Aerodynamics of the ejection-injection method of separation of entomophages

Kh D Irisov, R Z Olimjonov
Tashkent State Technical University, University street 2, Tashkent, 100174, Uzbekistan
E-mail: husniddin_bek@mail.ru

Abstract. This article reveals the peculiarities of the transition to a cluster management system in the agro-industrial complex (AIC) of the Republic of Uzbekistan based on the use of innovative techniques and technology. It is shown that, despite the widespread use of agrotechnical, chemical methods of combating pests, diseases and sulfur plants, the issues of mechanization of biological control agents still remain unresolved, and improvised means of controlling them do not give the expected results. As the top priority tasks of the study, the author poses the issues of mechanization of the technological process of dispersal of eggs or pupae of entomophages using an unmanned drone equipped with an ejector-injection dispenser. The work also contains questions of the theory of dispersal of eggs of entomophages through an ejector-injection dispenser under the action of the lifting force of a local air jet or a suction pneumodynamic (injection) force created in the area of the dispenser windows, which allowed not only to significantly improve the design of the dispenser, but also to expand the technological capabilities of the proposed unmanned unit apparatus.

1. Introduction
The introduction of cluster management systems into the agro-industrial complex (AIC) of the Republic of Uzbekistan requires the widespread use of high-performance and reliable agricultural machines and devices based on the latest innovative technologies [1].

The optimal soil-climatic conditional of our country provides the most favorable opportunities not only for the development of agricultural crops, but also for the many pests, diseases and weeds inhabiting them [2]. Existing agrotechnical, mechanical or chemical methods of dealing with them do not always allow you to completely get rid of them; requires huge labor and material expenditures.

Despite the high efficiency of biological methods of fighting pests and diseases due to their poor mechanization, they still have not found widespread use [3,4,5,6,7].

2. Materials and methods
Object and method of research. The object of research is an ejector-injection dispenser of entomophages. The research methodology is based on the theoretical aspects of the dispersal of entomophages. The improvised means of biological plant protection, in the form of light traps and others with sticky masses, used at the headlands of sown areas are ineffective. So far, there are no deep theoretical and practical developments on the creation of high-performance units and devices that provide mechanization and automation of the technological process of settling entomophages for large sown areas [8].
The objective of the study is to create an unmanned drone that provides an ejection-injection method for the dispersal of entomophages. Based on deep literary and patent search work, we have developed a promising design for an unmanned drone vehicle, which is shown in (Figure 1).

The proposed device is interchangeable and can be mounted on any unmanned drone or mobile unit [9].

The device and the principle of operation of the apparatus are as follows. The device consists of an unmanned drone with a device on supporting legs. The apparatus itself consists of a hopper 3, an ejector-injection dispenser 6, a receiver 7, with 8 inlet and outlet pipes, a valve 10, a cone-shaped nozzle 11, a ventilation element 17 with a cone-shaped nozzle projection 13.

An unmanned drone, rising to a predetermined height (up to 2-4 m) according to a given program, automatically turns on the ventilation element 17 for cutting work and part of the local portion of air through the supply pipe 8 and the fountain pipe into the bunker 3 and brings the particles of entomophages into suspension (with R "G), and from them through the side window of the dispenser 6 goes to the side of the outlet entomophage tube 8, where the force of the suction (injection) air flow created by the vacuum in the area of point A of the conical nozzle protrusion 13 of the ventilation element 17 acts. characteristic.

By regulating the flow rate of the local air flow through the valve 10 (or a spherical spring-loaded valve), an optimal mode of dispersal of entomophages is achieved.

The device can be mounted both on an unmanned drone and on a ground mobile unit (cultivator). They can move in the fields, according to the scheme shown in (Figure 2) [10].
Figure 2. Kinematics of movement of a ground mobile unit (a) and a drone vehicle (b) (where \( t \) is the width of the rut); A and B - places of filling the bunker with entomophages.

The physical essence of the process of ejection and injection of masses of entomophages is that each particle of entomophages inside the working chamber of the bunker is subject to the lifting force \( R \) and the force of gravity \( G = mg \) (\( m \) is the mass; \( g \) is the acceleration of gravity, A and B are the places of filling the bunker).

3. Results and Discussion

The pressure force \( R \) of the local air flow in the metering zone can be determined by the following formula [11,12,13,14]:

\[
R = C_l \cdot \rho_a \cdot S(\sqrt{V_a - V_{ae}})^2 \cdot H
\]

(1)

Where \( C_l \) – is the coefficient of resistance of the local air flow; \( \rho_a \) – air density; \( S \) – is the cross-sectional area of entomophages; \( V_a \) is the speed of the local air stream; \( V_{ae} \) – the speed of soaring entomophages inside the bunker.

