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Analysis of Results from Experimental Research on a Combined Plow for Flat Tillage and Parameter Optimization

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ABSTRACT

A combined machine has been proposed, consisting of an improved front plow design, special-profile disc batteries, and a roller through justifying the necessity of plowing and emphasizing the application of minimal soil cultivation technologies. Laboratory and field experiments have been conducted to study the structural, energy, and technological indicators of the proposed machine, as well as to outline ways to eliminate its technological shortcomings. The optimal angles of attack for individual discs of the disc batteries have been determined, considering traction resistance and cultivation quality as optimizing factors.

Introduction

Throughout history, soil cultivation has been accompanied by numerous shortcomings that have negatively impacted economic indicators while leaving undesirable effects on soil resources such as soil over-compaction, wind erosion, decreased fertility, and on slopes, water and mechanical erosion (Tsench, et al., 2018; Sobolevsky, 2023). The scientific community does not remain indifferent to these issues. New soil cultivation technologies, technical means, and approaches are being proposed (Gaifullin and Kashapov, 2022).

In the majority of improvement measures, many proposals relate to the application of combined machines (Kutsenko, 2016; Fedorov, et al., 2019). However, in almost all the aforementioned proposals, plowing is not included as a technological process, with certain justifications provided. Yet, in various studies, including those conducted by our working group, the opposite opinion is expressed, substantiating the importance of plowing with significant arguments (Fedorenko, et al., 2016).

We have proposed a combined machine consisting of three units: a frontal plough with improved parameters and without reversible plowshare, disc batteries of a special profile, and rollers (Yesoyan, et al., RA Patent No. AM 846Y, 2023). These three devices are intended to perform different technological processes, and their combination should result in obtaining a sufficient pre-sowing surface in a single pass of the aggregate.

In such a technological complex, the role of the first unit — the frontal plough without reversible plowshare is very important. If this plow works on a regular flat surface, the machine intended for the next technological process, i.e., stubble cultivation or harrowing, namely the disc batteries of special profile are forced to process the uneven surface cultivated/plowed by the first unit. The purpose of this research is to enhance the proposed combined machine. To achieve this goal, through laboratory experiments, it is planned to eliminate the shortcoming of the frontal plough without reversible plowshare forming the first unit of the combined machine and to improve and optimize the parameters of the disc battery in the machine's subsequent unit.

Materials and methods

The results of various experimental studies on the frontal plough of the first unit of the combined machine, both with and without reversible plowshare (including those conducted by us, Picture 1), showed that it is advisable to include the frontal plough in our proposed combined machine due to the compactness of its structure and frontal arrangement. The removal of reversible plowshare from the plow's design is justified, considering that their presence contributes to the emergence of numerous shortcomings.

Specifically, to reduce one of the main drawbacks of the frontal plough - high traction resistance - based on theoretical research we have proposed to form the plowshare-wing surface through a logarithmic spiral (Yesoyan, et al., 2023).

The appearance of the plowed field resulted from the frontal plough without reversible plowshares served as the basis for adjusting the parameters of the disc batteries that perform the next technological process. The experiments conducted showed that both on flat terrain and on slopes, the furrows plowed by the frontal plough are not fully overturned. According to the experimental results, the field plowed with this frontal plough acquires the appearance shown in Fig. 1. As can be seen from picture 1, the furrows overturned with opposing plough bodies mainly accumulate in the middle of the plough bodies. Similar results have been obtained during other studies conducted with the frontal plough (Yesoyan, et al., 2014; Sakun, et al., 1991; Gapich, et al., 2019).

Picure 1. Field testing of the frontal plough on a slope without reversible plowshares.

