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Effect of selected working parameters of disk spreader on the quality of ammonium nitrate distribution

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Abstract: *Effect of selected working parameters of disk spreader on the quality of ammonium nitrate distribution.* There is presented the statistical analysis of the results of measurements on the effect of spreading disk rotational speed, setting angle of disk vanes and number of vanes on size reduction of ammonium nitrate distribution, expressed by the share of granules bigger than 1 mm.

Key words: disk spreader, ammonium nitrate, disk rotational speed, setting angle of vanes, number of vanes, granule size reduction.

INTRODUCTION

One of the basic factors that determine the crop yield and its quality are agrotechnical operations to be performed in proper time, sequence and with required precision. Among these operations, the mineral fertilizing plays an important role in providing plants with nutrients, essential for proper development and growth of cultivated crops. It is assumed that fertilizing, as a yield-creating factor, determines the field size in about 40% [Czuba and Mazur 1988; Waszkiewicz et al. 2008].

In mineral fertilizing there are most often used the centrifugal (disk) spreaders, due to their simple design, high working output and width as well as high regularity of operation [Waszkiewicz and Kacprzak 2009]. One of the most important factors that affect the quality of mineral fertilizer distribution is resistance of granules to size reduction. It is particularly important in fertilizing with the use of centrifugal spreaders, where granules are subjected to dynamic impacts of vanes on spreading disk [Kram 1990; Walker et al. 1997]. Parish [2001] investigating several types of fertilizer distributors for granule damage during operation found, that the lowest damage occurred in the machines with pneumatic distribution system with distributing pipes, slightly higher in application of swinging nozzles, and the highest damage in centrifugal distributors.

METHODOLOGY OF INVESTIGATIONS

A specially designed and fabricated research stand was used in investigations; it consisted of the single-disk spreader with the hydraulic attachment. The spreader was equipped with two hydraulic motors that allowed for stepless adjustment of

disk rotational speed by hydraulic flow controllers and the agitator's speed. The spreading disks of the same diameter allowed for the change in number of vanes and their setting angle in relation to the disk.

The ammonium nitrate granulated according to PN-91/R-55029 and PN--84/C-87054, Standards was investigated at the following variable working parameters of the spreader: five rotational speeds of spreading disk (540, 610, 680, 750 and 840 rpm), three settings of disk vanes (left-side – reverse to direction of disk revolutions, right-side – compatible to disk revolutions, and middle-one – the setting compatible with disk axis), and number of disk vanes (2, 3, 4, 6). Each test was repeated three times. The fertilizer was subjected to grain size analysis on the grain size analyzer AWK.

The quantitative shares of fractions in the sample were recalculated to percentage. The mean value of three repetitions was calculated. The factory size distribution of ammonium nitrate was taken as the basic sample. Size distribution of granules bigger than 1 mm was taken as criterion for evaluation of the effect of working parameters on ammonium nitrate distribution quality.

ANALYSIS OF INVESTIGATION RESULTS

A single-factor analysis of variance at significance level $\alpha = 0.05$ was carried out to check significance of the effect of particular factors on breaking up of ammonium nitrate. The following measuring variants were included: disk speed – P (54, 61, 68, 75, 84), angle of disk vane setting – K (L – left, S – middle, P – right), number of disk vanes – L (2, 3, 4, 6) and their combinations.

Differences between particular levels of results were determined with the Tuckey-Kramer's procedure for multiple comparisons for non-orthogonal data (unequal number of observations within levels of factors).

Variance analysis on the main factors' effects in combinations proved that particular main factors influenced significantly the size reduction degree of ammonium nitrate. The significant interactions between disk rotational speed and setting angle of vanes as well as between setting angle of vanes and their number were found also (Table 1).

Considering the effect of an increase in disk rotational speed on ammonium nitrate granule size the four homogeneous groups were found (Table 2). The analysis showed an increase in granule size reduction with the increased rotational speed ranging from 540 to 750 rpm. No statistically significant differences were found in average granule share above 1 mm at speed 750 and 840 rpm.

The three homogeneous groups were found when compared the results of investigations on average share of ammonium nitrate granules > 1 mm for various angles of vane setting (Table 3). A decrease in the share of granules > 1 mm was found with shifting of setting angle towards direction of disk rotation (P).

The four homogeneous groups were found when the effect of number of spreading vanes on the share of granules bigger than 1 mm was analyzed. Less damage of granules was found at smaller number of spreading vanes (Table 4).

TABLE 1. Results of variance analysis on the effect of main factors and their combinations on ammonium nitrate granule size

	Degrees of freedom	Sum of squares	Mean square	F_{emp}	Significance level
Combinations	60	47571.39547	792.85659	15.49*	< 0.0001
Error	118	6040.65234	51.19197		
R-square	178	53612.04781			
Main factors					
P	4	12337.48802	3084.37201	60.25*	< 0.0001
K	2	6951.36703	3475.68352	67.90*	< 0.0001
L	3	12213.35031	4071.11677	79.53*	< 0.0001
Interactions					
P × K	8	1731.38652	216.42332	4.23*	0.0002
P × L	12	871.96534	72.66378	1.42	0.1665
K × L	6	8750.61986	1458.43664	28.49*	< 0.0001
P × K × L	24	4081.26126	170.05255	3.32*	< 0.0001

*significant at $\alpha = 0.05$

TABLE 2. Distribution of share of ammonium nitrate granules above 1 mm into homogeneous groups according to disk rotational speed

