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Application Effects of Various Herbicides and Essential Techniques in Corn and Soybean Strip Intercropping Fields

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Abstract [**Objectives**] To address the weeding challenges within the corn and soybean strip intercropping field and identify appropriate herbicide types and application methods suitable for the corn and soybean strip intercropping fields in Siyang County. [**Methods**] The trial comprised six herbicide treatments and one blank control, with investigations conducted to assess efficacy, safety, and yield. [**Results**] Each herbicide treatment effectively controlled weeds, demonstrated high safety, and enhanced the yields of both soybeans and corn. The combined application of soil sealing with stem and leaf spray exhibited superior overall weed control compared to soil sealing alone. At 28 d following stem and leaf spray, the plant control effect and fresh weight control effect against weeds in the combined treatment of soil sealing with stem and leaf spray all exceeded 89%. [**Conclusions**] This study offers technical support for advancing the practice of strip intercropping between corn and soybeans.

Key words Corn, Soybean, Strip intercropping, Control effect, Herbicide, Demonstration test

1 Introduction

In 2022, the No. 1 Central Document proposed to vigorously implement the project of enhancing the production capacity of soybeans and oilseeds, delineating specific measures and strategies. A primary approach includes promoting the strip intercropping of corn and soybeans in the Huang - Huai - Hai, northwest, and southwest regions. Strip intercropping of corn and soybeans addresses the challenges posed by limited cultivated land area and restricted crop growth space, enabling the scientific and rational utilization of arable land resources. While maintaining corn production at the same level or with only a slight reduction, this practice allows for an increase in the planting area and yield of a single soybean growing season. Consequently, the overall technical and economic benefits of this approach are enhanced. Therefore, regions with suitable conditions are encouraged to implement demonstration projects and promote its adoption[1-2]. Siyang County is situated in the northern region of Jiangsu Province, within the transitional zone between the Huang - Huai - Hai Plain and the middle to lower reaches of the Yangtze River Plain. The county actively implements national policies and strongly promotes the intercropping technology of corn and soybeans, achieving an average annual promotion area of approximately 2 300 hm^2. The intercropping fields exhibit a diverse range of weed species, densities, and quantities, presenting significant technical challenges in weed management that require urgent resolution.

Corn and soybean strip intercropping is an advancement and innovation in traditional intercropping methods, necessitating more rigorous scientific approaches to the prevention and control of diseases, pests, and weeds. This is particularly critical concerning the selection of crop varieties and the application techniques of herbicides[3]. To date, relatively few herbicide formulations have been approved for simultaneous use on both soybeans and corn. Currently, only older herbicide varieties, including S-metolachlor, pendimethalin, acetochlor, flumetsulam, thiamethoxam-methyl, 2, 4-D isooctyl ester, and bentazone, are available for this purpose.

In corn and soybean strip intercropping fields, herbicide application should primarily occur after sowing and prior to seedling emergence. Depending on the weed growth stage, soil treatment can be implemented using herbicides such as S-metolachlor (or pendimethalin, acetochlor) combined with thiamethoxam-methyl (or flumetsulam) to inhibit weed emergence[4-5]. Research indicates that combinations such as pyroxasulfone with metribuzin[6], as well as S-metolachlor with flumioxazin[7], are effective for weed control in corn and soybean strip intercropping fields, demonstrating substantial efficacy in managing weed populations. These herbicides have been identified as highly safe for use in corn and soybean cultivation. In 2023, the Agricultural Technology Extension Center of Siyang County conducted a preliminary small-scale field trial. The results indicated that individual herbicides, including pyroxasulfone, metribuzin, flumioxazin, and S-metolachlor, demonstrated effective control of weeds in corn and soybean strip intercropping fields. Thirty days following application, the fresh weight control effects against weeds were 80.19%, 83.94%, 81.13%, and 88.39%, respectively. The combined application of pyroxasulfone and metribuzin resulted in a weed control effect of 91.40%, while the combination of S-metolachlor and flumetsulam achieved a weed control effect of 90.59%. This experiment, conducted through field demonstrations, aimed to identify herbicide varieties suitable for strip intercropping of corn and soybeans in Siyang County, as well as to develop plans for their large-scale promotion and application.

