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DEVELOPMENT OF RESOURCE-SAVING TECHNOLOGIES FOR HARVESTING CEREAL CROPS TO PROVIDE LIVESTOCK WITH AVAILABLE FEED

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The technologies of combine harvesting and transportation of the grain and non-grain part of the grain crops harvest (barley, wheat, oats, rye, millet, etc.) are considered as the main finishing operations for growing grain crops. It is noted that harvesting technological operations sum up the entire complex of previous production operations and works that make up the technology of growing and harvesting grain crops. An analysis of operating costs for harvesting the crop from the field and its transportation to the post-harvest grain processing facility, which account for more than half of all costs for its production, has been made. The composition of the equipment of various technologies for harvesting grain cereal crops has been substantiated. The introduction of resource-saving technologies for growing and harvesting agricultural crops solves the problems of technological re-equipment of agricultural producers to reduce the cost of work on obtaining available livestock feed.

Key words: *production costs, resource saving, cereal crops, fodder, livestock, technology, crop storage conditions.*

FORMULATION OF THE PROBLEM

Cereal crops are the most important group of cultivated agricultural plants, providing grain as the main food product for humans, raw material for various industries and used for the production of fodder for livestock in agriculture. All grain fodder, which is used for feeding farm animals, belongs to the concentrated type with the content of a large amount of easily digestible nutrients. With its help, diets are balanced by the content of energy, protein, and amino acids [1].

Cereal grains are mainly energy feed. It contains 84-88% of dry matter, 10-14% of protein, 2-3% of fat, 60-70% of nitrogen-free extractive substances, represented mainly by starch, and 2-3% of ash. The level of fiber in naked grains ranges from 2-3%, and in whole grains (barley, millet, oats) – 5-9%. The nutritional value of 1 kg of cereal grain is 1-1.3 units with a content of 67-106 g of digestible protein. Cereal grains are the basis for compound feed. The non-grain part of the harvest of cereal grain crops – straw is used not only as bedding for livestock, but also as feed for animals. The straw is used in whole, crushed and pressed form. The problem for crop production is the high cost of produced products – grain. The livestock production receives high cost and low quality rough and juicy, so-called basic fodder produced in the farms. They are decisive in the structure of the cost price of milk, as their share is about 70% [2].

Harvesting and post-harvest processing of grain are finishing operations for grain crops production. They sum up the entire complex of previous works on the optimal selection of zoned varieties, seed preparation, soil cultivation, sowing, and plant care. However, these are the most resource-intensive operations. The operating costs for harvesting the crop from the field and transporting it to the point of post-harvest grain processing make up 50-55% of all costs for its production [3,4].

The purpose of the research is to develop resource-saving technologies for growing and harvesting grain crops to provide livestock with cheap concentrated feed.

ANALYSIS OF RECENT RESEARCH AND PUBLICATIONS

Agricultural enterprises mainly use two methods for machine harvesting of grain and leguminous crops with the use of combine harvesters – one-phase and two-phase. In the first method, all harvesting operations (mowing, threshing, grain cleaning, collecting straw and chaff) are performed simultaneously, while in the second method they are performed in two stages: after drying the stalks, mowed and placed in rolls, a combine equipped with a pick-up picks them up, threshes them, cleans grain and collects straw and chaff [5].

The two-phase (separate) method is used when harvesting weedy crops and those that easily fall off, with a density of more than 300 stems per m^2 and a height of not less than 60 cm. Mowing in swaths with this method begins in the middle phase of the waxy maturity of winter and spring wheat and multi-row barley, when grain moisture is 35...25% [6].

Recently, the fleet of wheeled tractors and tractor-trailers has increased significantly in farms. The research show that 60-70% of intra-farm transportation can be performed by tractor transport [7,8].

In agriculture, the components of production cycles have a probabilistic (stochastic) nature. This is especially true for harvesting. The duration of this period depends on weather conditions, biology of plant development, crop variety, soil composition, agricultural techniques, etc. [9,10,11]. In this regard, there is a need for scientific and industrial searches for such forms of harvesting process organization that would make it possible to harvest in a short agro-technical time and significantly reduce losses due to this.

PRESENTING MAIN MATERIAL

The objects of the study are: agricultural enterprises of the Odesa region, areas of cultivation and harvesting of grain crops, harvesting technological complexes, auxiliary machines for harvesting grain and non-grain parts of the crop, workers, energy material resources and means: grain harvesters, vehicles and tractors.

