Increase in Soil Moisture Reserves Due to the Formation of High Stubble Residues for the Accumulation of Snow Precipitation

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Abstract. The Orenburg region belongs to the dry-steppe regions with a sharply continental climate, the efficiency of crop production in which depends on the amount of precipitation. Due to the natural and climatic conditions of the region, precipitation in the form of snow is used irrationally, which leads to a decrease in the amount of potential soil moisture. Lack of moisture negatively affects the quality of crop production processes and the state of the soil itself. To solve this problem, it is proposed to implement measures for mechanized snow retention in agricultural fields. Technical and technological disadvantages of the classic mechanized snow retention are established. Negative components of the classical technology are the need for additional costs for winter events and the forced additional impact on the soil of heavy equipment. As a solution to the problem, it is advisable to accumulate snow on high stubble residues formed simultaneously with the process of harvesting grain crops. It was found that for the Orenburg region, taking into account the natural and climatic features, it is advisable to use a Reaper for two-phase harvesting of grain crops by a batch method with a device for the formation of high stubble residues. A dependence was established to determine the optimal share of the field area with stubble residues for effective snow retention. The optimal values of the interdependent parameters of the Reaper reel and the reel of the stubble residue formation device are revealed. The analysis of experimental field studies showed that the formed stubble residues allow accumulating the amount of snow, which increases the moisture reserves in the soil in the spring period by about two times. The feasibility study of the proposed solution showed the feasibility of its application and allowed us to establish the level of profit from the increase in yield due to an increase in the amount of moisture in the soil as a result of snow retention.

1. Introduction

One of the main indicators of agricultural production efficiency in the field of crop production is productivity. The value of this indicator depends on a variety of simultaneously acting factors, among which the water availability of the soil is of great importance. This is a very important point for the arid regions of Russia, which include the Orenburg region. Natural and climatic conditions in this region are such that scientists refer it to the zone of risky agriculture. However, this does not exclude the possibility of obtaining high yields [1].

The structure of the water balance of the soil suggests that it is advisable to pay attention to the use of precipitation in the form of snow. Without taking special measures, snow, which is a potential soil
moisture, is blown away from the surface of fields in winter, filling forests, ravines and other natural obstacles, thereby not participating in a significant part of the moisture charging of the soil in agricultural fields [1-2]. In addition, during the most intense snowmelt, all the moisture received does not have time to be absorbed by the soil and flows down from the fields. In addition to the loss of potential soil filling with moisture, this leads to the progression of such negative phenomena as water erosion and the formation of gullies.

Snow retention, depending on the goals and specific conditions, is carried out with the help of forest strips, specially planted high-stemmed plants, high stubble, the installation of shields, by means of mechanized snow retention [2-3] (first of all, the use of machines for plowing snow) and other techniques.

The use of forest strips is quite effective, but requires the allocation of space for their planting and additional costs. Shield snow retention is not effective enough. Advantages of snow retention on high-stemmed plants: localization of the process in the right areas; fairly high efficiency. Disadvantages – the cost of cultivating high-stemmed crops, the need for their proper integration into the crop rotation, as well as the additional impact on the soil of agricultural machinery when they are sown [1; 3].

There are several ways to classify the existing classic means of snow accumulation mechanization. At the same time one of the most relevant is the classification by type of impact on snow cover:

- technical means for forming a snow shaft;
- technical means for compacting the snow mass;
- combined technical means.

Among the technical means designed to form snow barriers, the most common machines for plowing snow, consisting of a frame and two dumps.

At the first stage of mechanized snow retention, when the height of the snow cover is on average 12-15 cm, two machines for plowing snow can be aggregated with a tractor of 30 kN traction class [3]. When establishing a greater depth of snow in the second stage, this tractor usually works with one technical means for plowing snow (Fig. 1).

![Mechanized snow retention](image)

**Figure 1.** Mechanized snow retention: a-operation of a serial machine designed for plowing snow; b-snow roll formed by a serial machine designed for plowing snow.

