Effects of alkyl ethyl sulfonate dosage on cotton defoliation efficacy sprayed by UAV

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Abstract: As a new low volume sprayer, unmanned aerial vehicle (UAV) application is developing quickly worldwide. Alkyl ethyl sulfonate soluble concentrate is a kind of spray adjuvants for defoliants, which is widely used in cotton defoliant application. The aim of this study was to compare the droplet deposition, defoliation and boll opening of a UAV added with six dosages of alkyl ethyl sulfonate on the cotton. Addition with 4.2 g a.i./hm^2 (one-sixtieth of the recommended dosage in the field) alkyl ethyl sulfonate could significantly increase the droplets coverage rate, and improve defoliation and boll opening effects. Added with lower dosage alkyl ethyl sulfonate (4.2 g a.i./hm^2 and 8.4 g a.i./hm^2), the droplet distribution uniformity was much better than that of moderate (84 g a.i./hm^2) and high dosage (252 a.i./hm^2) of alkyl ethyl sulfonate. It could not only ensure the effects of defoliation and boll opening, but also reduce the environmental pollution by alkyl ethyl sulfonate.

Keywords: defoliant, alkyl ethyl sulfonate dosage, droplet deposition, unmanned aerial vehicle

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1 Introduction

Cotton (*Gossypium hirsutum* L.) is an important raw material for textile industry. The quality of cotton is directly related to the product quality and production efficiency of textile enterprises[1]. Xinjiang has the natural conditions and resource advantages of planting cotton. In 2018, the area used for cotton planting reached 2.49 million ha, accounting for 74.32% of the cotton planting area in China, and the total output of cotton is 5.11 million tons, accounting for 83.84% of the cotton production in China[2]. Developing the machine-harvested cotton is conducive to realizing large-scale operation, greatly reducing cotton planting costs, improving labor productivity, and promoting the transformation of cotton production to modern agriculture[3]. In 2018, the planting area of machine-picked cotton reached 870,000 ha in Xinjiang, China[4]. The application of chemical defoliants is a key technology for the machine-harvested cotton. A high leaf defoliation rate is obtained when chemical defoliant is applied at the 40%-60% boll open stage[5,6]. However, temperatures are unstable in the Xinjiang cotton belt, with minimum temperatures dropping sharply in early autumn[7]. Under these conditions, the defoliants have to be sprayed early to facilitate machine harvesting.

Early defoliation adversely affects boll components and fiber development and significantly increases the percent of immature bolls and lint mass[8]. These reductions in fiber quality had caused declines in the sale of machine-harvested cotton from Xinjiang[9]. Therefore, improving the defoliation effect and reducing the impurities in broken leaves of seed cotton are the key to achieving high quality and high efficiency of machine-harvested cotton.

The highly density planting pattern has potential and prospects in oasis agriculture in Xinjiang. However, the cotton leaves overlap considerably. Boom sprayers are widely used for large farm crops due to their high working efficiency and effective spraying. As ground machinery, the boom sprayer spraying leads to problems, such as rolling cotton plants, hitting cotton bolls and pulling cotton branches, which reduce the yield and quality of cotton[10,11]. To adapt to this unique operating environment and improve the shortage of the defoliants spraying equipment supply, unmanned aerial vehicles (UAVs) have been rapidly developed in Xinjiang, China for pesticide application[12-15]. According to the statistics provided by the Ministry of Agriculture and Rural Affairs of the People's Republic of China, nearly 30,000 crop protection UAVs are used in the country[16,17]. The spraying area of cotton defoliants approached 6.7 million hectares in 2018[4]. Compared with boom sprayer, UAVs spraying cotton defoliant could avoid seed cotton yield loss of more than 6%, which display significant economic benefits[18]. At present, the study on the cotton defoliants spraying by UAVs mainly focused on the feasibility of spraying operation, that is, after cotton defoliant spraying by UAVs, the spraying quality were judged by the effect of cotton defoliation rate and boll opening rate. In 2016, in order to study the effect of UAV spraying cotton defoliant, and then selected the spraying parameters suitable for UAV spraying cotton defoliant, the National Aviation Plant Protection Science Technology Innovation

Alliance (NAPP) organized a joint test of UAVs spraying cotton defoliant in Shihezi, Xinjiang. That was the first large-scale joint test of UAVs spraying cotton defoliant in China, which has a positive significance for the promotion of UAVs[19]. Since then, UAVs spray cotton defoliant developed rapidly. Wang et al[20] and Hu et al[21] screened the defoliants suitable for UAV spraying. Zhang et al[22] and Xin et al[14] reported that UAV spraying cotton defoliants could achieve efficient utilization of the defoliants. Hu et al[15] and Wen et al[23] found that the efficiency of UAV spraying cotton defoliant was significantly higher than that of electric air-pressure knapsack (EAP) and boom sprayer. Xiao et al [13] and Meng et al[12] found that vegetable oil adjuvants had significant effects on improving the deposition of droplets and increasing the efficacy of defoliants. These studies had played a great role in promoting the development of cotton defoliant spraying technology by UAVs in Xinjiang cotton belt.