The subject of the research is: technologies for growing and harvesting agricultural crops, production technological processes for harvesting grain crops, production interaction of technical means of harvesting complexes and means for their maintenance. To implement the tasks, a program of experimental and statistical studies was developed, including the following stages: statistical studies of working conditions, duration, frequency and time of execution for the main cycles of work by harvesting equipment.

When solving the set tasks, the following methods of scientific research were used:

1. Analysis of advanced production indicators; statistical methods of research and processing of experimental data.
2. Experimental studies of the operation of the main machines of technological complexes for harvesting grain crops (hereinafter – complexes) and various composition sections.

For conducting experimental studies in production conditions, a complex was selected, the production and technological indicators of which are close to the indicators of the given zone. To determine the given production conditions of the region, an expert survey of the farms main specialists was conducted. The results of the survey were processed according to the methodology presented below and the main statistical indicators were determined, which are presented in Table 1: the area of grain sowing and the area of the field for sowing grain crops.

The processing of the experimental studies results was implemented in the following sequence: experimental histograms were constructed; then the parameters of the empirical distribution were found; after that hypotheses about the function of the studied quantity were put forward, based on the form of the experimental curve and the values of its parameters; later the alignment of the experimental curve was carried out according to the accepted theoretical curves; at the end, empirical and theoretical curves were compared according to one of the agreed criteria [12].

The following statistical values were determined: the average value of arithmetic samples that vary around the average arithmetic total – $\overline{x}$. This variation was measured by its root mean square deviation – σ_x.

If x_1; x_2; x_3..., x_n is the implementation of a random variable – «x», then the volume of the implementation forms a sequence called the original one.

To construct histograms, the range R, m; hours was determined by the formula:

$$R = X_{max} - X_{min}, \quad (1)$$

where X_{max} –is the maximum value of the measured quantity, m; hours;

X_{min} –is the minimum value of the measured quantity, m; hours.

The value of the interval ΔX was chosen as constant as possible for the intervals, because otherwise difficulties arise when calculating the average value. The choice of the interval depends on the amount of "n" measurements, on the scale and on the purpose of the statistical study. It is recommended to determine the number of intervals according to the formula:

$$K < 5\ln \cdot n, \quad (2)$$

where K – is the number of intervals, units;

n – is the number of measurements, units.

As a result of the statistical data processing on the conditions of mechanized work according to the method presented above, distributions were built for: grain sowing area in the farms of the region; area of fields for grain sowing by farms. The main parameters of the obtained experimental curves are shown in Table 1.

Table 1. Main distribution parameters characterizing the conditions of harvesting operations

Conditions for harvesting grain crops	Statistical parameters of distributions					
	Arithmetic average, $\bar{X}$	Average quadratic deviation, σ	Dispersion, σ_2	Coefficient of variation, V	Asymmetry, a_3	Kurtosis, a_4
Grain sowing area, ha	2184,50	1264,50	1598941,00	0,58	0,94	3,17
Field area for grain sowing, ha	103,70	71,32	5086,60	0,69	1,03	3,94

The area for grain sowing in farms ranges from 900 to 3400 ha, while the average area of the field occupied by grain is 103.7 ha with a standard deviation of 71.32 ha. Based on the available data, histograms of these distributions were constructed – Figures 1, 2.