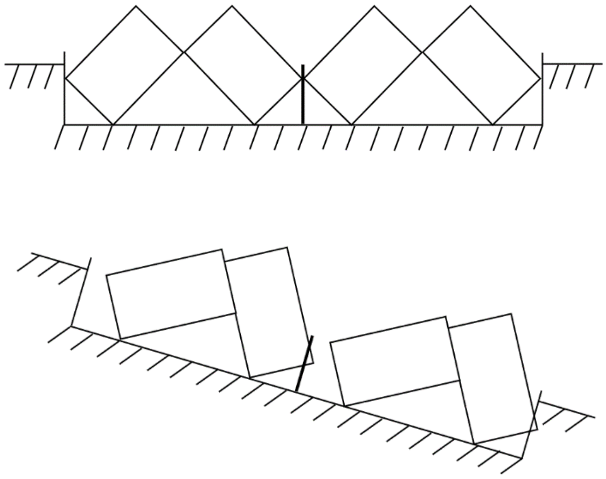

Fig. 1. The description of plowing process with a frontal plough without reversible plowshares on flat terrain and slopes. *(composed by the autors)*.

In this work, we are dealing with a non-standard situation; accordingly, the chosen research methodology is also non-standard. The methodology was selected based on the experimental results of the modified frontal plough included in the proposed combined machine, which revealed a non-standard situation. Under standard conditions, a plow inverts the furrow to some extent, producing a generally uneven surface that subsequent processes must smooth out. However, in the case of the proposed combined machine, a non-standard situation arises: the furrow segments created by the modified frontal plough bodies are not inverted but rather accumulate in the middle section of those bodies, resulting in a mound-shaped surface. In this case, the machine that follows the plow faces a non-standard task: leveling out the mound formed between the plow bodies. In other words, whereas under standard conditions all the discs on a machine equipped with disc-type working tools would perform the same technological process, here different discs on the same machine must perform different technological processes.

Therefore, we attempted to solve the problem by using a non-standard method. Under laboratory conditions, a mound-shaped surface similar to what is produced in field tests by the frontal plough was formed in a soil trench. Using a specially designed stand capable of altering the disc's attack angle and working depth we were able to determine the optimal parameters for the different discs within the disc assembly.

Results and descussions

In order to increase the operating efficiency of the proposed combined machine, we have presented recommendations for improving its first and second sections the frontal plough without reversible plowshare, and in particular, the special-profile disc assemblies.

Experiments demonstrated that, to ensure the required technological process with the proposed combined machine, different discs of the disc battery will perform tasks of varying volumes and natures. For instance, the first disc of the battery, which passes over the crest of the ridge, is responsible for the loosening of the largest volume of soil and its transfer to the lateral area. This disc deals with a half-turned, unbroken furrow rich in weeds. Here, the disc penetrates the soil to the maximum possible depth — up to 25–30 cm. In other words, the first disc in this position functions as a disc plow.

The second disc encounters the ridge in the middle part, where the ridge height has relatively decreased. This disc penetrates into the ridge about 20 cm, part of which is soil already loosened and shifted by the first disc. In other words, the second disc performs the role of a stubble cultivator.

The third disc does not reach the furrow half-turned by the plow's body at all. It spreads the loosened soil mass presented by the first and second discs toward the sides of the furrow. The third disc penetrates the soil no more than 10–12 cm. In other words, the third disc functions as a disc harrow.

Numerous scientific studies have established that the attack angles of disc plows, harrows, and stubble cultivators vary within different ranges. Specifically, in the case of a plow, it is 40–45°, for a stubble cultivator 10–35°, and for a harrow 10–22° (Kokoshin and Tashlanov, 2019; Sokht and Kirichenko, 2004; Bashnyak, et al., 2014).

Based on the results of laboratory and field experiments, it is proposed to set different attack angles for the various discs included in the combined machine's disc batteries according to the nature of work each performs. Specifically, the first disc was designated with the attack angle range intended for plows, the second one — for stubble cultivators, and the third one — for harrows. The optimal values of these attack angles were determined through laboratory experiments.

For this purpose, laboratory experiments were conducted using a special stand attached to a movable cart over the soil trench at the Armenian National Agrarian University (ANAU). The disc's traction resistance was measured, and the quality of the technological process was visually assessed by using the degree of lateral displacement and leveling of the soil mound (expressed in percentages) across the disc's working width as an indicator. The following scale was applied: very poor (30–50 %), poor (50–60 %), average (60–80 %), good (80–90 %), very good (almost 100 %), and much worse (up to 30 %).