Alkyl sulfonates are an anionic surfactant with good wetting, spreading and penetration characteristic. Alkyl sulfonates are used predominantly in pesticide[24], medicine[25], detergents[26], petroleum industry[27] and textile industry[28]. These chemicals show low acute and repeat dose toxicity[29]. However, the large number of alkyl sulfonate compounds could be form negative charged micelles in water, forth, covering the water surface, affecting the transmission of oxygen, reducing the amount of dissolved oxygen in water, which resulting in deterioration of water quality and affecting the growth of aquatic organisms[30]. 280 g/L alkyl ethyl sulfonate soluble concentrate is a kind of spray adjuvants for cotton defoliants, which widely used in Xinjiang. It could increase the wettability and permeability of defoliants on cotton leaves, improve the penetration rate, and reduce the negative effects of droplet drift and bounce, and improve the utilization rate of pesticides. However, in the current production, the recommended dosage of the alkyl ethyl sulfonate, is used for boom sprayer. Dosage of alkyl ethyl sulfonate used for UAVs spraying cotton defoliant is blank. For UAVs, the spray volume is only one-twentieth of that of boom sprayer, but there is no corresponding decrease in the use of alkyl ethyl sulfonate. This would not only cause waste of resources, but also bring great pollution to the environment. Herein, we report our results concerning the effect of alkyl ethyl sulfonate adjuvants on droplet deposition, defoliation and boll opening sprayed by a UAV. The purpose of this study was to provide scientific support for reducing defoliants and increase efficiency in Xinjiang.

2   Materials and methods

2.1   Spray equipment

A battery motive P30 four-rotor UAV (XAG Co., Ltd., Guangzhou, China) (Figure 1) was used in this study. The UAV was powered by a 12800 mAh Li-Po battery (XAG Co., Ltd., Guangzhou, China). The flying time was 15 min with full tank. The flight speed was 14.4-43.2 km/h. The interval of nozzles (iRASS intelligent centrifugal spraying technology, with a nozzle flow range of 2.7 to 5.6 L/min, droplet size 90-300 μm) was 1.18 m and the installation angle was vertically downward. The pesticide was transferred from the tank to the nozzles by a high frequency pulse peristaltic pump (XAG Co., Ltd., Guangzhou, China). The accuracy of the flying height and flying velocity was controlled in centimeter-level with the help of real time kinematic differential positioning technology. The flight height was 2.0 m and the effective spraying width was 3.5 m. The spray volume was close to 15 L/hm²[13].

Figure 1   P30 electric four-rotor plant protection UAV

2.2   Experiment design

2.2.1   Field plots

The experiments were conducted at the town of Beiquan, Xinjiang Production and Construction Crops, Shihezi, Xinjiang Uygur Autonomous Region, China (latitude 44°23′21″, longitude 85°58′48″). The test cotton material was "Hexin 47", which was sown on 28 April, 2018, using a machine-harvested cotton planting model with wide film planting 6 lines (10 cm + 66 cm), 192,000 cotton plants/ha, and drip irrigation under plastic film. The cotton in the whole test area grew well and consistently.

2.2.2   Spray-deposition measurements

According to the dosage of alkyl ethyl sulfonate (BIOPOWER®) (Bayer Crop Science Co., Ltd., Leverkusen, Germany), the experiment consists of six treatments: 0, 4.2, 8.4, 84, 168, 252 g a.i./hm² (active ingredient/ha, which 252 g a.i./hm² was the recommended dosage for the boom sprayer application). The droplets deposition, defoliation, boll opening, defoliant retention in cotton leaves and cotton yield characteristic and fiber quality were tested.

The spray deposition and the control efficacy were measured in a 109 m × 150 m area (Figure 2A). The sample layout was repeated three times, 20 m apart between adjacent repetitions. Each plot was a 14 m × 150 m area. 5-m buffer zones were set between plots to avoid drift pollution (Figure 2A)[31]. Sample collectors at each sample site consisted of one water-sensitive papers (WSPs; 25 mm × 75 mm; Figure 2B). The WSPs were used to evaluate the deposition characteristics such as droplet coverage rare and droplet size[32,33]. The WSPs were fixed to cotton leaves using paper clips[13].

Defoliation treatments were initiated at 40% boll opening time[5,6]. The first defoliant spraying was conducted on 15 September 2018, and the second defoliant spraying was conducted on 22 September 2018. The climatic condition was recorded using a Kestrel 5500 digital meteorograph (Loftopia, LLC, USA). The recorded temperatures of 19.5-30.5°C, a relative humidity of 17.8-31.3% and wind velocities of 0-14.4 km/h on 15 September 2018. The recorded temperatures of 22.0-35.9°C, a relative humidity of 18.7-43.0% and wind velocities of 0-14.04 km/h on 22 September 2018. There was no precipitation during the defoliation spraying.

In all tests, 360 g/L thidiazuron·180 g/L diuron suspension concentrate (Drop ultra®) at 121.5 g a.i./ha (Bayer Crop Science Co., Ltd., Leverkusen, Germany) and 40% ethephon at 480 g a.i./ha (September 22, 2018 was 600 g a.i. /ha) (Jiangsu Anpon Electrochemical Co., Ltd., Huaian, China) were added into the tank.

Nearly 30 s after spraying, all WSPs were removed and placed in self-sealing bags along with a label describing the treatment, replication, and WSPs site information. For each plot, there were 21 WSPs[13]. Samples were placed into light-proof sealed boxes immediately after collection and transported to the laboratory for analysis. In the laboratory, the WSPs were scanned at a resolution

