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# Control Effect of UAV Low Volume Spray Technology on Thrips and Tomato Spotted Wilt Virus in Tobacco Field

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**Abstract** [**Objectives**] The paper was to explore the influence of unmanned aerial vehicle (UAV) low volume spray technology on the control effect of viruliferous thrips and tomato spotted wilt virus (TSWV) under different pesticide concentrations, and to explore the effective control nodes and methods of thrips and TSWV. [**Methods**] According to the occurrence characteristics of thrips and TSWV, the field control effects of 4 pesticides on thrips and TSWV were tested by UAV with the thrips number and disease index as indicators, following the principle of regional and periodic control trials. [**Results**] In the groups of UAV and artificial prevention and control, 4 agents were used alternatively, including 1% emamectin benzoate ME, 1.7% abamectin imidacloprid ME, 5% emamectin benzoate WDG, and 30% pyriproxyfen dinotefuran SL. There was no significant difference in the control effect of thrips and TSWV among treatment 1 (recommended dosage of UAV agent), treatment 2 (reduction of recommended dosage of UAV agent by 25%) and treatment 4 (recommended dosage of artificial control agent), and the control effects on thrips were more than 83.16% in the 3 treatments. The disease index of TSWV in the 3 treatments decreased from 8.64 ± 1.37 in the blank control group to less than 3, which reached the prevention and control threshold. But treatment 3 (reduction of recommended dosage of UAV agent by 50%) did not reach the prevention and control threshold. The disease index of TSWV in the blank control area increased with the increase of the number of live nymphs of thrips, and there was a significant positive correlation, with good fitness. [**Conclusions**] UAV has a significant impact on the control effect of thrips and TSWV under different pesticide concentrations. In the actual flight control application, it is recommended that the amount of the pesticides is about 3/4 and not less than 1/2 of that of the artificial application. The control area should be extended to 100 m of the ridge of the tobacco field, and UAV is used periodically to control thrips and TSWV for 5 times from pre-transplanting stage to pre-squaring stage of flue-cured tobacco. The control effect is significantly different from the traditional artificial application.

**Key words** UAV; Tobacco thrips; TSWV; Control effect

## 1 Introduction

Tomato spotted wilt virus (TSWV), belonging to *Orthotospovirus*, Tospoviridae, Bunyavirales, was first discovered in Australia[1-2], and can infect more than 1 000 species of grain, vegetable and economic host plants[3-4]. TSWV is transmitted between host plants in a persistent way mainly through thrips vector. In the TSWV vectors of tobacco plant, 9 species of thrips such as *Frankliniella occidentalis* (Pergand), *F. intonsa* (Trybom), *Thrips tabaci* (Lindeman) and *T. palmi* (Karny), *etc.*, are the most widespread[5-7]. Yin Yueyan *et al.*[8] found that TSWV occurred widely in Yunnan tobacco field by constructing phylogenetic tree, and the incidence of TSWV in severe cases could exceed 80%, causing serious harm to the yield and quality of tobacco leaves. Through investigation, Yu Haiqin *et al.*[9] conclude that TSWV is spreading year by year in major tobacco-growing areas of Yunnan Province, and it is likely to replace tomato zonate spotvirus (TZSV) as the mainstream disease.

