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THE HEADER FOR A BREEDING PLOT COMBINE FOR SUNFLOWER HARVESTING

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Usage of modern technical means for sunflower harvesting, due to their construction designs, inevitably involves yield losses reaching up to 10–11%, as well as increasing of seed injury. Aim of the research presented was to develop a header for a breeding plot combine for sunflower harvesting. As a result, an experimental four-row header for the Delta plot combine for sunflower harvesting was developed and manufactured. The main values of the adjustable parameters are given, depending on the biometric characteristics of the plants being harvested. Using this experimental header, seed injury did not exceed 1.51% at a moisture content of 5.1% and seed losses did not exceed 1%.

Keywords: seed harvesting; construction; four-row header; auger feeder; seed injury and seed losses

Plant height and head diameter do not depend only on the sunflower variety, but also on the cultivation zone, weather and soil conditions. Cultivated varieties and hybrids of sunflower are also characterized by a significant variation in plant height, which makes it difficult to cut and thresh exclusively the productive plant part, leading to the head loss, deterioration of the thresher and necessity to clean the combine. Due to sunflower characteristics, utilization of technical means for its harvesting is inevitably related to the crop losses and seed injury (Dalmis et al., 2013a; Dalmis et al., 2013b; Doronin, 2006; Fedorenko, 1985; Csanadi and Hamphoff, 2007; Gonulol et al., 2009; Miklič et al., 2012; Mirzabe and Chegini., 2015; Mirzabe et al., 2012; Novák and Vitázek,, 2014; Sekhon et al., 2004; Sudajan et al., 2002; Trubilin and Kravchenko, 2001).

For purposes of research, several headers for sunflower harvesting by different producers were taken into consideration; however, it was observed that companies-producer tried to improve the construction of headers, increase the reliability of equipment, yet did not change the key operating principles. Producers have still not addressed adequately the issue of how to decrease stem length attached to sunflower heads before transporting them into the threshing drum during harvest (Csanadi and Hamphoff, 2007).

In recent years, the All-Russian Research Institute of Oil Crops has been carrying out research aimed at improving the work tools for gripping, feeding and cutting of sunflower plants in order to increase the height range of the harvested plants, to provide a cut of heads with a minimum stem length, as well as to reduce the level of seed injury during threshing. Due to the inclination of feeding screws, speed of horizontal component for stem transportation through the device channels, as well as combine speed and speed of other constructive designs, the length of stems entering together with heads for threshing decreases to 0.1–0.3 m, reducing the load of threshing machine and combine cleaning system by unproductive crop (Makarov et al., 2007; Sitchenko, 2001; Čanak et al., 2011).

The research aim is to develop the header for a plot combine, which would provide a maximum cut of sunflower stem off the head regardless of its original length.

Material and methods

For that purpose, a four-row header for the Delta plot combine for harvesting breeding plots was developed and manufactured; the scheme and general overview of this equipment is shown in Figs. 1 and 2. Header design is protected by the patent of the Russian Federation no. 179951.

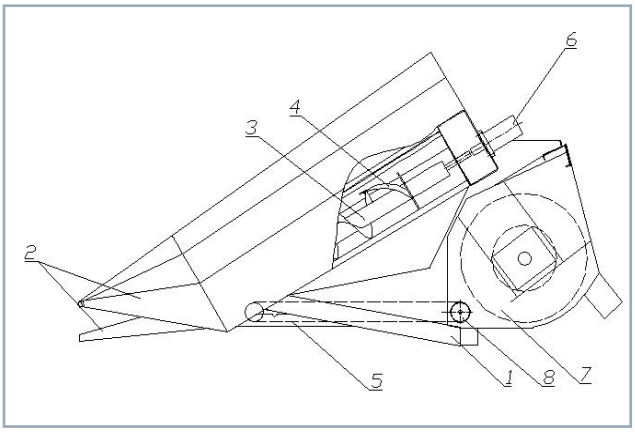

Fig. 1a Scheme of a four-row header for Delta combine for sunflower harvesting, a – side view
1 – frame; 2 – stem dividers, 3 – screws; 4 – cutting pair; 5 – belt conveyor; 6 – hydraulic motors; 7 – transverse screws of a header; 8 – drive shaft of conveyor