The technical means considered above, having their individual disadvantages, are generally able to ensure that the required measures are taken to ensure snow retention. However, we should mention a significant disadvantage of using the classic mechanized snow retention in the generally accepted sense, which today is not eliminated only by improving the technical means used. This process involves additional fuel costs for the tractors used. In addition, there is an additional impact on the soil of heavy machinery, which negatively affects its condition [1-3].

Based on the above, we can conclude that despite the importance of snow retention measures in agricultural production, the classical technology of this process, even with the use of modernized
means, has a number of organizational and technological disadvantages. Accordingly, it makes sense to search for and justify solutions that minimize the negative effects of the existing technology.

2. Materials and methods

The solution to the problems identified by the results of the analysis can be a combination of measures aimed at snow retention with the process of harvesting crops [1].

More than 50 years ago, the scientific team of the all-Union research Institute of grain farming conducted theoretical and practical research in this direction, developed various design and technological solutions, and produced prototypes. So, among other options, the designs of a number of serial reapers intended for harvesting grain crops were modernized. The tasks of this activity were primarily to develop and create a prototype by improving the design or introducing special additional mechanisms and devices into existing structures [1; 4]. In particular, one of the solutions proposed at that time was the following development: in the center of the experimental header (as opposed to serial models), segments of the knife were removed, which is an integral part of the device for cutting the stem, while in the reel of the prototype header, which serves for mowing grain crops, a cutout was made close to the triangular shape, based on the overall characteristics of the proposed device. In the space obtained in the above manner, a cutting device was built in, which was located above the standard cutting device. During operation of the reaper under consideration, the area occupied by high stubble residues fluctuated within 5-8% of the harvested field of grain crops. At the same time, short stems cut during the formation of high stubble residues were placed on top of the main roll formed from a beveled stem.

Another version of the technical means of a similar purpose was developed on the basis of the experimental design Bureau of the Siberian research Institute of agriculture [1; 5]. From its serial prototype, it differed primarily in the presence of a modified device that leads the stems to the cutting apparatus and a special additional element on the cutting apparatus (the authors of the development S. S. Sdobnikov, N. V. Krasnoshchekov, etc.).

At about the same time, teams of scientists from the Kazakh research Institute of agricultural mechanization and electrification, the research Institute of grain farming and the Siberian research Institute of agriculture jointly developed a design of a header used for two-phase harvesting of grain crops, adapted for the formation of high stubble residues (authors A. Sh. Jamburshin, M. G. Penkin, etc.) (Fig. 2); an experimental sample of this technical solution was made.

![Figure 2. Header for two-phase harvesting of grain crops with the function of leaving high stubble: 1-cutting apparatus, 2-bread mass conveyor, 3-device that leads the stems to the cutting apparatus, 4-screw, 5-guide fingers.](image)

The development in question is characterized by certain features of the technological process (in particular, the process of cutting ears), which are somewhat similar to the work of the header of the time of the Australian company «Horwood-Bagshaw» [1]. This shows that not only Soviet scientists, but also foreign specialists already saw the prospects of using reaping units that leave high stubble in
certain climatic and landscape conditions. However, the solution in question can in no way be considered a copy of a foreign technical means. Its significant difference from the product of the Australian company is the peculiarity of the position of the cutting apparatus – it is moved up and forward under the leveling screw, and its working stroke is reduced to 50 mm in comparison with the foreign version of the header design.

The design feature described above is primarily due to the need to create an opportunity for easy movement of the cut stem and laying ears on it. Otherwise, the leveling screw can cause the cut stems to be scattered, which, of course, will cause an increase in various types of grain losses. In the future, the technological process of the header in question involves covering the cut ears with a long-stem mass mown by the upper part of the unit [1; 6]. This allows us to assume that a group of short-stemmed ears will be located in the middle of the roll formed from the cut stem, and in the process of selecting it, these short-stemmed ears will not be lost.

