A proposed technology to ensure high-precision aerial seeding of certified seeds

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Abstract. The research to which this article is devoted relates to forestry and agriculture, in particular, to methods that provide accurate seeding in areas that are inaccessible or ineffective for ground-based mechanization. The existing approaches today have a number of significant drawbacks that do not allow to implement the stated tasks with sufficient accuracy. The main ones are: the presence of a mechanical system for creating air pressure, which significantly complicates the sowing process, without ensuring, at the same time, its sufficient accuracy; the impossibility of ensuring also accurate seeding due to the lack of control of the rotational speed of the auger feeder, depending on the speed of the unmanned aerial vehicle (UAV) itself. The result of this study was a developed technology that has no analogues in the world, which greatly simplifies the process of sowing from the air, does not require energy costs and additional equipment, and also increases the accuracy of seeding due to its uniformity at various values of the UAV speed.

1. Introduction

To date, known for a number of scientific publications dealing method that provides accurate sowing in areas inaccessible or ineffective for terrestrial mechanization [1-20]. The technologies developed for aerial seeding for reforestation, suggest the following:

1. Sowing using [21] disposed across the length of the airplane tanks, which for the purpose of spraying them grain through mouthpieces are installed air injectors connected by tubes with air channel from the fan, forcing the air.

The disadvantages of this technology are the complexity, due to the presence of the mechanical system by the air pressure and the inability to provide an accurate seeding.

2. Sowing using a dispenser [22] mounted under the fuselage, consisting of the seed hopper, whose output is the input of a screw feeder, and the output - dispersing seeds ejector.
When this is the inability to provide an accurate seeding due to the lack of control of the screw feeder rotation speed to seeding according to the speed of the unmanned aerial vehicle (UAV) movement.

3. Distribution of seeds with the UAV [23], providing them a continuous and uniform distribution. Provides for the use of modular hopper (hopper) for seeds, seed distribution head and the hydraulic system driven by a pump connected to an auxiliary unit of the UAV.

There are disadvantages of difficulty due to the presence of the hydraulic system by the air pressure and the inability to ensure accurate seeding due to the lack of control of seeding rates, depending on the speed of the UAV movement.

4. Sowing using a hopper lid and a dispenser of seeds [24], vas deferens, and rotatable drum with radial holes correlatively size seeds.

The disadvantage of the technology is the inability to provide an accurate seeding due to the lack of control of the drum rotation speed to seeding depending on the speed of the UAV movement.

5. Sowing using an automatically controlled pneumatic loading [25] comprising means for adjusting the passage section of the air passage. The technology involves the use of a compressed air source, inclined channel which is connected to the conduit, the double channel comprising a first channel exiting near the exit of said main hopper, and a second channel, exiting near the inlet of said conduit for transporting the product in said auxiliary hopper. Wherein at least one of the channels comprises means adapted to regulate the flow cross section for the air flowing through one of the channels.

It should be noted complexity of the process, due to the presence of the pneumatic system, and the absence of seeding rate control depending on the speed of the UAV.

2. Methods and materials
To solve this problem, a new technology is proposed, which, among other things, includes the use of a device for aerial seeding of seeds developed by the authors of the study [26], the functional diagram of which is shown in figure 1, where are indicated:

- hopper 1,
- conveyor belt 2,
- leading 3₁ and slave 3₂ rotors of the conveyor belt 2,
- two turbines 4₁, 4₂,
- three air ducts 5₁, 5₂, 5₃,
- vas deferens 6.

![Figure 1. Independent unit for high-precision aerial seeding of certified seeds.](image-url)
The hopper 1 is rigidly mounted on the body of the UAV and is designed to store seeds. In the lower part of the hopper 1 there is a flexible conveyor belt 2 with cells for seeds (the cell size is calculated from the condition of placing no more than one seed in it), the driven rotor 3 of which is fixed on an axis connected to the UAV body, and the leading rotor 3 is fixed on an axis, connecting the centers of the driving rotor 3, two turbines 4, 4 mounted on the UAV body. Turbines 4, 4 are located at an equal distance from the leading rotor 3 of the conveyor belt 2 in the first 5 and second 5 air ducts, respectively, and are made in the form of rotors with blades rigidly fixed to them. All 5, 5, 5 air ducts are made in the form of hollow cylinders with cone-shaped air intakes at the inlets, rigidly mounted on the UAV body and oriented along the UAV (parallel to its axis of rotation) to capture the maximum amount of oncoming (running on the UAV) air flow. The output of the third duct 5 is connected to the vas deferens 6, the input of which is connected to the output of the conveyor belt 2, and the output is the output of the device.

