STUDY OF FERTILIZER SPREADER CENTRIFUGAL TYPE UNDER FIELD CONDITIONS
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ДОСЛІДЖЕННЯ РОЗКИДАЧА МІНЕРАЛЬНИХ ДОБРИВ ВІДЦЕНТРОВОГО ТИПУ У ПОЛЬОВИХ УМОВАХ

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ABSTRACT

Methods for researching the effect of direction and force of wind on the result of the uniformity and width of mineral fertilizer application have been proposed. Researches on the experimental sample of centrifugal mineral fertiliser spreader in the field conditions have been made. The proposed rotary working body design, structural features of which enable to improve the dispersion evenness of mineral fertilizer, is presented.

РЕЗЮМЕ

Запропоновано методики дослідження впливу сили та напрямку руху вітру на результат рівномірності і ширини внесення мінеральних добрив. Проведено дослідження на експериментальному зразку відцентрового розкидача мінеральних добрив в польових умовах. Запропоновано відцентровий робочий орган, конструкційні особливості якого дозволяють поліпшити рівномірність розсіювання мінеральних добрив.

INTRODUCTION

The most important source of cultivated crops high yields is the mineral fertilizers use (*Lal R., 2008*). It is known that the application of granular fertilizers onto arable lands is mainly performed using centrifugal spreaders (*Biocca et al., 2013; Tijskens et al., 2008; Kobets et al., 2017a; Kobets et al., 2017b*). The effectiveness of mineral fertilizers largely depends on the uniformity of the distribution on the field surface (*Nukeshev et al, 2014*). Unevenness and instability of application reach 20–40% (*Nukeshev et al., 2016*) and leads to loss of grain crops (*Tekin and Sındır, 2014; Ning et al., 2015*). Spinner disc type spreaders simple design and little maintenance requirement made them very popular (*Tekin and Sındır, 2013*). Study of the working process of these devices is important because this knowledge will allow appropriate adjustment and will lead to achieving the desired distribution rules (*Petcu et al., 2015; Dong et al., 2013*). It was shown that flows of particles with a larger mean diameter achieve a higher velocity on the disc, causing the distribution patterns to shift to lower angular positions. It was concluded that a smaller average particle size leads to a higher mass discharge flow rate from the hopper (*Reumers et al., 2003*). Major differences in the quality of the spread pattern deposition can be observed in the field because of difficulties in adjusting the machines (*Vilette et al., 2005; Šima et al., 2013*). Numerous experiments with fertilizers found that the maximum value of the crop yield under certain conditions corresponds to the optimal dose of fertilizer (*Boldea et al., 2015; Andric et al., 2012; Hammad et al., 2012; Nazli et al., 2014*). An increase in the dose above the optimum level leads to a decrease in crop growth per unit of fertilizers, and if it is excessive - to a decrease in yield (*Vetsch and Randall, 2004; Lošák et al., 2011*).

Experimental researches have set the task to study the process of centrifugal mineral fertilizer spreader using an improved working body and compare it with a disc from serial production.

MATERIALS AND METHODS

The program of experimental research was supposed to determine the influence of force and direction of wind on the width of fertilizer spreading and uniformity of distribution over field surface. The fertilizer spreading machines (FSM) were used for tests. FSM - 900, FSM – 0.5 (Ukraine) and JarMet 500 (Poland) were used to compare effectiveness of experimental and serial discs. Machine ROTAFLOW RS-M

(Netherlands) was involved separately, for comparison. Field tests were held on fields of three farms, which are located in the north, east and south of the Dnipropetrovsk region. Experiments were conducted with the following fertilizers: granular superphosphate, sulfuric superphosphate, ammonium nitrate, urea, potassium salt. Quality of mineral fertilizers application was determined in following way. Transverse unevenness and fertilizers separation degree were determined by placing tin sheets (trays) with the size of 0.5 $\times$ 0.5 $\times$ 0.05 m on the spreading width, 0.5 m apart from each other, in 3 rows, with a 5 m interval between rows. Additional set of trays was arranged to determine the longitudinal unevenness across these three rows, which was equal to half of the spread width (fig.1).