To date, a certain spread has been received by headers that separate only the ear part of the stem, the specifics of whose functioning implies leaving high stubble, which in the future can theoretically be used for snow retention [7-8]. This technology of harvesting grain crops involves threshing the ears immediately after they are separated from the stem.

This technology allows you to get a heap for processing by a combine harvester, which up to 70.0% consists of free grain, chaff and fine straw, the proportion of straw particles does not exceed 8.0%, and the rest is a separated ear [7; 9]. Thus, the threshing and separation process is facilitated, which allows you to work at higher speeds with greater productivity and less fuel consumption. However, stubble plant material is left on the surface of the field, which creates great problems when preparing the soil for subsequent cultivation of grain crops, despite the very high technological efficiency of the plant material in the snow-holding capacity of the field. In addition, work on this technology involves significant losses of grain [2].

The disadvantages of this method of harvesting grain crops are currently being tried to eliminate by combining the standard method with the use of combine harvesters and the method of separating the ear part from the stems of grain crops. The essence of this method of harvesting grain crops is that the main area of the field is removed by a classic method using a combine harvester with a normal cut of the stems in height. During the operation of the combine in the paddock of the field, leave a strip of stalks with a width less than the width of the header intended for separating the ears [2; 7]. This strip of stalks is then mowed and threshed by a harvester equipped with a header designed to separate the ears from the stalks, thereby forming a wide strip of relatively high stubble on the field, which in winter delays and increases solid precipitation in the form of snow.

Practice and science show that the disadvantage of this method of harvesting grain crops is an uneven distribution of broad-band stubble residues in the field [2; 7; 10]. This arrangement leads to an uneven distribution of snow cover on the field, and consequently, moisture, which subsequently negatively affects the process of grain maturation and crop yield. In addition, the width of the formed strip of stubble remains is always less than the width of the header used in this case, as a result of which the combine harvester is used inefficiently, and this leads to an increase in costs [10].

As shown by the analysis, reapers that separate only the ear from the stalk, due to the shortcomings of the technology itself, should not be considered as a variant of the machine that allows you to harvest crops and simultaneously form high stubble for snow retention. This method needs serious improvement and is not equally appropriate for different landscape and climatic conditions. The proposed variants of reapers for two-phase harvesting of grain crops, which allow forming high stubble residues together with harvesting for further snow retention, were not put into mass production for a number of different reasons [1; 10].

Accordingly, based on the analysis of existing reapers, it can be concluded that the creation of a Reaper that forms high stubble residues simultaneously with harvesting remains promising and relevant.
Let's consider the research conducted by us on the basis of the Orenburg state agrarian University in the framework of the formation of high stubble residues during the harvesting of grain crops for subsequent snow retention.

The analysis of existing reapers allowed us to outline ways to improve the operating modes, as well as to implement them in the developed design of a header for two-phase harvesting of grain crops, which operates on the principle of batch formation of a roll from cut stems, with a device for the formation of high stubble residues [1] (Fig. 3).

**Figure 3.** Design scheme of a header for two-phase harvesting of grain crops, which operates on the principle of batch formation of a roll from cut stems, with a device for the formation of high stubble residues: 1-the main device for bringing the stalks to the cutting apparatus; 2-the main cutting apparatus; 3-devices to prevent cut stems from getting under the wheels; 4-conveyor; 5-drive roller; 6-conveyor belt; 7-flap; 8-brushes; 9-flap lifting mechanism; 10-inclined tray; 11-the mechanism of the device for the formation of high stubble residues, which is a device for supplying stems to the cutting apparatus; 12-cutting apparatus that is part of the device for the formation of high stubble residues.

This machine is made in a mounted version, as this version has a number of advantages over the trailer, in particular, it has greater performance and maneuverability.

In more detail, the design of the header for two-phase harvesting, working on the principle of periodic formation of the roll from cut ears, and its technological process are discussed in a number of publications, in particular, in the publication [1]. In this paper, we consider a variant of the header, the design of which is supplemented with a device for the formation of high stubble residues. Therefore, we will continue to mean the design and technological features of the header in this version.