Scene from laboratory and field experiments of the disc battery of the combined machine (Picture 2).

The traction resistance of the disc battery pair was also determined.

The results of the laboratory experiments are summarized in Table, and based on these, graphs were constructed showing the dependence of the disc's traction resistance and cultivation quality on the disc's attack angle (Figures 2, 3, 4). From the graphs, it is quite evident that increasing the attack angle of the disc leads to an increase in traction resistance. Therefore, it's impossible to determine the optimal attack angle of the disc based solely on the traction resistance indicator.

Picture 2. View of the disc battery of the combined machine captured from laboratory and field experiments.

Table. Results of Laboratory Experiments of Disc Working Elements*

Disc Number in Battery	Cultivation Depth, cm	Attack Angle, degrees	Traction Resistance, N	Quality of soil cultivation degree of mound leveling (lateral displacement) as a percentage relative to the disc's coverage width, %
First Disc (as Plow)	30	30	393	Medium (60-80 %)
		35	431	Good (80-90 %)
		40	502	Very Good (almost 10 0%)
		45	614	Poor (50-60 %)
		50	677	Very Poor (30-50 %)
Second Disc (as Stubble cultivator)	20	10	155	Poor (50-60 %)
		15	208	Medium (60-80 %)
		20	304	Good (80-90 %)
		25	339	Medium (60-80 %)
		30	373	Poor 50-60 %)
		35	402	Very Poor (30-50 %)
		40	444	Much Worse (up to 30 %)
Third disc (as Harrow)	10	10	52	Medium (60-80 %)
		15	83	Good (80-90 %)
		20	123	Medium (60-80 %)
		25	161	Poor (50-60 %)

*Composed by the authors.

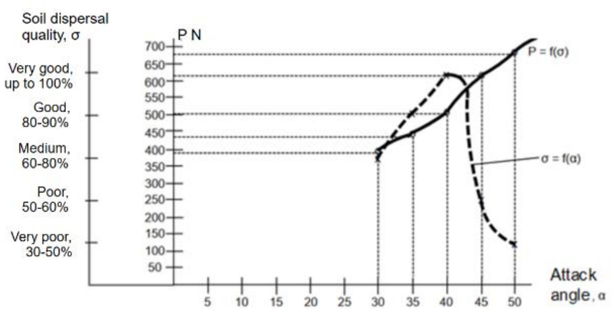

Figure 2. The dependence of the first disc's traction resistance and cultivation quality on the disc's attack angle *(composed by the authors)*.

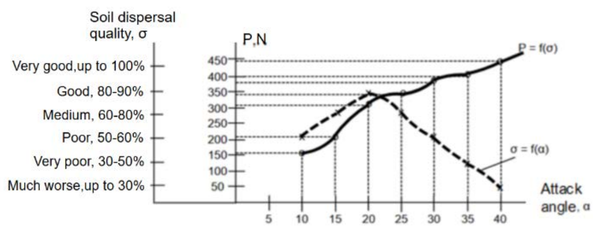

Figure 3. The dependence of the second disc's traction resistance and cultivation quality on the disc's attack angle *(composed by the authors)*.

The optimal angle has been determined by combining the indicators of traction resistance and cultivation quality, giving priority to the quality of cultivation. From Figure 2, it is apparent that the best cultivation quality for the first disc will be achieved at an attack angle of approximately 40 degrees (with a cultivation depth of 25 cm). Based on the same rationale, it can be stated from Figure 3, that the optimal attack angle for the second disc will be about 20 degrees (with a cultivation depth of 20 cm), and regarding Figure 4, the optimal attack angle for the third disc will be around 15 degrees (with a cultivation depth of 10 cm).

The technological scheme of the improved special-profile disc battery, based on the experimental results of the proposed combined machine, is presented in Figure 5.

