Unmanned aerial systems for biological plant protection based on UAV type CE-20

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Abstract. The article presents an analysis of the use of UAVs of the CE-20 type as part of unmanned aerial systems for biological plant protection. The relevance of the study is determined by the intensive development of modern unmanned technologies used to combat insect pests and plant diseases. The proposed analysis of modern practice of using UAVs of the CE-20 type for biological plant protection will reveal the relationship of technical characteristics with agrotechnological methods. This will provide effective technical support for unmanned aerial systems applications in precision agriculture. It is important to consider that the characteristics of the UAVs used significantly influence the process of spraying fertilizers and pesticides. The article analyzes the previously obtained results of test flights of the CE-20 of the Chinese company Wuxi Hanhe Aviation Technology. Testing was carried out taking into account a given field cultivation strip, on which the effective spray width of fertilizers and pesticides was determined and studied. The obtained droplet deposition coefficients of variation showed good deposition uniformity and penetration rate. It is shown that optimization of UAV parameters must be combined with agronomic requirements based on the choice of crop types, growth period, pest and disease characteristics, and environmental conditions.

1 Introduction

The practice of using modern unmanned plant protection systems (UPPS) today is quite extensive. Such systems are formed on the basis of UAVs of various types. At the same time, the characteristics of the UAV significantly affect the efficiency of using these systems. This new type of drone technology for crop protection is rapidly developing and widely used in China [1-3]. At the same time, many researchers working in this area note that currently the question of how to use BSZ from a scientific point of view has become a top priority [4-6].

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In [1, 2], the authors show that today the relationship between the operating parameters of the UPPS and the effective spray width (ESW), as well as between the characteristics of droplet distribution during spraying and the effect of combating insect pests and diseases is not yet clear. To identify these relationships, a number of experimental studies are being undertaken using various UAVs with varying basic technical parameters, such as flight speed, flight altitude, and spray volume.

In [1], for an electric single-rotor UAV of the CE-20 type, experiments were carried out with three levels of flight speed - 3, 4 and 5 m/s, three levels of flight altitude - 1.5, 2.0 and 2.5 m and a spray volume of 2. 0 l/min. It was studied how variable parameters affect the ESW, the uniformity of droplet deposition and the rate of droplet penetration [3].

Based on the results obtained, in combination with agronomic patterns of the occurrence of insect pests and plant diseases, the optimal parameters for the operation of the plant were selected. The results showed that the ESW for the UAV type CE-20 was not constant. The maximum ESW value was 5.78 m, and the minimum was 2.51 m. UAV flight speed had a highly significant effect on ESW ($p = 0.0033 < 0.01$), while flight altitude and the interaction between speed and altitude flights did not have a significant impact on the ESW. The coefficient of variation of droplet deposition ranged from 23.3% to 34.4%, indicating good deposition uniformity.

The research results we noted prove that by optimizing parameters and combining agrotechnological techniques with the help of UPPS, it is possible to achieve a significant increase in the efficiency of combating insect pests and plant diseases.

Our proposed analysis of the use of the CE-20 UAV as part of unmanned aerial plant protection systems will allow us to identify the main technical characteristics of the UAV and their relationship with agrotechnological techniques that provide technical support for UPPS applications in precision agriculture.

2 Materials and methods

Currently, unmanned aerial plant protection systems are being formed in China based on the CE-20 UAV (Crop Protection Unmanned Aerial System – CPUAS [1]). Appearance of CE-20 made by Wuxi Hanhe Aviation Technology Co., Ltd., China is shown in Figure 1.

Fig. 1. CE-20 crop dusting unmanned helicopter.

The CE-20 is an electric, single-rotor UAV with a real-time kinematic global positioning system (GPS). This allows for fully autonomous flight along routes planned using a mobile application. Moreover, the CE-20 is equipped with a real-time visual spray tracking system. This allows the operator to provide real-time feedback via an app on a smartphone or tablet. Therefore, the sprayed area can be calculated simultaneously with the UAV performing sequential operations of the transport and technological cycle, without interrupting the operation of the helicopter [6-8].

In addition, the GPS tracking system automatically adjusts the pesticide release rate depending on the helicopter's flight speed. The function maintains a uniform flow rate per unit area. Parameters such as flight speed (FS) and flight height (FH), as well as spray volume, are adjusted in the mobile application with an accuracy controlled within 0.30 m, 0.30 m/s and 0.05 l/min, respectively.

The main technical parameters of the drone are as follows [1]:

- drone size - 1880 mm × 618 mm × 758 mm;
- rotor diameter - 2388 mm;
- battery capacity - 28,000 mAh × 2;
- sprayer boom length - 1442 mm;
- maximum load - 20 L;
- number of nozzles – 2;
- type of nozzles – Hydraulic;
- nozzle location – 800 mm on both sides of the fuselage;
- spray volume - 2.0 L / min;
- spray width - 3–5 m.

Experimentally obtained characteristics, such as droplet dispersion during experimental spraying, are obtained using water sensitive paper (WSP). The drone is designed to use high concentrations of insecticides and fungicides for aerial spraying to control aphids, powdery mildew and late blight.

