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Environmental Parameters on Spray Performance of Light Plant Protection Drones

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Abstract: As a new type of pesticide spraying technology, light plant protection drones have become one of the main means of large scale farmland pest and disease defence. This paper analyzes the effects of environmental parameters such as wind speed, flight height, flight speed, nozzle spray speed and nozzle spray angle on the operational effects of multi-rotor plant protection drones in combination with field operations, and provides data support for improving plant protection drones as a means to achieve accurate application.

1. Introduction

As a large agricultural country, China has seen a trend towards agricultural mechanisation. As a new type of pesticide spraying technology, light plant protection drones have become one of the main means of large scale farmland pest and disease defense.

There are many factors that affect the operational effect of light plant protection drones, such as the external wind speed during plant protection drone operations, the flight height and flight speed of plant protection drones, the spray speed of plant protection drones and the spray angle of spray nozzles, all of which affect the operational effect of plant protection drones[1]. This paper takes the DP180 multi-rotor plant protection drone as an example, and takes wind speed, flight altitude and flight speed as variables to study the influence of environmental parameters on the operational effect of light plant protection drones, in order to provide data support for improving plant protection drones to achieve accurate application[2].

2. Operation Mode Selection

The light plant protection UAV is divided into two operation modes: manual operation mode and hybrid operation mode. The manual mode is controlled by the pilot using a remote control, while the hybrid mode is controlled by the flight control operator using ground equipment to control the aircraft in a "command mode"; from the data in Table 1, it can be seen that the manual mode takes the shortest time than the hybrid mode, but due to the short flight distance of the manual operation mode, the operation efficiency is low, the operation is complicated and the labour intensity is high. However, because of the short flight distance of manual operation mode, low operational efficiency, complicated operation and high labour intensity, taking into account the development trend of the plant protection machine and the advantages of the platform, the mixed control operation mode was chosen for this paper[3]. The mixed control operation mode is divided into: hovering position telemetry (the aircraft makes a 180 degree turn and then telemeters the position and enters the preset flight path.) The aircraft can be operated in the following modes: hovering position telecontrol (the aircraft makes a 145-degree turn and then accelerates to a given heading to enter the preset flight path), hovering with speed turn (the aircraft makes a turn with speed), coordinated turn (the aircraft makes a turn with speed); Table 1 shows that the hovering position telecontrol takes the least amount of time at the same flight height and speed, so the hovering position telecontrol mode was chosen for the plant protection machine spraying test.

Table 1: Comparison table of data of mixed control operation mode

Mode of operation	Flight Subjects	Data	Take off-land (min)	Height (m)	Velocity (m/s)	Remarks
Manual	Manual flight	7.24	6.67	15	18	
	Manual flight	7.28	6.15	10		
Mixed Control	Hover and turn	7.24	10.7	15	18	
	Hover turns with speed	7.24	8.07	15	18	
	Hover position remote adjustment	7.24	9.38	15	18	
	Coordinated turn	7.24	14.15	15-50	18	Climb to 15m Turn at 50 meters
	Hover turn	7.28	8.15	10	18	
	Hover turns with speed	7.28	8.72	10	18	
	Hover position remote adjustment	7.28	7.50	10	18	
	Coordinated turn	7.28	8.23	10-50	18	Climb to 15m Turn at 50m

3. Analysis of plant protection drone spraying performance tests

Table 2: Technical indicators of operational quality of different spraying types

Spraying type	Allowable error of spraying rate %	Fog droplet coverage density	Mist droplet distribution uniformity %	Mist droplet diameter μm	Fog droplet spectrum width
Constants	±5	≥25	≤50	250-400	≤2.5
Low volume	±5	≥20	≤60	150-300	≤2.0
ultra-low capacity	±5	≥10	≤70	≤150	≤1.5
Note 1: The uniformity of droplet distribution is expressed as the coefficient of variation of droplet coverage density.					
Note 2: The droplet diameter is expressed as the volume median diameter (VMD).					
Note 3: The width of the droplet spectrum is expressed as the ratio of the volume median diameter to the number median diameter (VMD/NMD).					
Note 4: Constant spraying: spraying operations with a spraying volume greater than 30 liters per hectare (inclusive).					
Note 5: Low-volume spraying: spraying operations with a spraying volume of 5 liters-30 liters per hectare.					
Note 6: Ultra-low volume: spraying operations with a spraying volume of less than 5 liters per hectare (included).					