In recent years, TSWV has showed a trend of continuous diffusion in Qujing tobacco-growing area, especially in Luliang with high multiple cropping potato index, there are a large number of thrips and TSWV sources accumulated in farmland ecosystem, leading to the prevalence of tobacco TSWV. Zhang Hongri *et al.*[10] suggested that the incidence time of TSWV in tobacco was coincided with the increase in the number of *F. occidentalis*, indicating that the vector thrips may be one of the main reasons leading to the prevalence of TSWV in tobacco. Therefore, in order to effectively control TSWV, it is necessary to prevent the occurrence of thrips, and adhere to the prevention and control strategy of "prevention first, pest control and disease prevention, preventing from entering and spreading within a region". At present, the prevention and control of vector thrips mainly relies on conventional chemical control, but the optimal time node of control has not yet been identified, and the prevention and control work face enormous challenges[11-12]. Meantime, traditional artificial control has poor penetration of droplets and is difficult to control large-area outbreaks of diseases and pests, with defects such as "running, bubpling, leaking and dripping", and easily lead to man-made transmission of diseases and pests in the field, especially viral diseases[13-17]. Therefore, it is difficult to control the widespread and concealed thrips by traditional method. However, UAV can ensure good penetration of small droplets, which can better control large-area outbreaks of diseases and pests, and effectively avoid the spread of man-made transmission of diseases and pests in the field[18-21]. In summary, the application of UAV to control thrips and TSWV can achieve the prevention and control goals of effi-

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cient, safe, economical and regional coverage.

The test used UAV to carry out regional, periodic control tests against thrips and TSWV around tobacco fields and ridges from pre-transplanting stage to pre-squaring stage in Luliang tobacco-growing area of Qujing, aiming to explore the relationship between the concentration of UAV spray agent and control effect. Meantime, the effective control nodes and control methods of thrips and TSWV in tobacco fields were investigated, in order to provide a basis for the establishment of application technology system of UAV for periodic control of thrips and TSWV.

## 2 Materials and methods

### 2.1 Materials

**2.1.1** Test conditions and objects. The test was conducted in standard tobacco fields in Shuangguanbao Village, Xiaobaihu Town, Luliang County, Qujing City (103°33′10″ – 103°33′19″ E, 25°9′49″ – 25°9′36″ N) from April to July 2021. Tobacco fields with similar land conditions and high incidence of TSWV were selected for the trial. Other field management measures were carried out in accordance with local technical standards for high-quality flue-cured tobacco production. During the test period from April to July, the average monthly temperatures were 18.3, 21.3, 21.2 and 20.9 ℃, and the monthly precipitations were 57.5, 21, 162.9 and 241.2 mm. The experimental tobacco variety was Hongda, which was planted at a row spacing of 120 cm × 60 cm. The tobacco plants were transplanted into trial fields from April 9 to April 15, 2021.

**2.1.2** Test equipment and agents. DJI T20 agricultural UAV was used for UAV spray operation. According to the application characteristics of DJI UAV and the conditions of test tobacco fields, operation parameters were set as follows: dosage 1.5 L/0.067 $hm^2$, flight speed 4.5 m/s, flight height 2 m, row spacing 4.5 m, sprinkler model XR TEE JET11001VS. 3WBD-20 L high pressure knapsack electric sprayer was used for manual application, and the nozzle flow rate was controlled at 1.5 L/min. The agents used in the test included 1% emamectin benzoate ME (Qingdao Runsheng), 1.7% abamectin imidacloprid ME (Henan Yintian), 5% emamectin benzoate WDG (Hebei Zhongbao Lunong), 30% pyriproxyfen dinotefuran SL (Noposion).

**2.2 Experimental design** The test tobacco field was divided into 5 regions, marked as A, B, C, D and E zones. Five different treatments were designed in each zone: recommended dosage of agent and UAV control (treatment 1), reduction of recommended dosage by 25% and UAV control (treatment 2), reduction of recommended dosage by 50% and UAV control (treatment 3), recommended dosage of agent and artificial electric spray (treatment 4), blank control (treatment 5), with a total of 25 test plots. According to the design method of field efficacy trials[22], random block arrangement method was adopted for each treatment. The specific arrangement is shown in Table 1.