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2 Materials and methods

2.1 Overview of the experimental field The experiment was conducted in the corn and soybean strip intercropping demonstration field at Qinhai Grain Planting Family Farm, located in Yanqian Village, Aiyuan Town, Siyang County, Jiangsu Province. The experimental plots were contiguous and concentrated, encompassing a total area of 5.47 hm^2. The field was flat and featured favorable drainage and irrigation conditions. The soil was sandy with moderate fertility. The corn variety used was Huangjinliang my73, and the soybean variety was Qihuang 34. The preceding crop was wheat.

An intercropping system consisting of two rows of corn and four rows of soybeans was implemented. On July 6, sowing was conducted in a single operation using a mechanical integrated machine, with a corn planting density of 60 000 plants/hm^2 and a soybean planting density of 150 000 plants/hm^2. The soil was sealed for herbicide application on July 7, followed by herbicide spraying on the stems and leaves on July 23. During the sowing period, a compound fertilizer with an N-P-K ratio of 15-15-15 was applied at a rate of 450 kg/hm^2. Throughout the growth period, insecticides were applied twice using a drone, fungicides were sprayed twice, and foliar fertilizers as well as plant growth regulators were each applied once. Except for the variations specified in the experimental design, all management practices were consistent across the treatment areas.

2.2 Test reagents and schemes The test reagents utilized in this study included 45% S-metolachlor CS and 33% S-metolachlor · flumioxazin ZC, both manufactured by Jiangsu Mindleader Crop Technology Co., Ltd. Additionally, 960 g/L S-metolachlor EC was supplied by Syngenta (China) Investment Co., Ltd. The 30% topramezone SC and 480 g/L bentazone AS were produced by BASF (China). Furthermore, 80% flumetsulam WG, 250 g/L fomesafen AS, 10% quizalofop-p-ethyl EC, 80% pyroxasulfone · metribuzin WG, and 24% clethodim EC were provided by Qingdao Hansence Biotechnology Co., Ltd.

The experiment comprised six distinct herbicide treatments, with physical stubble cleaning conducted prior to the application of these treatments. For treatments ①–③, soil sealing was implemented, and soil treatment was performed post sowing but prior to seedling emergence. Each treatment was applied to a demonstration area measuring 0.67 hm^2. Treatment ① consisted of 45% S-metolachlor CS applied at 1 500 mL/hm^2 combined with 33% S-metolachlor · flumioxazin ZC at 1 500 mL/hm^2. Treatment ② involved 80% pyroxasulfone · metribuzin WG applied at 450 g/hm^2. Treatment ③ comprised 960 g/L S-metolachlor EC applied at 1 275 mL/hm^2 combined with 80% flumetsulam WG at 75 g/hm^2. For treatments ④–⑥, soil sealing + stem and leaf spray were implemented. Soil sealing was performed after sowing and prior to seedling emergence, whereas stem and leaf spray was conducted following seedling emergence, specifically when the weeds had developed 2 to 4 leaves. Each treatment was applied to a demonstration area measuring 0.67 hm^2. Treatment ④ consisted of the application of 80% pyroxasulfone · metribuzin WG at a rate of 450 g/hm^2 for soil sealing, combined with 480 g/L bentazone AS applied as stem and leaf spray at 3 000 mL/hm^2. Treatment ⑤ involved the use of 960 g/L S-metolachlor EC at 1 275 mL/hm^2 and 80% flumetsulam WG at 75 g/hm^2 for soil sealing. The stem and leaf sprays were applied separately using physical curtains, with a mixture containing 480 g/L bentazone AS at 3 000 mL/hm^2, 30% topramezone SC at 150 mL/hm^2, and 1 650 mL/hm^2 of adjuvant for the corn strip. For the soybean strip, the application included 480 g/L bentazone AS at 3 000 mL/hm^2 combined with 24% clethodim EC at 450 mL/hm^2. Treatment ⑥ involved the application of 45% S-metolachlor CS at a rate of 1 500 mL/hm^2 and 33% S-metolachlor · flumioxazin ZC at 1 500 mL/hm^2 for soil sealing. No herbicides were applied to the corn strip, whereas the soybean strip received 10% quizalofop-p-ethyl EC at 600 mL/hm^2 combined with 250 g/L fomesafen AS at 1 050 mL/hm^2. Additionally, a blank control without any herbicide application was included.

