Selecting the best planter option based on Harrington function

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Abstract. The assessment of modern grain seeders was carried out according to five indicators: price of the seeder, metal consumption and energy intensity of sowing, specific productivity and technical level of the seeder. Weight coefficients were introduced for each indicator. A method for making an objective decision for choosing the best seeder option from alternative options based on the Harrington function is substantiated. The desirability function has been modernized into a graphical form using rating scales. Any intermediate value of the estimated indicator was projected onto a segment of a straight line connecting the points of intersection of the lines of the minimum and maximum values of the estimated indicators and the extreme lines of the same indicators, projected from the Harrington desirability function to a dimensionless scale. Dependences of the indicators of the desirability function for all evaluated indicators are determined. A generalized indicator of a comprehensive assessment is formulated for making a final decision. As a result, it was found that the ALFA-6 seeder has the best performance. Seeders SZT-3.6 and SZP-3 received the worst rating. Their overall score is 42.9% lower than the ALFA-6 planter. The developed assessment methodology made it possible to outline ways for further improvement.

1 Introduction

Sowing is one of the main technological operations for growing vegetable agricultural raw materials. The conditions of growth and development of plants, and the future harvest largely depend on the quality of sowing. Currently, there is a wide variety of grain seeders [1-2]. However, not all used seeders fully meet the agro technical requirements of sowing. The main task of the grain seeder is the uniform distribution of seeds over the coulters [3], the uniformity of the sowing depth [4-6], the creation of an optimal density of the soil layer between the seeds, the control of reliable seeding of seeds and its automation [7-9].

The seeders of the Swedish company VADERSTAD and the German company AMAZONE are distinguished by high reliability and durability [10]. These planters are

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made of steel, which ensures their operation for several consecutive seasons without replacement. This characterizes the technical level of the seeder, which was achieved only by well-known manufacturers of products in the world. Raising the technical level of seeders should take into account the achievements of agronomic science using new wear-resistant materials [11].

However, an integrated approach when designing a seeder is not always taken into account. The use of an integrated approach is of particular relevance when improving the working bodies of the seeder [12-17].

The need for further improvement of the technology of sowing grain crops and the choice of the best design of the seeder determine the relevance of this study. The choice of the best grain planter design depends on the rating system [18]. The decision can be made on the basis of the suitability of the evaluated planter design to the selected indicators.

The purpose of the research was to propose a decision-making method for choosing the best design of a grain seeder from alternative options based on five evaluation indicators.

2 Materials and methods

The method of analysis and synthesis of compared designs of grain seeders was used in the work [19]. Comparison of eleven grain drills was carried out on the basis of five partial evaluation indicators (Table 1):

- j_1 is unit price per 1 m of working width (thousand rubles/m);
- j_2 is sowing metal content (kg/ha);
- j_3 is sowing energy intensity (MJ/ha);
- j_4 is specific productivity per 1 m of working width (per/hour/m);
- j_5 is seeding width (m/ha).

Table 1. Partial j-th estimates of grain seeders.

Seeder brand	**j_1**	**j_2**	**j_3**	**j_4**	**j_5**
AMAZONE DS-3500	645.7	1.50	40.0	0.86	0.9
AMAZONE DS 60	391.7	1.28	39.7	0.85	0.9
AMAZONE DS 900	288.9	3.31	44.1	0.84	0.9
AMAZONE DS 1200	255.8	2.94	44.1	0.83	0.9
ALFA-6	148.3	1.38	39.7	0.86	0.85
ASTRA-SZ-5.4	211.1	2.90	39.7	0.86	0.85
SZ-5.4	163.9	1.38	39.7	0.20	0.80
SZT-3.6	105.6	2.14	59.4	0.80	0.80
Kuhn Premia TKC	588.9	3.50	45.0	9.0	0.90
SZP-3.6	165.6	1.91	59.4	3.6	0.80
ASTRA-3.6 (P)	241.7	2.27	59.5	3.6	0.85

To conduct a multivariate analysis, the weight coefficients k_i, were taken, the sum of which is equal to one. The value of the weighting coefficient k_i, was taken depending on the importance of the particular estimated indicator j_i (Table 2).

Table 2. Weight coefficients of private j-th estimated indicators of grain seeders.

Estimated indicator	j_1	j_2	j_3	j_4	j_5
Weight factor	0.3	0.1	0.1	0.3	0.2

The Harrington desirability function has long been widely used in various scientific fields [20-22]. In relation to the task set, it has been modernized in graphical form [23-24]. In accordance with the estimated indicators, direct and inverse scales were formed:

- E is unit price scale per 1 m of working width;
- G is sowing metal intensity scale;
- M is sowing energy intensity scale;
- W is scale of specific productivity per 1 m of working width;
- TU is scale of the technical level of the seeder design in fractions of a unit. It takes into account ergonomics, reliability, wear resistance of working bodies, equipment with modern devices and automation, compliance with environmental safety requirements.