of 600 dpi with a scanner. After that, Image J software (ImageJ 1.3 8, National Institutes of Health, Bethesda, MD, USA) was used to extract droplet deposits in the digital image for the analysis of the droplet size, number of spray deposits and the area of coverage. Coverage was determined as the percent cover of the card from the stain of the deposited image[34]. The distribution uniformity of the spray deposition in the cotton canopy was analyzed using the value corresponding to the coefficient of variation (CV), calculated as the quotient between the standard deviation and the average of the spray deposits on the cotton[31].
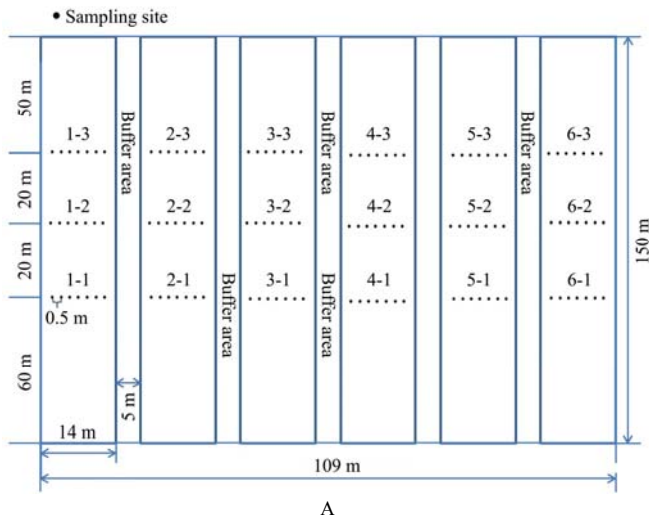

A

B

Figure 2   (A) Experimental layout of each treatment and (B) placement of water-sensitive papers (WSPs) at each sampling position within the cotton canopy

2.2.3   Contact angle

The contact angle was measured from 0° to 180° and the measurement accuracy is ±0.1°. Collected the fresh and clean cotton inverted three leaves, selected the flat part to cut the small leaf surface (to avoid veins, disease spots, etc.) and lay it flat in the sample slot of the contact angle instrument. Using a micro syringe to draw each solution respectively, and drop 4 μL of the solution on the cotton leaf surface. The contact angle was observed 30 seconds later and repeated 10 times. The average and standard deviation were calculated.

2.2.4   Defoliation and boll opening

The cotton defoliation rate and the boll opening rate were chosen as the field test targets to analyze the field efficacy of alkyl ethyl sulfonate dosage with different spray deposition characteristics. Defoliation rate and boll opening rate were selected based on previous reports[13,14]. Prior to treatment application, 30 cotton plants were randomly tagged to count the number of leaves on each cotton plant. The number of leaves were investigated and recorded four times according to defoliant field efficacy test criteria (4, 7, 12 and 15 days after spraying). The defoliation rate was calculated using Equation (1):

$$\text{Defoliation rate (\%)} = ((N_a - N_b)/N_a) \times 100\% \quad (1)$$

where, N_a is the number of leaves before treatment and N_b is the number of leaves after treatment.

Boll opening rate was determined on the same tagged 30 cotton plants. The number of cotton bolls (opened and closed) were investigated and recorded four times according to defoliant field efficacy test criteria (4, 7, 12 and 15 days after spraying). Boll opening rate was calculated by:

$$\text{Boll opening rate (\%)} = (N_c/N_d) \times 100\% \quad (2)$$

where, N_c is the number of opened bolls and N_d is the total number of bolls.

2.2.5   Cotton yield characteristics and fiber quality

The cotton bolls weight was measured after all the cotton bolls opened. For this measurement, 50 cotton bolls from the canopies (upper, middle and lower layers) were randomly collected in each experimental area to determine the bolls weight and fiber quality (determined by the Key Laboratory of Cotton Biology and Genetics and Breeding in the Northwest Inland Region of the Ministry of Agriculture, Shihezi, China)[13].

2.3   Data statistics and processing

The percentage of the area covered on the WSP, defoliation rate and boll opening rate, were transformed to arcsin √X/100. The deposition on different canopies, number of spray deposits and droplet size were log ($x+1$) transformed prior to analysis in order to stabilize the wide variances and meet normal assumptions. After transformation, the data were analyzed for normality using the Kolmogorov–Smirnov test and for equal variance across the treatments and replicates using Levene's test ($p<0.05$). Data were compared across different application rates using analysis of variance (ANOVA) (Origin 9.1 originLab, Northampton, MA, USA). By comparing the mean one-way ANOVA, the least significant difference (LSD) was selected. The confidence interval was set to 95% and $p<0.05$ was chosen to indicate a significant difference between the two groups.

3   Results and discussion

3.1   Spray deposition

3.1.1   Droplet coverage rate

To obtain a satisfactory defoliation efficiency, it is meaningful to optimize the dosage of alkyl ethyl sulfonate to obtain better droplet coverage and penetration. As shown in Figure 3, the droplets average coverage rate without alkyl ethyl sulfonate was only 0.85% (Figure 3a), while that of spraying with alkyl ethyl sulfonate was 2.01%. These results indicated that the average droplet coverage ratewith alkyl ethyl sulfonate was significantly higher than that without alkyl ethyl sulfonate. When the added dosage of alkyl ethyl sulfonate was 4.2 g a.i./hm² (one-sixtieth of the recommended dosage in the field) and 8.4 g a.i./hm² (one-thirtieth of the recommended dosage in the field), the average droplet coverage rate was 1.56% and 1.92%, respectively (Figure 3b and 3c). When the added dosage of alkyl ethyl sulfonate was 84 g a.i./hm² (one-third of the recommended dosage in the field) and 168 g a.i./hm² (a half of the recommended dosage for boom sprayer), the droplet average coverage rate after the first spraying was 3.26% and 2.38%, respectively. After the second spraying, the average droplet coverage rate reached 2.31% and 2.35% respectively. These results showed the average droplet coverage