Based on the summary and understanding of the occurrence rules of TSWV and viruliferous thrips in tobacco field, the trial designed 5 times of prevention and control of thrips from pre-transplanting stage to pre-squaring stage of flue-cured tobacco. UAV and artificial control were carried out simultaneously under the same control scheme. The first control was conducted 1 d prior to transplanting, and the remaining four controls were conducted at an interval of 15 d. The control operation was conducted in tobacco field and other crops, miscellaneous grasses, shrubs, *etc.* within 100 m. Considering the resistance of tobacco plants and other reasons, 50 mL/0.067 $hm^2$ emamectin benzoate ME + 50 mL/0.067 $hm^2$ 1.7% abamectin imidacloprid ME were sprayed in the first, third and fifth applications, while 25 g/0.067 $hm^2$ 5% emamectin benzoate WDG + 20 mL/0.067 $hm^2$ 30% pyriproxyfen dinotefuran were sprayed in the second and forth applications. The above agents were sprayed at their recommended dosages, and the dosages of different treatment groups shall be adjusted according to the test.

**Table 1 Random block arrangement diagram**

| Zone code | Random block treatment | | | | |
|---|---|---|---|---|---|
| A | 4 | 5 | 3 | 1 | 2 |
| B | 2 | 4 | 1 | 3 | 5 |
| C | 5 | 3 | 2 | 4 | 1 |
| D | 1 | 3 | 4 | 5 | 2 |
| E | 2 | 5 | 1 | 4 | 3 |

According to the procedure for field efficacy test of pesticide registration, 5 repeat regions were designed in the test, and 5 tobacco plants were selected from each treatment plot[22]. The Z-shaped five-point sampling method was adopted to investigate tobacco plants. The occurrence of thrips and TSWV on the whole tobacco plant was investigated. The flight route of UAV and specific sampling points are shown in Fig. 1.

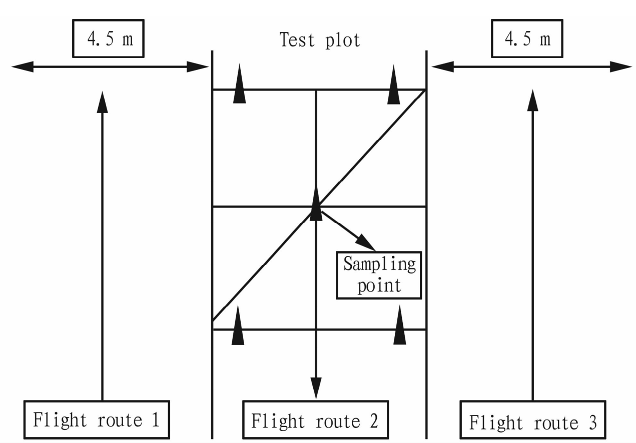


**Fig. 1 Flight route of UAV and experimental design of specific sampling points**

**2.3 Investigation methods and indicators** The investigation methods and calculation indexes of control effect vary among crop pests and diseases. According to the characteristics and prevention and control ideas of TSWV mentioned above, this test mainly investigated two indexes: live nymphs of thrips and disease index of TSWV, and used these two indexes to evaluate the control effect against thrips and TSWV in tobacco.

**2.3.1** Survey of tobacco thrips control. According to the design of field efficacy test of thrips[23], tobacco seedlings had not been transplanted in the first control, so weeds in tobacco field were taken as the survey object of thrips initial number. Five-point sampling method was used in the test plot, and 5 weeds were selected at each point to investigate the number of live nymphs of thrips. In the following 4 investigations, 5 tobacco plants were selected from each point according to the sampling method in Section **2.2**, and the number of live nymphs of thrips in the whole tobacco plant was examined.

DMRT biostatistical method was used for statistical analysis of pesticide effect. The control effect of pests was calculated according to formula (1):

$$E_1(\%) = (1 - \frac{CK_0 \times PT_1}{CK_1 \times PT_0}) \times 100 \quad (1)$$

where $E_1$ is the control effect of pests; $PT_0$ is the number of live nymphs before application in the treatment area, head; $PT_1$ is the number of live nymphs after application in the treatment area, head; $CK_0$ is the number of live nymphs before application in the blank control area, head; $CK_1$ is the number of live nymphs after application in the blank control area, head.

**2.3.2** Survey of TSWV control. According to the classification method of disease severity[24], five-point sampling method was adopted to conduct random classification survey by plant. Ten plants were investigated at each point, and a total of 50 plants were investigated in each plot.