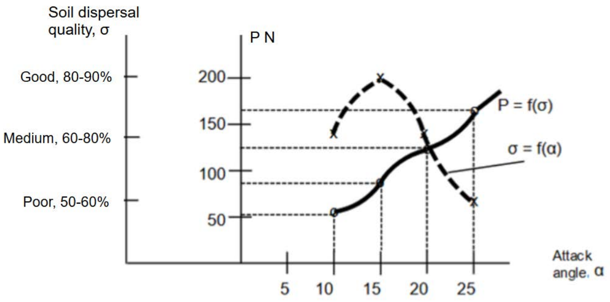

Figure 4. The dependence of the third disc's traction resistance and cultivation quality on the disc's attack angle *(composed by the authors)*.

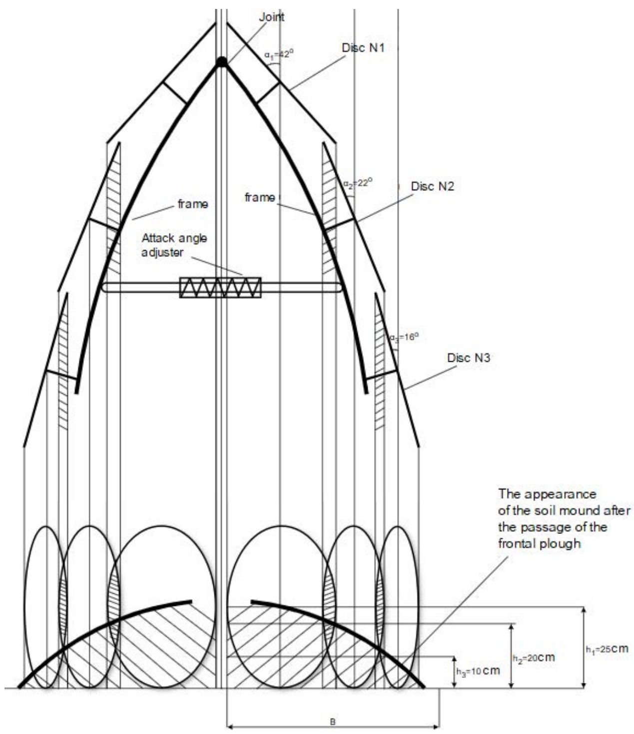

Figure 5. Improved scheme of the disc unit of proposed combined machine based on experimental results *(composed by the authors)*.

Conclusion

By justifying the importance of both plowing and minimum tillage, a combined frontal plough for smooth plowing has been proposed. This machine includes a frontal plough with improved design and parameters, special-profile disc batteries, and a roller.

Based on the results of laboratory and field experiments of the proposed machine, it was found that both on flat terrain and slopes, the frontal plough of the combined machine does not perform sufficient overturning and loosening of the furrows. After the passage of the plow, the furrows accumulate in the middle of the plough bodies without loosening, creating an unloosened mound-shaped surface. To fully execute the subsequent technological process, it was proposed to include special-profile disc batteries in the machine's design. Through these, the mound-shaped surface formed between the plough bodies is loosened and dispersed within the entire width covered by the plough bodies.

Considering the nature and volume of work performed by each disc in the disc assembly, we proposed arranging the discs with different attack angles. Specifically, we set the first disc to have attack angles corresponding to those used for disc plows; the second disc to have angles suitable for disc stubble cultivator; and the third disc to have angles appropriate for disc harrow. Within the ranges determined by laboratory experiments, we established the optimal attack angles by taking traction resistance and cultivation quality as the optimizing factors.

References

1. Bashnyak, S.E., Sharshak, V.K., Bashnyak, I.M. (2014). Justification of the Design of a Combined Machine for Pre-Sowing Soil Cultivation of Rice Fields in the Conditions of the Rostov Region. Bulletin of the Don State Agrarian University, - No. 4-1 (14), - pp. 140-147 (in Russian).
2. Fedorenko, V.F., Goltyapin, V.Ya., Mishurov, N.P. (2016). Trends in Machine-Technological Modernization of Agriculture Abroad. Based on materials from the international exhibition "Agritechnica-2015", Scientific Analytical Review, Moscow (in Russian).
3. Fedorov, S.E., Zhalnin, A.A., Zhdankina, A.O. (2019). Application of Modern Combined Machines and Aggregates for Surface Soil Cultivation. In: Materials of the XXIII Scientific-Practical Conference of Young Scientists, Postgraduates, and Students of the National Research Mordovia State University named after N.P. Ogarev. Compiled by A.V. Stolyarov, edited by P.V. Senin, - pp. 279-282 (in Russian). https://sciup.org/

primenenie-sovremennyh-kombinirovannyh-mashin-i-agregatov-dlja-poverhnostnoj-170177611.