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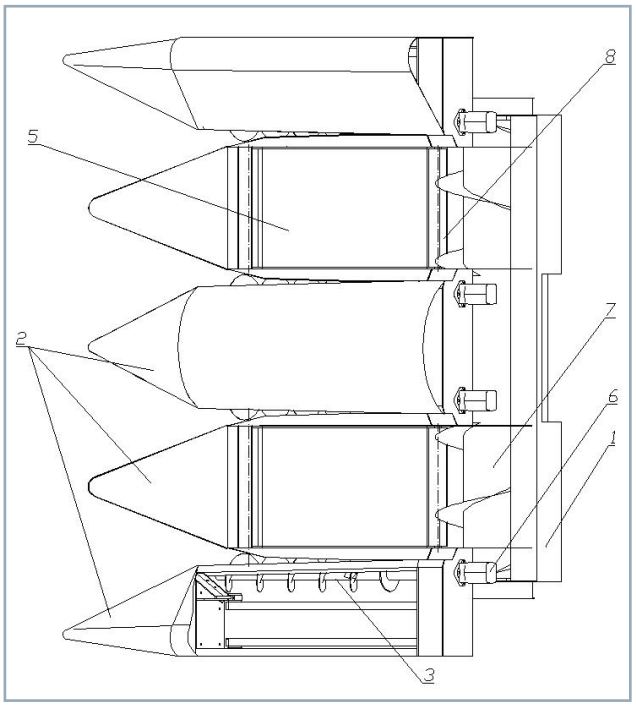

Fig. 1b Scheme of a four-row header for Delta combine for sunflower harvesting, b – top view
1 – frame; 2 – stem dividers, 3 – screws; 4 – cutting pair; 5 – belt conveyor; 6 – hydraulic motors; 7 – transverse screws of a header; 8 – drive shaft of conveyor

Fig. 2 The four-row header for Delta combine for sunflower harvesting

Fig. 3 Four-row header during harvesting of sunflower line VK-678B

Header consists of a frame [1], upon which dividers [2] with screws [3] are positioned, with a cutting pair [4] mounted on the latter. Between the dividers [2], belt conveyors [5] are horizontally placed on the frame [1]. The feeding screws [3] are driven by means of hydraulic motors [6]. A transverse feeding screw of the header [7] is installed behind the belt conveyors and the drive shaft of the belt conveyors [8] is placed under the transverse feeding auger.

The values of the main adjustable header parameters are given in Table 1.

The positive effect includes reduction of sunflower seed yield loss in harvesting of both dwarf and tall sunflower plants by a reliable technological process, as well as reduction of the length of stems attached to sunflower heads entering the combine threshing machine. The explanation is as follows. The inclination angle of the screws to the soil surface should fall within the optimal values (from 25° to 35°) depending on the biometric characteristics of sunflower plants. During sunflower harvesting, height of the lead-in part of screws should be adjusted to the minimum head height by raising and lowering the header by means of the combine hydraulic cylinder. At the same time, the inclination angle of screws [3] to the soil surface also changes and outsteps the optimal limits, resulting in an increase in the losses of whole heads. The ability to adjust the inclination angle of screws [3] to the header's plane of the frame [1] during its lowering and raising by means of the header hydraulic cylinder allows for the optimum inclination angle of screws to the soil during harvesting of both dwarf and tall sunflower plants, i.e. to reduce losses.

During harvesting of dwarf sunflower (Fig. 3), the header frame is set to the lowest position – such that the lead-in part of the stem divider is at the height equal to the minimum height of head position above the surface level; however, the cutting pair can end up higher than the plant height, which can lead to the direct losses as described above. To prevent this from happening, the operator in the combine cabin lowers the screws by means of the hydraulic cylinder, optimizing their inclination angle to the soil surface and thereby improving the technological process of harvesting and avoiding direct losses of heads and seeds.

During harvesting of tall sunflower (Fig. 4), the header frame is set to the highest position – such that the lead-in part of the stem divider is at a height equal to the minimum height of heads position above the surface level. However,

Table 1 The values of the main adjustable parameters of a header for the sunflower breeding plot combine

Properties	Line VK-678B	Variety Dzhinn
1. The grip height (m)	0.3–0.4	0.5–0.7
2. Rotation frequency of screw feeders (min^{-1})	140–150	130–140
3. Travel speed during harvesting ($km \cdot h^{-1}$)	4–5	4–5

Fig. 4 Four-row header during harvesting of sunflower variety Dzhinn

the inclination angle of the screws to the soil surface is decreasing automatically and the lower it is, the smaller the amount of stem being cut. To ensure the cutting off of the maximum amount of sunflower stem material off the head, the operator in the combine cabin lifts the frame [3] of the screws using the hydraulic cylinder, optimizing their inclination angle to the soil surface and thereby improving the technological process of harvesting – reducing the cut length of stems and headers entering the threshing machine, thereby preventing the indirect losses of certified sunflower seeds. Screws adjusted to an optimal angle to soil surface during the combine traveling guarantee decreasing the cut stem length cutting, as well as head and seed losses.