According to the <Technical Indicators for Agricultural Aerial Spraying Operations>, different spray types have different droplet coverage densities (pcs/cm^2) when spraying. Assuming that constant spraying is met, a droplet coverage density of ≥25 droplets/cm^2 is required to meet the constant spraying index. The distance between sampling cards for meeting the standard is called the effective spray width. The criteria are detailed in Table 2 Technical indicators of operational quality for different spray types.

2.1 Data Acquisition and Processing

Before each test the collection cards need to be arranged in advance, the cards need to be marked with a number and the spacing between the cards is 1m. When the test is completed, the droplets on the collection cards are dried, the droplet collection cards are collected according to serial numbers and scanned one by one using a scanner. The scanned images are analysed by DepositScanlnstall software to derive parameters such as droplet coverage density, settling volume and droplet particle size for different aerial spraying parameters. The fog droplet collection photos and the processed images are shown in Figure 1.

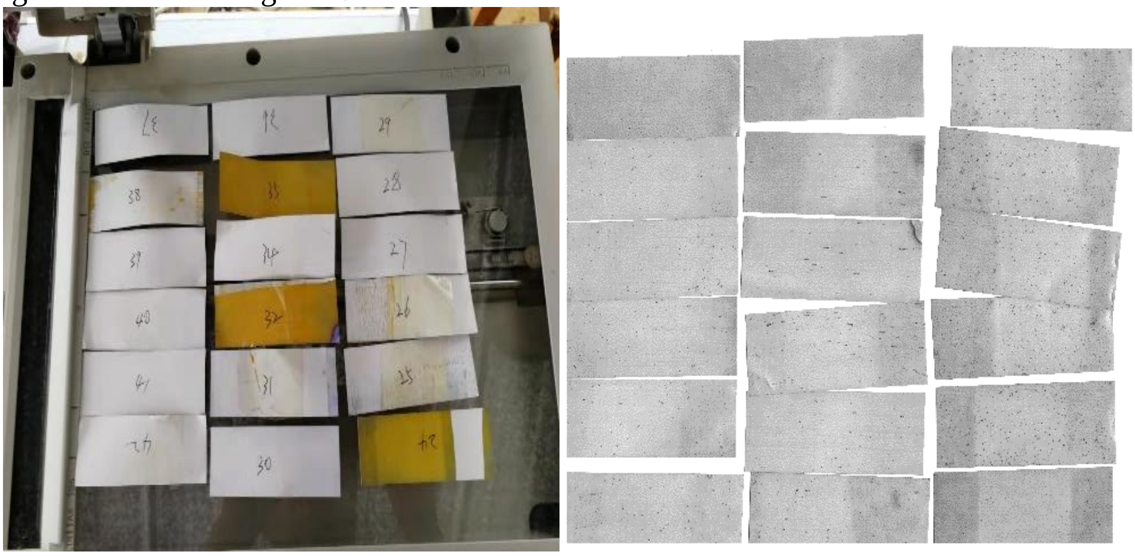

Figure 1: Fog droplet collection photos and the processed images

The data collection was carried out in four groups, the first three groups for the same wind speed and operating height, different operating speed for mist droplet sampling, sampling results are shown in Table 3, Table 4, Table 5. The fourth group is for single sortie spraying effect, the same operating height and operating speed, different wind speed conditions fog droplet adoption results. The fifth group is the same wind speed and operating speed, different operating heights for fog droplet sampling.

2.2 Analysis of the Effect of Flight Speed on the Spray Performance of the UAV

The data collection was carried out in three groups, for the same wind speed and operating altitude, different flight speed for spray droplet sampling, sampling results are shown in Table 3, Table 4 and Table 5 respectively.