2.3 Experimental investigation

2.3.1 Investigation on efficacy and safety. The weed control status in soybean at the two-leaf cotyledon stage and in corn at the two-leaf and one-heart stages was evaluated across treatments ①–③. Five samples were collected diagonally, each covering an area of 1 m^2. The number of remaining weed plants and their fresh weight were recorded, and both the plant control effect and fresh weight control effect were calculated. The emergence status of soybeans and corn was monitored, and the effects of herbicides on their emergence were documented. Observations included delayed emergence, seedling mortality, growth inhibition, chlorosis, deformities, leaf wilting, and the death of growth points.

Following the stem and leaf spray at 1, 7, and 14 d, treatments ④–⑥ were evaluated for potential phytotoxic effects on soybeans and corn. Observations focused on indicators such as growth inhibition, chlorosis, deformities, leaf wilting, and necrosis of growth points. Detailed records of phytotoxic symptoms were maintained, and the severity of phytotoxicity was systematically classified. Following the stem and leaf spray at 14 and 28 d, the weed control status in each treatment area were respectively assessed. Five samples were collected diagonally, each covering an area of 1 m^2. The number of remaining weed plants and their fresh weight were recorded, and both the plant control effect and fresh weight control effect were calculated.

2.3.2 Yield survey. Corn yield: A diagonal five-point sampling method, excluding the edge rows, was employed for seed testing and yield assessment. At each sampling point, 10 ears of corn were randomly selected, resulting in a total of 50 ears per treatment area. The number of grains per ear and the 1 000-grain weight were recorded. Actual harvesting and yield measurements were conducted using a combine harvester. Moisture content was determined, and yield was calculated standardized to a moisture content of 13%.

Soybean yield: A diagonal five-point sampling method was employed for seed testing and yield assessment. At each treatment area, five sampling points were established, and 10 soybean plants were selected in the same direction at each point. The number of pods, the number of full pods, and the number of shriveled pods were recorded, and the shriveled pod rate was subsequently calculated. All beans were harvested and weighed, and the yield was extrapolated based on the number of plants. Additionally, the number of grains per plant was calculated to get the 100-grain weight. The actual harvest and yield measurements were conducted using a combine harvester. Moisture content was assessed, and the total output was calculated based on a standardized moisture content of 13%. Additionally, the yield increase rate was determined.

3 Results and analysis

3.1 Safety Observations conducted during the two-leaf cotyledon stage of soybeans and the two-leaf and one-heart stage of corn indicated that corn and soybeans in treatments ①-③ all germinated normally. However, following germination, heavy rainfall caused slight inhibition of soybean seedling growth in the waterlogged area of treatment ①, after which growth resumed to normal levels.

Following stem and leaf spray at 1, 7, and 14 d, no discernible symptoms of phytotoxicity were observed in soybeans and corn across all herbicide treatment areas. Consequently, all herbicide treatments were deemed safe for the growth of both soybean and corn plants.

3.2 Prevention and control effect

3.2.1 Weeding effect following soil sealing treatment. The weeding effect of soil sealing treatments on soybeans during the two-leaf cotyledon stage and on corn during the two-leaf and one-heart stage is presented in Table 1. The results indicated that all treatments effectively controlled weeds in the corn and soybean strip intercropping field. Treatment ③ demonstrated the most effective control effect, achieving an average plant control effect of 95.81% and an average fresh weight control effect of 98.51%. Treatment ② exhibited an average plant control effect of 93.66% and an average fresh weight control effect of 97.91%. Similarly, treatment ① showed an average plant control effect of 93.54% and an average fresh weight control effect of 97.49%.

