CROP PRODUCTION

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CHAFF COLLECTION DURING SOYBEAN COMBINE HARVESTING WITH THE AIM OF CREATING FODDER SUPPLIES FOR LIVESTOCK FARMING

Research article

Abstract

The article examines the issues of soybean production in Amur Oblast and assesses the ratio of soybean yield to soybean chaff as a resource for providing animal feed as well as provides the chemical composition and nutritional value of the soybean chaff. The study presents a chaff saver with a trough-shaped auger for removing, chopping, and spreading straw from both sides along the course of the combine by the sidewalls and installing an additional stacker behind the grating mill for collecting the chaff with automatic unloading on the field. A multi-factor analysis was also carried out to justify the optimal volume of the soy chaff stacker during harvesting.

Keywords: soybean, combine, straw, chopping, discarding, soy chaff, feed value, chaff saver.

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СБОР ПОЛОВЫ ПРИ КОМБАЙНОВОЙ УБОРКЕ СОИ, ДЛЯ СОЗДАНИЯ КОРМОВОЙ БАЗЫ ЖИВОТНОВОДСТВА

Научная статья

Аннотация

Рассмотрены вопросы производства сои в Амурской областии соотношения к зерну сои выхода половы, как ресурса обеспечения животноводства кормами. Приведены химический состав и питательность соевой половы. Предложен половосборник с корытообразным шнеком для отвода, измельчения и разбрасывания соломы с обеих сторон по ходу комбайна за боковины и установка за решетным станом дополнительного копнителя для сбора половы с автоматической разгрузкой на поле. Проведен многофакторный эксперимент по обоснованию оптимального объема копнителя сбора соевой половы при уборке сои.

Ключевые слова: соя, комбайн, солома, измельчение, выбрасывание, полова, кормовое достоинство, половосборник.

1. Introduction

One of the main factors in the development of animal husbandry and in increasing its efficiency and gross production is the improvement of fodder supplies. In Russia, Amur Oblast remains an important soybean producer with its 33.1 % share in the all-Russian volume of gross production as of 2018 and more than 50 % in the Russian Far East while the planting acreage of soybean cultivation in 2020 equaled more than 850 thousand hectares [1].

The analysis of the biological soybean crop demonstrates that with a soybean yield of more than 2 t/ha, the yield of the chaff is (48-50 %) to the grain weight. With such a large volume of soybean production, chaff collection is an important reserve for the development of fodder supplies [6].

Soybean is a legume crop and during its combine harvesting and threshing, its leaves, which make up to 90 % of the chaff, are separated. The chemical composition and nutritional value of the chaff are shown in Table 1. Soy chaff is much more nutritious than grain crop chaff, and it is necessary to collect its output from the sieve boot of the combine when harvesting soybean to provide public and private stock farming with fodder. The chaff with a high content of digestible protein, fat, and carotene in its composition has a high feed value and is consumed by large and small cattle [3].

Table 1 – Chemical composition and nutritional value of the soybean crop in the Amur Oblast farms

Name	Nutrient content per dry matter (in %)							
	Raw protein	Raw fat	Raw fiber	Crude Ash	Calcium	Sugar	Phosphorus	Fodder units
Chaff	5,75	0,53	34,6	6,17	4,2	0,99	1,6	0,56
Shells	5,82	0,55	35,5	6,10	4,06	1,10	1,68	0,56

The main nutrient that is part of the chaff and shells is fiber. Its content in the chaff amounts to 34.6% and 35.5 % in the shells. The composition of the chaff and shells also contains nitrogen-free extractive substances, their group consists of sugar, starch, hemicellulose, pectin substances, pigments, resins, tannins, organic acids. The chaff and shells are characterized by a certain amount of raw protein content up to 6% and 1.8% of digested protein. The content of mineral elements (calcium and phosphorus) in the chaff and shells ranges from 4.2 to 1.6%, while vitamins in the chaff are virtually absent. The exception is vitamin D, which accumulates in the leaves in sunny weather up to 50 IU per 1 kg [7].

2. Methods

The manufactured trough-shaped auger with a 400 mm diameter of the right and left winding of the spiral, a 420 mm pitch, and an angular rotation speed of 26.1 rad/s along with chopping knives ensures uniform removal of the chopped straw behind the sidewalls to the left and right along the course of the combine with a grain yield up to 3.0 t / ha (Figs. 1).

