Determination of application parameters for cotton defoliants in the Yellow River Basin

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Abstract: The differences in the growing conditions and the cotton varieties used in the cotton-growing areas in Xinjiang and the Yellow River Basin result in different operating parameters required for unmanned aerial vehicle (UAV)-based plant spraying operations in the two regions.   In this experiment, a multi-rotor plant protection drone was used for the application of cotton defoliant in the Yellow River Basin to determine the optimum dosages of the defoliant ethepon.   The experiment consisted of six treatments; 40 g of thidiazuron, 1 mL of an additive, and different amounts of ethephon (50, 70, 90, 110, and 130 mL) were applied.   The defoliation rate was measured on the 5, 10, 15, and 20 days after the chemical application and the correlation between the ethepon concentration and the defoliation rate as well as the cotton boll opening rate was determined.   The results showed that the application of 90 mL ethephon resulted in the optimal defoliation effect and ripening of the cotton on 5 and 15 days respectively after the chemical application.   It was found that the ethephon application had a larger effect on the cotton defoliation than the ripening rate.   The results of this study provide reference data for the use of a plant protection drone for applying cotton defoliants in the Yellow River Basin.

Keywords: drone, UAV, cotton defoliant, ethephon, defoliation rate, Shandong

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1   Introduction

The Cotton is an important commodity and staple agricultural product related to the national economy and people's livelihood. It is one of the three major raw materials of important cash crops and textile industry in China[1-4].   Shandong province is located in the Yellow River basin of China's three major cotton producing areas (The Yangtze river basin, The Yellow River basin and Xinjiang), belongs to the warm temperate zone monsoon climate, There are 180-200 frost-free days and 2500-2800 hours of light per year; Autumn day high air, which is beneficial to the bolls mature boll opening, cotton production has the advantageous conditions for development[5-8].   However, due to the irregular land in Shandong, the cotton fields are scattered and the general planting area is small.   Therefore, the cotton industry in Shandong Province is less mechanized than the other two cotton areas[9-11]. In recent years, the use of UAVs has resulted in the development of a set of empirical parameters for cotton varieties and planting methods in the Xinjiang cotton-growing area and comparisons were conducted of the cotton varieties and the geographical environment in Shandong and Xinjiang.   The difference between the cotton varieties results in large differences in plant characteristics and leaf growth position between the of Shandong and Xinjiang cotton.   In

the Shandong cotton, the branches are longer and cross each other, which is lush growth than the cotton grown in Xinjiang and other areas.   This has resulted in a lack of plant protection in Xinjiang. The flight parameters of the UAV are not applicable to the Shandong cotton[12-16].   Moreover, in Shandong, cotton farmers are not very satisfied with the defoliant application by drones. Most farmers still use human machinery or ground machinery for defoliation; therefore, most of the drone operating parameters are in the exploratory stage[15-17].   In this study, we conduct experiments to determine the optimum application ratio of cotton defoliants for drone-based spraying of Shandong cotton varieties.   The objectives are to improve the ripening and defoliation of cotton for earlier harvesting in Shandong, improve the efficiency of cotton harvesting, and the grade of the cotton[17-25].

2   Materials and methods

2.1   Laboratory equipment

The plant protection drone used in the test is a Guangzhou Pfeiffer P30 2018 quadrotor plant protection drone equipped with GPS navigation; the body size is 1945×1945×440 (mm) and the sprayer has four centrifugal nozzles that produce particle atomization of 85-295 micron.   The drone system is equipped with route planning and is suitable for continuous spraying and other functions.

The tested defoliation agent consisted of 50% of thidiazuron as a water-soluble powder, ethephon, and special additives provided by the Anyang Quanfeng agricultural aviation company.

2.2   Overview of the test site

The test site is located at the experimental base of the Lufeng Company in Wudi County, Binzhou.   The site is also the Ministry of Agriculture and Rural Areas core demonstration area for mechanization technology for cotton production.   The area covers more than 2,000 acres.   The soil texture of the test site is saline-alkali land.   The planting type of "a mulch has three rows"

is used and the row spacing of the cotton plants is 76 cm.

The test was carried out on Tuesday, 25 May 2018 at 10:00 am; the weather was clear with no wind and the air temperature was 25.3°C.

2.3　Test varieties

The cotton variety tested was Yufeng 103 (Figure 1).

