Results of the production test of sunflower harvesting attachment with an auger reel

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Abstract. Sunflower is the main oil crop in Russia. Sunflower plantings occupy more than 95% of the area under oil crops and annually make 7.07% of the area under grain crops. The urgent problem is the loss of oilseeds behind the header during sunflower harvesting which, according to agro-technical requirements, should not exceed 2.5% of the actual yield. The article presents the average loss of oilseeds behind various sunflower harvesting attachments. The analysis of rationality of their use depending on the area under sunflower plantings is given. The design is offered and the scheme is substantiated of the performance of an auger-reel for sunflower harvesting attachment. The developed auger-reel is equipped with a winding, which allows reducing the acceleration of the sunflower head movement during the harvesting and minimizing the loss of oilseeds behind the header to 0.63%. The results of the production tests of the developed attachment with "Niva" SK-5-M-1 and ACROS 530 combine harvesters are presented. Their comparison with the average losses of oilseeds using different by design attachments is given.

1. Introduction

The main criterion determining the operation of adapters, headers and attachments for sunflower harvesting is the loss of oilseeds which, according to agro-technical requirements, should not exceed 2.5% of the actual yield [1]. Attachments for sunflower harvesting can be divided into adapters, headers and attachments for sunflower harvesting. Adapters are considered to be attachments for harvesting, the working parts of which are focused on the geometric parameters of the crop to be harvested [2]. Adapters are equipped with chain conveyors with grips or hooks for stems (figure 1a). These attachments are characterized by high material and energy intensity, structural complexity and high cost [3]. However, the loss of oilseeds behind these headers is minimal and the average value makes up 1.15%. It is obvious that not all agricultural enterprises in Russia have significant areas for sunflower planting. Therefore, for some of them, the payback period for these headers can be more than 5 years, which makes their purchase unprofitable [2,4]. Sunflower headers are equipped with a reel and dividers for stems, and the technology of their operation is similar to the technology of grain crop harvesters (figure 1b). In this case, threshing occurs due to the shock action of the reel blades on the sunflower plant stand. The loss of oilseeds behind the header is 1.17%. Grain crop harvesters are re-equipped with harvesting attachments. They consist of a specialized reel, dividers and side and back shields (bluff boards) (figure 1c). It should be noted that it is cost-effective for small agricultural enterprises to use these attachments.
considering their low cost and material intensity [2,5]. However, the results of the attachments operation show high losses of oilseeds – 2.75 %.

![Image](a)

![Image](b)

![Image](c)

**Figure 1.** Attachments for sunflower harvesting: adapter Falcon-1200-3 (a), rowless header “Dominoni Free Sun” (b), attachment “Lifter” (c).

Within the research, it was found that the high loss of oilseeds behind the attachments is due to the shock of the stem or head against the tube shaft of the reel, which has a diameter of 0.5 m. Since the use of attachments can be considered cost-effective for agricultural enterprises with different areas for sunflower planting, it is advisable to modernize them through the development of additional structural elements [6].

The purpose of the study was testing of sunflower harvesting attachment with an auger-reel under production conditions, confirmation of the established design-and-operating parameters of the developed auger-reel: the diameter of the tube shaft of the reel $D_{\text{shaft}}$; the width of auger winding $H_{\text{turn}}$; a lift angle of the working part to the platform $\chi$; the length of the stripper knife $L_{\text{str}}$; the gap between the end point of the stripper knife and the winding turns of the header auger $S_{\text{auger}}$; the gap between the end point of the stripper knife and the cutterbar plane $S_{\text{cbp}}$; as well as the influence of these parameters on the loss of oil seeds [7].

### 2. Materials and methods

Mathematical and engineering calculations based on the geometrical dimensions of the sunflower plant stand, the speed of the combine harvester running and the number of revolutions of the auger-reel, were used for the development of the auger-reel. The parameters of the auger-reel defined previously by theoretical calculations were taken into account: **operating parameters** – the gaps between the end point of the stripper knife and the winding turns of the header auger $S_{\text{auger}} = 0.025$ m; the gap between the end point of the stripper knife and the cutterbar plane $S_{\text{cbp}} = 0.025$ m; and **design parameters** – the diameter of the tube shaft $D_{\text{shaft}} = 0.32$ m; the width of the auger winding $H_{\text{turn}} = 0.15$ m; the $T$-shaped stripper knife with a lift angle of the working part to the platform $\chi = 140^\circ$; the length of the stripper knife $L_{\text{str}} = 0.34$ m.