Scales A {E; G; M} is direct scales of desirability. Scales A'{W; TU} is inverse desirability scales. Straight lines BC; BC' are obtained by graphical construction for projecting the values of the estimated indicators of scales A and A' onto the Harrington curve (figure 1).

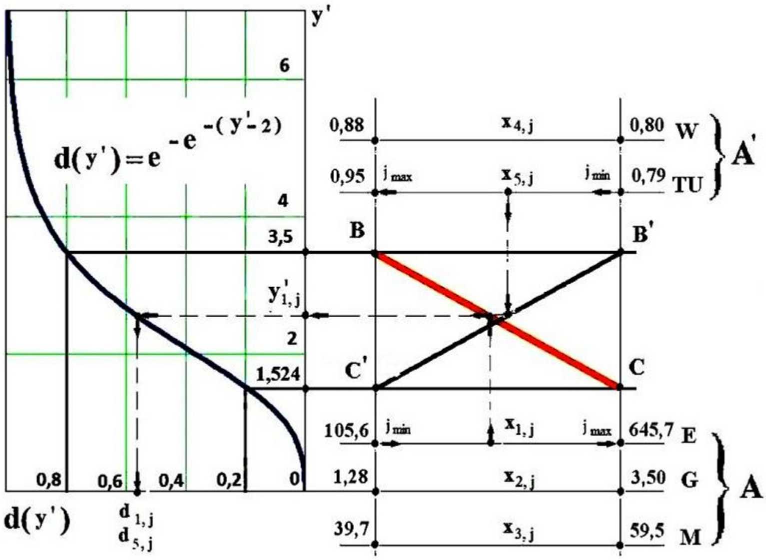

Fig. 1. Modernized Harrington Desirability Function.

The desirability functiond (y') is limited to 0.2 and 0.8. The value of the desirability function d(y') = 0.8 on the dimensionless ordinate axis y' corresponds to the value 3.5 (figure 1). The value of the desirability function d(y') = 0.2 on the dimensionless y' axis corresponds to the value 1.524. Straight lines were built to the right from these points y' = 3.53 and y' = 1.524. Direct, limiting rating scales A and A' extended. Points B' and C' were obtained at the intersection of these lines. The straight line B'C' is used to convert the values of the evaluation indicators of the A scale into values on the desirability scale d(y') through the dimensionless scale y'. The straight line BC is used to translate the values of the direct scales A {E; G; M} from the minimum x_{min} to the maximum x_{max} value. The straight line B'C' is used to translate the values of the inverse scales A'{W; TU}. The value of the inverse scale indicator A' changes from the maximum x_{max} to the minimum x_{min} value with increasing desirability function d(y'). This is due to the nature of the change in the desirability function d(y'), the values of which increase as the values of y' increase from 1.524 to 3.5.

The transfer of estimated indicators from scales A and A' to a dimensionless scale of final indicators y' was carried out according to the following dependencies (figure 1):

$$y_1' = \frac{-1.976x_1 + 3.5\left(a_{max}^1 - a_{min}^1\right) + 1.976a_{min}^1}{a_{max}^1 - a_{min}^1} = -0.004x_1 + 3.9 \quad (1)$$

$$y_2' = \frac{-1.976x_2 + 3.5\left(a_{max}^2 - a_{min}^2\right) + 1.976a_{min}^2}{a_{max}^2 - a_{min}^2} = -0.89x_2 + 4.64 \quad (2)$$

$$y_3' = \frac{-1.976x_3 + 3.5\left(a_{max}^3 - a_{min}^3\right) + 1.976a_{min}^3}{a_{max}^3 - a_{min}^3} = -0.09x_3 + 7.5 \quad (3)$$

$$y_4' = \frac{-1.976x_4 + 1.524\left(a_{max}^4 - a_{min}^4\right) - 1.976a_{min}^4}{a_{max}^4 - a_{min}^4} = 24.7x_4 - 18.2 \quad (4)$$

$$y_5' = \frac{-1.976x_5 + 1.524\left(a_{max}^5 - a_{min}^5\right) - 1.976a_{min}^5}{a_{max}^5 - a_{min}^5} = 12.4x_5 - 8.2 \quad (5)$$

Where $y_1', y_2', y_3', y_4', y_5'$ are dimensionless values of estimated indicators (E;G;M;W;TU); $a_{\max}^i$ and $a_{\min}^i$ are maximum and minimum values of scale indicators A and A'.