Figure 1　Drone flying over the experimental cotton site

2.4　Experimental design

The experiment consisted of six treatments (Table 1); each treatment area covered 1 acre and all areas were sprayed by drones. The dosage of 50% thidiazuron was 40 g and the same for treatments 1-5 treatments. The ethephon dosages for the 5 treatments were 50, 70, 90, 110, and 130 mL and treatment 6 was the control group with water.

Table 1　Experimental plan processing design

Treatment	Area/m^2	667 m^2 Dosage	667 m^2 water consumption/kg
1	667	thidiazuron 40 g + ethephon 50 mL + additive 1 mL	0.8
2	667	thidiazuron 40 g + ethephon 70 mL + additive 1 mL	0.8
3	667	thidiazuron 40 g + ethephon 90 mL + additive 1 mL	0.8
4	667	thidiazuron 40 g + ethephon 110 mL + additive 1 mL	0.8
5	667	thidiazuron 40 g + ethephon 130 mL + additive 1 mL	0.8
6 (CK)	667	water	0.8

2.5　Dispensing method

Because ethephon is strongly acidic and thidiazuron is weakly alkaline, the pesticides were dispensed using the repeat the method of dilution twice:

1) First, a sufficient amount of water was added to the vat;

2) The thidiazuron and ethephon were diluted separately using a small barrel:

3) The diluted thidiazuron and ethephon were mixed in a large bucket;

4) The additive was added, the mixture was stirred, and water was added to the required amount.

2.6　Experimental investigation

Three points were randomly selected in each treatment area and 10 representative cotton plants were selected for labeling at each point as a survey point. The sample points did not include seedlings and double plants were not counted. The growth of the cotton plants at the survey points was consistent.

During the test period, four investigations were conducted. Prior to the application, the total number of leaves, the total number of bolls, and the number of bolls of each cotton plant were determined. When the base of the plants was investigated prior to the experiment, the new small leaves of the cotton plants (leaf width less than 1 cm) were not counted. The number of leaves and the number of bolls were measured at 5, 10, 15, and 20 d after application and the defoliation rate and the boll opening rate of each treatment were calculated.

The effect of medicament on cotton defoliation:

$$\text{Defoliation rate}(\%) = \frac{A - B}{A} \times 100\% \tag{1}$$

where, A = Total number of cotton leaves before application; B = Number of leaves remaining on cotton plants at the time of investigation.

$$\text{Defoliation effect}(\%) = \frac{C - D}{1 - D} \times 100\% \tag{2}$$

where, C = Treatment area leaf drop rate; D = Control area leaf drop rate.

The medicament promote the effect of the cotton boll opening:

$$\text{Cotton boll rate}(\%) = \frac{E}{F} \times 100\% \tag{3}$$

where, E = The number of cotton bolls; F = The total number of bolls.

$$\text{Ripening effect }(\%) = \frac{G - F}{1 - F} \times 100\% \tag{4}$$

where, G = Treatment area cotton boll rate; H = Control boll rate.

SPSS software was used for the statistical analysis to conduct multiple comparisons of the ripening effect and defoliation effect between the treatments[26].

3　Results and analysis

3.1　Defoliation rate and defoliation effect of the different treatments for the same spraying conditions

Table 2 shows that 5 d after the application, the defoliation rate did not differ much between the 5 treatments and the control group. However, there are large differences between the treatments. It is assumed that the defoliation agent did not have an effect at five days after application. Ten days after the application, the defoliation rate of the cotton was in the range of 30%-50%; the defoliation rate was 60%-70% after 15 d and 70% to nearly 90% after 20 d. A rapid change in the rate of defoliation occurs between 10 and 15 d after application. Moreover, the defoliation rate of treatment 3 was significantly higher than that of the other treatments at different times.

Table 2　Defoliation rate of cotton for different treatments

Treatment	Total number of blades	5 days after application		10 days after application		15 days after application		20 days after application	
		Number of blades	Defoliation rate	Number of blades	Defoliation rate	Number of blades	Defoliation rate	Number of blades	Defoliation rate
1	1589	1430	10.00%	1087	31.50%	564	64.50%	402	74.70%
2	1866	1536	17.68%	1278	31.50%	665	64.30%	611	67.20%
3	1837	1487	19.00%	887	51.70%	501	72.70%	233	87.30%
4	1664	1392	16.30%	1040	37.50%	518	68.80%	373	77.23%
5	1898	1503	17.28%	1166	38.56%	670	64.69%	537	71.70%
CK	1363	1237	9.24%	994	27.07%	898	34.11%	855	37.20%