Figure 1 – Removal of chopped straw by the auger in the harvester stacker installed on the "Enisey – 1200R" combine harvester

The chaff collected in the harvester stacker during the field experiments was unloaded in a designated place, collected in bags, and weighed in the experimental workshop of the Far Eastern Research Institute of Agricultural Mechanization and Electrification (Figs. 2). Weighing was performed using a "DPU–0.5/2" dynamometer.

Figure 2 – Weighing the collected chaff

Based on the results of screening experiments, three factors were left for the main series of the experiment to determine the volume of the harvester-stacker, which were assigned the following designation (Table 2). The experiment was conducted using a standard matrix.

Table 2 – Factors and levels of their variation in the collection of soybean chaff in the harvester-stacker

Factors	Yield, t / ha	Combine speed, m / s	Header width, m
Designation	X_1	X_2	X_3
Upper level	2,5	2,0	8,0
Main level	1,75	1,7	7,0
Lower level	1,0	1,4	6,0

3.Results

According to the data provided by Yu. A. Pugachev, the results of feeding soybean meal to young cattle on fattening and to a milking herd demonstrate high efficiency of use of the chaff in feeding different groups of animals. Feeding soybean meal at 4 kg per day (based on the feeding ration) per head of cattle provides an average 66 g daily increase in live weight and the average daily milk yield increases by 0.15 kg per head of cow per stall period [2].

The small volume weight of the soybean crop complicates the mechanization of its harvesting and transportation to livestock complexes.

Technological processes of harvesting chaff are interconnected in the interaction of many continuously changing factors of influence, the two main natural-and-production as well as technical groups. The natural-and-production group of factors consists of crop yield, humidity, low volume weight, short terms and weather conditions of harvesting, the state of the field surface (waterlogging), the distance from the soybean fields to the feeding sites. This limiting group of factors can be overcome by the technical and technological re-equipment of soybean harvesting with the collection of the chaff based on the development of combine chaff collectors for soybean harvesting.

The technology is created for the culture under study and its varieties. Amur Oblast has the largest soybean field and the lowest energy supply for harvesting in the country. The combine harvester load is 474.6 ha, which significantly exceeds the operational and technical and technological standards. To stimulate the development and manufacture of modernized harvesting equipment, it is important to increase its target functions. For example, for seed farms, it is necessary to develop combine harvesters aimed at obtaining biologically complete and high-quality seeds that are released directly during harvesting in the combine and used for sowing without post-harvest processing. For livestock farms, combine harvesting of soybeans should be combined with the simultaneous collection of hay in a hopper or stacker with the development of transport means of delivery to livestock complexes [5].

When harvesting soybeans, the chaff coming off the sieve boot of the combine can be collected using various technologies. One of them is based on collecting it in a separate hopper, which is installed on a combine harvester with the use of the "PUN-5, PUN-6" general-purpose devices. However, according to the safety standards, this technology has not been used due to the

lack of an appropriate place on the combine for installing a chaff collection hopper. According to the results by Yu. A. Pugachev, with this technology of soybean harvesting, the productivity of combines decreases by up to 15 %, which is unacceptable with limited harvesting periods associated with weather conditions and resulting losses**.** In this regard, the aim of the work is to develop a technology for collecting chaff in the hopper when harvesting soybeans with the development of its optimal volume and automated unloading. For this purpose, a stacker for a combine harvester has been developed (Figs. 3) [4].