Duncan's new multiple range method was used for statistical analysis of pesticide effect. The test started before the tobacco plant was transplanted and met the condition of no disease index before application, so the disease index and disease control effect were calculated using the following formula.

$$I(\%) = \frac{\sum Nini}{9M} \times 100 \quad (2)$$

where $I$ stands for the disease index; $Ni$ stands for the number of diseased leaves at each level; $ni$ stands for the relative level; $M$ stands for the total number of leaves investigated.

$$E_2(\%) = \frac{I_{CK} - I_{PT}}{I_{CK}} \times 100 \quad (3)$$

where $E_2$ represents the disease control effect; $I_{PT}$ represents the disease index after application in the treatment area; $I_{CK}$ represents the disease index after application in the blank control area.

## 3 Results and analysis

**3.1 Effect of pesticide concentration on control effect against thrips** The test results of UAV low volume spray control against thrips in tobacco field are shown in Table 2. Treatments 1, 2 and 4 all reached the control threshold. There was no significant difference in the control effect at 10 d post treatment ($P<0.01$), and the control effects at 10 d post the fifth application were 87.61%, 83.16% and 85.27%, respectively. Low volume UAV spray can ensure the maximum increase of droplet dispersion and adhesion amount under the condition of small particle size of liquid droplets, while traditional artificial spray has large particle size of droplets and poor penetration, with limited distribution of liquid adhesion and coverage among tobacco canopy and weeds[13-15]. In the experimental tobacco field, it was found that thrips also occurred on the back of tobacco leaves and among weeds in the field. UAV application could increase the deposit rate and coverage of liquids on the back of tobacco leaves and between weeds in the field with the help of airfoil wing force. The survival number and recurrence rate of live nymphs of thrips in the field after application were relatively low, while traditional artificial spray showed liquid loss on leaf surface and no liquid adhesion on the back of leaves, resulting in poor efficacy.

**Table 2 Control effect of different pesticide concentrations on thrips in tobacco field**

| Treatment | Number of insects before application head/25 plants | 10 d post the first application | | Number of insects before application head/25 plants | 10 d post the second application | | Number of insects before application head/25 plants | 10 d post the third application | |
|---|---|---|---|---|---|---|---|---|---|
| | | Number of insects head/25 plants | Control effect//% | | Number of insects head/25 plants | Control effect//% | | Number of insects head/25 plants | Control effect//% |
| 1 | 28.72±3.60 | 5.20±1.52 | 85.17±4.88 A | 4.12±1.02 | 0.58±1.14 | 85.16±2.92 A | 2.16±0.84 | 0.36±0.28 | 83.67±4.25 A |
| 2 | 21.44±3.28 | 4.72±1.56 | 81.97±5.85 A | 5.76±1.84 | 0.96±1.56 | 82.43±3.35 A | 4.24±0.92 | 0.88±1.16 | 79.66±4.81 A |
| 3 | 24.56±3.44 | 14.68±2.08 | 51.04±7.05 B | 18.46±3.32 | 7.96±2.12 | 54.54±5.53 B | 16.40±4.48 | 7.68±1.88 | 54.12±6.67 B |
| 4 | 31.72±3.36 | 6.36±1.52 | 83.58±5.32 A | 5.32±1.84 | 0.72±1.16 | 85.73±8.85 A | 6.20±2.36 | 1.12±1.28 | 82.30±10.20 A |
| 5 | 26.44±3.28 | 32.28±3.96 | | 44.36±3.12 | 42.08±4.64 | | 36.88±2.44 | 37.66±3.52 | |