Fig. 1 - Placement of trays on the field to determine the uniformity of fertilizer spreading

Longitudinal and transverse unevenness was determined in 5 passes. Separation degree was estimated in 10 passes of the unit. Variation coefficient during the test was 3-5%. Field tests of JarMet 500 (Poland) with developed working body were held in a motion that was deviated from the progressive movement with the developed working body. Working width and coefficient of heterogeneity were the main indicators of the quality of the machines for applying mineral fertilizers.

The variation characteristic of fertilizer application heterogeneity degree on a centrifugal spreader was obtained before tests. This experiment was held using an upgraded disc (fig. 2).

Fig. 2 - Upgraded centrifugal spreader disc

Variation coefficient of dosing apparatus with an average sample size of 1 kg was 12%. Machine work was performed on equal field areas at the working rate of 250-300 kg/ha. Wind speed on the field was from 1 to 5 m/sec. The research scheme of air flow effect on mineral fertilizers application unevenness is shown in fig. 3. Research methodology of air flow influence allows determining influence of wind speed in laminar mode, which is as close as possible to actual conditions for fertilizer machine. Technological process of mineral fertilizers spreading included the following operations: fertilizers load into spreader, fertilizers transportation by spreader or by car to a field and fertilizers spreading. Tests were made both on unilateral fertilizers and fertilizer mixtures.

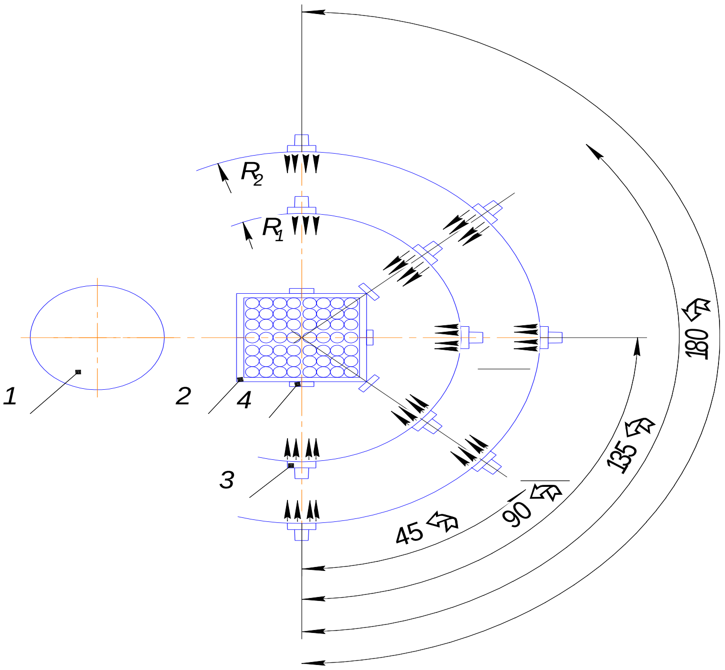

Fig. 3 - Research scheme of air flow effect:
1 – spreader disc; 2 – tray with samplers; 3 – fan; 4 – anemometer

RESULTS

The results of experimental study for centrifugal mineral fertilizer spreader are given in table 1.

Table 1

Parameters of centrifugal mineral fertilizer spreader testing in field experiments

Fertilizer and its humidity		Wind parameters: Speed [m / s]	Wind parameters: Direction [degree]	Rate of application [kg / ha]	Delivery of fertilizers, [kg / s]	Effective spreading width, [m]	Hetero geneity coefficient [%]
Granular superphosphate	W = 4.8%	1.0	0	250	0.82	14.5	12.9
	W = 4.8%	2.8	0	300	1.73	15.3	15.5
	W = 4.8%	3.0	0	300	1.96	17.0	16.2
	W = 4.8%	2.1	180	300	1.56	13.8	12.5
	W = 4.8%	2.1	90	300	1.49	13.2	14.25
	W = 4.8%	3.1	45	250	0.76	13.4	18.0
	W = 4.8%	2.2	45	300	1.65	14.6	16.0
	W = 4.8%	2.2	135	300	1.53	13.5	16.25
	W = 4.8%	1.0	180	250	0.68	12.1	12.2
	W = 4.8%	3.0	180	300	1.13	10.0	13.9
Powdered superphosphate, W =16.4%		2.5	0	300	1.79	15.8	-
Ammonium nitrate, W = 1.3%		2.1	0	250	0.92	16.2	-
Urea, W = 0.3%		3.4	0	250	1.03	18.1	-
Potassium salt	W = 2.8%	3.0	0	250	0.77	13.6	-
	W = 2.8%	3.0	0	300	1.58	14.0	-
	W = 2.8%	5.5	0	300	1.76	15.6	-
	W = 2.8%	3.0	90	300	1.27	11.2	-
	W = 2.8%	2.4	180	300	1.46	12.9	-
	W = 2.8%	2.4	45	300	1.24	11.0	-
Mixture of granular superphosphate with ammonium nitrate		2.8	0	300	1.72	15.2	-

