Pneumatic boom applicator for dispersion of mineral fertilizers

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Abstract. Almost 90% of machines are used with throw-type seeding devices. Serious disadvantages of such machines include uneven application of 25% or more, depending on air humidity and wind force and can reach about 50%. The best seed-fertilizer seeders have the best performance of about 10% irregularity of application, but they have a small width of application and productivity, and in practice they are not used to fertilize the soil when preparing for sowing crops. The solution to the problem of increasing productivity and improving the uniformity of fertilizer application can be found by creating pneumatic boom applicators with a greater width than that of grain-seeders. It was found that the test machines in the field had 8% non-uniformity of the introduction of ammonium nitrate that was lower than in a case of machines equipped with throwing working bodies and approved by agricultural requirements for them. The obtained non-uniformity of the fertilizer application allows to evaluate its indicators even at the design stage of the machines, depending on the quality of dosing and the distance between the sowing ejectors.

1. Introduction

Modern science is in constant search for improving the uniformity of the application of solid mineral fertilizers in the system of agriculture and the production of high-quality products.

When determining the quality indicators of boom applicators for solid mineral fertilizers, special attention is paid to the uniformity of dispersing their particles on the field surface [1, 2, 3, 4, 5]. In this regard, granulometric composition of fertilizers, the uniformity of their supply by roller feeds, air humidity, wind direction and speed relative to the axis of movement of the unit across the field are important for machines with throwing working bodies.

The purpose of the study is the creation of a pneumatic boom applicator that allows increasing the uniformity of fertilizer dispersion when making the main dose and top dressing on vegetating plants.

2. Research objective
The development of a pneumatic boom applicator with a working width of 12 meters and irregularity of application within 10%, regardless of temperature fluctuations, humidity and wind direction.

3. Materials and methods
In the second half of the 20th century, boom applicators for dispersing mineral fertilizers were widely used in the world practice. Legalized in Russia agrotechnical requirements for machines for fertilization found that the uneven application for machines of a throwing type should not exceed 25% of the width of the application and no more than 10% in the direction of movement. For boom applicators these figures should not be more than 10% and 5%, respectively. The technological scheme of the machine, the shape and dimensions of metering and distribution devices (as design parameters), the seeding rate of the fertilizer, the distance between the holes in the boom, air pressure and the machine speed (operational parameters) can be considered as factors influencing the quality of dispersion in pneumatic machines [6].

The uniformity of distribution of fertilizers on the area will depend on many factors. First, it will depend on the even distribution of fertilizers in individual boom ejectors, caused primarily by the main parameters of the working bodies of the centralized seeding system.

Such factors as the seeding rate, air pressure, speed of the machine and parameters of the outlet section have no less influence on the uniformity of distribution of fertilizers. The required width of the sowing strip with one ejector outlet in the boom and the quality of fertilizers distribution over the width are directly related to their flight range when they hit a reflecting scattering surface, which, in turn, is determined by the initial velocity of fertilizer particles when they arrive at a distribution reflecting surface.

The schematic diagram of the boom applicator for dispersion of solid mineral fertilizers is shown in Figure 1.

To solve the problem of increasing the uniformity of the surface dispersion of solid mineral fertilizers and eliminating the shortcomings of existing spreaders, it is possible to solve the problem by using pneumatic boom applicators (Figure 2).

![Diagram of boom applicator](image)

1 – hopper; 2 – dispenser; 3 – flow divider; 4 – air supply direction, 5 – fan; 6 – pipeline with ejectors; 7 – spheres of dispersion

Figure 1. The schematic diagram of the device for dispersion of mineral fertilizers
Figure 2. The schematic diagram of a pneumatic boom applicator for dispersing solid mineral fertilizers

1 – frame; 2 – driveshaft; 3 – overrunning clutch; 4 – elastic coupling; 5 – belt drive; 6 – fan; 7 – mixing chamber; 8 – duct; 9 – fertilizer spreader; 10 – bunker; 11 – sowing unit; 12 – support wheel; 13 – hydraulic cylinder; 14 – boom with ejector

4. Results and discussion
The quality of fertilizers dispersion by a pneumatic boom applicator with holes along the length of the boom is mainly influenced by the uniformity of fertilizers supply by roller feeds into the air stream created by the fan and into the boom with holes (let's call them ejectors) and the nature of the distribution of fertilizers depending on the distance between these ejectors (Figure 3).

