Sorghum harvester work quality assessment

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Abstract: The article presents the results of experimental research on the sorghum harvester, equipped with a threshing-separating device of the inertial-combing type for harvesting Donskoe-35 variety broom sorghum, work quality in the conditions of farms in the south-western zone of the Volgograd region of Russia. The heads losses change \( Q_{m} \) dependences on the combine speed \( V_{k} \) were determined: before the threshing chamber \( Q_{m} = -0.079 V_{k}^2 + 0.426 V_{k} + 0.01 \), behind the header \( Q_{m} = -0.133 V_{k}^2 + 1.2V_{k}^2 - 3.567V_{k} + 4.1 \) and after the threshing chamber \( Q_{m} = 0.057 V_{k}^2 - 0.321V_{k} + 1.046 \), as well as grain losses \( Q_{z} \): behind the normalizer \( Q_{z} = 0,03V_{k}^3 - 0.241V_{k}^2 + 0.686V_{k} - 0.083 \), by the \( Q_{z} = 0,004V_{k}^2 + 0,025V_{k} + 0,28 \) and under-threshing in a head \( Q_{z} = 0,033V_{k}^2 - 0,032V_{k} + 0,204 \). The sorghum harvester threshing growing heads by a threshing-separating device of an inertial-combing type showed a high quality of work: an increased level of heads losses was observed behind the header at combine speeds up to 1.5 m/s, but they did not exceed 2.6% at a combine speed of 0.5 m/s; while studying types of grain losses, the losses behind the normalizer reached the level of 0.6% at a combine speed of 3.0 m/s; the loss of grain behind the thresher and under-threshing in the head did not exceed 0.4%.

1. Introduction

Sorghum belongs to crops that are capable of providing high and stable yields in the arid regions of different countries. Sorghum is cultivated in many countries around the world, such as India, the United States of America, Sudan, China and others. Sorghum is also cultivated in some regions of the Russian Federation, for example, in the Nizhneje Povolzhje region and in the North Caucasus. Such a spread of this culture is associated with its salt and heat resistance [1], as well as undemanding to soils. The sorghum crop finds a wide application as green fodder, in the production of silage, grass meal, and grain forage. The sown area of sorghum crops in Russia is about 150 thousand hectares. Expansion of sorghum crops is observed in the arid regions of the Nizhneje Povolzhje region.

It is known that according to the direction of use, sorghum is divided into groups:
1. Grain sorghum - undersized, little tillering grain that is easily hulled. The grain is used for fodder and food purposes, as well as in the alcohol and starch industry.
2. Sugar sorghum - tall, highly bushy. It is used for silage and for making sweet syrup.
3. Herbaceous sorghum or Sudanese grass has a large tillering and thin non-coarse stems. It serves to obtain green forage and hay.
4. Broom sorghum has very long and elastic heads; it is about half a meter. They are used to make brushes and brooms. At a young age, the leafy mass can also be used for fodder.

A special attention should be paid to broom sorghum, since the production of brooms is now widely developed, for which broom sorghum is the main material, its heads have indisputable advantages over other materials, including plastic. The advantages of this material include environmental friendliness, both its production and operation and disposal, resistance to oil products, cheapness, beautiful appearance, lightness and elasticity.
The increase in the cultivation of broom sorghum is restrained by a number of problems, the main of which arises at the harvesting stage and is due to the biological characteristics of this crop, which do not allow harvesting the entire crop with the help of serial harvesting machines. The industry does not produce machines for harvesting broom sorghum.

2. Materials and methods

When harvesting broom sorghum, there are two goals.

The first one is getting quality material for the production of brooms, sweep brooms. A head with a stem with a total length of 0.8 ... 1.0 m is used for the production of brooms. The head should be threshed with minimal damage to the branches.

The second one is getting high-quality seed material.

At present, the harvesting of broom sorghum is organized as follows.

On small areas, less than 1 hectare, manual harvesting of broom sorghum is allowed. This is a very time-consuming operation, carried out, moreover, during the period of the economy main workers’ maximum employment. After such harvesting, the broom sorghum heads must also be threshed with a minimum of damage. Often, primitive pin threshers with hand-fed plants are used, which greatly thin out the head.

On areas of more than 1 hectare, manual harvesting is unacceptable, due to the need to employ a large number of workers, the quality of manual threshing is low, harvesting periods are extended, losses from damage to heads and the cost of raw materials are significantly increased. In most farms, existing equipment, for example, KS-2.1, SM-2.6; ZhSK-2.1; ZhK-1.9 and some others are adapted for harvesting broom sorghum, although the production of grain binders in the Russian Federation has already been stopped, and there are no analogues for replacement. These machines perform mowing followed by manual gathering of the heads (KS-2.1, ZhK-1.9), mowing and picking-up of heads into bundles and dropping them on the field in rows (ZhSK-2.1), heads mowing and picking-up in a trailer (SM-2.6). When laying the cut plants on the ground, the heads loss from decay, head stalk breakage, incomplete manual picking-up, and harvesting period prolongation with the grain loss by wheat shedding increase significantly.

A common disadvantage of using the above machines is that a subsequent threshing of the harvested raw material is required at stationary establishments. Plants are fed into the thresher by hand and involves a lot of manual labor. Often, due to a shortage of workers, the raw material is threshed after storage, just before the manufacture of brooms. Raw sorghum heads stored in stacks attract rodents because of their grain, which also damage heads branches - more than 30% of the raw material is lost.

Constructions of the combing type headers [2, 3, 4], intended for obtaining grain from grasses, panicle crops, have high efficiency. However, when threshing a broom sorghum, there is a specific task - it is necessary to preserve, if possible, all branches of the head: of the first, second, third order ones. The combing type header does not meet this requirement.