It is clear that mineral fertilizer rate does not significantly affect spread width. The most effective width (up to 20 m) is obtained with powdered fertilizer. The effective width reaches 18 m during spreading of granulated and crystalline fertilizers. Less width was fixed when fine crystalline fertilizers were applied. It was found that granular fertilizers with a spreading rate of 10 m/sec were the least affected by the wind. Thus, difference in spreading width with wind, directed at 90° angle to spreading direction (lateral wind) and wind that blows along the spreading direction (passing wind), is more than 12% for granular superphosphate, and 20% - for potassium salt. The increase in the tailwind speed from 1 to 3 m/s contributes to an increase in the effective spreading width of the granular superphosphate by an average of 15%. Results of experimental evaluation of air flow velocity and direction influence on granules distribution are shown in Fig 4.

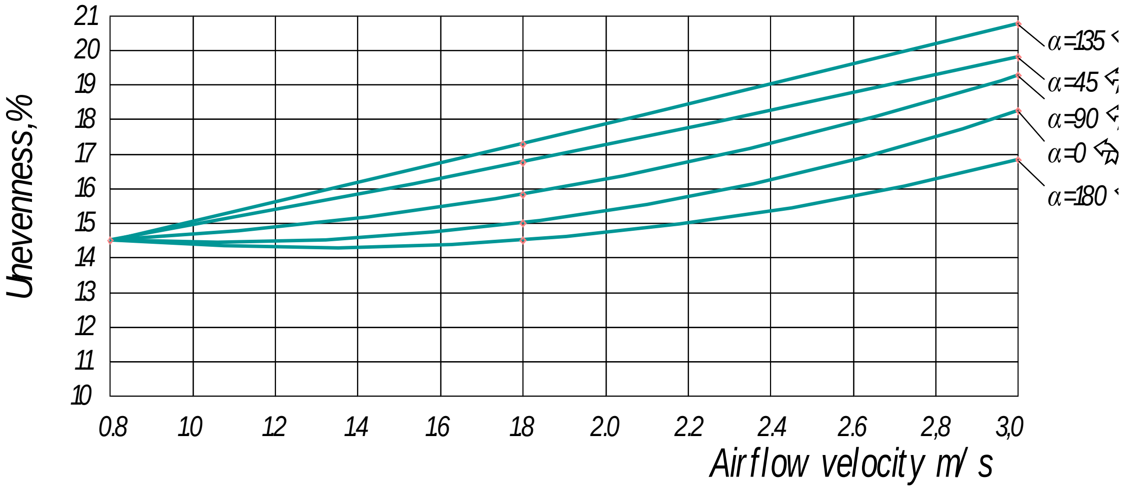

Fig. 4 - Air flow velocity and direction influence on granules distribution

It was established that the wind acting at an angle of 180° to the direction of spreading increases fertilizers separation insignificantly. Side and counter wind, comparing with the action of a passing wind, affects the distribution of particles of fertilizers significantly. Coefficient of heterogeneity increases almost in 2 times. So, fertilizers application at above - mentioned wind directions should be avoided. Fertilizers were applied on an area of 600 hectares during the testing process. Shift productivity reached 55 ha/s (hectare per shift). Quality of fertilizers application met all agrotechnical requirements of the process. Test conditions characteristics: total plot area is 1 ha, field relief is even, microrelief is absent; area inclination - within 2%, type of fertilizer - superphosphate. Presence of wind is up to 2 m/s in opposite direction in relation to machine-tractor unit. Results of determining granules distribution unevenness depending on experimental disc location height above ground level are shown in figure 5.