The device operates as follows.

During the flight of an UAV sowing seeds, the air flowing onto the UAV (oncoming) creates air flows in the air ducts 5, 5, 5, the speed of which is determined by the diameter of the air ducts 5, 5, 5 and the speed of the UAV. Acting on the blades of the turbines 4, 4, these air currents lead to their rotation and, accordingly, to the rotation of the drive rotor 3 of the conveyor belt 2 rigidly connected to the turbines 4, 4. As a result of the rotation of the drive rotor 3, the conveyor belt 2 moves, collecting seeds into the cells from hopper 1, with a speed depending on the speed of the UAV. From the cells of the conveyor belt 2, the seeds enter the vas deferens 6, where they acquire an additional speed, depending on the speed of the UAV, due to the impact of the air flow incident on the UAV, entering the vas deferens 6 through the air duct 5:

- increase (decrease) in the speed of UAV leads to an increase (decrease) in the speed of conveyor belt 2 and, therefore, to increase (decrease) the frequency of seeds entering the vas deferens 6, which ensures uniform sowing of seeds at different values of the speed of UAV;
- also an increase (decrease) in the horizontal speed of the UAV leads to an increase (decrease) in the speed of the air flow entering the vas deferens 6 through the air duct 5, and, therefore, to increase (decrease) the vertical component of the rate of fall of the seed, which stabilizes the direction of the general vector of the speed of fall of the seed, additionally contributing to uniform sowing of seeds at different values of the speed of the UAV.

3. Results and discussion

Most studies of aerial seeding reflect this process from one side, abstracting from other conditions and parameters or considering them to be insignificant. Hsu et al. (2019) note the low carrying capacity of UAV and develop “a recipe for granular vegetating materials which are not too heavy for UAV to carry and still achieve satisfactory seed germination and survival rates [15]”. When modeling rice aerial seeding (not encapsulated) performed with UAV by scattering by centrifugal sowing device. Wu et al. (2020) argue that “three factors produce influences on the distribution, and they are the rotation of the disc, UAV flying height and the angle of the baffle ring [6]” have the greatest impact on the process in decreasing order of importance. Vann et al. (2018) imitate mechanized aerial seeding on a rectangular section of 3 × 7.5 m, producing “Crimson clover was aerially broadcast by hand [16]”. In field trials of the distribution of trichograms over forested land from a manned helicopter using centrifugal slinger Hope et al. (1990) point to uneven distribution and insufficient loading hopper volume, “to provide power from the helicopter's 24-V DC electrical system [10]”. Régnière (1982) pointed the "seed deposition patterns resulting from air turbulence and UAV motion, as well as variability in seedbed distribution across a seeding chance, to decrease potential stocking [12]”. Sai et al. (2020) are engaged in the design of the wing structure for UAV of the UAV type, which, according to their statement, is intended for aerial seeding of seeds [13].

Careful consideration existing aerial seeding methods revealed their shortcomings, the main of which are:
complexity due to mechanical or hydraulic air pressure systems dependent on an external power source, which increases the take-off mass of the UAV with a payload;
- the inability to ensure accurate sowing of seeds due to the lack of control of the speed of sowing seeds depending on the speed of movement aviation system.

The result of the study is a developed technology that has no analogues in the world and is devoid of the above disadvantages. At the same time, an analysis of its economic efficiency showed the presence of quantifiable indicators that make the proposed method of aerial seeding of conditioned seeds attractive from a financial and economic point of view. The main of these indicators are:
- performance;
- seed survival;
- the cost of the hardware component of the technology;
- the cost of sowing 1 hectare.

Using these indicators, a comparative analysis was carried out based on expert methods based on the Delphic procedure, a proposed technology with the following technologies currently on the market:
- the use of a metering unit with a seed hopper with an inlet in the form of a screw feeder installed under the fuselage (technology 1) [22];
- application of a dispenser and a rotating drum with radial holes (technology 2) [24];

This analysis showed that the approximate economic effect, even without taking into account the cost of the hardware complex itself, is about 8-12 thousand rubles per hectare. The values of the indicators are presented in table 1.

4. Conclusions
Thus, as a result of research and practical development, a new technology was obtained that significantly simplifies the sowing process, does not require energy and additional equipment to perform the seed sowing procedure, and differs from other existing ones in increased sowing accuracy due to uniform sowing of seeds at different values of UAV speed.

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