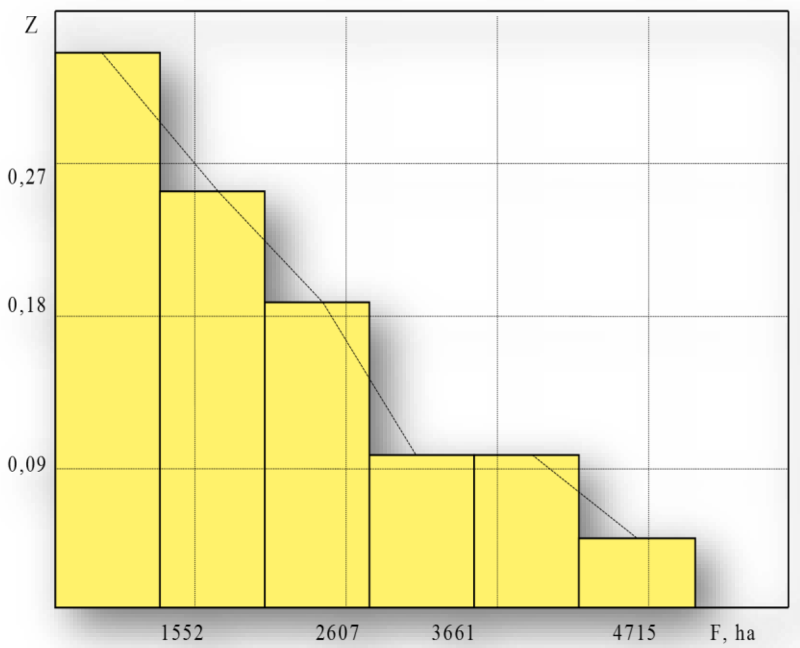

Fig. 1. Histogram of areas for sowing of grain crops in farms

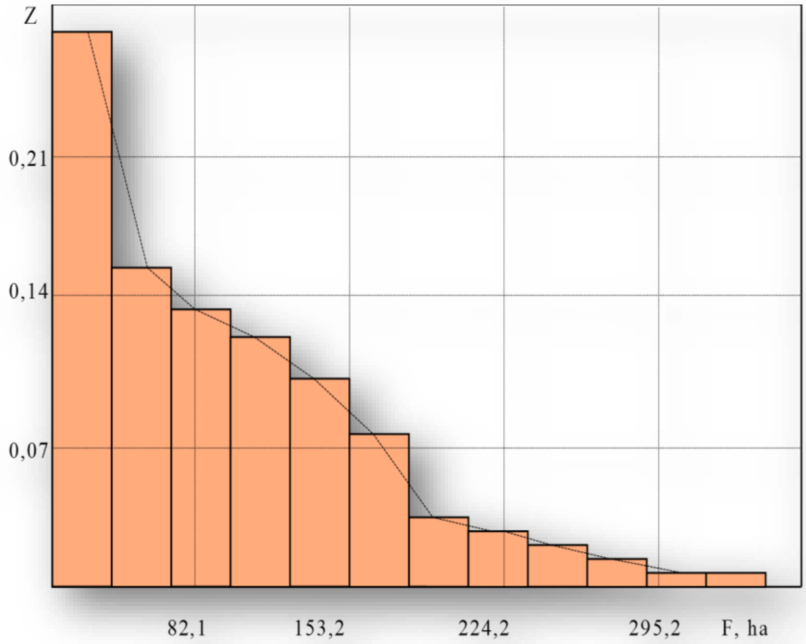

Fig. 2. Histogram of the area of the sown field of grain crops in farms

For a comparative assessment of production costs – complex fuel and operating costs, four winter wheat harvesting technologies were considered [13]:
1. Traditional technology – direct harvesting without straw crushing.
2. Traditional technology – separate combine harvesting of grain crops.
3. Zero technology – use of machinery and harvesters of domestic production.
4. Zero technology – use of imported harvesting equipment.
On the basis of these technologies, promising technological maps for growing and harvesting winter wheat have been developed [14]. All developed technologies are designed for the following production conditions: the area of cultivation and harvesting is 630 hectares; the duration of harvesting when the grain is fully ripe is 7 days; the productivity of the main products is 4.6 t/ha; the productivity of by-products is 4.6 t/ha; the standard crop losses are 3%.
1. Traditional technology – direct harvesting. 6 "Don-1500" harvesters were used for harvesting. Grain was transported by KamAZ-55102 trucks with GBK-8527 trailers in the amount of 6 units. Each harvester is serviced by a personal vehicle. Straw – non-grain products are pulled to the edge of the field by the T-150K-05-09 unit – VTU-10 – 4 units and transported for shredding by the MTZ-80-2PTS-4-887A unit. The total number is 16 units. Shredding of straw – unit YuMZ-6AKL – PF-0.5B – 4 units. Fuel consumption: for the entire volume of work is 42787,1 kg; per unit of work – 67,9 kg/ha. Operating expenses: for the entire volume of work are 72987,75 USD; for a unit of work – 115,85 USD/ha. (Table 2).

Table 2. Comparison of various winter wheat harvesting technologies by operating costs

Harvesting technology	Operating costs of complex fuel and funds			
	Complex fuel		Operating expenses (wages, fuel, depreciation, maintenance, repairs - current, capital)	
	For the entire amount of work, kg	Per unit of work, kg/ha	For the entire volume of work, USD	Per unit of work, USD /ha
1. Traditional - direct	42 787,1	67,9	72 987,75	115,85

harvesting (with straw collection at the complexes)				
2. Traditional - separate harvesting (with collecting straw at the edge of the field)	33 670,2	53,4	54 193,00	86,02
3. Zero technology - domestic production equipment (direct harvesting without straw collection)	25 336,5	40,2	46 176,89	73,30
4. Zero technology – imported harvesting equipment (direct harvesting without harvesting straw)	22 596,2	35,9	48 030,54	76,24