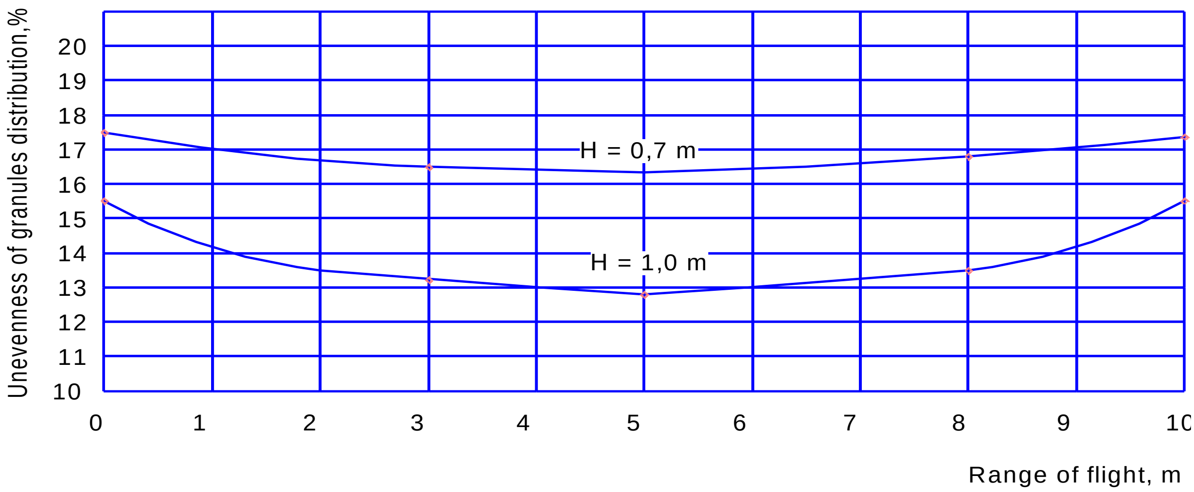

Fig. 5 - Distribution of granules using machine FSM-900 depends on designed disc location height above the ground level and the flight range of granules

The analysis of obtained dependences confirms that uneven distribution of granules is generally satisfactory. It is noteworthy that with the increasing of disc location height above ground level, the unevenness of fertilizer application decreases. This result is due to a longer flight of the particle and, consequently, a longer flow distribution (fig. 6), using machine FSM - 0,5 depending on designed disc location height above the ground level.

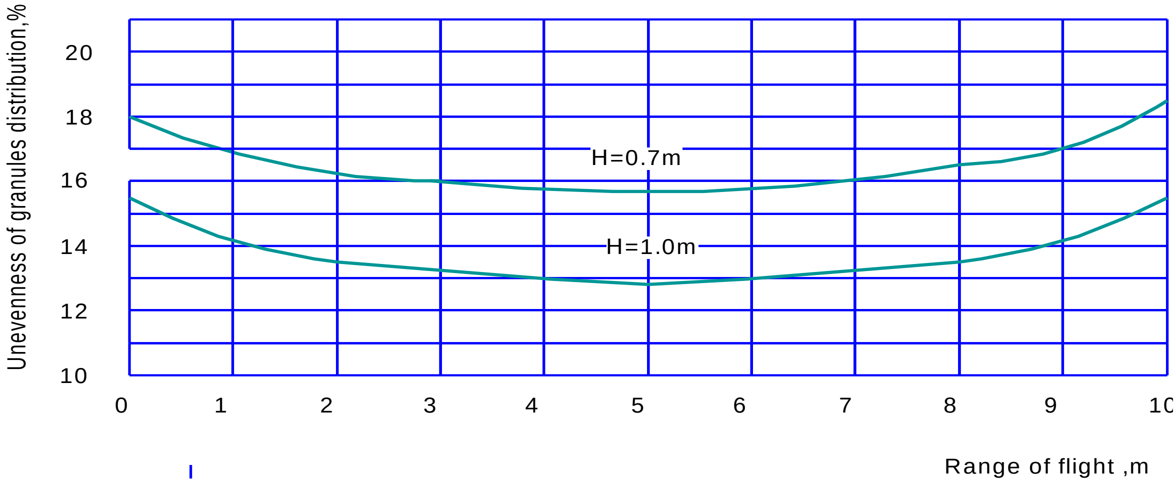

Fig.6 - Distribution of granules depending on designed disc location height above the ground level and the flight range of granules

Results of granules distribution definition for JarMet 500 machine with a designed disc are shown in Fig. 7.