rate after the second spraying was significantly higher than that of other treatments (Figure 3d and Figure 3e).   At the recommended dosage in the field (252 g a.i./hm^2), the defoliant droplet coverage was 1.50% (Figure 3f).
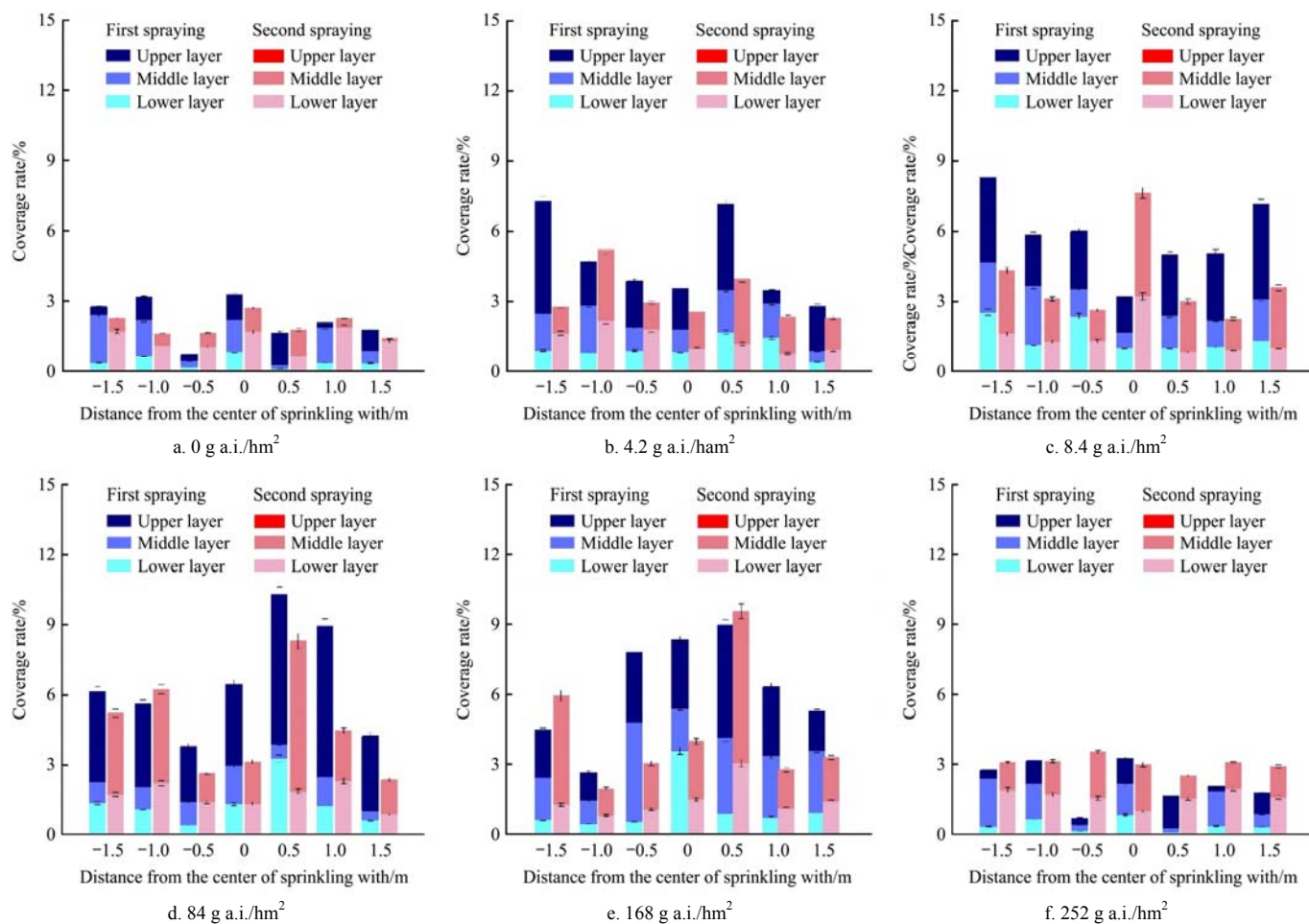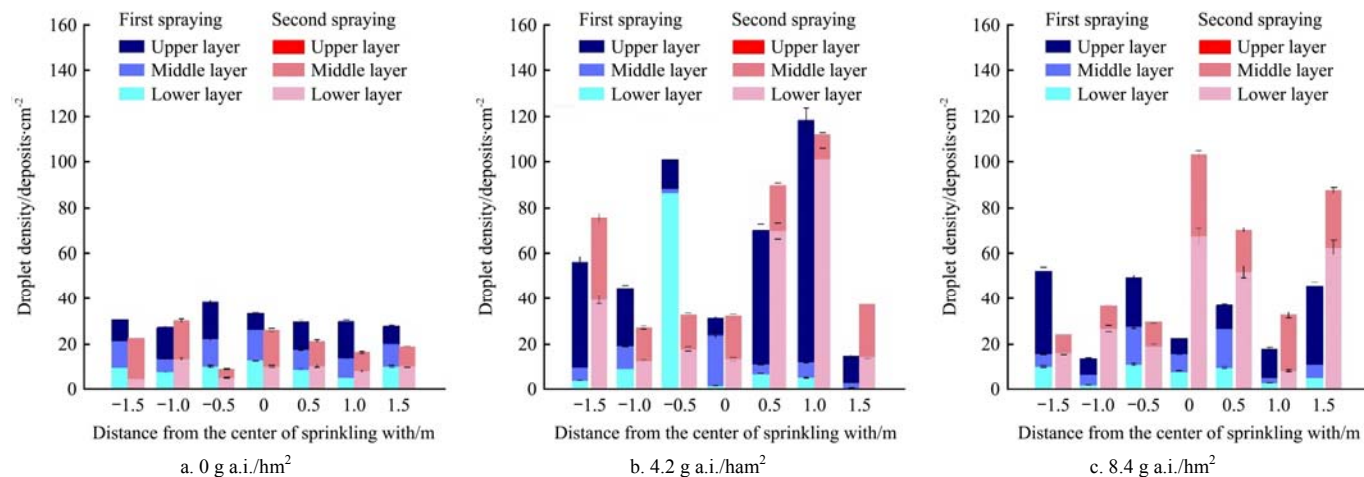

Figure 3   Effect of alkyl ethyl sulfonate dosage on droplets coverage rate.