Table 1 Weeding effect following soil sealing treatment

Treatment	Number of weeds plant/m^2	Plant control effect//%	Weed fresh weight//g/m^2	Fresh weight control effect//%
①	22.2	93.54	0.96	97.49
②	21.8	93.66	0.80	97.91
③	14.4	95.81	0.57	98.51
Blank control	343.6		38.20	

3.2.2 Weeding effect following stem and leaf spray. The control effects of each treatment at 14 and 28 d following stem and leaf spray are presented in Table 2. Fourteen days post treatment, the plant control effect of treatments ①-③ against field weeds ranged from 90.80% to 92.22%, while the fresh weight control effect ranged from 93.15% to 94.96%. At 28 d post treatment, the plant control effect of treatments ①-③ decreased to a range of 77.05% to 82.06%, and the fresh weight control effect ranged from 80.31% to 85.87%.

In treatments ④-⑥, 14 d after the stem and leaf spray, both the plant control effect and fresh weight control effect against weeds exceeded 97%. Twenty-eight days following the treatment, these control effects remained above 89% for all treatments.

Table 2 Weeding effect at 14 and 28 d following stem and leaf spray

Treatment	14 d post treatment				28 d post treatment			
	Number of weeds//plant/m^2	Plant control effect//%	Weed fresh weight//g/m^2	Fresh weight control effect//%	Number of weeds//plant/m^2	Plant control effect//%	Weed fresh weight//g/m^2	Fresh weight control effect//%
①	31.2	91.14	12.6	93.31	89.3	77.05	61.4	81.46
②	27.4	92.22	9.5	94.96	69.8	82.06	46.6	85.87
③	32.4	90.80	12.9	93.15	95.1	77.17	65.2	80.31
④	8.6	97.56	4.8	97.45	41.6	89.31	29.9	90.97
⑤	4.7	98.67	1.9	98.99	23.4	93.99	18.7	94.35
⑥	9.2	97.39	5.1	97.29	42.5	89.08	31.3	90.55
Blank control	352.3		188.4		389.1		331.2	

3.3 Yield analysis The results of corn seed testing and yield measurements are presented in Table 3. Compared to the blank control, the number of grains per ear, 1 000-grain weight, and overall yield in the herbicide-treated plots all exhibited varying degrees of increase. Notably, the corn yield was higher in plots receiving both soil sealing and stem and leaf spray than in those subjected to soil sealing alone. In treatments ①-③, the corn yield ranged from 411.9 to 414.6 kg/667 m^2, corresponding to a yield increase rate of 19.53% -20.31%. In treatments ④-⑥, the yield ranged from 440.3 to 450.7 kg/667 m^2, with a yield increase rate between 27.78% and 30.79%.

Table 3 Effect of different treatments on the yield structure of corn

Treatment	Number of grains per ear//grain	1 000-grain weight//g	Theoretical yield//kg	Actual yield//kg	Yield increase rate//%
①	369	309.2	570.5	411.9	19.53
②	367	312.8	574.0	413.2	19.91
③	368	311.1	572.4	414.6	20.31
④	370	319.7	591.4	440.3	27.78
⑤	381	324.3	617.8	450.7	30.79
⑥	372	317.5	590.6	441.9	28.24
Blank control	316	298.7	471.9	344.6	

NOTE The yield data in the table are based on an area of 667 m^2. The same below.