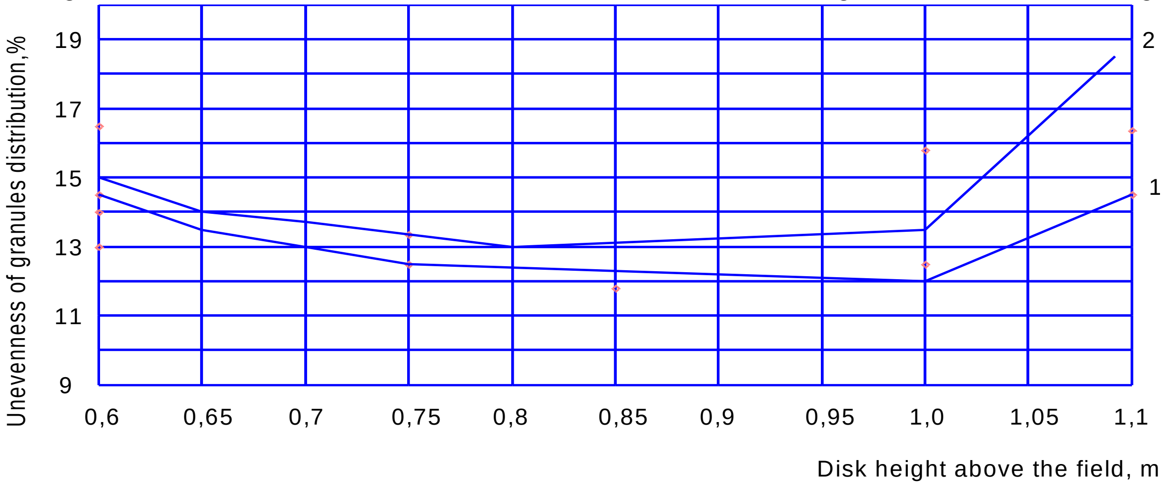

Fig. 7 - Distribution of granules depending on disc height above the field

1 - for steady motion; 2 – deviation from forward motion

After analyzing the obtained dependences, we see that the quality of fertilizer application is influenced by disc location height above ground surface. This applies both to motion deviated from translational with developed working body and steady movement of modernized machine. Thus, fertilizer application uniformity sharply worsens by 5.5 - 6% at the height of 1.1 m. So, optimum disc location height above ground surface level should be considered 1.0 m.

It is obvious that less uniform fertilizer application is observed in single - disc machines FSM-0.5 (Ukraine) and JarMet 500 (Poland). This is due to construction features of the aggregates. Results of determining granules distribution by using the two machines: FSM-0.5 with modernized working body (1) and ROTAFLOW RS-M (2) are shown in Fig. 8.

The machine with serial discs shows unevenness at level of 23-27%, which significantly exceeds indicator of modernized machine, as well as ROTAFLOW RS-M. Uneven distribution with proposed design is less than with the imported one on average by 7-10%.

However, this indicator in ROTAFLOW RS-M is more stable in terms of capture width. Uneven application of mineral fertilizers within limits of agrotechnical requirements does not affect crops harvest and can be considered satisfactory. However, index of a serial machine up to 27% does not meet stated requirements.

