Single disc couler with gauge wheel for pneumatic seed drill

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Abstract. The production of competitive, ecological agricultural products by agricultural producers in modern conditions is impossible without the modern equipment that provides a combination of technological operations in sowing and fertilizing. As a result of an analytical review of modern coulter designs used in modern seed devices for sowing, planting seeds of grain crops and granules of mineral fertilizers during their application, it was found that the most efficient single disc coulters with press wheels used as gauge-wheels, which ensure high-quality grain crops sowing. The design of the coulter with a gauge wheel of the pneumatic seeder has been developed and its design parameters have been determined. The conducted laboratory field tests of a pneumatic seeder equipped with experimental coulters with a gauge wheel made it possible to determine its optimal design parameters: coulter disc diameter 0.4 m, diameter and width of the copying wheel - 0.27 m and 0.04 m, taking into account the standard deviation of the distribution of seeds at the depth of planting.

1. Introduction
According to the results of an analytical review of modern devices for planting seeds of grain crops during sowing and granules of mineral fertilizers into the soil at a high-quality and efficient level, single disc coulters with a gauge wheel could help to achieve these results [1-7]. However, they have a number of disadvantages, which include: the need for replaceable flanges for deep sowing of seeds at different levels, as well as the instability of the coulter stroke in depth due to the mismatch between the direction of the coulter movement and the traction line. All this affects the quality of sowing, which leads to a decrease in crop yields and an increase in production costs [5-12]. To improve the estimated indicators of the quality of sowing and planting seeds of grain crops and granular mineral fertilizers when applying them by the single-disc coulters with gauge wheels, it is necessary to take into consideration their disadvantages.

Thereby, an increase in the productivity of the sowing unit and the quality of sowing grain crops is possible due to the implementation of modern technical devices and single coulter disc pneumatic seeders with gauge-wheels. These devices could significantly improve the uniformity of seed distribution over the sowing area and increase the yields of grain crops.

2. Materials and methods
In the frame of the laboratory and field experiments, there were used methods connected with the theory of a multifactorial experiment, mathematical statistics and the current STO AIST (Russian Agricultural Machinery and Technology Testers Association Standards) 5.6-2018, STO AIST 1.12-2006, GOST (Russian State Standards) 20915-2011, GOST 24055-2016, GOST 31345-2017 and others. Processing
of experimental data was carried out with the applied programs "Statistica 6.0", "MathCAD", Simcenter 12, 3D modeling programs, etc.

Figure 1 shows a single coulter disc seeder, which contains a vertically located disc knife 1, made in the form of a cone, which provides cutting of the soil and encountered weeds in the vertical plane. The disc coulter 1 is attached to the coulter body 4 by means of a bearing unit. On the inner side of the disc knife 1, a seed pipe 6, a groove former 2 and an elastic gauge wheel 3 are installed.

The seed pipe 6 and the groove former 2 are rigidly fixed to the housing 4. And the elastic gauge wheel 3 is attached to the bracket with the bearing unit affixed to the coulter body 4 by joints, with the possibility of height adjustment relative to the disc knife 1 by the mechanism. The elastic gauge wheel 3 has the shape of a truncated cone, and its working surface is ribbed. The coulter is attached to the seeder frame with a leash. The coulter pressure on the ground is spring-adjusted.

When the seeder moves across the field, the disc knife 1 cuts the soil and plant residues in a vertical plane to the depth of planting seeds and fertilizers, which is provided by an elastic gauge wheel 3. The cut soil layer is shifted to the left due to the conical shape of the disc knife 1, the groove former 2 forms a groove, where seeds and fertilizers get through the seed line 6. Sowing seeds and fertilizers is carried out with a harrow from the seeder (sowing unit). In the process of sowing, the elastic gauge wheel is pressed against the disc knife 1, realizing the function of a scraper. The elastic gauge wheel 3 with the ability to adjust in height relative to the disc knife 1 and the groove former 2 could help to avoid the problem with replaceable flanges for different depth seed sowing and significantly reduce the time for adjusting the seeder to the sowing depth.

3. Results and Discussion

In order to clarify the design parameters of the coulter, laboratory-field experiments were carried out at the private company owned by N.I. Nesterov. The fields of the company are located in the Kolyshleysky district of the Penza region. In 2019-2020 the company used a pneumatic seeder S-7.2PM4 with designed single-disc coulters with gauge wheels for sowing grain crops (Figure 2) according to the methods of STO AIST 5.6-2018 “Tests of agricultural machinery. Sowing and planting machines. Indicators of appointment”. The agrotechnical assessment was carried out according to GOST 31345-2017.

The optimal design parameters of the coulter seeder were determined by changing its main parameters and determining the standard deviation of the distribution of grain seeds along the seeding depth. When specifying the most significant design and operating parameters of the coulters, in particular, the diameter of the coulter disc, the diameter of the support wheel, the width of the support
wheel, it was noticed that only one parameter changed, the rest remained constant - equal to the optimal values had obtained in laboratory experiments.

Figure 2. General view of an experimental seeder with openers in operation.

After processing the experimental data, graphs were built and correlations were determined between the value of the deviation of the seeds distribution along the sowing depth during planting and the geometric parameters of the component units of the coulter.

Figure 3. Influence of the coulter disc diameter on the standard deviation in seeds distribution along the sowing depth.