2. Traditional technology – separate harvesting of grain crops. The ratio of the area of harvesting grain crops separately and directly is 40% and 60%. Two harvesters “Don-1500”, reaper machines ZhVN-6, pick-up machine PL-150 in the amount of two units are used for mowing and selection of grain crops. Direct harvesting of grain crops – “Don-1500B” – four units, vehicles – KamAZ-55102+GBK-8527 – four units. Straw is pushed to the edge of the field by machines and stored at the edge of the field. The number and composition of machines are the same as in the first technology. Fuel consumption: for the entire volume of work is 33670,18 kg; per unit of work is 53,4 kg/ha. Operating expenses: for the entire volume of work are 54 193,0 USD, for a unit of work are 86,02 USD/ha (Table 2).
3. Energy-saving zero technology – machines of domestic production – direct combining of grain crops. Straw is not collected, but is crushed by a combine harvester and spread over the field, creating mulch on the surface of the field – saving costs for collecting, transporting and shredding straw. The number of technological operations decreases, therefore the composition of the equipment of the collection complex also decreases. There are no units for collecting straw, transporting and skirting straw. The equipment composition: “Don-1500” grain harvesters – 6 units, grain transportation vehicles – KamAZ-55102-053 – 6 units. Fuel consumption: for the entire volume of work is 25336,46 kg; per unit of work is 40,2 kg/ha. Operating expences: for the entire volume of work are 46 176,89 USD; per unit of work are 73,30 USD/ha (Table 2).
4. Energy-saving zero technology – with machines of imported production. The differences from the previous technology consist in the use of combine harvesters with twice bigger productivity compared to the domestic ones and in smaller quantities, twice as well, model “Lexion-480” – 3 units. The number of vehicles for transporting grain is also reduced – KamAZ-55102-053 – 4 units, due to the use of a hopper-accumulator with a capacity of V=40 m^3 and unloading into vehicles with a capacity of 4 t/min. Fuel consumption: for the entire volume of work is 22596,17 kg, for a unit of work is 35,87 kg/ha. Operating expences: for the entire volume of work are 48 030,54 USD; per unit of work are 76,24 USD /ha (Table 2).
Analyzing the calculations results of complex fuel operating expences (wages, fuel, depreciation, maintenance, current and capital repairs of complex machines) indicates that:
1. The lowest fuel consumption per unit of production in zero technology using harvesting machinery of imported production is 35,87 kg/ha, due to higher productivity of harvesting machinery and reduction of technological operations – no straw harvesting. The lowest operating expences per unit of production are 73,30 USD /ha – zero technology with domestically produced equipment – due to the lower cost of equipment compared to imported equipment.
2. The highest fuel consumption is 67,9 kg/ha in the case of traditional technology – direct

harvesting due to transport operations for harvesting straw. The largest operating expenses are 115,85 USD /ha – traditional technology – direct harvesting – due to the large number of harvesting equipment and technological operations for transporting straw.

CONCLUSIONS

Analyzing the calculations results of complex fuel and funds operating expences indicated that the zero-technology using domestically produced equipment is the least expensive. The first technology – the traditional one with direct harvesting is the most expensive. Among traditional technologies, the technology of separate harvesting is the least expensive: fuel consumption is 53,4 kg/ha; operating expences are 86,02 USD /ha.

The use of energy-saving technologies for harvesting cereal crops will provide the livestock industry with cheap and affordable fodder.