Achieving this goal was carried out by theoretical and experimental studies. A theoretical study is devoted to obtaining dependencies that allow obtaining rational structural and kinematic parameters of the device for dosing and distributing fertilizers through ejectors and scattering surfaces according to laws and methods of classical mechanics and mathematics [7, 8].

If the irregularity of fertilizers supplies to the air flow to the sowing ejectors, the nature of their distribution and the supply of the air-mineral mixture to the ejectors are known, then the quality of the distribution of fertilizer particles depending on the distance between the ejectors can be assessed even at the design stage of boom applicators and timely necessary adjustments made in their design [4, 5, 9, 10]. The uneven dispersion of fertilizers into ejectors is characterized by average supply $m$, and standard deviation $\sigma_y$ found in the experiment.
The distribution of fertilizers by ejectors can be described by a functional dependence of the form $y = f(x)$, which allows determining the uneven distribution when changing the distance between the ejectors. Then, in the area between two adjacent ejectors, the distribution of fertilizers can be described by the following dependence:

$$f(x) + f(x + l) + (x - l)$$

when $0 \leq x \leq x_1$;

$$F(x) = \begin{cases} f(x) + f(x - l) & \text{when } x_1 \leq x \leq x_2; \\ f(x) + (x - 1) + f(x - 2l) & \text{when } x_2 \leq x \leq l \end{cases}$$

where $l$ is the distance between adjacent ejectors, m.

The average value of function $F(x)$ in this section is represented as

$$\bar{y} = \frac{1}{l} \int_{0}^{l} F(x) dx$$

(2)

The root-mean-square deviation of the distribution of fertilizers by ejectors over the working width is presented in the following form:

$$\sigma_p = \sqrt{\frac{1}{l} \int_{0}^{l} [F(x) - \bar{y}]^2 dx}$$

(4)

The standard deviation of the distribution of fertilizers over the field surface, taking into account the error in their supply into ejectors, can be determined by the following dependence:
\[ \sigma = \sqrt{\sigma_{dl}^2 + \sigma_p^2 + 2r_{dp}\sigma_{dl}\sigma_p} \]  \hspace{1cm} (5)

where \( r_{dp} \) is the correlation coefficient of fertilizers supply into ejectors and their distribution \( \sigma_{dl} \) is standard deviation of fertilizers supply into ejectors.

Thus, the uneven distribution of fertilizers on the surface of the field along the width of the machine will be represented as the following dependence:

\[ N_p = \sqrt{\sigma_{dl}^2 + \sigma_p^2 + 2r_{dp}\sigma_{dl}\sigma_p} \times 100/\bar{y} \]  \hspace{1cm} (6)

That is, the non-uniformity of fertilizers distribution along the field surface is equal to the sum of the metering unevenness in ejectors.

For rough calculations, one can take \( r_{dp}=1 \). Then formula (6) takes the following form:

\[ N_p = \frac{\sigma_{dl} + \sigma_p}{\bar{y}} \times 100 = N_d + N_p \]

That is, the non-uniformity of fertilizers distribution along the field surface is equal to the sum of the metering unevenness in ejectors.

So the uneven distribution of fertilizers on the field surface is equal to the sum of uneven metering in ejectors \( N_p \) and their distribution by ejectors \( N_d \).

Thus, the proposed method for determining the irregularity of fertilizers distribution can be used when designing a pneumatic boom applicator with ejectors along the length of the boom.

The dispersion unevenness of ammonium nitrate and ammonophos in laboratory studies was 6-7\% (with a total boom length of 12 m and a spreading rate of 600 kg/ha), which is somewhat lower for machines equipped with throwing working bodies and approved by agro requirements.

The nature of the distribution of ammonium nitrate over the capture width is established by the results of experiments.

When checking the pneumatic boom applicator under production conditions, the dispersion non-uniformity of ammonium nitrate amounted to 7.5-8.0\% over the length of the boom (with a total boom width of 12 m and application doses of 200 and 600 kg/ha), which indicates satisfactory match results.

5. Conclusion

Thus, determining the non-uniformity of solid mineral fertilizers distribution over the field, taking into account the non-uniformity of their supply to the sowing ejectors, makes it possible to evaluate the quality indicators of the machine as a whole.

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