Dimensionless values y' of each estimated indicator were calculated for each i-th planter according to the Harrington desirability function:

$$d_{ji}\left(y_{ji}'\right) = e^{-e\left(y_{ji}' - 2\right)} \quad (6)$$

Where $d_{ji}(y_{ji}')$ is desirability of the estimated indicator for each i-th seed drill; y_{ji}' is dimensionless value of the j-th estimated indicator for each i-th planter; *e* is Napier number; 2 is shift of the Harrington curve to the right by 2 units.

The generalized criterion for the comprehensive assessment of the seed drill D_i was determined by the Harrington function [25-26]:

$$D_i = \sqrt[n]{\prod_1^n d_i^{k_i}} \quad (7)$$

Where D_i is generalized criterion for a comprehensive assessment of the seed drill; n is number of compared seeders; k_i is weight of the j-th estimated indicator in fractions of a unit.

The largest value of D_i determines the choice of solution for the seeder.

3 Results

The decision to choose the best option of the seeder was made according to the values of the generalized criterion of the complex assessment D_i. For this, the values of D_i were calculated taking into account the weighting coefficients of the estimated indicators k_i and without them (Table 3).

Table 3. Generalized indicators of the assessment of seeders.

Seeder brand	Generalized performance indicators	
	without weight coefficients	taking into account the weight coefficient
AMAZONE DS-3500	0.583	0.872
AMAZONE DS 60	0.632	0.892
AMAZONE DS 900	0.546	0.898
AMAZONE DS 1200	0.571	0.897
ALFA-6	0.675	0.920
ASTRA-SZ-5.4	0.596	0.913
SZ-5.4	0.551	0.874
SZT-3.6	0.369	0.829
Kuhn Premia TKC	0.451	0.856
SZP-3.6	0.334	0.805
ASTRA-3.6 (P)	0.445	0.868

According to the calculations, the smallest values of the generalized indicator of the complex assessment were received by seeders SZP-3.6 (D_i = 0.334) and SZT-3.6 (D_i = 0.369). The generalized indicator of the complex assessment was slightly higher for seeders ASTRA-3.6 (P) (D_i = 0.441) and Kuhn Premia TKS (D_i = 0.451). The ALFA-6 seeder (D_i = 0.675) received the highest value of the generalized indicator of the complex assessment. The difference in the values of the generalized indicator of the complex assessment D_i between the best and worst seeder is 0.341, which is 42.9 %.

The ALFA-6 seeder has a significant advantage over the SZT-3.6 and SZP-3.6 seeders. This advantage of the ALFA-6 seeder is observed in four out of five indicators (Table 1). Only for the first j indicator (unit price) of the ALFA-6 seed drill has a slightly lower value.

Seeders Kuhn Premia TKS and ASTRA-3.6 (P) take the second place among the studied seeders. Their generalized indicator of the complex assessment D_i is 28.6 % higher than that of the worst versions of the SZP-3.6 and SZT-3.6 seeders. The other six seeders have a comprehensive assessment D_i higher than the lower values by 14.3% only due to the lower unit price.

Calculations taking into account the weighting coefficient of each the estimated indicator gave practically the same results. The SZP-3.6 and SZT-3.6 seeders have the lowest values of the integrated assessment indicator D_i. Their D_i comprehensive score is 11.1% lower than other planters. The reason for this is: high metal consumption, high energy consumption of the sowing process and low technical level of the design. The ALFA-6 seeder has the highest value of the integrated assessment indicator D_i, which indicates its advantage over other seeders.

4 Discussion

Recently, the Harrington function has been used quite widely in various industries, including agriculture. It deserves more and more credibility compared to other methods of comparative assessment [27-28]. The results of the comparative evaluation of seeders, obtained on the basis of the Harrington function, show the advantage of the ALFA-6 seeder, which correlates well with the data in [29].

5 Conclusion

The new method proposed in the article makes it possible to compare various designs of grain seeders and choose the best option according to the generalized indicator of a comprehensive assessment, taking into account the weight coefficients of each evaluating indicator or without them. As a result, it was found that the ALFA-6 seeder is the best option. It has the highest value of the generalized indicator of a comprehensive assessment:

- Taking into account weight coefficients $D_i = 0.920$;
- Without taking into account weight coefficients $D_i = 0.675$.

The worst option was the grain seeders SZT-3.6 and SZP-3.6. Their values of the generalized index of complex assessment are 42.9% less than those of the ALFA-6 seeder.

The methodology showed that the greatest influence on the choice of a seeder is exerted by: the unit price of a seeder (30%), machine performance (30%) and the technical level of design (20%).

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