| Treatment | Number of insects before application head/25 plants | 10 d post the forth application | | Number of insects before application head/25 plants | 10 d post the fifth application | |
|---|---|---|---|---|---|---|
| | | Number of insects head/25 plants | Control effect//% | | Number of insects head/25 plants | Control effect//% |
| 1 | 4.76±1.04 | 0.86±0.72 | 83.05±3.48 A | 8.72±6.80 | 1.36±1.04 | 87.61±5.49 A |
| 2 | 5.48±1.08 | 1.24±1.20 | 78.77±3.71 A | 9.24±1.52 | 1.96±0.68 | 83.16±5.24 A |
| 3 | 19.76±5.04 | 11.36±2.08 | 46.07±4.05 B | 25.20±5.40 | 13.64±2.24 | 57.02±6.19 B |
| 4 | 6.44±1.08 | 1.68±0.56 | 75.53±3.09 A | 9.92±1.32 | 1.84±0.76 | 85.27±5.11 A |
| 5 | 79.02±2.12 | 84.24±1.84 | | 116.56±4.88 | 146.78±4.32 | |

Note: Different capital letters in the same column represent extremely significant difference at 0.01 level; the same below.

The control effect of treatment 3 at 10 d post application was significantly lower than those of the other three treatments ($P<0.01$), and the control effect was only 57.02% at 10 d post the fifth application. At the same time, the survival number and recurrence rate of live nymphs of thrips in the field after application were relatively high, which did not reach the control threshold.

**3.2 Effect of pesticide concentration on TSWV control in tobacco field** In the UAV control test on TSWV of tobacco plants, it can be seen from Table 3 that the disease control effects of treatments 1, 2 and 4 at 10 and 20 d post application (before squaring stage) were significantly better than that of treatment 3 ($P<0.01$). There was no significant difference in disease control effect at 20 d post the fifth application among the three treatments ($P<0.01$), reaching 73.26%, 71.41% and 72.45%, and the disease index was controlled below 2.47 ± 0.34. Under the test principle guidance of "treating insects and preventing diseases", the three treatments all realized good control effects against TSWV.

TSWV control in tobacco field has obvious periodic control characteristics, and the use of UAV low volume spray technology can achieve better control effect within a reasonable pesticide concentration. In the test, the doses of 4 pesticides per 0.067 $hm^2$ in treatment 1 and treatment 4 were 50 mL, 50 mL, 25 g and 20 mL; the doses of 4 pesticides per 0.067 $hm^2$ in treatment 2 were 37.5 mL, 37.5 mL, 18.75 g and 15 mL; the doses of 4 pesticides per 0.067 $hm^2$ in treatment 3 were 25 mL, 25 mL, 12.5 g and 10 mL. The phytotoxity test showed that no chemical injury symptoms occurred in tobacco plants in the whole test period after the application of different pesticide concentrations in each treatment.

**Table 3 Control effect of different pesticide concentrations on TSWV in tobacco fields**

| Treatment | 10 d post the first application | | 10 d post the second application | | 10 d post the third application | |
|---|---|---|---|---|---|---|
| | Disease index | Control effect//% | Disease index | Control effect//% | Disease index | Control effect//% |
| 1 | 0.02 ± 0.01 B | 83.33 ± 6.52 B | 0.20 ± 0.01 C | 74.70 ± 7.45 B | 0.3 ± 0.08 C | 76.19 ± 6.42 B |
| 2 | 0.02 ± 0.01 B | 80.83 ± 6.20 B | 0.20 ± 0.02 C | 71.08 ± 9.20 B | 0.37 ± 0.07 C | 70.63 ± 6.46 B |
| 3 | 0.05 ± 0.02 AB | 58.33 ± 7.43 A | 0.62 ± 0.12 B | 25.30 ± 15.23 A | 0.96 ± 0.08 B | 23.81 ± 9.22 A |
| 4 | 0.02 ± 0.01 B | 81.42 ± 5.26 B | 0.2 ± 0.03 C | 75.90 ± 8.39 B | 0.32 ± 0.11 C | 74.60 ± 11.45 B |
| 5 | 0.12 ± 0.06 A | | 0.83 ± 0.05 A | | 1.26 ± 0.09 A | |
| Treatment | 10 d post the forth application | | 10 d post the fifth application | | 20 d post the fifth application | |
| | Disease index | Control effect//% | Disease index | Control effect//% | Disease index | Control effect//% |
| 1 | 1.49 ± 0.03 C | 65.27 ± 8.54 B | 2.06 ± 0.11 C | 72.24 ± 6.48 B | 2.31 ± 0.17 C | 73.26 ± 7.16 B |
| 2 | 1.62 ± 0.07 C | 62.24 ± 7.88 B | 2.17 ± 0.03 C | 70.75 ± 10.32 B | 2.47 ± 0.34 C | 71.41 ± 8.38 B |
| 3 | 3.21 ± 0.62 B | 25.17 ± 4.95 A | 5.18 ± 0.75 B | 30.19 ± 15.82 A | 6.13 ± 1.58 B | 29.05 ± 13.95 A |
| 4 | 1.56 ± 0.33 C | 63.64 ± 9.49 B | 2.17 ± 0.04 C | 70.75 ± 14.49 B | 2.38 ± 0.12 C | 72.45 ± 15.23 B |
| 5 | 4.29 ± 0.17 A | | 7.42 ± 0.69 A | | 8.64 ± 1.37 A | |