Before starting work, the device for the formation of high stubble residues is configured based on the required height of the cut of the stems, so that only the ears are cut, and the stem remains uncut. When the harvester main part of the harvested crop in the traditional way (without the formation of high stubble residues) is cut off and fed to the conveyor, and a device for the formation of high stubble residues cuts only ears that arrive at the chute and move it on a conveyor belt, where they join the main stem cut weight.

The stability of the snow layer on high stubble residues formed from grain stalks is an essential and indicative parameter of the snow retention process and is evaluated by a special coefficient (the coefficient of snow deposition on high stubble residues). This coefficient is determined from the following regularity [1]:

\[
\theta = \frac{H_K}{H_N - c \cdot \Delta S} \cdot 100\%
\]  

(1)

where \(H_N\) – the height of the snow layer on high stubble residues (the first measurement), m; \(H_K\) – the height of the snow layer on high stubble residues at the last measurement, m; \(c\) – the average density of the stems on the field, \(1/m^2\); \(\Delta S\) – part of the area of the field with high stubble residues (the part of the field within which the measurements were made), \(m^2\).
3. Results and discussion

During experiments to study the stability of the snow layer on high stubble residues, the height of the remaining stems was assumed to be the same (based on the settings of the device for the formation of high stubble curtains) – 0.4 m on average. To analyze the level of snow subsidence, a cross section of the snow mass located on high stubble remains was performed, and every 3 meters of the strip of high stubble remains, the height of the snow layer was recorded (the distance from the soil surface to the upper border of the snow layer). Then the arithmetic mean value of the snow height for each section was set. Measurements were made in five-fold repetition along the entire length of the strip. The coefficient of subsidence of the snow mass was determined on the tenth day after the fall of snow precipitation, which was not amenable to melting due to weather conditions for the specified period. Then the measurements were repeated at intervals of a month. The last measurements were made on the tenth day of the thaw in accordance with information from weather services [1].

Based on the results of the above actions we can say the following:

– the average value of the height of the snow layer on high stubble remains was 0.49 m for all measurements before the beginning of snowmelt;

– the average height of snow cover on high stubble remnants by the tenth day from the beginning of snowmelt was 0.38 m;

– subsidence of the snow mass accumulated due to the presence of high stubble residues was characterized by comparative uniformity throughout the entire time [1].

The profile of the section of the snow layer on experimental high stubble residues along the width of the strip is shown in figure 4. It shows that the snow layer is located on high stubble residues relatively evenly, the greater subsidence of the layer on one side of the strip at the last measurement is due to the fact that this part was more exposed to sunlight due to its location [1].

![Figure 4. Section profile of the snow layer on experimental high stubble residues along the width of the strip: — for the first measurement; - - - for the last measurement.](image)

The dynamics of changes in the subsidence coefficient for all measurements is shown in table 1 [1].

**Table 1.** Change in the coefficient of subsidence of the snow layer on high stubble residues over time.

| Sequential number of measurement | Coefficient of subsidence of the snow layer \( \alpha, \% \) |
|---------------------------------|--------------------------------------------------------|
|                                 | Control measurement point №1 | Control measurement point №2 | Control measurement point №3 | Control measurement point №4 | Control measurement point №5 | Average value of the coefficient \( \alpha \) |
| 1                               | 7                          | 4                          | 11                         | 12                         | 1,5                         | 7,1                          |
| 2                               | 11,3                       | 9,2                        | 9                          | 8                          | 2,5                         | 8                            |
| 3                               | 4                          | 3,7                        | 3,9                       | 6                          | 4,1                         | 4,43                         |
| 4                               | 8                          | 5,6                        | 6,7                       | 3                          | 6,4                         | 5,94                         |
| 5                               | 24,6                       | 21                         | 19,2                      | 17,3                       | 20,3                        | 20,48                        |
The data of the conducted studies show, among other things, that the coefficient of subsidence in most control points of the first and second measurements exceeds the similar coefficients of the third and partially fourth measurements. This is due to the fact that the snow in the first two months of lying is more loose than in the future. The sharp increase in the coefficient based on the results of the fifth measurement is caused by the seasonal beginning of the thaw.

