Physico-mechanical characteristics of connections and biological features of separating grain from ear

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Abstract. The study was aimed at studying the dynamics of connections between wheat plant elements under external mechanical forces. Biological and physico-mechanical features of separating grain from ear were determined. The effect of physical and mechanical impact, changes in parameters of moisture and temperature of the environment and the effect of varietal features on quality indexes of winter wheat grain were studied (mass fraction of protein and gluten). Problems of seed micro damages were studied using two varieties, different in the strength of connections between grain and ear. It was discovered that the largest amount of micro damages of the studied “Luchezar” and “Admiral” varieties was registered when grain with its maximum moisture content was threshed and the amount of micro damages was 54% and 55% (moisture content 34.3%). The highest mass fraction of protein was registered in the phase of milk-wax ripeness of grain of “Luchezar” variety (14.67%) and “Admiral” variety (14.60). Gluten content changed depending on grain moisture, in case of “Luchezar” variety from 23.9% to 19.7%, and “Admiral” variety from 24.6% to 22.5% (grain moisture content 19.5-9.7%). On the overripe stage (5-10 days), gluten content declined from 24.6% (the beginning of harvesting) to 22.5% (15 days of the overripe stage). The research goal was to study physico-mechanical features in the separation of grain from ear due to changes in its biological characteristics.

1. Introduction

Over 60.0 % of land in the structure of plough land of the Russian Federation in 2018 were cultivated areas of grain crops and grain legumes, 34.6 % of which was wheat grain [1]. Wheat is the key crop in crop production. Economic efficiency of agricultural enterprises in large depends on quality indexes of produced grain and its production cost.

To achieve best results, agricultural producers give their preference to the wheat varieties that have high yield capacity, winter resistance, drought-resistance, lodging resistance. Agricultural producers do not consider other physio-morphological features significant, such as magnitude of self-shedding of different varieties, strength of connections between grain and ear, grain damage resistance and they are not subject for consideration. For example, there is no assessment indicator of “grain damage degree" in the standard of grain harvester testing [2]. Meanwhile, fraction of the damaged grain from the total harvested grain is 15.0-30.0 % [3, 4] when wheat is harvested by modern grain combine-harvesters. Presence of the damaged grain, which is placed for long storage, results in serious decline in grain quality and deterioration of sowing properties of seeds [4, 5].

The crop and quality of winter wheat grain are formed throughout all period of growing and
developing from sowing to maturation and in large depend on soil and climatic conditions of the zone [6]. Expansion of areas under winter wheat leads not only to deterioration of phytopathogenic conditions, increase in weed infestation or crops and number of pests, but causes stress in critically tense periods during sowing, pesticide treatment and harvesting. Timely harvesting of all crop kinds ensures the best crop of high quality [7]. The increased or delayed time of harvesting, which prolongs the effect of unfavorable factors on winter wheat crops, results in serious decline in both qualitative properties and crop amount [8, 9].

This research is of current interest because the problem of dynamics of shedding resistance has not been thoroughly studied for winter wheat varieties with different ripening period. It is necessary to study more carefully what causes grain shedding and fragility of ear of different winter wheat varieties. Plant breeders consider the priority to improve selection methods for creating varieties which give grain of high quality in unfavorable conditions and have balanced content of protein. The results of this research can be useful for creating new promising varieties of wheat that have the balance of coarse graininess and multi-flowering. This balance is necessary for reducing the ability to shed during harvesting and overripe stage of grain.

The design of modern combine-harvesters considers the use of traditional threshing methods. The proportion of grain release is up to 20% of the grain energy they consume, while the rest 80% is spent on grinding straw. To develop less energy consuming and traumatic threshing methods, it is necessary to obtain scientific knowledge and information about physical and-mechanical characteristics and morphological features of wheat, which presently are fragmented or often absent both about new varieties and the varieties being used in agricultural production. The available information is clearly insufficient to identify common dependencies between features, crop characteristics and crop varieties. It is important to know the magnitude of the biological relationship of grain with ear, because the degree of shedding and damaging during threshing, range of changes in different periods due to variety features are dependent on it. This knowledge is necessary for creating new more productive varieties not only resistant to unfavorable conditions, but also more technologically advanced and for development of less energy intensive and traumatic methods of threshing that can be implemented in the design of advanced threshing machines.

At the same time, necessary for solving this problem certain mathematical tools, which describe the interactions in the stem-grain-ear system, for their numerical expressions require characteristics of identification links and mechanical features of a stem, ear and grain of wheat.