3.1.2 Droplet density

As shown in Figure 4, the effect of alkyl ethyl sulfonate dosage on cotton droplet density was similar to that of droplet coverage rate.   When added alkyl ethyl sulfonate as 4.2, 8.4, 84, 168 g a.i./hm^2, the average droplet density was 20.9 droplets cm^{-2}. The control treatment (Figure 4a) and added alkyl ethyl sulfonate as 252 g a.i./hm^2 (Figure 4f), the average droplet density was 11.25 droplets cm^{-2} and 15.25 droplets cm^{-2}, respectively.   With the addition of 4.2 g a.i./hm^2 alkyl ethyl sulfonate, the average droplet density after the first spraying reached 20.77 droplets cm^{-2} (Figure 4b), while the average droplet density of others was less

than 20 droplets cm^{-2}.   After the second spraying, the average droplet density reached 28.95 droplets cm^{-2} (4.2 g a.i./hm^2), 27.74 droplets cm^{-2} (8.4 g a.i./hm^2), 28.33 droplets cm^{-2} (84 g a.i./hm^2) and 28.84 droplets cm^{-2} (168 g a.i./hm^2), respectively.   The control treatment (Figure 4a) and added alkyl ethyl sulfonate as 252 g a.i./hm^2 (Figure 4f), the average droplet density was 10.38 droplets cm^{-2} and 11.39 droplets cm^{-2}, respectively.   The results showed that the addition of alkyl ethyl sulfonate had a significant effect on droplet density, and the droplet density in cotton canopy was the most significant when the addition amount was 4.2 g a.i./hm^2.
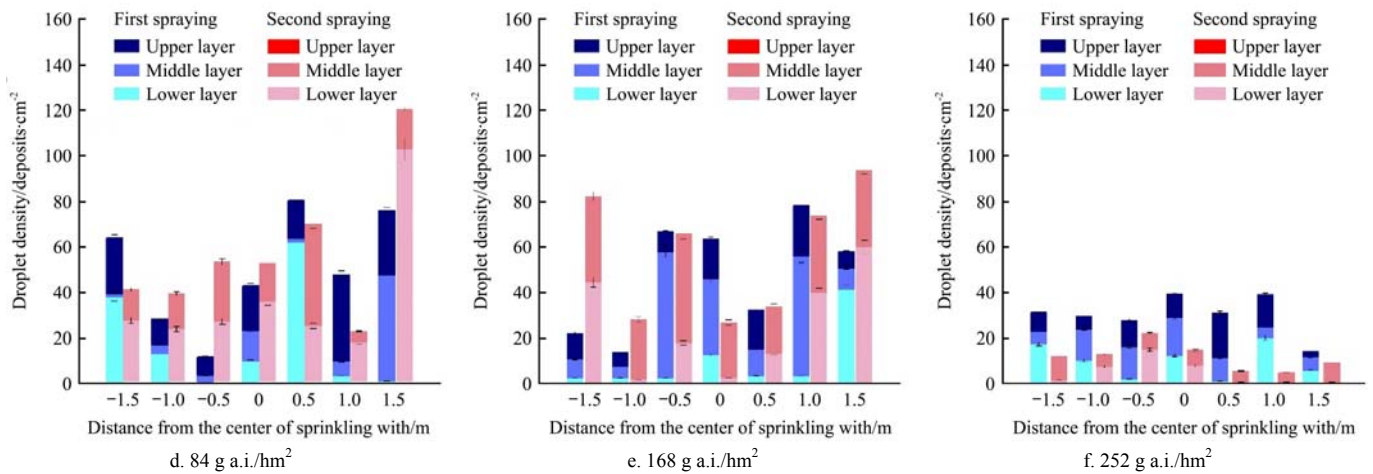
Figure 4   Effect of alkyl ethyl sulfonate dosage on droplets density

The size, number and concentration of droplets had an important influence on the field efficacy of pesticide[35]. Table 1 showed the effect of alkyl ethyl sulfonate on the defoliant droplets size on cotton leaves. The droplet size of defoliant increased significantly with alkyl ethyl sulfonate, which was significantly higher than that without alkyl ethyl sulfonate. The result showed that alkyl ethyl sulfonate had excellent plate-out ability. The droplet size of the control treatment was smaller ($Dv_{50} < 200$ μm), which could easily cause droplet evaporation and drift, resulting in lower droplet density and coverage rate. Zhang et al found that the type and concentration of adjuvant had a great influence on the droplet size[36]. Lan et al found that addition of a spray adjuvant resulted in significantly lower airborne drift[37]. Meanwhile, the adjuvants had a considerable influence on the efficiency[38]. This is probably due to the improvement of the wetting and extending properties of defoliant droplets on the water sensitive paper, resulting in a large reading droplet size.

3.1.3   Uniformity of the deposition

To comprehensively evaluate the droplet deposition distribution in the cotton canopy, the coefficient of variation (CV) of the droplet deposition characteristics (droplet density and coverage rate) was calculated to characterize the droplet distribution uniformity after the addition of alkyl ethyl sulfonate (Table 2). For low volume spraying, the relevant quality indicators could be achieved when the droplet distribution uniformity is less than 60%[39]. The results showed that the CV of droplet distribution was more than 60% added with moderate

dosage alkyl ethyl sulfonate (84 g a.i./hm², 168 g a.i./hm² and 252 g a.i./hm²). When added with 4.2 g a.i./hm² and 8.4 g a.i./hm² alkyl ethyl sulfonates, the CV was 47.9% and 55.39%, respectively. The results showed that added with lower dosage alkyl ethyl sulfonate, the droplet distribution uniformity was much better than that of moderate and high dosage alkyl ethyl sulfonate.