4. Conclusions
The uniformity of the distribution of the snow subsidence coefficient across all measurement points indicates that the experimental high stubble residues formed during the operation of the developed header for harvesting grain crops ensure the uniformity of the snow retention process. This effect persists while the snow cover is lying after snowfall until the beginning of the snowmelt process. Accordingly, high stubble residues created using the proposed device for their formation, installed on the header, provide high-quality snow retention and the use of this device is appropriate.

Experimental field studies have shown that the high stubble remnants left after the operation of the developed header allow the accumulation of snow mass with a height of about 0.45-0.50 m, which, in turn, gives an increase in soil moisture reserves at the beginning of the spring period by 1.8-2.3 times. Against the background of snow retention, due to the formation of high stubble residues, an increase in yield was obtained by an average of 26%.

5. References
[1] Konstantinov M M 2019 Assessment of the quality of snow retention on high stubble residues formed during the operation of the harvester for two-phase harvesting of grain crops, working in a batch way, with a special device Bulletin of the Ryazan state agrotechnological University named after P A Kostychev 1(41) pp 114-119
[2] Lovchikov A P, Lovchikov V P, Pozdeev E A 2017 To substantiate the regularities that characterize the process of direct combine of grain crops with the formation of a stubble strip in the track of the combine Tractors and agricultural machines 4 (M) pp 51 – 57
[3] Konstantinov M M 2012 Justification of the technology of forming barriers from snow and the construction of snow cover in the collection: agrarian science and education in the conditions of formation of innovative economy: materials of the international scientific and practical conference (Orenburg) OGAU publishing center pp 53-59
[4] Ovchinnikov A S, Ryadnov A I, Fedorova O A, Fomin S D, Sharipov R V 2017 Evaluation of reliability of sorghum harvester ARPN Journal of Engineering and Applied Sciences 12(7) pp 2277-2284
[5] Fedorova O A 2017 Factors affecting the indicators of the use of the combine harvester Izvestiya Nizhegorodskogo agrouniversitetskogo complex: Science and higher professional education 4(48) pp 239-245
[6] Bumber I V, Epifantsev V V, Shchegorets O V, Sinegovskaya V T, Kuznetsov E E, Kuvshinov A A, Lontseva I A, Kapustina N A 2018 Optimization ofagrotechnicalterms of harvesting of crops, design and operating parameters of crop-harvesting machines under conditions of the Amur region, Russian Federation Plant Archives 18(2) pp 2567-2572
[7] Mkrtchyan S R, Ignatov V D, Zhalnin E V, Struzhinin N I 2013 Reapers separating the ear part from the stem: state and prospects of development Agricultural machines and technologies 4 pp 18-21
[8] Wang Haifei, Zhou Zhonghua, Zhang Chuanling 2013 Modeling and simulation of sugar cane harvester hydraulic system based on AMESim Journal Of the Chongqing Transport University of Natural Science 32 5 pp 1063-1067
[9] Safonov V, Lapa M, Bordan D, Zhalnin E 2019 Use of vortex flows for aerodynamic threshing of agricultural crops Proceedings of International conference «International conference on modern trends in manufacturing technologies and equipment ICMTMTE 2019» September 09-13 (Sevastopol) Source: E3S WEB OF CONFERENCES Publisher: EDP Sciences P 00004
[10] Lovchikov A P, Lovchikov V P, Pozdeev E A 2017 Justification of direct combine of grain crops with the formation of a strip with high stubble in the track of the combine *Izvestiya Orenburg state agrarian University* 3(65) pp 90 – 93