2. Materials and methods
The analysis of morphological features, biological and physico-mechanical characteristics of winter wheat is given in the technological range from easy to hard to thresh varieties: “Luchezar” (awned, easy to thresh) and “Admiral” (awnless, hard to thresh), selected by FSBSI “ASC “Donskoy”. The efforts in separating grain from ear were evaluated in accordance with [12].

The mass fraction of protein and gluten was determined on INFRATEC device 1241.

The analysis of micro damages was done in accordance with [13].

The following research methods were used: full-scale experiment in the laboratory and field conditions, comparisons.

3. Results and discussion
It was determined that both moisture and temperature of soil and air were not important factors in the range of their changes during the testing period.

Ear flakes hold grain weaker and have less resistance to grain separation than the flower disk. As the grain ripens, the force holding the grain in the flower disk decreases while the flake strength increases. Changes in the effort of grain separation in three selected zones (figure 1) of the ear had relatively low degree of correlation (0.08-0.27) which allows to conclude that they are less sufficient than in the central part of the ear. At the same time, samples were taken for biochemical analyzes of quality changes in
grain content and moisture and temperature of the environment, including soil, grain and ear, were recorded. The efforts of grain separation were evaluated during all the harvesting period characteristic to the southern zone of Rostov region (21 June – 14 July) from the beginning of milk-wax ripeness to full ripeness.

![Diagram of the ear during evaluation of the grain separation effort](image)

It was determined that varietal features of winter wheat, degree of its ripening and moisture in harvesting period (also due to precipitation) are significant factors which impact on the strength of grain and ear connections and grain biological value. Soil and air moisture and temperature were not important factors in the range of their changes during the testing period.

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At the beginning of the harvesting period, maximum effort (figures 1 and 2) in separation of grain from ear for the variety “Luchezar” equaled 11.6 H, for “Admiral” it was 17.8 H, which is 1.5 times higher. Then the maximum effort of grain separation for the winter wheat variety “Luchezar” gradually declined to 6.0-7.0 H, for “Admiral – to 9.0-11.0 H, excluding periods of increased moisture due to precipitation, but also with the difference of 1.5 times.

![Figure 2. Value changes of the effort in separation grain from winter wheat ear, variety “Admiral”, depending on the grain temperature and moisture, temperature of the environment and testing date.](image)
Figure 3. Value changes of the effort in separation grain from winter wheat ear, variety “Luchezar”, depending on the grain temperature and moisture, environmental temperature and testing date.

The increase in the moisture value of wheat variety “Luchezar” from 8.1% to 14.6% in the middle of the harvesting period due to precipitation caused the increase of maximum effort of grain separation from 2.6 H to 7.9 H. The average values of the grain separation effort also increased in this period from 0.9 H to 2.7 H, correspondingly by 3 times. It is important to note that correlation relationship between maximum and average values of effort is quite high and equals 0.7.

During the last period of harvesting, when the temperature of the environment and grain (correlation of these two factors 0.88) was in the range 35-39°C, and the grain moisture decreased to 8-9%, the maximum grain separation efforts decreased to 2.5 H.

The determined tendencies in changing of grain separation effort due to external factors are identical for both tested varieties of winter wheat. However, both maximum and average values of grain separation effort for the winter wheat variety “Luchezar” are 1.5 times lower than for the variety “Admiral”.

As the length of the stay on the root of the winter wheat varieties “Admiral” and “Luchezar” increases, the connection of grain with ear decreases to its minimum values with every day of over ripening after the full ripeness. By the end of the agro-term the grains of the “Luchezar” variety were characterized by the grain separation effort not over 4.0 H, and the variety “Admiral” demonstrated the grain separation effort in the similar range, by the end of the agro-term it did not exceed 80.6%.

Thus, the connections of grain and ear and respectively the grain separation effort sufficiently depend on the varietal features of winter wheat (over 1.5 times); plant moisture during the ripening period and harvesting time, for different varieties from 30 to 100%; changes in the moisture of grain and ear due to precipitation up to 3.0 times.

Crop productivity and seed quality are in large effected by the harvesting dates and methods which cause the increase of grain damaging. The degree of grain damaging during harvesting depends on the design of harvesting machines and operation mode of their working parts. Among other physico-mechanical properties, grain moisture which depends on harvesting dates and weather conditions during harvesting has the largest effect on the seed quality.