The force of gravity \( G \) of an entomophage is always directed against the lifting force \( R \), therefore, the rate of deposition of eggs is also directed against the rate of rise of the supplied local air stream and depends on the shape and state of the surface of the entomophages. With \( G > R \), entomophages descend to the side of the bunker, and with \( G = R \), they pass into a suspended state. To maintain the conditions \( G = R \), the rate of weighing or hovering of entomophages inside the bunker can be estimated using the following formula:

\[
V_{ae} = \sqrt{\frac{G}{C_l \cdot \rho_a \cdot S}} \text{ m/s}
\]

(2)

In this case, the coefficient in the foaming of entomophages will be equal to: \( K_{ae} = \frac{9.81}{V_{ae}} \).

Thus, to create conditions for foaming or soaring of entomophages, providing a reliable transition through the side windows of the ejection-injection dispenser towards their settlement, it is necessary to select not only the optimal speed of the local air stream in front of the ejection-injection dispenser, but also their rational design parameters of the tube inside the hopper.

According to, at the moment of a local aerodynamic flow around a spherical entomophage, a circulation of the local flow velocity occurs inside the side windows of the dispenser.

Curvilinear integral on the segments AB (Figure 3) of the arc curve drawn in the vector field through \( dr \):
\[
\Gamma_{AB}(a) = \int_{A}^{B} a \cdot dr = \int_{A}^{B} a \cdot ds \cdot \cos(\alpha, dr) = \int_{A}^{B} a \cdot \cos \alpha \cdot ds = \int_{A}^{B} as \cdot ds = \int_{A}^{B} (a_x d_x + a_y d_y + a_z d_z)
\]

Figure 3. Features of the formation of the speed of circulation around the spherical entomophage (a) and the formation of a thin layer of the air cushion at the moment it passes through the windows of the dispenser (b): 1- spherical entomophage; 2- dispenser; 3- dispenser window (thin layer of “air cushion”).

Determines the circulation of the vector "a" along the contour c in the section AB. So, for example, the work of force \(F\) on the section AB of the trajectory with

\[
W_{AB} = \int_{A}^{B} F_x d_x + F_y d_y + F_z d_z = \int_{A}^{B} F \cdot dr
\]

allows to interpret the main factor \(F\) as the work of the circulation of the force on the selected section of the trajectory.

Since the contour of the spherical entomophage is closed, the circulation of the vector is determined by the contour integral along the closed contour:

\[
F_c(a) = \oint_{c} (a_x d_x + a_y d_y + a_z d_z) = \oint_{c} a \cdot dr
\]

At the moment of coincidence of the centers \(\lambda = 0\) (where \(\lambda\) is involved in eccentricity), the main vector of reactions of the local streamlined flow is determined only by the translational motion of the inner sphere (entomophage) and will be equal to:

\[
F = \frac{8 \pi \mu R^4}{\varepsilon^3} \nu_0,
\]

where \(\mu\) – is the viscosity of the streamlined air; \(\nu_0\) – is the speed of the streamlined air.

The distribution of velocities over the spherical surface of the entomophage \((R = a)\) is characterized by the equality (Figure 3):

\[
\nu_0 = \frac{3}{2} \int_{\infty}^{3} \sin \theta
\]

Points A and B (Figure 3) are critical in them, the velocity vanishes. The maximum speed takes place in the midsection plane at \(\theta = \pi/2\), it is equal in absolute value:

\[
(\nu_0)_{\text{max}} = \frac{3}{2} \nu_\infty.
\]
According to Bernoulli’s theorem, the formula for estimating the pressure coefficient has the following form:

\[ C_p = \frac{P - P_{\infty}}{\rho v_{\infty}^2} = 1 - \left( \frac{v}{v_{\infty}} \right)^2 = 1 - \frac{9}{4} \sin^2 \theta. \]  

(9)

The locally streamlined suction air flow, carrying them into the inside of the dispenser, according to the theory of probability, ensures the reliability of the dispersal of spherical entomophages on the cultivated areas.

We recommend evaluating the reliability of the technological process of settling the eggs of entomovagi through the dispenser using the following formula [11]:

\[ P(A) = \frac{m}{N} \times 100\%. \]  

(10)

where \( m \)– is the actual number of settled entomophages, pcs; \( N \) – is the number of settled entomophages per 1 hectare according to agricultural requirements, pcs.

Due to the formation of an air cushion around the entomophages, their mechanical damage is excluded, and by choosing the height of the dispenser, the most rational mode of the dispensing tube inside the tanker is selected.

Laboratory field experiments will determine the optimal operating modes and design parameters of the proposed apparatus.

The results of theoretical studies made it possible to deeper reveal the physical essence of the dispensing process through the dispenser and more purposefully improve the design of the ejector-injection dispenser. When the device operates without a discharge tube, the device works as an ejector, and when installed, its dispenser as an injector, that is the suction injection flow created inside the tube ensures the dispersal of entomophages over a relatively large distance.

4. Conclusion

1. The proposed ejector-injection method of settling the aggregates entomophages provides mechanization of the technological process of their settlement not only on large, but also on small sown areas of farms and cluster farms.

2. Theoretical developments made it possible to reveal the physical essence of the technological process of dosing and resettlement of entomophages, more purposefully to improve the design of the ejector-injection batcher.

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