The results of soybean seed testing and yield measurements are presented in Table 4. Compared to the blank control, treatment with each herbicide resulted in varying degrees of increase in the number of pods, the number of full pods, the 100-grain weight, and overall yield. Notably, soybean plants subjected to both soil sealing and stem and leaf spray exhibited higher numbers of full pods, greater 100-grain weight, and increased yield compared to those treated with soil sealing alone. In treatments ①–③, the soybean yield ranged from 58.6 to 59.1 kg/667 m^2, corresponding to a yield increase rate of 20.33% – 21.36%. In treatments ④–⑥, the yield ranged from 64.3 to 66.5 kg/667 m^2, with a yield increase rate between 32.03% and 36.55%.

Table 4 Effect of different treatments on the yield structure of soybeans

Treatment	Number of full pods//pod	Number of shriveled pods//pod	Shriveled pod rate//%	100-grain weight//g	Theoretical yield//kg	Actual yield//kg	Yield increase rate//%
①	27	5	15.63	20.9	124.2	58.6	20.33
②	27	6	18.18	20.9	124.1	58.8	20.74
③	28	5	15.15	21.1	129.9	59.1	21.36
④	29	4	12.12	21.3	135.9	64.3	32.03
⑤	31	3	8.82	21.6	147.3	66.5	36.55
⑥	30	3	9.09	21.2	139.9	64.6	32.65
Blank control	23	7	23.33	19.6	99.2	48.7	

4 Conclusions and discussion

The yield of corn and soybean fields has been somewhat affected by climatic factors, including waterlogging resulting from multiple heavy rainstorms during the early growth stages and the influence of elevated temperatures on fruit setting in later stages. Nevertheless, the positive impact of various herbicide treatments on enhancing the yields of both soybeans and corn remains pronounced. Among the treatments, soil sealing alone resulted in a yield increase for corn ranging from 19.53% to 20.31%, whereas the combination of soil sealing with stem and leaf spray led to a higher yield increase of 27.78% – 30.79%. For soybeans, soil sealing treatment alone produced a yield increase between 20.33% and 21.36%, while the combined treatment of soil sealing and stem and leaf spray yielded an increase of 32.03% – 36.55%. The combined application of soil sealing with stem and leaf spray exhibited a significantly greater efficacy in controlling field weeds and enhancing the yield of soybeans and corn compared to soil sealing treatment alone.

The herbicides employed in the experiment are safe for both corn and soybeans, effectively control field weeds, and contribute to increased yields of these crops. Treatment ⑤ involved the use of 960 g/L S-metolachlor EC at 1 275 mL/hm^2 and 80% flumetsulam WG at 75 g/hm^2 for soil sealing. The stem and leaf sprays were applied separately using physical curtains, with a mixture containing 480 g/L bentazone AS at 3 000 mL/hm^2, 30% topramezone SC at 150 mL/hm^2, and 1 650 mL/hm^2 of adjuvant for the corn strip. For the soybean strip, the application included 480 g/L bentazone AS at 3 000 mL/hm^2 combined with 24% clethodim EC at 450 mL/hm^2. This treatment effectively controlled weed growth and significantly increased yield. The findings of this study are consistent with those reported by Zhao Yuqi *et al.* [8–10].

The foregoing analysis indicates that weed management in corn and soybean strip intercropping fields should primarily emphasize soil sealing treatments applied after sowing and immediately before seedling emergence, complemented by post emergence stem and leaf spray applications[11]. This study identified herbicides effective for weed control in the corn and soybean strip intercropping fields of Siyang County, thereby offering technical guidance to facilitate the broader adoption of this intercropping practice.

References

[1] CHEN SN, CHEN XL, LIU D, *et al.* Research on weed control technology in maize-soybean strip intercropping system[J]. Crop Research, 2023, 37(4): 364–368, 434. (in Chinese).

