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

Xin Han, Jinyou Yu, Yubin Lan, Fanxia Kong, Lili Yi

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 ethephon. 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 ethephon 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

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 bulls mature boll opening, cotton production has the advantageous conditions year; Autumn day high air, which is beneficial to the bolls mature. 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 bulls mature boll opening, cotton production has the advantageous conditions year; Autumn day high air, which is beneficial to the bolls mature. 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 bulls mature boll opening, cotton production has the advantageous conditions year; Autumn day high air, which is beneficial to the bolls mature. 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 bulls mature boll opening, cotton production has the advantageous conditions year; Autumn day high air, which is beneficial to the bolls mature. 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 bulls mature boll opening, cotton production has the advantageous conditions year; Autumn day high air, which is beneficial to the bolls mature.

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 ethephon. 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 ethephon 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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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 Qianfeng 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).

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

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Area/m²</th>
<th>667 m² Dosage</th>
<th>667 m² water consumption/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>667</td>
<td>thidiazuron 40 g + ethephon 50 mL + additive 1 mL</td>
<td>0.8</td>
</tr>
<tr>
<td>2</td>
<td>667</td>
<td>thidiazuron 40 g + ethephon 70 mL + additive 1 mL</td>
<td>0.8</td>
</tr>
<tr>
<td>3</td>
<td>667</td>
<td>thidiazuron 40 g + ethephon 90 mL + additive 1 mL</td>
<td>0.8</td>
</tr>
<tr>
<td>4</td>
<td>667</td>
<td>thidiazuron 40 g + ethephon 110 mL + additive 1 mL</td>
<td>0.8</td>
</tr>
<tr>
<td>5</td>
<td>667</td>
<td>thidiazuron 40 g + ethephon 130 mL + additive 1 mL</td>
<td>0.8</td>
</tr>
<tr>
<td>6 (CK)</td>
<td>667</td>
<td>water</td>
<td>0.8</td>
</tr>
</tbody>
</table>

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:

\[ \text{Defoliation rate}(\%) = \frac{A - B}{A} \times 100\% \]  \hspace{0.5cm} (1)

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

\[ \text{Defoliation effect}(\%) = \frac{C - D}{1 - D} \times 100\% \]  \hspace{0.5cm} (2)

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

The medicament promote the effect of the cotton boll opening:

\[ \text{Cotton boll rate}(\%) = \frac{E}{F} \times 100\% \]  \hspace{0.5cm} (3)

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

\[ \text{Ripening effect}(\%) = \frac{G - F}{1 - F} \times 100\% \]  \hspace{0.5cm} (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

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Total number of blades</th>
<th>5 days after application</th>
<th>10 days after application</th>
<th>15 days after application</th>
<th>20 days after application</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number of blades</td>
<td>Defoliation rate</td>
<td>Number of blades</td>
<td>Defoliation rate</td>
<td>Number of blades</td>
</tr>
<tr>
<td>1</td>
<td>1589</td>
<td>1430</td>
<td>10.00%</td>
<td>1087</td>
<td>31.50%</td>
</tr>
<tr>
<td>2</td>
<td>1866</td>
<td>1536</td>
<td>17.68%</td>
<td>1278</td>
<td>31.50%</td>
</tr>
<tr>
<td>3</td>
<td>1837</td>
<td>1487</td>
<td>19.00%</td>
<td>887</td>
<td>51.70%</td>
</tr>
<tr>
<td>4</td>
<td>1664</td>
<td>1392</td>
<td>16.30%</td>
<td>1040</td>
<td>37.50%</td>
</tr>
<tr>
<td>5</td>
<td>1898</td>
<td>1503</td>
<td>17.28%</td>
<td>1166</td>
<td>38.56%</td>
</tr>
<tr>
<td>CK</td>
<td>1363</td>
<td>1237</td>
<td>9.24%</td>
<td>994</td>
<td>27.07%</td>
</tr>
</tbody>
</table>
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.