Damaging – one of the major reasons in the decline of sowing qualities of seeds [15].

During threshing of the winter wheat variety “Luchezar” the amount of micro damages varied from
54% (moisture 34.3%) to 25% (moisture 12.2). The increase in the amount of micro damages was recorded when the seed moisture decreased to 8.4% and 9.7% and was 36% and 34% respectively (figure 4).

**Figure 4.** Histogram of the damaging degree of the winter soft wheat grain, “Luchezar” variety, depending on the grain moisture.

The determined differences in the degree of damaging are shown in the absolute values of these indicators. The number of micro damages directly depended on the features of the selected variety and grain moisture.

During threshing of “Admiral” grain variety, almost all increase and decrease tendencies of damaging remain versus “Luchezar” variety (figure 5).

**Figure 5.** Histogram of the degree of damaging of winter soft wheat grain, “Admiral” variety, depending on the grain moisture.
Ripening period (harvesting germination) and wheat variety among the other changeable indicators have the greatest effect on the value of mass protein fraction and gluten amount.

At the early stage of taking the “Admiral” variety samples (figure 6) the protein content was 14.6% with the grain moisture 34.3%. Gradual decline in the mass protein fraction was recorded when the moisture of grain decreased. It can be explained the following way. On the milk-wax stage of grain ripening, the content of protein is higher, but in the process of drying to the condition with the grain moisture lower that standard (lower 14%), indicators of the mass fraction of protein decline to 12.2%.

Similar changes in the protein content were also observed in the variety “Luchezar” (figure 7).

Gluten content in the grain correlates well with protein content, because gluten basically is a protein substance. It is common knowledge, that gluten content and physical features characterizing its quality may vary in large ranges because the biochemical composition of winter wheat grain depends on the interaction of a number of external factors. Such factors as hydrothermal conditions of active vegetation and the initial formation of grain can be considered the most important [10].

![Figure 6. Histogram of the mass fraction of protein in the grain variety “Admiral” depending on the grain moisture and testing dates.](image)

![Figure 7. Histogram of the mass fraction of protein in the grain variety “Luchezar” depending on the grain moisture and testing dates.](image)
Studies conducted to determine the gluten content in the grain of the winter soft wheat varieties “Admiral” and “Luchezar” with different moisture showed that with that grain moisture the gluten content of the “Admiral” variety (figure 8) was 24.6%, “Luchezar variety (figure 9) – 23.9%

![Figure 8](image1.png)

**Figure 8.** Histogram of the gluten content in the grain variety “Admiral” depending on the grain moisture and testing dates.

![Figure 9](image2.png)

**Figure 9.** Histogram of the gluten content in grain variety “Luchezar” depending on the grain moisture and testing dates.

During threshing the gluten content in the variety “Admiral” changed according to the decrease in the grain moisture.

The maximum decline of the gluten content to 22.7% was recorded with the moisture of grain 9.7%.

The decline of the gluten content is related to the maximum observed air temperature (38.7-39.3°C). As a result, gluten dehydration (compaction) occurs and its quality indicators decrease, it loses its...
connectivity, elasticity and extensibility.

With the overripe (5, 10 and 15 days), the content of gluten decreased to 22.7% versus the gluten content 24.6% at the beginning of the harvesting.

The analysis of the studies determined the same patterns of growth and decrease of the gluten content of the “Luchezar” variety depending on the grain moisture and harvesting time, as of the “Admiral” variety.

However, at all research stages, the absolute values of the gluten content in the grain of the “Luchezar” variety were lower (on average by 2.0%) compared with the “Admiral” variety.

As a result of the studies, it was determined that the mass fraction of protein and the content of gluten in the grain depend on the moisture and temperature mode of the environment and on the varietal features of studied genotypes.

4. Conclusions

Biological and physico-mechanical features in the separation of grain from ear were determined.

It was discovered that the largest number of micro damages of the “Luchezar” and “Admiral” varieties was recorded during threshing grain with its highest value of moisture and equals to 54% and 55%

It was determined that the largest content of the mass fraction of protein in the grain was observed during the milk-wax phase of grain ripeness, for the “Luchezar” variety (14.67%) and “Admiral” (14.60%).

The content of gluten changed depending on the grain moisture of the “Luchezar” variety from 23.9% to 19.7% and “Admiral” – from 24.6% to 22.5% (grain moisture 19.5-19.7%).

The determined value of seed damage and quality indicators (protein, gluten) depend on the selected variety, harvesting time and grain moisture.

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