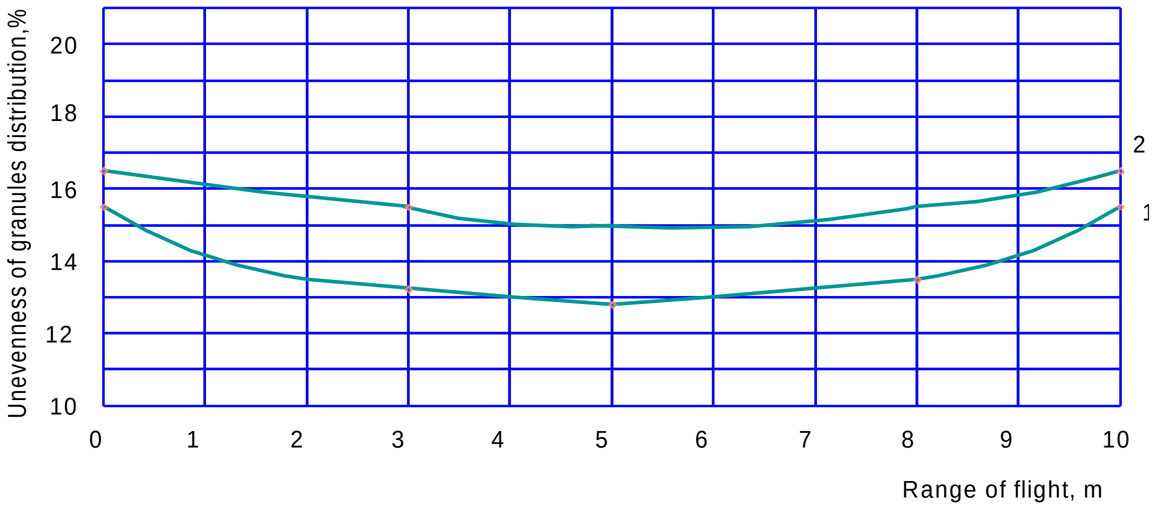

Fig.8. - Distribution of granules depending on designed disc height above the field
1 - for machine FSM - 0,5; 2 –for machine ROTAFLOW RS-M

Experimental research results made it possible to compare work of centrifugal type mineral fertilizer spreader with disc which was designed and serial disc (Table 2). The unit included Ukrainian tractor MTC-82.1 and machine JarMet 500 (Poland).

Table 2

Performance indicators of centrifugal type mineral fertilizer spreader using designed and serial disc of JarMet 500 machine

Indicator	Basic option	Designed option
Field square [ha]	600	600
Productivity per 1 hour work shift, [ha/hour]	12.20	15.96
Number of operating personnel, [people]	1	1
Fuel consumption, [kg / ha]	0.7	0.5
Shift duration, [hour]	7	7
Unevenness of mineral fertilizer application, [%]	20-35	7-12

Thus, as a result of improvements made to the working body, reduction in unevenness of mineral fertilizers application to admissible standards was achieved. When using the designed option of spreader disc compared to base option, productivity of machine - tractor unit increases by 30.8%, and fuel consumption is reduced by 40%.

CONCLUSION

It is proved that air resistance substantially affects final distribution of fertilizer granules along soil surface. This is mainly due to changes in flight range of individual granules. As a result of research it was established that resistance was not proportional to granule velocity. In range of wind velocities up to 0.5 m/s impact of air flow on granule flight distance did not exceed 5%, which corresponded to an increase of uneven distribution by 0.35%. Influence of other factors on unevenness indicator was much higher. It allowed us to not count wind velocity in calculations in the given range. In this case, estimated uneven fertilizer application was 10.02% for indicated constructive and kinematic indicators at accepted granulometric composition of 1-5 mm.

Mechanical and technological properties of fertilizers, which influenced distribution process the most, were experimentally determined. It was established that mineral fertilizers application rate did not affect spreading width significantly. The most effective width (up to 20 m) was obtained during powdered fertilizer spreading, and when granulated and crystalline fertilizers were applied effective width reached 18 m. The width was smaller when applying fine crystalline fertilizers. It was established that the influence of wind was selective. Air flow directed at an angle from 45 to 135 degrees had the greatest impact on fertilizers uneven distribution by surface. At wind velocity more than 2.0 m/s application qualitative indicators were sharply deteriorated. Comparative field tests proved that the proposed design of centrifugal type spreader ensured fulfilment of agrotechnical requirements for uneven spreading (did not exceed 16%). Uneven spreading was 2 times lower than on serial native spreaders on average and by 7-10% lower than on known foreign analogs. Influence of machine oscillations on this indicator ranges from 5% to 8% of overall unevenness. Implementation of developed recommendations will reduce fertilizer consumption, increase unit's productivity and optimize norms of application.

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