Figure 2 shows the Histogram of defoliation rate of cotton under different treatments, from which it can be more intuitive to see the variation differences among different treatments.   In treatment 3, the peak value and growth trend of defoliation rates of cotton are obviously better than other treatments.
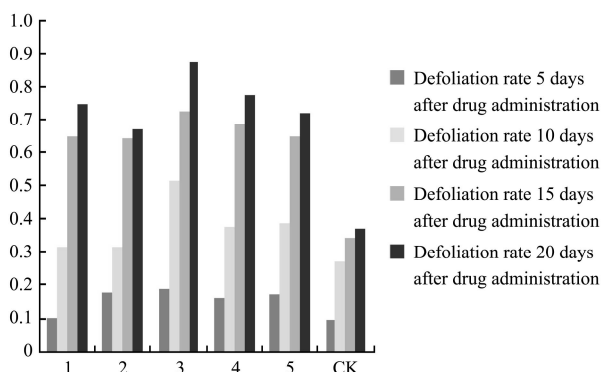

Figure 2   Cotton defoliation rate under different treatments

Table 3 shows a marked change in the defoliation effect 10 d after application; treatment 3 results in a significantly larger defoliation effect than the other treatments.   The defoliation effect 5 d after application in treatment 1 drug was 0.837, i.e., the defoliation effect was very small compared to the control group.   In addition, there is only a difference of 0.76% between treatment 1 and the control group.

Table 3   Defoliation of cotton for different treatments

Treatment	Defoliation effect 5 days after application	Defoliation effect 10 days after application	Defoliation effect 15 days after application	Defoliation effect 20 days after application
1	0.837	6.074	46.122	59.713
2	9.299	6.074	45.819	47.771
3	10.754	33.772	58.567	79.777
4	7.779	14.301	52.648	63.742
5	8.859	15.755	46.411	54.936

3.2   Ripening effect of the cotton for different spraying conditions

As it was shown in Figure 2, the acquired ratio of lignans was increased slightly with increasing of the extraction temperature.   This observation suggests that the extraction temperature had no significant effect on the acquired ratio of lignans.

The extraction of lignans was increased slightly with increasing of the extraction temperature by enhancing the solubility of lignans in solvent.   But very high extraction temperatures will decrease the activity of lignans and increase the consumption of solvent sharply, because the boiling point of ethanol is as low as 78.3°C.   Manipulation steps and extraction costs are expected to increase with increasing of the extraction temperature.   Thus, the extraction temperatures ranging from 20°C to 40°C were selected as the extraction temperatures for the optimization design.   Experiments for selecting the optimal extraction time were conducted at room temperature.

3.3   Influence of extraction time course on acquired ratio of lignans

It can be seen from Table 4 that the trend of the cotton boll opening rate was almost the same as that of the cotton defoliation rate.   However, the stage when a marked change occurred in the boll opening rate was at 10 d after application and was in the range of 50%-60%; the boll opening rate was 60% or higher at 15 d after application.   At 20 d after application, all 5 treatments achieved a boll opening of more than 70%.   The highest boll opening rate of 87% was observed for treatment three; this value was significantly higher than that of the other treatments.

It can be seen from Table 5 that 5 d after application, only treatment 1 resulted in a positive ripening effect of the cotton; all other treatments exhibited a negative effect.   However, it is observed that the ripening effect is slightly lower for treatment 5 than for the control.   At 5 d after application, the ripening effect was limited.   The ripening rate of treatment 1 was higher than that of the control group and treatments 2 to 5 did not reach the initial ripening rate of the control group.   Therefore, a negative number was obtained for the ripening effect.   In addition to the ripening effect, the ripening rate is generally consistent.   The results indicate that the ripening effect is optimal for treatment 3 at 15 d after application.   In addition to the ripening effect, the ripening rate is generally consistent.   The results indicate that the ripening effect is optimal for treatment 3 at 15 d after application.