Table 3: Height 7m, speed 10m/s, wind speed 0-1m/s, droplet sampling

Collection No.	Droplet diameter			Coverage area	Image area	Settlement density	
ID	DV 1 (μm)	DV 5 (μm)	DV 9 (μm)	% Coverage	Image Area /cm^2	Deposits/cm^2	Deposition (μL/cm^2)
1	166	276	376	0.99	6.35	10.6	0.049
2	227	368	581	505	658	34.4	0.318
3	150	263	366	186	492	215	0.089
4	169	287	466	493	958	498	0.263
5	165	295	445	329	1016	325	0.172
6	160	278	438	266	1006	271	0.136
7	165	278	449	23	1133	227	0.18
8	203	404	954	575	1078	403	0.41
9	203	338	443	24	1229	184	0.141
10	186	318	457	228	927	167	0.13
11	172	269	382	169	974	172	0.184
12	152	278	502	293	86	35	0.146
13	190	287	492	328	1147	275	0.179
14	129	191	293	0.63	102	123	0.025
15	159	268	379	0.66	1088	81	0.032
16	167	330	476	0.58	725	63	0.034
17	251	540	646	0.91	125	64	0.071

Table 4: Height 7m, velocity 12m/s, wind speed 0-1m/s, droplet sampling

Acquisition number	Droplet diameter			Coverage area	Image area	Settlement density	
ID	DV 1(μm)	DV 5(μm)	DV 9(μm)	% Coverage	Image Area /cm^2	Deposits/ cm^2	Deposition (μL/cm^2)
1	173	280	476	2.55	7.28	24.9	0.136
2	179	330	409	1.9	7.52	21.8	0.103
3	184	265	431	2.72	24.25	25.6	0.14
4	184	288	397	3.99	20.27	34.5	0.209
5	181	297	425	4.4	22.53	37.3	0.237
6	181	321	424	2.72	19.22	24.9	0.149
7	173	237	297	2.02	3.87	21.2	0.094
8	206	331	441	4.94	7.93	36.2	0.285
9	162	268	410	2.56	17.45	30.6	0.126
10	173	270	392	1.71	5.26	21.3	0.086
11	161	329	695	0.98	21.01	14.9	0.056
12	148	246	418	0.63	22.51	8.5	0.03
13	157	274	745	1.26	23.05	15.7	0.07
14	169	394	820	0.S4	24.56	9	0.054
15	173	276	324	0.72	22.58	6.9	0.036
16	152	208	298	0.64	23.47	9.8	0.027
17	157	253	349	1.17	22.53	14.5	0.055

Table 5: Height 7m, speed 15m/s, wind speed 0-1m/s, mist droplets using

Acquisition number	Droplet diameter			Coverage area	Image area	Settlement density	
ID	DV 1(μm)	DV 5(μm)	DV 9(μm)	% Coverage	Image Area /cm^2	Deposits/cm^2	Deposition (μL/cm^2)
1	342	470	573	0.37	9.98	0.6	0.033
2	296	402	705	1.42	12.87	3.7	0.11
3	260	532	1019	2.44	16.32	13.7	0.202
4	240	363	605	2.03	13.35	11.5	0.136
5	226	290	487	0.84	23.06	5	0.049
6	322	701	1323	2.71	14.22	13.7	0.278
7	311	526	956	2	12.83	6.5	0.177
8	263	362	537	1.79	9.46	7.5	0.122
9	218	368	527	1.75	13.21	9.1	0.111
10	204	386	497	0.64	13.61	4.5	0.04
11	194	327	489	0.79	14.93	6	0.046
12	237	356	521	0.74	13.08	3.7	0.051
13	204	400	496	0.72	11.36	4.7	0.046
14	220	359	620	0.85	12.94	5.6	0.056
15	179	346	610	0.92	12.68	8.3	0.056
16	155	239	342	0.49	10.31	5.7	0.022
17	244	633	747	1.08	13.6	5.2	0.089

Table 2 shows that the wind speed in 0-1m/s, height 7m, speed 10m/s, ID: 1-13 for the effective spraying width, to meet the constant spraying; Table 3 shows that the wind speed in 0-1m/s, height 7m, speed 12m/s, ID: 1-10 for the effective spraying width, to meet the constant spraying; 4 shows that the wind speed in 0-1m/s, height 7m, speed 15m/s, does not meet any type of spraying quality technical indicators.