The developed auger-reel was tested on “Niva” SK-5-M-1 and ACROS 530 grain harvesters during sunflower harvesting [8].

Sunflower harvesting with a header with an auger-reel was carried out in Russia, in the Saratov region, in the Balashovsky district from September 20 till October 10, 2018 at the private agricultural enterprise “The Head of the Farm E B Zaikin” on the “Lakomka” variety with a biological yield – 1.08 t/ha, at oilseeds moisture content – 7.9%, heads height – 110 cm, plant height – 135 cm, and at the private agricultural enterprise “The Head of the Farm A V Zharkov” of the Lysogorsky district of the Saratov region on “Saratovsky 20” variety with a biological yield – 1.67 t/ha, at oilseeds moisture content –12.5 %, heads height – 118 cm, plant height – 145 cm.

When gripping the sunflower plant stand, there is a shock against the stem or the head against the tube of the reel, which leads to the threshing of oilseeds. In this case, the acceleration of the sunflower head $W_{\text{head}}$ plays an important role [7].

Therefore, for reducing the loss of oilseeds, it is necessary to strive for careful interaction of the working parts of the header or attachment with the sunflower plant stand [9]. This can be achieved by the development of new working parts, due to which the value $W_{\text{head}}$ will be reduced.
For this purpose, an auger-reel of the header for sunflower harvesting was developed. Reducing the loss of oilseeds is achieved by using an auger winding in the design, the determined width of which reduces the acceleration of the head movement $W_{head}$ (figure 2).

Figure 2. Technological scheme of the auger-reel operation: 1 – combine harvester; 2 – header; 3 – auger-reel; 4 – sunflower plant stand; 5 – lifters; 6 – stripper knives; 7 – winding turns; 8 – cutterbar; 9 – header auger; $W_{head}$ – acceleration of the head movement; $v_c$ – linear speed of the combine harvester running.

These parameters were optimized according to the results of experimental studies of the operation of the attachment equipped with the auger-reel.

3. Results
Within the production tests, the use of the auger-reel for sunflower harvesting on “Niva” SK-5-M-1 and ACROS 530 grain harvesters showed a decrease in the loss of oilseeds behind the header to 0.63% of the actual yield. The conducted production tests showed a decrease in the loss of oilseeds behind the header with a bat reel in comparison with the average loss behind the attachment with a tube reel 16.2 times greater. This is due to the fact that the headers with a bat reel are not adapted for sunflower harvesting but are focused on harvesting eared grain [10]. Reduction of loss in comparison with: adapters equipped with chain conveyors for stems and heads – 1.82 times; rowless reapers – 1.86 times; attachments with a tube shaft and grippers – 4.36 times (Table 1).
Table 1. Comparative evaluation of oilseeds loss behind the attachments for their harvesting.

| Name of attachment                               | Headers with a bat reel | Adapters equipped with chain conveyors | Rowless reapers | Attachments with a tube shaft and grippers | Attachments with an auger-reel |
|--------------------------------------------------|-------------------------|----------------------------------------|-----------------|-------------------------------------------|-------------------------------|
| Loss of oilseeds, %                              | 10.2                    | 1.15                                   | 1.17            | 2.75                                      | 0.63                          |

An adapter PSP-10-M1 aggregated with “Niva” SK-5-M-1 and ACROS 530 and attachment for sunflower harvesting with “Lifter” were used for a comparative evaluation of attachments (figures 3, 4).

![Figure 3](image1.png)  
**Figure 3.** Operation of the ZhSK-5 header with an auger-reel in the field.

![Figure 4](image2.png)  
**Figure 4.** "Niva" SK-5-M-1 combine harvester with a header equipped with an auger-reel.

The auger-reel was produced in accordance with the results of the experimental studies: a tube shaft with a diameter $D_{\text{shaft}} = 0.32$ m; a winding width $H_{\text{turn}} = 0.15$ m. The stripper knife had a $\Gamma$-shape with a lift angle of the working part to the platform $\chi = 140^\circ$ and a length $L_{\text{str}} = 0.34$ m (figures 5, 6).