For harvesting sorghum at the Volgograd State Agrarian University, a threshing-separating device of inertial-combing type was developed, which was the basis for the design of a sorghum harvester [5]. This harvester allows to start harvesting when the grain reaches wax ripeness with the moisture content of the leafy mass up to 70%.

The design of the sorghum harvester allows to thresh the standing sorghum plants heads up to 3.5 m in height, before cutting them. The heads are fed for threshing by the combine harvester normalizer into a direct-flow threshing chamber of the inertial-combing type, which rollers perform threshing. The threshed grain is fed into the grain bin by a grain thrower, and the plants emerging from the threshing chamber are cut off by the header cutter bar and fed into the trailed tractor cart.

Field studies of an experimental sorghum harvester to assess the quality of harvesting broom sorghum variety Donskoye-35 were carried out for a number of years in the farms of the Volgograd region.

The procedure for carrying out laboratory field tests was as follows.

Before starting the experiments, the plot was cleared of broken plants, heads lying on the ground. The experiments started with the machine steady-state operating mode. Registration plots were carried out at three values of the combine speed. The combine speed was determined by measuring the registration plot passage time. The experiments were carried out in three repetitions. Sampling and processing were carried out according to the methodology set forth in All-Union Standard 70.81.30. Losses were taken into account within the frames, imposed three times on the registration plot at equal distances. The size of the frames for determining the loss of free grain: the length is 0.15 m, the width was equal to the width of the machine - 0.7 m. To determine the loss of under-combed grain, the size of the frame was 3 m by 0.7 m. The average sample for the analysis of the hopper heap was taken from the initial sample weighing 1 ... 2 kg.
3. Results and discussion

The sorghum harvester quality most important indicator when harvesting broom sorghum is the loss of heads before they are threshed in the threshing chamber and behind the header after threshing, as well as the head stalks loss behind the threshing chamber.

![Figure 1. Losses: 1 - heads before the threshing chamber, 2 – heads behind the header, 3 – heads stalks.](image)

As the result of obtained results by mathematical processing, the dependences of changes in the head loss before the threshing chamber were determined with high accuracy:

\[ Q_m = -0.079 V_k^2 + 0.426 V_k + 0.01, \]  

(1)

losses of threshed heads behind the header:

\[ Q_m = -0.133 V_k^3 + 1.2 V_k^2 - 3.567 V_k + 4.1 \]

(2)

and stalks loss behind the threshing chamber

\[ Q_m = 0.057 V_k^2 - 0.321 V_k + 1.046. \]

(3)

The heads quality, from which brooms and brushes are subsequently made, is also assessed by the presence of non-threshed grain in them. In this regard, the grain under-threshing in heads was determined (Fig. 2).

When harvesting broom sorghum, the by-product is grain, which is used as seed material, as well as for poultry feed. In this regard, grain losses behind the combine are determined, in particular, the loss of free grain behind its normalizer and thresher. The research results are shown in Fig. 2.
Figure 2. Loss of grain: 1 - behind the normalizer; 2 - behind the thresher; 3 – under-threshing.

The presented experimental data are approximated with high accuracy by the following equations:

- **grain loss behind the normalizer**
  \[ Q_z = 0.03 V_k^3 - 0.241V_k^2 + 0.686V_k - 0.083, \]  
  \( (4) \)

- **behind the thresher**
  \[ Q_z = 0.004V_k^2 + 0.025 V_k + 0.28 \]  
  \( (5) \)

- **and grain under-threshing in a head**
  \[ Q_z = 0.033 V_k^2 - 0.032 V_k + 0.204. \]  
  \( (6) \)

Experimental studies have shown that a large share of grain losses are the losses behind the normalizer at the combine operation speeds of more than 1.0 m/s.

It also was established that incomplete grain threshing insignificantly reduces the heads quality as raw materials for the production of brooms, and the increase in the rotation frequency of the threshing-separating device of the threshing beaters reduces grain under-threshing from the heads, but leads to the increase in the stalk heads damage, significantly worsening the resulting raw material quality.

The increased level of head losses at combine speeds up to 1.5 m/s is due to losses behind the header. These losses are largely determined by the design of the cutter bar, which needs to be improved.

Based on the analysis of research works on the features of the reapers cutting units existing designs, the basic requirements for the designs of the cutting units being developed are determined.

The header cutting device of a new design must:
- provide a high quality cut of various crops plants and agricultural crops varieties;
- have low energy consumption;
- have high structure reliability in a wide range of operating conditions;
- have high indicators of manufacturability;
- be compact and safe to service.

Experimental studies showed that the heads and grain loss behind a sorghum harvester designed by the Volgograd State Agrarian University, which performs threshing of growing sorghum with a inertial-combing type threshing-separating device, is 2 - 5 times lower than the corresponding crop losses for serial harvesters.

4. Conclusion

Experimental studies showed that the main share of head losses are the losses behind the header at combine speeds up to 1.5 m/s. They reached 2.6% at a combine working speed of 0.5 m/s. Heads losses before the threshing chamber increased with the increase in the combine speed, but did not exceed 0.6%.

The heads stalks loss behind the threshing chamber varied from 0.9% to 0.6% with the increase in the combine speed from 0.5 m/s to 3.0 m/s.

A large proportion of grain losses are losses behind the normalizer. They reached 0.6% at a combine speed of 3.0 m/s. The loss of grain behind the thresher and under-threshing in the head did not exceed 0.4%.

Thus, the sorghum harvester, performing growing heads threshing by a threshing-separating inertial-stripping type device, showed a work high quality.

References

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