits in different plots of the same village. Therefore, in weed management, it is necessary to accurately and reasonably change the application method based on the specific plot according to the application habits.

With extensive research on predicting the evolution and management dynamics of weed resistance, it is believed that resistance may be an inevitable result of herbicide use [7]. Especially, Nicosulfuron methyl, an ALS inhibitor herbicide, acts on a single target site and is more likely to induce weed resistance. Wang Ruomeng et al. found that the ED_{50} value of Matang for Nicosulfuron, collected from five provinces and cities in Liaoning, Heilongjiang, Jilin, Hebei, and Henan, ranged from 77.97 to 1252.66 g a.i./hm^2 [8]. Wu Cuixia et al. conducted a study on the resistance of the main weeds in corn fields to Nicosulfuron from 2010 to 2011, and found that the ED_{50} value of resistant amaranth to Nicosulfuron ranged from 14.23 to 78.97 . Huang et al. determined the resistance of Setaria viridis collected from Jilin, Heilongjiang, and Henan provinces from 2017 to 2019, and found a ED_{50} value range of 7.9 to 232.4 for Nicosulfuron.

According to current reports, the target resistance mechanism for inhibiting ALS herbicides is due to the substitution of amino acids at 8 sites in the ALS enzyme [9]. In addition, non target resistance mechanisms may also confer weed resistance, which is more complex and diverse compared to target resistance. The development of cross resistance and multiple resistance has also posed greater challenges to the management of antagonistic weeds [10]. This study has preliminarily explored the resistance level and distribution status of the field population of Amaranthus retroflexux L. in corn fields in North China to Nicosulfuron. The resistance mechanism of Amaranthus retroflexux L. population to Nicosulfuron will be further revealed from both target and non target perspectives. Furthermore, whether this population has cross resistance and multiple resistance with other conventional herbicides still needs further research. At the same time, in response to the current resistance status of Amaranthus retroflexux L. to Nicosulfuron in North China, in addition to strengthening the application and management of herbicides, comprehensive management measures are actively adopted in field production, improving cultivation methods, and attempting physical grass control and ecological weeding methods to effectively delay the development of Amaranthus retroflexux L. resistance. In the subsequent weed control and management work, we will strengthen regular monitoring of the resistance level of Amaranthus retroflexux L. populations in corn fields in North China, continuously follow the evolution trend of weed resistance, and formulate corresponding weed control strategies.

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