Table 1   Effects of alkyl ethyl sulfonate dosage on droplets size

Date of spraying	Alkyl ethyl sulfonate dosage/g a.i.·hm⁻²	D_{V50}/μm		
		Upper layer	Middle layer	Lower layer
2018.9.15	0	142.81c	185.45d	181.1d
	4.2	560.29ab	546.14a	375.86b
	8.4	568.00ab	351.43c	353.43c
	84	572.43a	386.71ab	474.43a
	168	485.29b	374.86b	385.57ab
	252	341.29bc	409.71a	365.57bc
2018.9.22	0	-	161.71c	109.14d
	4.2	-	540.86ab	599.57a
	8.4	-	498.43b	448.14bc
	84	-	572a	422.71c
	168	-	539ab	449.43bc
	252	-	578.86a	452.14b

Note: The data in the table are the original data and have not been converted. Means within a column followed by the same letter are not significantly different according to LSD at *p*=0.05. The data were from WSP samples and that thus the data may differ from the actual values on the leaves.

Table 2   Effects of the dosage of alkyl ethyl sulfonate on the coefficient of variation of droplet distribution

Alkyl ethyl sulfonate dosage /g a.i. ·hm⁻²	CV/%							Average
	First spraying				Second spraying			
	Upper layer	Middle layer	Lower layer	Average	Middle layer	Lower layer	Average	
0	65.12	31.67	23.87	40.22	54.30	29.50	41.90	41.06
4.2	53.63	68.39	43.75	55.25	42.30	38.77	40.54	47.90
8.4	54.17	60.26	53.12	55.85	54.19	55.66	54.93	55.39
84	69.03	88.28	88.31	81.87	61.07	67.83	64.45	73.16
168	39.17	75.73	118.44	77.78	42.23	66.45	54.34	66.06
252	78.18	55.05	91.66	74.96	56.53	49.02	52.77	63.87

3.1.4   Droplet contact angle

Contact angle is the main indicator to measure the effect of droplets on the spreading and retention of cotton leaves. Figure 5 showed the effect of alkyl ethyl sulfonate dosage on pesticide droplet contact angle. When the added dosage of alkyl ethyl

sulfonate was 8.4 g a.i./hm², displayed the lowest contact angle. The contact angle could be significantly increased without the addition of alkyl ethyl sulfonate and the highest dose of alkyl ethyl sulfonate. This result is consistent with the results of droplet coverage and droplet density.
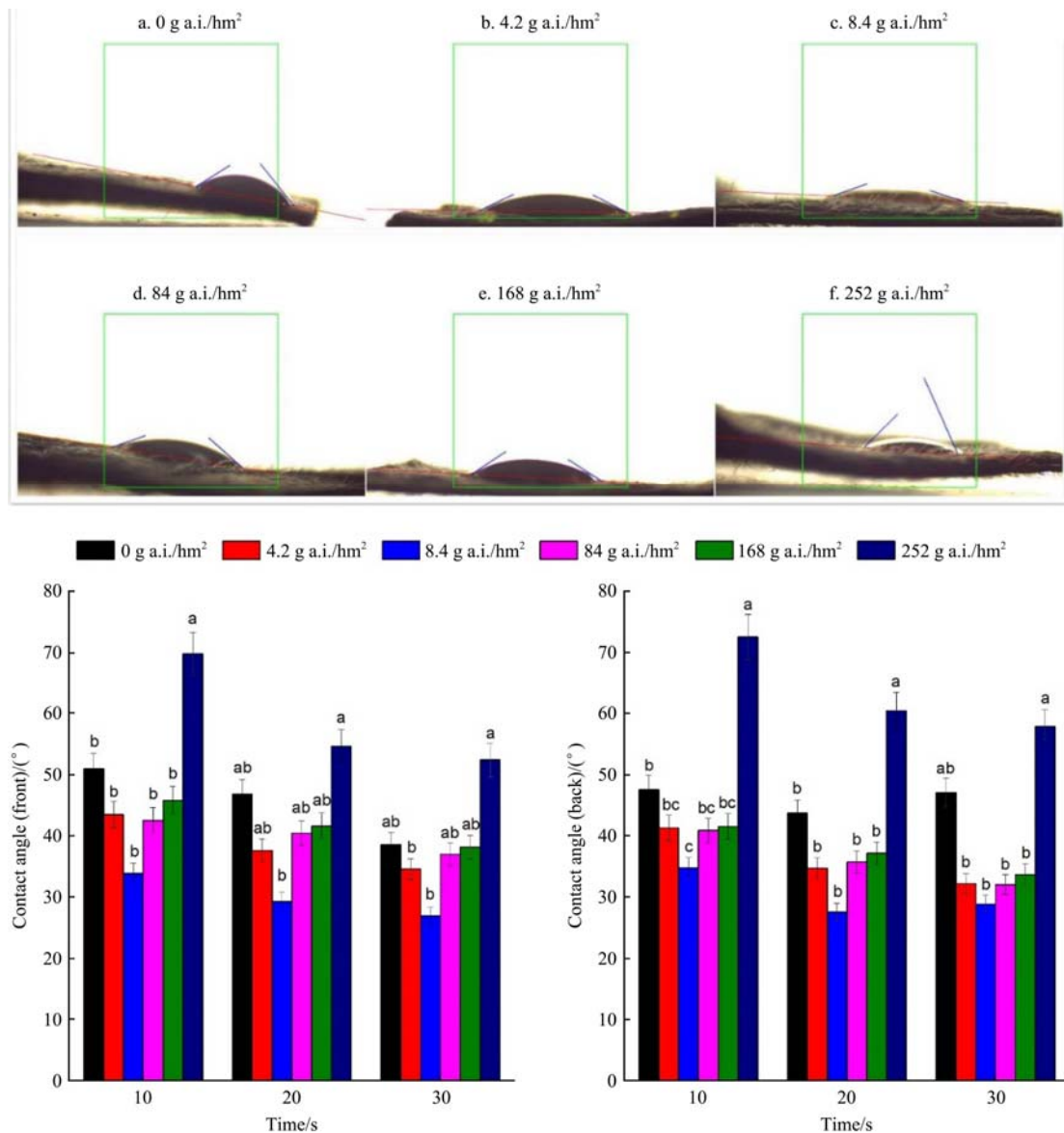
Figure 5   Effects of alkyl ethyl sulfonate dosage on contact angle