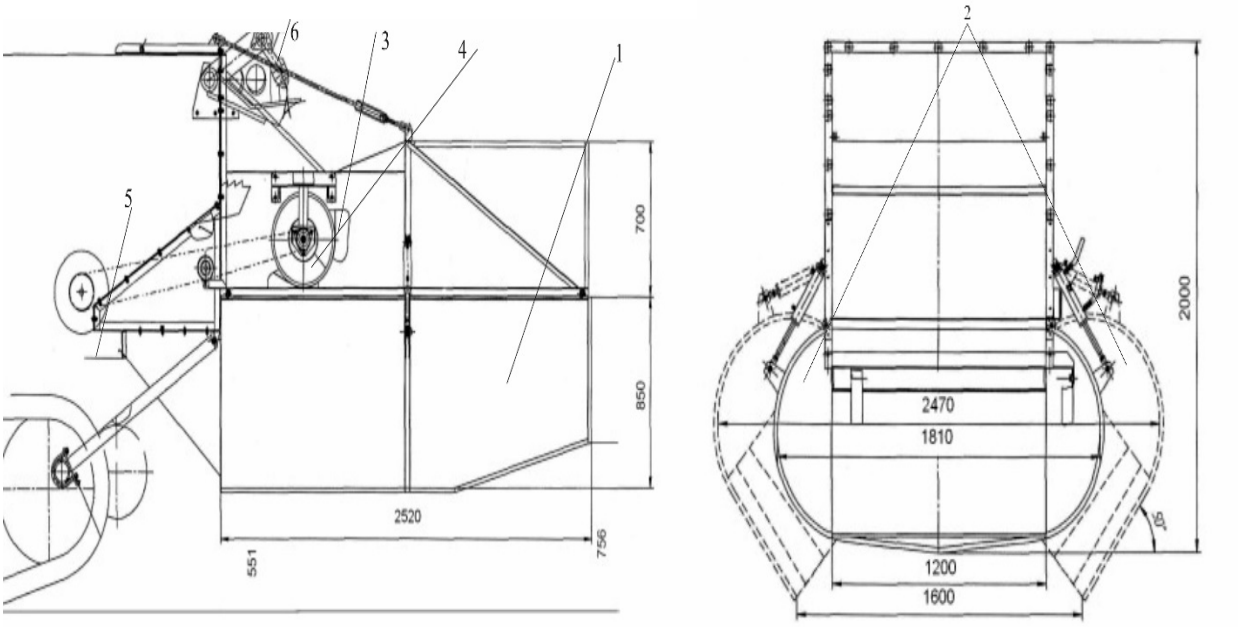

Figure 3 – Chaff harvest stacker (side and rear view):
1 – storage chamber; *2* – hinged sidewalls passing into the bottom; *3* – distribution trough-shaped open auger casing; *4* – screw with right and left winding of the spiral; *5* – chaff tucker; *6* – straw tucker

The stacker installed on the combine "Enisey-1200R" instead of the factory stacker and included a trough-shaped auger with the right and left winding of the spiral for the removal, chopping, and discarding the straw from the straw rake out of the sides of the combine. The auger drive was carried out from the shaft of the chaff tucker through a chain drive, on which an additional sprocket was installed. When installing the stacker on the combine, the height of the main body from the ground level equaled 551 mm, and its rear part was 756 mm to prevent contact with the soil. The process of unloading the stacker was carried out by diluting the sidewalls of its lower part with the help of hydraulic cylinders, and with the full withdrawal of the sidewalls, the combine moved forward, leaving a pile of chaff.

4. Discussion of results

When examining a stacker for a combine harvester for chaff collecting, the volume of the stacker have been decided as an optimization criterion while the most significant factors that significantly affect its filling with the chaff when harvesting soybeans have also been identified (Table 2). After the implementation of 15 attempts of the experiment, according to the matrix and the obtained values of the optimization criteria, the mathematical processing of the results and the construction of a model of the process of filling the volume of the stacker in the form of a regression equation were carried out: $Y=-1.7067+0.5*Y+4.68*V+1.7174*B+0.8*V*B-2.761*V^2$

In order to analyze the paired influence of factors on the optimization criterion (collection of the chaff into the stacker), the response surfaces are constructed from two factors – the speed of the combine and the width of the header - at a constant level of yield Y=1.75 t / ha, with varying speed of the combine and yield and a constant width of the header B=7 m, with varying yield and width of the header and at a constant speed of the combine V=1.7 m (Figs. 4 a, b, c).