Therefore, respectively, the following conclusions can be drawn: the same conditions, with the increase in speed spray width gradually decreasing trend. And there are several places in Tables 2 and 3 do not meet the criteria for constant spraying, the preliminary judgment of the aircraft landing gear obscured caused.

2.3 Analysis of the effect of wind speed on UAV spray performance

Table 6: Statistics on the effectiveness of single sortie spraying

No.	Flight altitude (m)	Flight speed (m/s)	Wind power (m/s)	Spraying effect			Pass " √ " Fail " × "
				Number of mist drops (drops/cm^2)	Droplet diameter μm	Spray width (m)	
1	7	10	1	54	448	15	√
2	7	10	2	28	305	12	√
3	7	10	2.5	20	260	11	×
4	7	12	0	27	289	10	√
5	7	12	2	8	420	9	√
6	7	12	3	17	328	9	×
7	7	15	1	8	420	0	×

Three groups were divided to test the results of droplet adoption at the same flight altitude and speed and under different wind conditions.

From the data in Table 6, at the same operating height and operating speed part of the spraying data is to meet the standard of constant spraying, but by increasing wind speed spraying effect gradually does not meet the standard of constant spraying.

2.4 Wind Speed and Flight Height on Spray Droplet Drift

During the spraying process, the droplets are not uniformly sprayed directly below the flight path due to wind speed and rotor airflow, but have a certain amount of drift, and different droplet diameters have different drift under the same conditions[4]. Due to the limitations of the test conditions, it was not possible to calculate the drift of the droplets of different diameters, but only to examine the drift of the droplets in terms of the overall spraying interval are shown in Figure 2.

A------------------D-----------C--O-------------E--------------------B

Figure 2: Different droplet diameters have different drift

Referring to the diagram above, the length of the test paper layout is between points AB, DE is the interval where there are droplets of fog on the test paper after the helicopter has flown (the calculation of this interval does not take into account the droplet density, diameter size and other indicators, as long as there is test paper with droplets, it is counted), point C is the point that the helicopter flies over, point O is the midpoint of the spraying interval, approximating that the distance between the two points OC is the amount of spraying drift.

Table 7: Spraying drift and associated data

Name	Drifting OC	Flight speed	Wind speed	Against the Wind	Sidewinds
Unit	m	m/s	m/s	m/s	m/s
NOte	East is +, West is -	Flight speed at point C		Direction of travel	Vertical heading
2021.08.01	1.341	10.39	1	0.791	-0.612
2021.08.01	11.228	10.14	2	1.303	-1.517
2021.08.02	1.46	15.73	0.9	-0.043	-0.899
2021.08.02	12.959	3.82	1.6	-0.932	-1.300
2021.08.02	8.796	15.15	1.5	-0.844	-1.240
2021.08.04	6.37	12.22	1	-0.340	-0.940
2021.08.05	-1.026	12.39	0	0.000	0.000
2021.08.05	9.007	12.46	0.9	0.789	-0.433

Table 7 shows that wind speed and flight altitude have a large impact on spray droplet drift, and the two show a negative correlation. Therefore, it is recommended that the drift of the droplets can be reduced by reducing the flight altitude during windy operations, thus increasing the amount of droplets deposited on the target area.

4. Conclusions

In this paper, the effects of wind speed, flight height and flight speed on the drift of spray droplets are studied. The results show that the droplet deposition can be improved by the appropriate wind speed, but the droplet displacement increases with the increase of wind speed. The droplet deposition density and droplet deposition coverage decreased with the increase of UAV operation speed[5]. It has different effects on different crops and different drugs, so it is necessary to establish drift buffer zone according to air pesticide pair, improve pesticide utilization rate and reduce air pesticide spraying.

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