Approximation of the data by the second degree polynomial within the coulter disc diameter $d_d$ relation to the standard deviation of the distribution of seeds along the sowing depth (Figure 3) made it possible to obtain the following correlation:

$$\sigma = 1378,8d_d^2 - 1187,8d_d + 257,57$$  \hspace{1cm} (1)

the accuracy of the approximation was (coefficient of determination) $R^2 = 0.9776$. 

After analyzing the graphical correlations (Figure 4), it could be concluded that the diameter of the opener disc \(d_o\) should be at least 0.39 m, while the standard deviation in the seed distribution along the sowing depth would not exceed 4 mm.

In the course of research to determine the effect of the diameter of the gauge wheel \(d_k\) on the standard deviation in the seeds distribution along the sowing depth during planting, a graphical correlation was obtained (Figure 4).

Approximation of the data by the second degree polynomial within the gauge wheel diameter \(d_k\) relation to the standard deviation in the seeds distribution along the sowing depth (Figure 4) made it possible to obtain the following correlation:

\[
\sigma = 3809.5d_k^2 - 2250.5d_k + 334.29
\]  

(2)

the accuracy of the approximation was (coefficient of determination) \(R^2 = 0.9575\).

After analyzing the graphical correlations (Figure 4), it could be concluded that the gauge wheel diameter \(d_k\) should be at least 0.27 m, while the standard deviation in the seeds distribution along the sowing depth would not exceed 4 mm. When identifying correlations to determine the effect of the gauge wheel width \(m\) on the standard deviation in the seeds distribution along the sowing depth during planting, the data presented in Figure 5 were obtained.

![Figure 4. Influence of the gauge wheel diameter on the standard deviation in the seeds distribution along the sowing depth.](image)

![Figure 5. Influence of the width of the gauge wheel on the standard deviation of the distribution of seeds of grain crops along the seeding depth.](image)
Approximation of the data by a third degree polynomial of the gauge wheel width relation to the standard deviation in the seeds distribution along the sowing depth (Figure 5) made it possible to obtain the following correlation:

\[ \sigma = -511111m^3 + 189649m^2 - 4813.8m + 8455 \]  

(3)

the accuracy of the approximation was (coefficient of determination) \( R^2 = 0.991 \).

After analyzing the graphical correlations (Figure 5), it could be concluded that the gauge wheel width \( m \) should be 0.039… 0.043 m, while the standard deviation in the seeds distribution along the sowing depth would not exceed 3 mm.

4. Conclusion

The final assessment in comparative field experiments of sowing devices was determined by the yield of the crops. The biological yield of the “Bezenchukskaya Niva” spring wheat variety obtained in the course of field research was taken as an estimated indicator in the efficiency of seeder equipped with experimental coulters for sowing seeds of grain crops.

Thus, the crops produced by the experimental pneumatic seeder S-7,2PM4 equipped with coulters with gauge wheels (the diameter of the coulter disc \( d_c = 0.4 \) m, the diameter of the gauge wheel \( d_k = 0.27 \) m, the width of the gauge wheel \( m = 0.04 \) m), due to a more even distribution of wheat seeds along the sowing depth, the yield of wheat was 23.0 c/ha, and when sown with an ordinary pneumatic seeder S-7, 2PM2 yield was - 21.2 c/ha, thus, the increase in yield was 8.3%.

References

[1] Shumayev V, Kulikova J, Orekhov A and Polikanov A 2020 Investigation of the grain seeder opener operation for environmental friendly technologies of crops production. Scientific papers-series A-agronomy Vol. 63 1 527–532

[2] Ovtov V A 2021 Construction and Design Parameters of the Reducer-Variator Journal of Engineering Science and Technology Review Vol. 14 3 202–204

[3] Laryushin N P, Pivovarov V F, Kukharev O N and Vershinin Yu A 2019 Complex of machines for onion production using resource-saving technologies Vegetables of Russia 6 141

[4] Aksenov A and Sibirev A 2020 Technical support of vegetable growing in countries of the Eurasian Economic Union AMA, Agricultural Mechanization in Asia, Africa and Latin America 3 12–18

[5] Ovtov V A and Abrosimov M Y 2020 Justification of coulter design for sowing small-seeded crops Agrarian Scientific Journal 8 89

[6] Hevko R, Tkachenko I and Synii S 2016 Development of design and investigation of operation processes of small-scale root crop and potato harvesters Agricultural Engineering 49 (2) 53

[7] Kalabushev A, Larushin N and Zubarev A 2020 Scientific results on justification the parameters of a combine u-shaped furrow-opener Scientific papers-series A-agronomy Vol. 63 1 80–85

[8] Dorokhov A S, Aksenov A G and Sibirev A V 2019 Dynamic systems modeling using artificial neural networks for agricultural machines Agricultural Engineering 2 63–64

[9] Kalabushev A N, Larushin N P, Shumayev V V 2019 Theoretical calculation certain parameters of a combined coulter Volga Region Farmland 1 151–156

[10] Cheremisinov D A and Demshin S L 2016 Determination of the parameters of the coulter group during the development of the tillage sowing unit Agricultural science of the Euro-North-East 6 67

[11] Shevchenko A and Begunov M 2013 Theoretical studies of the traction resistance of the keeled opener Omsk Scientific Bulletin 3 (123) 135

[12] Finch-Sawage W and Bassel G 2016 Seed vigour and crop establishment extending performance beyond adaptation Journal of Experimental Botany 67 567