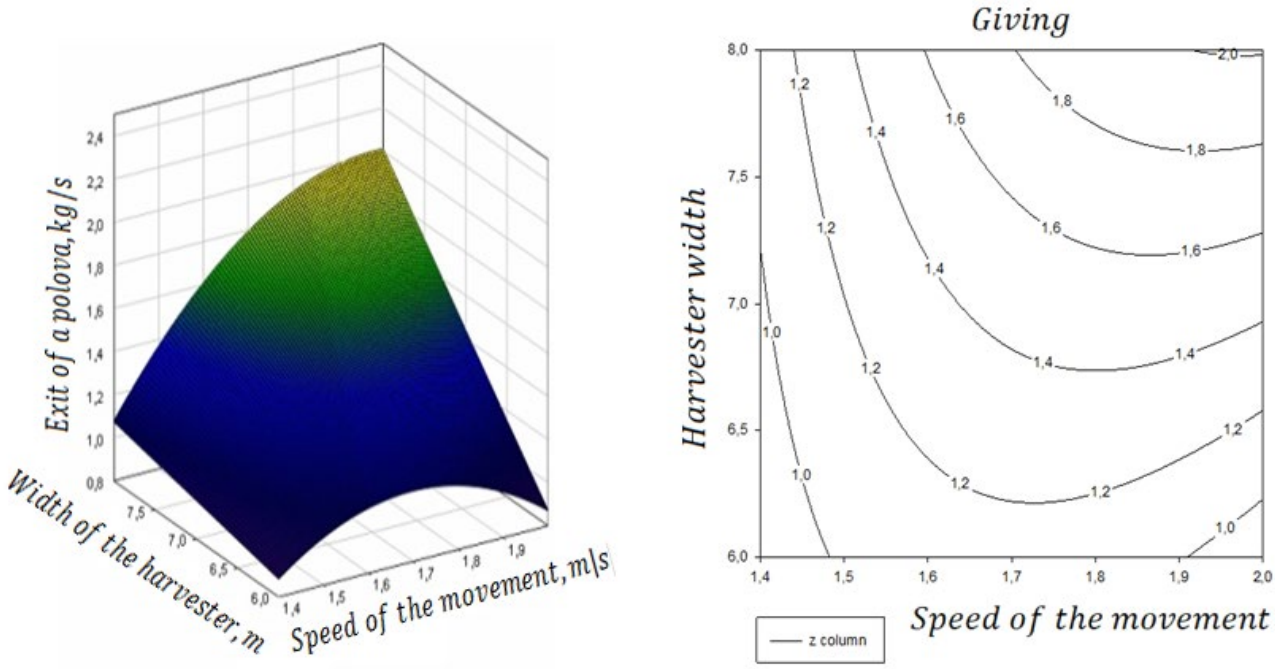

Figure 4.a – The response surface Y= f (V,B) at zero level Y and the cross-section of the response surfaces V and B:
a) Y=-0.8317+4.68*V+1.7174*B+0.8*V*B-2.761*V^2

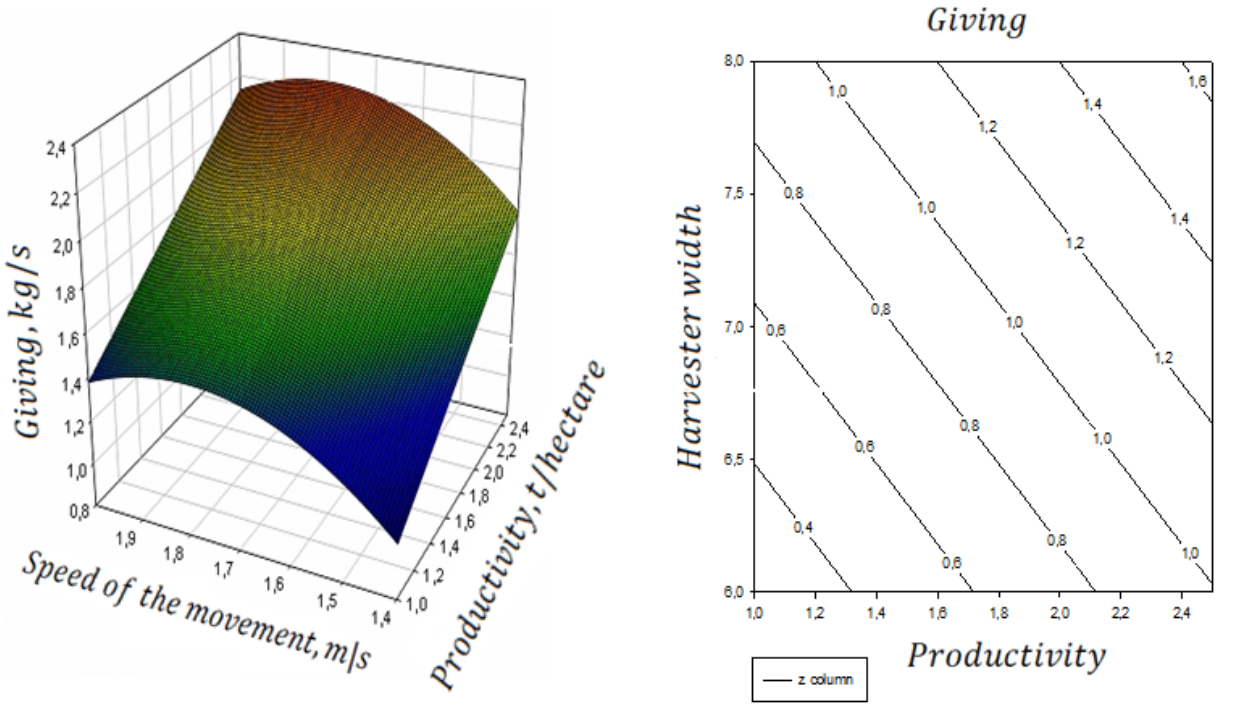

Figure 4.b – The response surface Y= f (B,Y) at zero level V, and the cross-section of the response surfaces B and Y:
b) Y=10.31+10.28 V+0.5 Y-2, 761V^2