Factor	Level of factor	Homogeneous groups	Average share of granules > 1 mm [%]
Rotational speed	540	x	32.80
	610	x	31.31
	680	x	29.45
	750	x	27.65
	840	x	25.84

TABLE 3. Division of share of ammonium nitrate granules > 1 mm into homogeneous groups according to spreading vane setting angle

Factor	Level of factor	Homogeneous groups	Average share of granules > 1 mm [%]
Setting angle	L	x	30.80
	S	x	28.15
	P	x	27.85

TABLE 4. Division of share of ammonium nitrate granules > 1 mm into homogeneous groups according to number of spreading vanes

Factor	Level of factor	Homogeneous groups	Average share of granules > 1 mm [%]
Number of vanes	2	x	30.32
	3	x	31.68
	4	x	28.01
	6	x	26.87

Comparison of significant differences between the basic sample and the variants of investigated factors (combinations) at significance level $\alpha = 0.05$ showed highest differences in combinations: 84S3K, 75P6K, 68P6K, 61P6K, 75P3K, 75S3K (Table 5). Considering the upper confidence limit, the maximal possible difference (with probability 95%) in the share of granules bigger than 1 mm between the basic sample and mentioned combinations can exceed 76%. Basing on most significant differences in average values (from 39.416 to 41.904) it was found that under real conditions the differences can range from 4.693 to 76.626.

The analysis of the effect of vane setting angle and disk rotational speed on granule size reduction showed significantly higher share of granules > 1 mm at the left-side setting of vanes and distinct decrease in granule share for this setting at disk rotational speed 610 rpm. At middle-one and right-side settings a quite similar level of granule size reduction was found at all the investigated disk rotational speeds. At speed 840 rpm the highest intensity of granule breaking-up was found; it did not exceed 3% for all values of vane (Fig. 1).

Considering the effct of number of vanes and their setting angle on the share of granules above 1 mm one can find the higher granule share for the left-side setting in samples with 2 and 3 vanes on the disk. It was found that at right-side and middle setting of vanes the results

TABLE 5. Combinations of most significant differences in the share of granules bigger than 1 mm for basic sample and investigated factor variants, with application of Tukey-Kramer

Comparison of combinations	Difference between averages	Confidence interval limits for difference in average values	
Basic samp. – 75P3K	39.416	4.693	74.138
Basic samp. – 75S3K	39.758	5.036	74.481
Basic samp. – 75P6K	40.421	5.698	75.143
Basic samp. – 61P6K	40.448	5.726	75.171
Basic samp. – 68P6K	41.671	6.948	76.394
Basic samp. – 84S3K	41.904	7.181	76.626

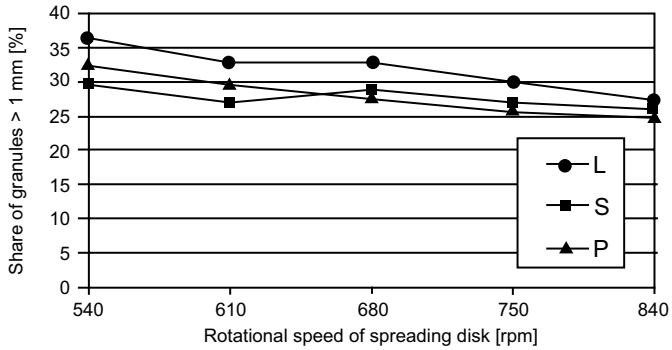

FIGURE 1. Effect of rotational speed and setting angle of vanes on the share of granules above 1 mm

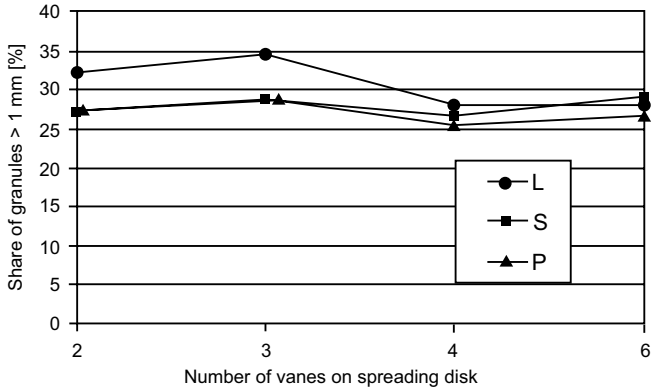

FIGURE 2. Effect of number of vanes and their setting angle on the share of granules above 1 mm

obtained with 2, 3 and 4 vanes differed by up to 1.5%, while with 6 vanes the difference of 2% was found for all setting angles (Fig. 2).

SUMMARY

The carried out statistical analysis of the obtained investigation results showed that all the main factors: spreading disk rotational speed, setting angle of vanes on the disk and number of vanes significantly affected the quality of ammonium nitrate distribution.

The difference in the share of granules bigger than 1 mm between the basic sample and particular combinations can exceed 76%.

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Streszczenie: *Wpływ wybranych parametrów roboczych rozsiewacza odśrodkowego na jakość wysiewu saletry amonowej.* Analiza statystyczna wyników badań wykazała, że wszystkie czynniki: prędkość obrotowa tarczy rozsiewającej, kąt ustawienia łopatek na tarczy oraz liczba łopatek na tarczy rozsiewającej, w istotny sposób wpływają na jakość wysiewu saletry amonowej, a różnice w udziale granul o wielkości powyżej 1 mm między próbą bazową a poszczególnymi kombinacjami mogą wynosić powyżej 76%.

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