The influence of the working bodies of a single-disk centrifugal apparatus on the range of nitrogen fertilizer particles

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Abstract. The results of studies of blade shape influence on the particles flight range are presented. There are three forms of blades of a single-disc centrifugal apparatus. They are rectangular shape, the rectangular trapezium shape and the isosceles trapezium shape. The rectangular trapezium and the rectangular shapes define a downward trajectory, and the isosceles trapezium shape defines an upward trajectory of the particles free flight. The particles flight range created by blades of a rectangular shape is less than that of the isosceles blade shape. However, the rectangular blade shape sets the trajectory of a free flight less affected by wind speed. The installation of a limiting ring on the blades of the centrifugal apparatus increases the particles flight range.

1. Introduction

In the work of J. Kivelä the influence of a meat-and-bone meal as a fertilizer on the yield of sugar beet and carrots was studied [1]. Meat-and-bone meal (MBM) is a byproduct of the meat industry and contains all the main mineral components – sodium, potassium, phosphorus, calcium. Studies have shown that crop treatment using MBM does not provide sugar beets and carrots yield increasing, compared with mineral fertilizers. It was established that the low yield of roots is compensated by the high sugar content in them [1]. The authors note that meat-and-bone meal can be an equivalent substitute for mineral fertilizers to the soils with low phosphorus content.

The research by K. Różyło aimed at reducing the negative impact of mineral fertilizers by mixing them with coal industry wastes [2]. Based on the results of the assessment studies of the impact of a mixture of mineral fertilizers on the yield and quality of wheat grain, it was found that there was a bioaccumulation of heavy metals in grain in comparison with common ones [2].

In the work of R. Uusitalo the possibility of replacing nitrogen fertilizers for phosphoric ones, applied to the onion and cabbage crops, was studied [3]. Phosphoric fertilizers do not lead to the accumulation of heavy metals in the soil and products. According to the results of the performed studies, it is advisable to apply phosphoric fertilizers instead of mineral ones to soils with a high content of phosphorus in the soil. Soils with low phosphorus content do not ensure yield increasing [3].

The prospects of replacing mineral fertilizers for organic ones were studied by C. A. Kwiatkowski regarding winter and spring wheat crops. It was proved that the organic farming system, in comparison with a traditional one, allowed obtaining high-quality wheat grain. Wheat yield when applying organic fertilizers was lower than that when applying mineral fertilizers. The reason, as the authors note, lies in
the low rate of nitrogen assimilation when applying manure [4]. On the basis of the research, it was established that there was no alternative replacement to mineral fertilizers. The technology of winter wheat cultivation provides for top-dressing crops with nitrogen fertilizers. The studies proved the effect of different doses of nitrogen fertilizers on the mass of 1000 grains [5, 6].

The conducted researches proved the prospects of nitrogen fertilizers application during the vegetation period. The high unevenness of mineral fertilizers application is caused, on the one hand, by the physical and mechanical properties of fertilizers – caking, excessive hygroscopicity, different granulometric composition and a number of other properties [7], and, on the other hand, by the imperfection of the fertilizer supply to the scattering disc. The design of the single-disc centrifugal apparatus, which has a technical novelty, has been developed [8].

![Figure 1](image)

**Figure 1.** The single-disc centrifugal apparatus: 1 – conical part of the dispenser; 2 – activator; 3 – feed sector; 4 – ring; 5 – centrifugal disc; 6 – blade; 7 – end blade limb; 8 – limiting ring.

The single-disc centrifugal apparatus includes a hopper, a dispenser consisting of a conical and a cylindrical parts in the lower part of which there is a feed sector 3. In the discharge zone of the dispenser, the activator 2 is installed coaxially with the scattering disc 5. In the process of rotation of the accumulator, not only the destruction of stable masses in the zone of the discharge window occurs, but also the initial velocity is given to particles. As the scattering disc 5 rotates, the blade 6 approaches the zone of the feed sector and captures the flying material with the end flap 7. Further, as the disc rotates, the particles under the action of centrifugal force, gain acceleration, and fly off the blades, forming a fan of sieving. On the blades, the limiting ring 8 is installed coaxially with the scattering disc. Rebound of incoming particles from the working edge is eliminated by sharpening the end flap in the height of the blade. At a sharpening angle of 15°, the relative velocity vector of the particles coincides with the reflected inner surface of the blade end flap [9].

2. Materials and methods

Urea was used as a material for research. Three variants of the shape of the working bodies of the blades are selected and presented in figure 2.