[2] JIAO YX, YANG JT, YU LY, *et al.* Control effects and safety evaluation of 40% pyroxasulfone SC mixed with other herbicides against weeds in soybean-corn strip compound planting fields[J]. Pesticide Science and

Management, 2023, 44(8): 49 – 54. (in Chinese).
[3] ZHANG S, WANG YP, LI YP, *et al*. Key techniques and suggestions of weed control in soybean and maize strip compound planting field[J]. Modern Agrochemicals, 2023, 22(5): 46 – 48. (in Chinese).
[4] ZHANG Y, GU LL, CAO L, *et al*. Herbicides and their application for corn-soybean strip compound planting[J]. China Plant Protection, 2022, 42(5): 71 – 75. (in Chinese).
[5] FAN XP, WANG QW, ZHANG K, *et al*. Field efficacy evaluation of four kinds of herbicides on weeds in soybean-corn strip compound planting area [J]. Shaanxi Journal of Agricultural Sciences, 2023, 69(9): 64 – 70. (in Chinese).
[6] GAO XX, FENG K, ZHANG GF, *et al*. Effect of combination of pyroxasulfone and metribuzin in maize and soybean intercropping patterns[J]. Journal of Plant Protection, 2024, 51(2): 361 – 368. (in Chinese).
[7] ZHAO FY, CHENG DQ, WANG XC, *et al*. Efficacy and safety evaluation of 52% flumioxazin · S-metolachlor EC against annual weeds in maize-soybean strip intercropping fields[J]. Contemporary Horticulture, 2024, 47(13): 96 – 98. (in Chinese).
[8] ZHAO YQ, WANG JS, ZHOU RW, *et al*. The control effects of different herbicides combinations on weed in corn-soybean strip compound planting field[J]. Modern Agrochemicals, 2023, 22(5): 49 – 52. (in Chinese).
[9] GENG YL, WANG H, WANG LH, *et al*. Effects of 10 pre-emergence herbicides applied in soybean-maizestrip intercropping field[J]. Acta Agrestia Sinica, 2023, 31(9): 2890 – 2895. (in Chinese).
[10] XU P, JU YW, WANG HC, *et al*. Selectivity of several herbicides to different varieties of soybean and maize and their biological activity of weed in soybean-maize strip compound planting fields[J]. Journal of Weed Science, 2023, 41(4): 67 – 73. (in Chinese).
[11] ZHU DH, YU T, CHEN Y, *et al*. Preliminary study on the optimization experiment of herbicides on weeds in soybean-corn strip compound planting field in the Northern Anhui Province[J]. Modern Agrochemicals, 2023, 22(5): 53 – 58. (in Chinese).