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

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Total number of cotton bolls</th>
<th>Number of split</th>
<th>Boll opening rate</th>
<th>Number of split</th>
<th>Boll opening rate</th>
<th>Number of split</th>
<th>Boll opening rate</th>
<th>Number of split</th>
<th>Boll opening rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>486</td>
<td>253</td>
<td>52.05%</td>
<td>272</td>
<td>55.90%</td>
<td>321</td>
<td>66.00%</td>
<td>337</td>
<td>70.30%</td>
</tr>
<tr>
<td>2</td>
<td>549</td>
<td>248</td>
<td>45.17%</td>
<td>278</td>
<td>50.60%</td>
<td>378</td>
<td>68.80%</td>
<td>442</td>
<td>80.50%</td>
</tr>
<tr>
<td>3</td>
<td>502</td>
<td>243</td>
<td>48.40%</td>
<td>256</td>
<td>50.90%</td>
<td>373</td>
<td>74.30%</td>
<td>437</td>
<td>87.00%</td>
</tr>
<tr>
<td>4</td>
<td>552</td>
<td>203</td>
<td>36.77%</td>
<td>258</td>
<td>46.70%</td>
<td>337</td>
<td>61.00%</td>
<td>401</td>
<td>72.60%</td>
</tr>
<tr>
<td>5</td>
<td>557</td>
<td>261</td>
<td>46.85%</td>
<td>284</td>
<td>50.90%</td>
<td>356</td>
<td>63.90%</td>
<td>398</td>
<td>71.40%</td>
</tr>
<tr>
<td>CK</td>
<td>400</td>
<td>213</td>
<td>53.25%</td>
<td>218</td>
<td>54.50%</td>
<td>246</td>
<td>61.30%</td>
<td>280</td>
<td>66.00%</td>
</tr>
</tbody>
</table>

Table 5  Cotton ripening effect for different treatments

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Ripening effect 5 days after application</th>
<th>Ripening effect 10 days after application</th>
<th>Ripening effect 15 days after application</th>
<th>Ripening effect 20 days after application</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3.076</td>
<td>13.446</td>
<td>11.688</td>
<td>9.705</td>
</tr>
<tr>
<td>2</td>
<td>−8.571</td>
<td>−0.564</td>
<td>18.961</td>
<td>42.647</td>
</tr>
<tr>
<td>3</td>
<td>−7.912</td>
<td>3.05</td>
<td>33.246</td>
<td>61.764</td>
</tr>
<tr>
<td>4</td>
<td>−17.142</td>
<td>−1.242</td>
<td>−1.298</td>
<td>19.411</td>
</tr>
<tr>
<td>5</td>
<td>−7.912</td>
<td>9.83</td>
<td>6.233</td>
<td>15.882</td>
</tr>
</tbody>
</table>

Table 6  Correlation of defoliation rate between different treatments

<table>
<thead>
<tr>
<th>Treatment</th>
<th>5 days after application</th>
<th>10 days after application</th>
<th>15 days after application</th>
<th>20 days after application</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>9.566b</td>
<td>32.533ab</td>
<td>63.100b</td>
<td>72.333a</td>
</tr>
<tr>
<td>2</td>
<td>16.400b</td>
<td>30.460ab</td>
<td>63.466b</td>
<td>65.500b</td>
</tr>
<tr>
<td>3</td>
<td>17.766b</td>
<td>50.300d</td>
<td>65.066c</td>
<td>82.100d</td>
</tr>
<tr>
<td>4</td>
<td>16.266b</td>
<td>38.733bc</td>
<td>67.166b</td>
<td>81.533bc</td>
</tr>
<tr>
<td>5</td>
<td>25.266b</td>
<td>43.900cd</td>
<td>68.633b</td>
<td>75.700bc</td>
</tr>
<tr>
<td>CK</td>
<td>8.000a</td>
<td>26.133a</td>
<td>25.866a</td>
<td>36.633a</td>
</tr>
</tbody>
</table>
4 Advantages of drone spraying over traditional 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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