The rectangular blade shape provided a flight parallel to the plane of the disc and in free flight the particles moved along a downward trajectory. The blade, which has the shape of a rectangular trapezium, provided a gathering of fertilizer particles on a downward trajectory. The gathering of fertilizer particles from the blade, which has the shape of an isosceles trapezium, occurred along an upward trajectory. The evaluation criterion of the rational shape of the blades is the particles flight range. To exclude the fertilizer particles rebound from the working bodies of the scattering disc, the limiting ring was installed
on the upper shelf of the blade coaxially with the scattering disc. During the rotation of the scattering
disc, an airflow is created by the blades, which increases the particles flight range.

![Blade shapes](image)

**Figure 2.** Blade shapes: a – a rectangular; b – a rectangular trapezium; c – an isosceles trapezium

The maximum and minimum flight range was determined by expression 1 and expression 2, respectively [9]:

\[ L_{min} = L_{ave} - 2\sigma \]
\[ L_{min} = L_{ave} - 2\sigma \]

where \(L_{ave}\) – the average measurement in determining the average range, m; \(\sigma\) – the standard deviation, m.

The average of measurements is determined by the expression [9]:

\[ L_{ave} = \frac{\sum n_i m_i}{m_{tot}}. \]

where \(n_i\) – the sequence number of the container in a row; \(m_i\) – the mass of fertilizer in the \(i\)-container, g; \(m_{tot}\) – the total weight of fertilizers in containers of a row, g.

The total weight of fertilizers in containers was determined by the expression:

\[ m_{tot} = \sum m_i. \]

3. The study of the flight range of the particles

At the initial stage, the angle of sieving of nitrogen fertilizers was determined by a single-disc centrifugal apparatus. The obtained value of the sieving angle relative to the axis of the centrifugal disc was divided into sectors. One row of containers was installed close to the 40-60° of a sieving zone. The first container was installed at a distance from the center of the disc equal to 0.5 m. The number of containers in a row was 26, and each of them had dimensions: 0.5 × 0.5 × 0.15 m according to the GOST 28714-2007 “Machines for applying solid mineral fertilizers. Test methods”. To eliminate particles ricocheting, the lattice inserts were set inside the container. The mass of fertilizers in the containers was weighed with an accuracy of ± 20 g. According to the presented dependences, the parameters of the sieving zone were determined – maximum and minimum flight range, the sieving angle relative to the axis of the centrifugal apparatus.

A comparative experiment was conducted to assess the effect of the limiting ring on the particles flight range. The sieving zone of urea particles created by a centrifugal apparatus with blades having the shape of a rectangular trapezium and the installed limiting ring has a maximum flight range of 7.8 m, a minimum of 1.6 m from the end of the centrifugal disc. The mineral fertilizers sieving zone is created by the centrifugal apparatus with rectangular blades and the removed limiting ring: the maximum flight range of 6.2 m, the minimum 0.9 m from an end face of a centrifugal disc.

The sieving zone of urea particles created by the single-disc centrifugal apparatus with rectangular blades and the installed limiting ring had a maximum flight range of 8.1 m, a minimum of 2.5 m from the end of the centrifugal disc.
The particles sieving zone created by the single-disc centrifugal apparatus with blades having the shape of an isosceles trapezium has a maximum flight range of 8.9 m and a minimum flight range of 2.9 m from the end of the centrifugal disc.

4. Conclusion
According to the results of the studies of the working bodies of the single-disc centrifugal apparatus, it was found that the shape of the blades and the installation of the limiting ring affects the parameters of the sieving zone. The limiting ring mounted on the blades creates a following airflow, which increases the particles flight range by an average of 20%.

The sieving zone of urea particles created by the single-disc centrifugal apparatus with blades having the shape of an isosceles trapezium creates an upward trajectory of the particles free flight at the moment of their flight from the disc. And the downward trajectory of flight is provided by blades having a rectangular shape, and blades having the shape of a rectangular trapezium. The particles flight range, as shown by studies, in the centrifugal apparatus with blades having the shape of an isosceles trapezium is 8.9% higher than that with blades having a rectangular shape. The rectangular shape blade provides a maximum flight range of particles 3.2% of more than the blade having the shape of a rectangular trapezium.

On the basis of the research conducted, it was established that optimum working bodies of the single-disc centrifugal apparatus are the rectangular blade with the mounted limiting ring. The trajectory of the particles free flight created by the blades of this type was less affected by the wind speed, which would increase the uniformity of distribution of nitrogen fertilizers during the fertilization of winter wheat crops.

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