4. Gaifullin, A.R., Kashapov, I.I. (2022). Development of a Combined Machine for Surface Soil Treatment. In: Current State and Prospects for the Development of the Technical Base of the Agro-Industrial Complex. Proceedings of the All-Russian (National) Scientific-Practical Conference dedicated to the memory of Doctor of Technical Sciences, Professor A.P. Martyanov. Kazan State Agrarian University, Kazan, - pp. 60-66 (in Russian).
5. Gapich, D.S., Kosulnikov, R.A., Chumakov, S.A. (2019). Methods of Soil Layer Destruction with Minimal Energy Expenditure [To Reduce the Traction Resistance of the Working Body and the Soil-Cultivating Machine as a Whole]. In: Global Scientific and Technological Trends of Socio-Economic Development of the Agro-Industrial Complex and Rural Areas. Volgograd State Agrarian University, Volgograd, - Vol. 2, - pp. 246-252 (in Russian).
6. Kokoshin, S.N., Tashlanov, V.I. (2019). Energy Assessment of Various Methods of Soil Destruction. Agro-Food Policy of Russia, - No. 1 (85), - pp. 42-46 (in Russian).
7. Kutsenko, K.N. (2016). Combined Machine for Pre-Sowing Soil Cultivation. In: Actual Issues of Agrarian Science. Scientific-Practical Conference, - pp. 122-126 (in Russian).
8. Sakun, V.A., Lobachevsky, Ya.P., Sizov, O.A. (1991). The Modern Stage of Development of Plowing Aggregates. Machinery in Agriculture, - No. 3, - pp. 9-12 (in Russian).
9. Sobolevsky, I.V. (2023). Development of a Soil Protection System of Minimum Tillage for the Southern Regions of the Russian Federation. Research Project: Grant No. 23-29-10012, Russian Science Foundation (in Russian).
10. Sokht, K.A., Kirichenko, A.K. (2004). Features of the Design of Disc Soil-Cultivating Implements and Trends in their Development. In: Evolution of Scientific Technologies in Crop Production. Collection of Scientific Works dedicated to the 90th anniversary of KNIISH named after P.P. Lukyanenko. Russian Academy of Agricultural Sciences, Krasnodar Order of Lenin and Order of the Red Banner of Labor Scientific Research Institute of Agriculture named after P.P. Lukyanenko, Krasnodar, - pp. 3-10 (in Russian).
11. Tsench, Yu.S., Maslov, G.G., Trubilin, E.G. (2018). To the history of agricultural machinery development. Bulletin of the Bashkir State Agrarian University, - N 3 (47), - pp. 117-123 (in Russian).
12. Yesoyan, A.M., Harutyunyan, A.V., Karapetyan, G.A. (2023). The Theory of Calculating the Least Resistance Surface of the Bulldozer Blade Wing. Scientific Works of the Engineering and Construction University, 3(87), - pp. 10-18 (in Armenian).
13. Yesoyan, A.M., Mkrtchyan, H.D., Karapetyan, G.A., Mikayelyan, G.M. (2023). Combined Frontal Plough For Smooth Plowing. RA Patent No. AM 846Y. https://old.aipa.am/search_mods/patents/view_item.php?id=846YAM20230036Y&language=en.
14. Yesoyan, A.M., Mkrtchyan, H.D., Virabyan, M.S. (2014). Analysis of Experimental Research Results of Plowing with a Frontal Plough on Weakly Cohesive Soils. In: Materials of the International Scientific Conference on Problems of Food Security and Biodiversity, Yerevan, ANAU, - pp. 71-75 (in Armenian).

Declarations of interest

The authors declare no conflict of interest concerning the research, authorship, and/or publication of this article.

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