![Figure 5](image3.png)  
**Figure 5.** Scheme of the auger-reel operation: 1 – header; 2 – dividers; 3 – auger-reel; 4 – header auger; 5 – feeder house; 6 – sunflower plant stand.

![Figure 6](image4.png)  
**Figure 6.** Production sample of the auger-reel.
In the process of adjusting the auger-reel on the ZhSK-5 header, the gaps were held: between the end point of the stripper knife and the winding turns of the header auger \( S_{\text{auger}} = 0.025 \) m; between the end point of the stripper knife and the cutterbar plane \( S_{\text{cbp}} = 0.025 \) m (figure 5).

The results of the conducted tests are presented in Tables 2-3.

**Table 2.** Test results with “Niva” SK-5-M-1 combine harvester.

| Indicator name          | Harvesting with a blade reel of the ZhSK-5 header | Harvesting with a tube reel, “Lifter” attachment | Harvesting with an auger-reel |
|------------------------|---------------------------------------------------|-------------------------------------------------|-------------------------------|
| Biological yield, t/ha | 1.08                                              | 1.08                                            | 1.08                          |
| Actual yield, t/ha     | 0.96                                              | 1.02                                            | 1.07                          |
| Area under test, ha    | 180                                               | 180                                             | 180                           |
| Coverage width of the header, m | 5     | 5                                               | 5                              |
| Working width of the header, m | 4.9  | 4.9                                            | 4.9                           |
| Working speed, km/h    | 8                                                 | 11.2                                            | 11.2                          |
| Production per hour, ha/h | 2.6  | 3.55                                           | 3.55                          |
| Labor costs, man-hour/ha | 0.38 | 0.28                                           | 0.28                          |
| Fuel consumption rate, kg/ha | 4.5  | 3.5                                            | 3.1                           |
| **Loss of actual yield, %** | 10.2 | 4.3                                           | 0.63                          |

**Table 3.** Test results with ACROS 530 combine harvester.

| Indicator name          | Harvesting with a blade reel of the PSM-081.27 header | Harvesting with a tube reel, “Lifter” attachment | Harvesting with an auger-reel |
|------------------------|-------------------------------------------------------|--------------------------------------------------|-------------------------------|
| Biological yield, t/ha | 1.67                                                  | 1.67                                             | 1.67                          |
| Actual yield, t/ha     | 1.56                                                  | 1.61                                             | 1.62                          |
| Area under test, ha    | 700                                                   | 700                                              | 700                           |
| Coverage width of the header, m | 6.8  | 6.8                                           | 6.8                           |
| Working width of the header, m | 6.7  | 6.7                                           | 6.7                           |
| Working speed, km/h    | 9.0                                                   | 9.7                                              | 9.7                           |
| Production per hour, ha/h | 3.92 | 4.22                                           | 4.22                          |
| Labor costs, man-hour/ha | 0.25 | 0.24                                           | 0.24                          |
| Fuel consumption rate, kg/ha | 9.3  | 8.2                                            | 7.9                           |
| **Loss of actual yield, %** | 10.4 | 4.2                                           | 0.63                          |

**4. Conclusion**

As a result of the conducted production tests, it can be concluded that the minimum loss of oilseeds behind the header during sunflower harvesting is provided by the combine harvesters equipped with a header with the auger-reel – 0.63 %. This is achieved by the use of auger winding, which allows reducing the acceleration of the head movement on contact with the tube shaft. Moreover, the developed attachment should conform to the following design-and-operating parameters: the diameter of the tube shaft \( D_{\text{shaft}} = 0.32 \) m; the width of the auger winding \( H_{\text{auger}} = 0.15 \) m; the \( I \)-shaped stripper knife with a lift angle of the working part to the platform \( \chi = 140^\circ \); the length of the stripper knife \( L_{\text{str}} = 0.34 \) m; the gap between the end point of the stripper knife and the winding turns of the header auger \( S_{\text{auger}} = 0.025 \) m; the gap between the end point of the stripper knife and the cutterbar plane \( S_{\text{cbp}} = 0.025 \) m.

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