It was found that with the increase of adjuvants ratio, the decrease degree of contact angle was lower and even higher.   This showed that in practical application, the excessive addition of adjuvants is meaningless[40].   This is consistent with our research conclusion.   In order to obtain better contact angle of defoliant droplet on cotton leaves, the dosage of alkyl ethyl sulfonate should not exceed 8.4 g a.i./hm².

3.2   Defoliation and boll opening

3.2.1   Defoliation

According to the results of spray deposition and high cotton plant density, the droplet coverage rate of the UAV spray treatments is low in the middle and bottom layers with single round spraying due to dense cotton leaves in the upper canopy, which blocks the descent of the droplets.   Hence, second-round harvest aid spraying was carried out after seven days.   The effect of added alkyl ethyl sulfonate on cotton defoliation was shown in Figure 6. Leaf abscission began to form four days after the first spraying, and the alkyl ethyl sulfonate had a considerable effect on the defoliation effect.   For the upper layer of the cotton canopy, only the 8.4 g a.i./hm² treatment showed the worst defoliation efficacy; the other treatments were similar with the control treatment (without alkyl ethyl sulfonate, Figure 6a).   For the middle layer of the

cotton canopy, after 7, 12, and 15 days after spraying, the defoliation rate of the 4.2 g a.i. /ha alkyl ethyl sulfonate treatment was 95.98%, 96.81% and 98.17%, respectively, which was significantly better than other dosages (Figure 6b).   Due to the poor penetrability of the canopy sprayed by UAV, the defoliation of the lower layer of cotton canopy was significantly lower than that of the upper and middle canopies, and the defoliation effect of 4.2 g a.i./hm² alkyl ethyl sulfonate treatment was slightly higher than that of others (Figure 6c).   For the cotton canopy, four days after the spraying, the defoliation rate was more than 40% when treated with different dosages of alkyl ethyl sulfonate, and 15 days after spraying (nine days after the second spraying), the defoliation rate was more than 80% (Figure 6d).   In general, the cotton canopy demonstrated the highest defoliation rate when treated with 4.2 g a.i./hm² alkyl ethyl sulfonate.   Comparing with the information of droplet deposition, it could be found that 4.2 g a.i./hm² alkyl ethyl sulfonate treatment had the best droplet coverage rate, droplet density and droplet size.   The results were consistent with the defoliation rate.   It also showed that the large diameter droplets could increase the retention of defoliant on cotton leaves by reducing drift and evaporation, thus increasing the defoliation effect.
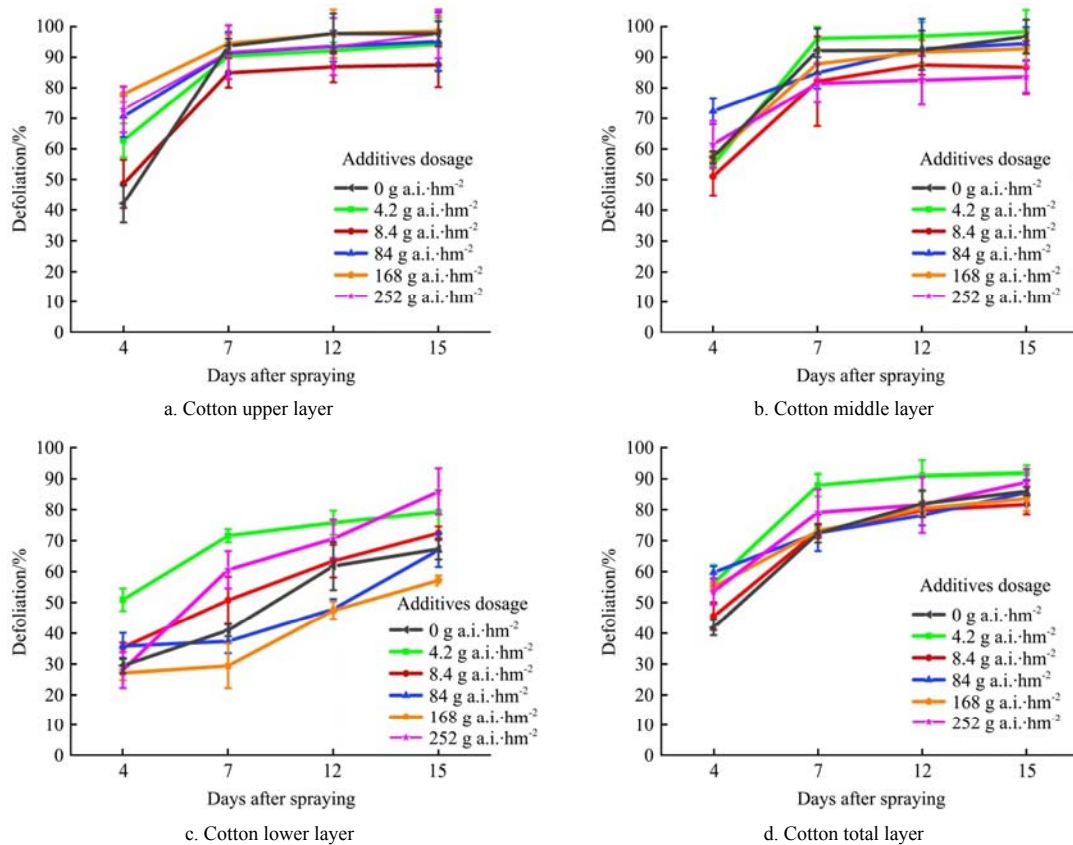
a. Cotton upper layer