**3.3 Correlation analysis between TSWV and thrips in blank control area** In order to further scientifically and systematically verify the feasibility of the idea of "treating insects and preventing diseases" as the design idea of the test, the regression equation of the explanatory variable ($x$), the cumulative number of live nymphs of thrips in the blank control group, and the explained variable ($y$), the cumulative disease index of TSWV, was obtained: $y=0.99x-1.49$, $r=0.973$.

The explanatory variable was positively correlated with the explained variable, and the closer the correlation coefficient $r$ to 1, the better the fitting degree of the linear correlation. The results indicated that the disease index of TSWV in the blank control area increased with the increased number of live nymphs of thrips, and there was a significant positive correlation, which is also consistent with the research results of Duan Yanru *et al.* [3] and Zhang Hongrui *et al.* [10]. In other test plots, the thrips and disease index were investigated from the early stage of transplantation, and each variable contained the lag value of endogenous variables, so correlation analysis was not carried out.

## 4 Conclusions

As one of the most prevalent tobacco viral diseases in recent years, tobacco TSWV disease has caused underestimated economic loss. Moreover, the best time node for prevention and control of TSWV disease in the tobacco field has not been ascertained, leading to increased difficulty in prevention and control. Therefore, in this paper, five times of periodic UAV prevention and control of thrips and TSWV were explored from pre-transplanting stage to pre-squaring stage of flue-cured tobacco, and the control area was extended to the range of 100 m in the tobacco field. The control effect was remarkable, which was obviously different from the traditional artificial application. The following conclusions were also drawn, in order to provide ideas and references for the professional unified control of TSWV in tobacco field.

In the blank control area, the disease index of TSWV increased with the increased number of live nymphs of thrips, and there was a significant positive correlation, with excellent fitness. The test followed the control idea of "treating insects and preventing diseases", and used the advantages of UAV control to overcome the difficulties of controlling thrips with good concealment and widespread existence. From pre-transplanting stage to pre-squaring stage of flue-cured tobacco, planned regional and periodic control was carried out to effectively break the law of natural occurrence of thrips in tobacco fields, and thus achieved good results in TSWV control in tobacco fields.

There was no significant difference in the control effects among treatments 1, 2 and 4, and the pest control effects of the 3 treatments were all above 83.16%. The disease index of the 3 treatments decreased from 8.64 ± 1.37 in the blank control group to less than 3, and all reached the prevention and control threshold, but treatment 3 did not reach the prevention and control threshold. The results indicated that both UAV and artificial control can achieve good control indicators, and the dose of pesticide can be reduced in a certain range when UAV was applied compared with artificial application. At the same time, considering the influence of the mass concentration of pesticide on the control effect, it is recommended that the dosage in the actual flight control application is about 3/4 and not less than 1/2 of the artificial application.

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