REFERENCES

1. Provatorov G.V., Provatorava V.O. Feeding of farm animals. Sumy:University book, 2004.509 p.
2. Drobot V.I. Economic guide of the agrarian / V.I. Drobot, G.I. Zub, P.M. Kononenko and others. ; ed. Yu. Ya. Luzan, P.T. Dress up K.: Press of Ukraine, 2003. 800 p.
3. Vitvitsky V.V., Bosiy M.A. Economic aspects of determining costs for the operation of agricultural machinery. Productivity of agro-industrial production. 2007. No. 6. P. 89–93.
4. Skibchyk V.I., Dnes V.I. Determining the volume of losses of impressively grown grain crops under various parameters of technical equipment for their harvesting and post-harvest processing of grain. Agro-industrial complex technologies of the 21st century: problems and prospects of development: Collection. the mother international science -practice conf. (April 13-14, Nizhin). - Nizhin, 2017. P.157–159.
5. Domushchi D. P. Supruniuk V. P. (2022). Analysis of technologies and methods of machine harvesting of cereal grain and leguminous crops. Agrarian science: state and prospects of development: materials of the II All-Ukrainian scientific and practical conference (Odesa, November 24-25, 2022)/ Odesa State Agrarian University. Odesa: OSAU, 2022. P. 48-51.
6. Domushchi D.P., Novakovskyi M.A. Peculiarities of the organization of the technological process of harvesting grain crops. Agrarian Bulletin of the Black Sea Region: Collection. of science Ave. Odesa DAU/Technical Sciences. Odesa: 2013. No. 65. P.157–161.
7. The method of substantiating the parameters of the collection and transport complexes/Sydorchuk O.V., Dnes V.I., Skibchyk, etc. Mechanization and electrification of agriculture: NNC "IMESG": state. Nauk Coll.. Glevakha, 2015. Issue No. 1 (100). pp. 224–234.
8. Sosnovska O.O. Technical and economic substantiation of economic decisions in crop production: training. manual / O.O. Sosnovska, P.P. Yaroshenko, M.V. Ivanyuk K.: Center of Educational Literature, 2006. 384 p.
9. Domushchi D. P. Molchaniuk E. V. (2022). Justification of the optimal duration of harvesting grain crops. Agrarian science: state and prospects of development: materials of the II All-Ukrainian scientific and practical conference (Odesa, November 24-25, 2022)/ Odesa State Agrarian University. Odesa: OSAU, 2022. P.45-47.
10. The set of main events and peculiarities of their planning in the projects of harvesting early grain crops/ Sydorchuk O.V., Dnes V.I., Skibchyk et al.. Mechanization and electrification of agriculture: interdisciplinary. subject College of Sciences Glevakha, 2011. Issue 95. P. 375-374.
11. Domushchi D. A., Osadchuk P. I., Ustuianov A. D., Lysenko A. S., Enakiev Yu. I. (2022). Model of optimization of the structure and composition of complex technological systems of harvesting grain crops.*Proceedings of the scientific forum with international participation “Ecology and agrotechnologies – fundamental science and practical realization”*. 21-22.10.

2021, Sofia, Volume 3. 184–192. http://www.issapp-pushkarov.org/sites/default/files/pictures/ecology_and_agrotechnologies_vol_3.pdf

12. Domushchi D. A., Osadchuk P. I., Ustuianov A. D., Enakiev Yu. I. (2020). Methods of optimizing the composition of grain harvesters of harvesting and transport complexes. Proceedings of the scientific forum with international participation "Ecology and agrotechnologies - fundamental science and practical realization". October 27-28, 2020, Sofia. Volume 2. 62-68.
13. Norms of costs of living and embodied labor for the production of grain crops / V.V. Vitvytskyi, P.M. Music, M.F. Kislyachenko, I.V. Lobastov. K.: Research Institute "Ukragropromproductivnist", 2010. 352 p. (B-ka specialist of agro-industrial complex "Economic standards").
14. Sabluk P.T. Technological maps and costs for growing agricultural crops / P.T. Sabluk, D.I. Mazarenko, G.E. Maznev K.: NNC IAE, 2005. 402 p.

РОЗРОБКА РЕСУРСОЗБЕРІГАЮЧИХ ТЕХНОЛОГІЙ ЗБИРАННЯ ЗЕРНОВИХ КУЛЬТУР ДЛЯ ЗАБЕЗПЕЧЕННЯ ТВАРИННИЦТВА ДОСТУПНИМИ КОРМАМИ

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Розглядаються технології комбайнового збирання й транспортування зернової та незернової частини урожаю зернових злакових культур(ячменю, пшениці, овсу, жита, проса та ін.), як основні фінішні операції вирощування зернових культур. Відмічається, що збиральні технологічні операції підбивають підсумок усьому комплексу попередніх виробничих операцій і робіт, які складають технологію вирощування та збирання зернових культур. Зроблено аналіз експлуатаційних витрат на збирання врожаю з поля і його транспортування на господарський пункт післязбиральної обробки зерна, які становлять більше половини всіх витрат на його виробництво. Обґрунтовано склад техніки різних технологій збирання зернових злакових культур. Реалізацією ресурсозберігаючих технологій вирощування та збирання сільськогосподарських культур вирішуються проблеми технологічного переоснащення сільськогосподарських виробників для зменшення собівартості робіт з отримання доступних кормів для тваринництва.

Ключові слова: *виробничі витрати, ресурсозбереження, злакові культури, корм, тваринництво, технологія, умови збирання.*