Minimal losses in whole heads and free seeds, as well as the increased cut length of stem attached to the head that enter the threshing machine can be attributed to the header operation quality indicators during sunflower harvesting.

The inclination angle of the screws to the field surface was set in three positions: 25°, 35°, 45°.

The losses of entire heads and free seeds were determined according to the Russian National Standard 28301-2015 (GOST 28301–2015). Twine frames were laid to record losses at each record passage (not less than 100 meters). To determine losses of whole heads, the frame area was limited to 1.4 m widthwise and 3 m lengthwise. To determine losses of free seeds, the frame area was limited to 1.4 m widthwise and 0.15 m lengthwise. Three frames were laid on each record passage. The obtained data was recorded in the register of input data.

The obtained experimental data was processed by methods of mathematical statistics. A total of 14 ha of seed production plots of sunflower varieties and about three thousand breeding plots were harvested.

The cut length of stems on the head was determined indirectly. The cut length of the stems remaining in the field on root was measured after the passage of the combine equipped with the experimental header. The obtained data was statistically processed and compared with the biometric characteristics of plants prior to harvesting.

Results and discussion

Experimental research was carried out in accordance with the Russian National Standard 28301-2015 (GOST 28301–2015).

The main performance properties of the Delta breeding plot combine with a four-row header are provided in Table 2 and 3.

The analysis of the obtained data shows that the size of stem cut with head is almost the same in dwarf hybrid plants and in Dzhinn plants – a tall confectionery variety – at 15.0 and 25.8 cm, respectively. The fact that the heads enter the thresher of the combine only with such small stem material amounts significantly improves the combine performance.

Confectionery Dzhinn variety was chosen to study the obtained bulk, since its seed coat is less resistant to the impact of applied force.

Characteristics of the obtained seed bulk of sunflower variety Dzhinn were determined according to the Russian

Table 2 The main performance properties of the Delta breeding plot combine with a four-row header during harvesting of sunflower hybrid VK 678 B

Properties	Arithmetic average (cm)	Standard deviation (cm)	Error of sampling average (cm)	Variation factor (%)	Relative error of sampling average (%)
Length of a stem before cutting of heads (cm)	146.9	6.5	0.7	4.41	0.46
Length of a stem after cutting of heads (cm)	131.9	13.7	1.4	10.38	1.01
Losses (%)	0.25				

Table 3 The main performance properties of Delta breeding plot combine with four-row header during harvesting of sunflower variety Dzhinn

Properties	Arithmetic average (cm)	Standard deviation (cm)	Error of sampling average (cm)	Variation factor (%)	Relative error of sampling average (%)
Length of a stem before cutting of heads (cm)	199.1	17.68	1.86	8.88	0.94
Length of a stem after cutting of heads (cm)	173.2	20.5	2.16	11.84	1.2
Losses (%)	0.97				

Table 4 Characteristics of seeds of Dzhinn sunflower variety harvested by the Delta breeding plot combine with a four-row header

No.	Characteristics	Mean value of characteristics (%)
1.	Seed content of the main crop	
	– total	96.64
	– including hulled	1.11
2.	Waste products	
	– broken sunflower seeds	0.40
	– shrunk, unformed seeds	1.58
	– organic impurity	1.38

National Standard 12037-81 (GOST 12037-81) and are provided in Table 4.

The analysis of the presented data shows that the purity of the bulk taken in by a combine equipped with the new header is 96.64%; seed injury is only 1.51% at a moisture content of 5.1%, which indicates that the threshing device works well, and seed losses do not exceed 1%.

Conclusion

The research results show that the Delta breeding plot combine equipped with a new four-row header enables harvesting of both dwarf and tall sunflower plants with the least possible losses. The header working tools provides a maximum cut-off of sunflower stems from the heads, regardless of their initial length. Since sunflower heads enter the threshing drum only with small stem material, optimal conditions are created for complete threshing of seeds, while the purity of the received bulk is much higher than purity provided by other equipment.

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