3 Results and discussion

In actual applications of CE-20 the following levels are set for FS - three levels: 3, 4 and 5 m/s; for FH - three levels: 1.5, 2.0 and 2.5 m.

Spray volume is 2.0 l/min during operation. Typically, the CE-20 flies from the acceleration zone to the stopping zone to spray along the centerline of the sampling area in an autonomous manner. The processing parameters and results of the performed functions of the CE-20 are presented in [2].

Taking into account the fact that the carrying capacity of the CE-20 is up to 35 kilograms of agricultural chemicals, for each transport and technological cycle this UAV allows spraying up to 2.7 hectares of land in 20 minutes, depending on the operator’s skills. Note that this is 60-80 times more effective than traditional manual spraying.

When spraying pesticides, the intense downdraft from the rotation of the helicopter rotor can help open the crops, and the pesticides can be evenly applied to the lower or root parts of the crops, which contributes to better plant protection.

In precision agriculture, the use of ultra-low spray volumes reduces water and pesticide costs. Using 95 octane gasoline as fuel can also reduce mission costs. In addition, the use of remote control allows the operator to avoid interaction with chemicals, which significantly reduces both the harm to the operator and the impact on the environment.

In this work, the experimental modes correspond to nine UAV transport and technological cycles (TTC): TTC-1, ..., TTC-9. Each experimental flight included typical operations performed by ground means, the operator and the UAV itself. The values of the TTC parameters in each feasible implementation were different and reflected the costs of resources and time. Based on the results of experiments, one or more TTCs can be determined that provide the best results. However, it should be noted that these results correspond to the selected field strip that was processed.

We also note that it is necessary to pay attention to the mixture of pesticides used when spraying from drones. It is known that traditional pesticide formulations cannot be used for aerial spraying, because the concentration of the substance entering the soil will be 200 times less than the original one. Specialized mixtures make it possible to achieve a concentration that is 2-5 times less than the original one. In addition, the composition of the mixture must meet all the requirements set for such substances by the international community.

Increasing the spraying efficiency makes it possible to increase the TTC parameters, since usually the quantitative ratio of solid to liquid in suspension is 80%, and the particle size is less than 5 microns. The implementation of TTC will be more effective if the pesticide sprayed into the air has a substance ratio of 95%. In this case, it is necessary to avoid conditions for blocking the spray head. This depends on the size of the sprayed particles. That is, the particles of the active substance must be 2 microns in size or less. This will ensure maximum effect from the use of aviation biological plant protection systems.

The test data presented in [1] give an idea of the results of the tests for a given processing strip (the strip width varied from 2.51 m to 5.43 m). The uniformity of droplet deposition and penetration rate were studied. The processing bandwidth of the CE-20 was not constant and decreased as the overall flight speed increased. The minimum width was 2.51 and the maximum was 5.78 m.

For all test flights of the UAV, the coefficient of variation of droplet deposition did not exceed 35%, of which the minimum was 23.30% for two experimental treatments of the transport and technological cycles of UAV: TTC-1 and TTC-4, and the maximum was 34.40% (experimental processing TTC -6). This confirmed the good uniformity of deposition in ESW.

A general overview of the tests performed on the CE-20 [1] is given in Table 1.

Table 1. Test results for the CE-20.

Number of transport and technological cycle (TTC-1-TTC-9)	Effective Spray Width (ESW)	Coefficient of variation of droplet deposition (HF)
TTC-1	5.42	23.30%
TTC-2	5.78	24.80%
TTC-3	4.58	26.20%
TTC-4	3.51	23.30%
TTC-5	5.75	26.20%
TTC-6	4.17	34.40%
TTC-7	2.58	27.20%
TTC-8	2.77	28.15%
TTC-9	2.51	32.65%

The results of the study show that ESW and HF, affecting the spraying efficiency, are closely related and depend on the UAV parameters. Thus, a review of the results given in [1-5] shows that when optimizing the parameters of aerial spraying, an effect against aphids, powdery mildew and late blight is achieved that meets real requirements. However, optimization must be combined with agronomic requirements based on the selection of crop types, growth period, pest and disease characteristics, and environmental conditions [8-10].

4 Conclusion

Performed analysis the use of UAVs as part of unmanned aerial biological plant protection systems presents the results of testing the UAV type CE-20. Accordingly, our conclusions apply only to this UAV. UPPS created on the basis of other types of UAVs may have different spraying and droplet deposition characteristics from those considered, for example, for multi-rotor UPPS. Therefore, in cases where other types of UAVs are used, it is necessary to perform systematic experiments to determine the optimal combinations of parameters [11]. The obtained statistical data from the results of experimental flights will make it possible to simulate the transport and technological cycles of UAVs and determine their acceptable implementations under various conditions. Each TTC will correspond to optimal combinations of spraying parameters under different natural and climatic conditions and characteristics of the treated field, which significantly affect the effect of deposition of droplets of sprayed pesticides. In the future, it is necessary to take into account the influence of the structure of the cultivated field [12] and wind force [13] on the effect of droplet deposition in order to establish their correlation, which will contribute to the achievement of best practices in the field of control and monitoring of UAVs in precision agriculture.

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