b. Cotton middle layer

c. Cotton lower layer

d. Cotton total layer

Figure 6   Effects of defoliant supporting adjuvant alkyl ethyl sulfonate dosage on defoliation and boll opening

3.2.2   Boll opening

Compared with the control, the cotton boll opening rate was significantly improved by adding alkyl ethyl sulfonate (Table 3). Four days after spraying, the boll opening rate of control treatment was 41.97%, and that of 168 g a.i./hm^2 alkyl ethyl sulfonate treatment was 54.61%, which was consistent with the results of high droplet coverage and defoliation rate.   Seven and twelve days after spraying, the boll opening rate of 168 g a.i./hm^2 alkyl ethyl sulfonate treatment both showed the best boll opening effect. Interestingly, fifth days after spraying, the boll opening rate of 4.2 g a.i./hm^2 alkyl ethyl sulfonate treatment increased sharply, reached 85.27%, which was no significant difference with 168 g a.i./hm^2 treatment.

3.3   Cotton yield characteristics and fiber quality

The effects of alkyl ethyl sulfonate on cotton yield and quality factors are shown in Table 4.   Compared with the control, the cotton boll weight (BW) increased after the addition of alkyl ethyl sulfonate, of which all alkyl ethyl sulfonate treatment reached significant levels.   All alkyl ethyl sulfonate had no effect on upper half mean length (UHML), uniformity index (UI), breaking strength (Str) and maturity rate (MR) of cotton fiber quality factors. 84 g a.i./hm^2 alkyl ethyl sulfonate treatment had significant effect on micronaire (Mic), 4.2 g a.i./hm^2 alkyl ethyl sulfonate treatment had little effect on short fiber index (SFI).   Previous studies showed that spraying defoliants had significant effects on Boll and fiber development[6].   No direct report on the impact of alkyl ethyl sulfonate on cotton yield and fiber quality has been published.

Table 3   Effects of alkyl ethyl sulfonate dosage on cotton boll opening

Alkyl ethyl sulfonate dosage /g a. i.·hm^{-2}	Days after spraying				
	0	4	7	12	15
0	36.32b	41.97ab	43.55c	55.47c	74.76b
4.2	38.87b	47.78b	55.62c	66.85bc	85.27ab
8.4	42.10a	50.88ab	57.51b	70.91b	83.85ab
84	41.29ab	47.13ab	55.91b	75.18ab	84.35ab
168	45.65a	54.61a	72.90a	80.46a	88.38a
252	40.98b	44.36b	61.45ab	68.86bc	75.94b

Note: means within a column followed by the same letter are not significantly different according to LSD at p=0.05.

Table 4   Effects of alkyl ethyl sulfonate dosage on cotton fiber quality and yield

Alkyl ethyl sulfonate dosage /g a. i.·hm^{-2}	BW/g	UHML/mm	UI%	Mic	Str/cN·tex^{-1}	Elg/%	MR	SFI
0	4.66c	28.76a	84.05a	4.68ab	29.35a	6.85a	0.84a	7.70ab
4.2	5.72ab	28.35a	84.75a	4.65ab	28.75ab	6.85a	0.84a	7.45b
8.4	5.96ab	29.48a	84.85a	4.74b	29.45a	6.95a	0.84a	7.40bc
84	5.05b	28.42a	84.15a	4.23c	29.50a	6.85a	0.83ab	7.65b
168	6.23a	27.58ab	84.40a	4.79a	29.45a	6.80a	0.85a	7.70ab
252	5.63ab	28.25a	83.35ab	4.89a	29.60a	6.75ab	0.85a	8.30a

Note: a: BW, Boll weight; UHML, Upper Half Mean Length; UI, Uniformity Index; Mic, Micronaire; Str, Breaking Strength; Elg, Elongation rate; MR, Maturity Rate; SFI, Short Fiber Index.

4   Conclusions

In this study, six dosages of alkyl ethyl sulfonate adjuvants were used for defoliants spraying by UAV.   The uniformity of the deposition, droplets penetrability, characteristics of the deposition, defoliation rate and boll opening rate were compared in this research.   The dosage of alkyl ethyl sulfonate had a great influence on defoliant droplet deposition.   Added with lower dosage alkyl ethyl sulfonate, the droplet distribution uniformity was much better than that of moderate and high dosage alkyl ethyl sulfonate.   Addition with lower dosage alkyl ethyl sulfonate (4.2 g a.i./hm^2, which was the one-sixtieth of the recommended dosage in the field) could significantly increase the droplets coverage rate, and showed better defoliation and boll opening effects.   Therefore, the experiment demonstrated the feasibility of the alkyl ethyl sulfonate dosage could be reduced.   This not only reduced the environmental pollution caused by excessive alkyl ethyl sulfonate, but also avoids the waste of resources.

Acknowledgments

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