Table 4   Effect of different treatments on the cotton boll opening rate

Treatment	Total number of cotton bolls	Number of spit	Boll opening rate	5 days after application		10 days after application		15 days after application		20 days after application	
				Number of spit	Boll opening rate	Number of spit	Boll opening rate	Number of spit	Boll opening rate	Number of spit	Boll opening rate
1	486	253	52.05%	272	55.90%	300	61.70%	321	66.00%	337	70.30%
2	549	248	45.17%	278	50.60%	305	55.50%	378	68.80%	442	80.50%
3	502	243	48.40%	256	50.90%	287	57.10%	373	74.30%	437	87.00%
4	552	203	36.77%	258	46.70%	305	55.20%	337	61.00%	401	72.60%
5	557	261	46.85%	284	50.90%	335	60.10%	356	63.90%	398	71.40%
CK	400	213	53.25%	218	54.50%	223	56.00%	246	61.50%	280	66.00%

Table 5   Cotton ripening effect for different treatments

Treatment	Ripening effect 5 days after application	Ripening effect 10 days after application	Ripening effect 15 days after application	Ripening effect 20 days after application
1	3.076	13.446	11.688	9.705
2	−8.571	−0.564	18.961	42.647
3	−7.912	3.05	33.246	61.764
4	−17.142	−1.242	−1.298	19.411
5	−7.912	9.83	6.233	15.882

Table 6   Correlation of defoliation rate between different treatments

Treatment	5 days after application	10 days after application	15 days after application	20 days after application
1	9.566b	32.533ab	63.100b	72.333a
2	16.400b	30.466ab	63.466b	65.500b
3	17.766b	50.300d	65.066c	82.100d
4	16.266b	38.733bc	67.166b	81.533bc
5	25.266b	43.900cd	68.633b	75.700bc
CK	8.000a	26.133a	25.866a	36.633a

4   Advantages of drone spraying over tradtional spraying methods

4.1   Working efficiency

When the plant protection drone flies over the crop, the rotor produces a downward airflow that disturbs the crop leaves, allowing the liquid to penetrate easily and reducing the amount of pesticide by more than 20%; therefore, spraying is more effective. The ideal flight altitude is less than 3 m and the flight speed is less than 10 m/s.   This greatly improves the work efficiency and it is also more effective for achieving the desired effect of the defoliant. Traditional spraying methods are slow, inefficient, and prone to failure

4.2   Safety

Most plant protection drones now carry cameras and can conduct farm inspections during flight operations.   This helps farmers better understand crop growth.   Therefore, targeted applications of pesticides can be used to control pests or spray pesticides.   Moreover, when the drone is flying, the spraying is controlled remotely, which separates the spraying personnel and the pesticide.   This is safer and avoids the danger of poisoning by manually applying pesticides.

4.3   Cost advantage

The cost of the chemicals used in this trial was as follows: Thiabendron 0.37 yuan/g, ethephon 0.04 yuan/mL, additives 0.35 yuan/mL.   The cost per acre for treatments 1-5 was 17.15, 17.95, 18.75, 19.55, and 20.35 yuan.   The cost of hiring a pilot and drone to spray the cotton defoliating agent is about 10 yuan/acre.   In this study, the P30 drone was used; it has a battery capacity to cover five acres.   Each battery charge requires 0.8 kW of electricity, which is 0.16 kWh per acre.   At the price of electricity of 0.6 yuan, the electricity fee is 0.096 yuan per acre. The cost of the water used in the experiment is negligible. Moreover, due to the high pesticide concentration and low volume carrying capacity of the drone, the degree of atomization of the liquid is high, which results in a lower cost of the defoliant compared to manual spraying or ground-based mechanical spraying. It takes 5-10 minutes for a drone to operate an acre of land, saving a lot of manpower and time.

5   Conclusions

The acceptance of drone operations is not as high in Shandong province as in Xinjiang and many drone operating parameters have not been developed to date.   This study was conducted to improve the ripening and defoliation methods used for cotton in Shandong to ultimately improve the cotton grade and the efficiency of machine-based cotton picking.   We determined the number of cotton leaves and cotton bolls and the defoliation rate of plants for treatments with different chemical concentrations to determine the optimal dosage.   The following conclusions were obtained:

1) The optimum treatment in terms of defoliation and ripening of the cotton in Shandong was treatment 3, i.e., thidiazuron 40 g + ethephon 90 mL + fly defense additive 1 mL.

2) During the 20-day test period, the defoliation rate and ripening rate increased most rapidly between 5 d and 15 d after the application of the defoliant.

3) The chemical application had a larger effect on the defoliation than the ripening of the cotton and the differences in the defoliation effect were relatively large for the different ethephon concentrations.   However, the effect of the ethephon concentrations on the cotton boll ripening rate was not very large.

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