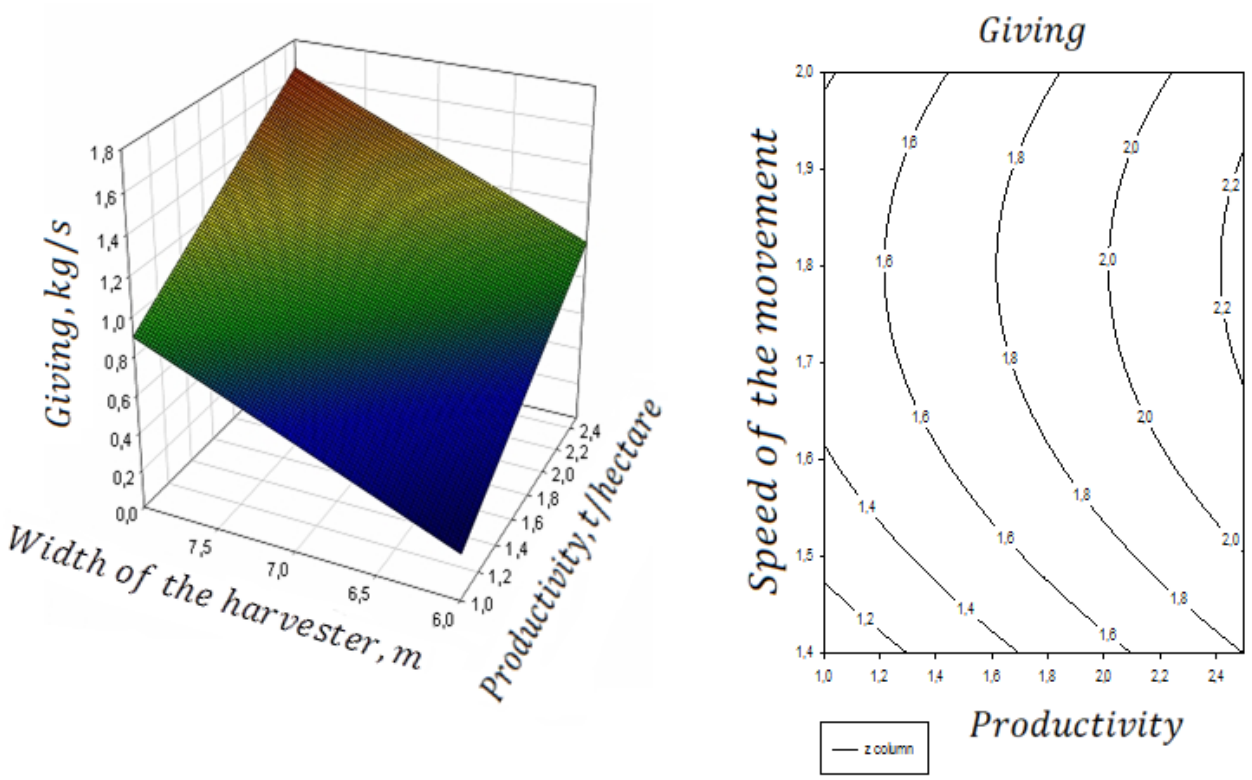

Figure 4.c – The response surface Y= f (Y,V) at zero level B, and the cross-section of the response surfaces Y and V:
c) Y = 0.5 Y+3.077 B-1.7307

The graphs show that the maximum yield of the crop is provided at the speed of 1.95 m/ s, the yield of 1.75 t / ha with the width of the header amounting to 7.0 m.

5. Conclusion

1. To increase the volume of livestock production, it is necessary to use the reserves of fodder supplies, which is the non-grain part of the soybean crop and especially the protein-rich chaff.
2. To collect the chaff during the combine harvesting of soybeans, it is necessary to use the developed and tested device for the combine harvester for the collection of the soybean chaff in the stacker with the removal and chopping of straw (RU patent No. 2417572-2009133149/21, publ. 10.05.2011).
3. On the basis of the conducted research, taking into account the optimal parameters of its length and width with chaff moisture of 30 % as well as the average length of the fields, the volume of the stacker equals 4.5 m^3.

Conflict of Interest | **Конфликт интересов**

None declared. | Не указан.

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