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[22] LIU ZY, GONG BY, HUANG CY, *et al*. Decrement and synergism effect of plant-derived glyceride combined with several pesticides to control citrus psyllid[J]. Hunan Agricultural Sciences, 2024(11): 51 – 54. (in Chinese).
[23] SONG XB, CUI YP, PENG AT, *et al*. Resistance to commonly used insecticides of *Diaphorina citri* field populations in Zhaoqing City, Guangdong Province[J]. Journal of Environmental Entomology, 2021, 43(5): 1321 – 1324. (in Chinese).
[24] HU SS. Monitoring of occurrence dynamics and evaluation and screening of control agents for citrus psyllid in southern Hunan[D]. Changsha: Hunan Agricultural University, 2021. (in Chinese).
[25] XIANG M, LIU H, GONG BY, *et al*. Toxic effects of four kinds of insecticides on nymphs and adults of *Diaphorina citri* Kuwayama[J]. Hunan Agricultural Sciences, 2022(12): 63 – 65. (in Chinese).
[26] TANG ML, ZHANG SY, MEN YJ, *et al*. Field efficacy trials of 22% wente SC against citrus psyllid[J]. Southern Horticulture, 2019, 30(5): 29 – 31. (in Chinese).
[27] LIANG ZL, CAO XY, YANG YN, *et al*. Efficacy of 20% clothianidin SC against *Diaphorina citri* in the field[J]. Guangxi Plant Protection, 2018, 31(1): 22 – 24. (in Chinese).
[28] CHEN H, WEI SL, CHEN W, *et al*. Field efficacy trials of 30% clothianidin and diflubenzuron SC against citrus psyllid[J]. Agriculture and Technology, 2017, 37(10): 48,148. (in Chinese).
[29] LU HX, HUANG YD, ZHANG JH, *et al*. Field efficacy trials of several insecticides against citrus psyllid[J]. Guangxi Plant Protection, 2016, 29(4): 21 – 22. (in Chinese).
[30] YAN JQ, LIU H, CHEN FH, *et al*. Isolation and identification of a *Purpureocillium lilacinum* GDIZM-2 isolate and its toxicity evaluation against *Diaphorina citri*[J]. Journal of Environmental Entomology, 2023, 45(6): 1718 – 1729. (in Chinese).
[31] SUN Y, XIE XT, QIN WJ, *et al*. Screening and field control experiments of different complex formulations of amitraz and cyantraniliprole to control *Diaphorina citri* Kuwayama[J]. Journal of Anhui Agricultural Sciences, 2019, 47(6): 132 – 135. (in Chinese).
[32] DENG MX, PAN ZX, TAN YL, *et al*. Monitoring of resistance of citrus psyllid in Guangxi orchards to six pesticides including chlorpyrifos[J]. China Plant Protection, 2012, 32(4): 48 – 49. (in Chinese).
[33] GUO QZ, WU HY, ZHU TY. *Diaphorina citri* and its control techniques[J]. Modern Horticulture, 2023, 46(7): 94 – 96. (in Chinese).
[34] ZHAO QY, YUAN H, ZHANG WM, *et al*. Field control effect of 25% chlorfenapyr and tolfenpyrad SC against *Diaphorina citri*[J]. Hubei Plant Protection, 2022(6): 44 – 46. (in Chinese).
[35] HU W, WANG K, ZHONG X, *et al*. Enhanced control efficacy of different insecticides mixed with mineral oil against Asian citrus psyllid, *Diaphorina citri* Kuwayama, under varying climates[J]. Insects, 2024, 16(1): 28.
[36] GAO J, YANG QY, FENG YH, *et al*. Evaluation of laboratory toxicities of nC22 agricultural mineral oil and its mixture with imidacloprid against the Asian citrus psyllid, *Diaphorina citri* (Hemiptera: Liviidae) [J]. Acta Entomologica Sinica, 2020, 63(2): 191 – 198. (in Chinese).
[37] WANG FF. Study on the pathogenicity of *Verticillium lecanii* against *Diaphorina citri* and its joint toxicity with flupyradifurone[D]. Fuzhou: Fujian Agriculture and Forestry University, 2019. (in Chinese).
[38] TIAN FJ, LIU JL, ZENG XN. Progress in research on insecticide resistance in the Asian citrus psyllid, *Diaphorina citri*[J]. Chinese Journal of Applied Entomology, 2018, 55(4): 565 – 573. (in Chinese).
[39] HU YY, SUN Y, ZOU ZW, *et al*. Resistance of *Diaphorina citri* Kuwayama to five conventional insecticides in Jiangxi Province[J]. Chinese Journal of Applied Entomology, 2022, 59(2): 419 – 425. (in Chinese).
[40] HUSSAIN ASR, FENG X, SIQUAN L, *et al*. Development and evaluation of emulsifiable concentrate formulation containing *Sophora alopecuroides* L. extract for the novel management of Asian citrus psyllid[J]. Environmental Science and Pollution Research, 2019, 26(21): 21871 – 21881.
[41] LI SJ, LIANG QY, YU YH, *et al*. Research on asian citrus psyllid YOLO v8-MC recognition algorithm and insect remote monitoring system [J]. Transactions of the Chinese Society for Agricultural Machinery, 2024, 55(6): 210 – 218. (in Chinese).
[42] MIRANDA PM, EDUARDO IW, SCAPIN SDM, *et al*. Insecticide application using an unmanned aerial vehicle for *Diaphorina citri* control in citrus orchards[J]. Journal of Applied Entomology, 2023, 147(9): 716 – 727.