RESEARCH OF QUALITY INDICATORS OF WHEAT SEEDS SEPARATED BY PRE-THRESHING DEVICE
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ДОСЛІДЖЕННЯ ПОКАЗНИКІВ ЯКОСТІ НАСІННЯ ПШЕНИЦІ ВІДДІЛЕНОГО ПРИСТРОЄМ ПОПЕРЕДНЬОГО ОБМОЛОТУ ЗЕРНА

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ABSTRACT

The influence on wheat grain quality indices of the preliminary threshing machine parameters of combine harvester header was investigated. The value of the trauma and the germination energy of the grain collected by the combine with the serial and experimental harvester were determined. It was established that as a result of passing the grain through the entire technological chain of the combine, germination energy decreased by 1.13 - 1.15 times. For the proposed options for preliminary threshing of grain, rational throughput values have been established, which correspond to high levels of germination energy. The highest germination energy level of the grain 99% was noted in the header, the drum of which contained four strips, according to the combine throughput 7.5 kg/s. This level was 7% higher than the serial header.

ABSTRACT

Досліджено вплив параметрів пристрою попереднього обмолоту зерна жниварки зернозбирального комбайна на показники якості зерна пшениці. Визначено значення травмування та енергії проростання зерна, зібраного комбайном з серійною та експериментальною жниваркою. Встановлено, що внаслідок проходження зерном усього технологічного ланцюга комбайну відбувається зменшення енергії проростання у 1,13 – 1,15 рази. Для запропонованих варіантів пристроїв попереднього обмолоту зерна встановлено раціональні значення пропускної здатності, яким відповідають найвищі рівні енергії проростання. У жниварки, барабан якої містить чотири планки, за пропускної здатності комбайна 7,5 кг/с зерна, найвищий рівень енергії проростання встановлено на рівні 99%, що на 7% більше ніж у серійної жниварки

INTRODUCTION

Mechanical damage of the grain leads to deterioration of its quality and storage, reduction of baking, technological, sowing qualities, etc *(Puzik L. and Puzik V., 2013).*

The level of seed damage is an integral indicator that allows evaluating the effectiveness of a number of decisions (factors) that are used to implement the technological process. The degree of seeds damage depends on the adjustment of the working units and aggregates of the combine, the biological phase of the plants development, the variety and the type of crops. Harmful are the micro damages in the grain embryo zone, mechanical damage to the germ and endosperm *(Kyrpa M. et al, 2009; Pecen J, 1994)*. A high level of micro damage of seeds is one of the reasons preventing it from promotion to European and world markets.

Low quality of domestic seed is due to significant damage in the conditions of its harvesting and primary processing. As a consequence, there is a discrepancy with the main indicators for seeding. In response to such circumstances, agrarians increase the sowing rate by 20-25% compared to the sowing by conditional seeds *(Harbar I. et al, 2010; Shpokas L. et al, 2016)*.

The research is based on the hypothesis that it is possible to intensify the process of separating cereal seeds from grain-straw mass (GSM) in the transportation phases by the preliminary threshing device of the header before the threshing-separating system (TSS) of the combine. Note that the previously threshed grain settles (concentrates) in the lower part of the process mass flow and is not damaged by the main threshing drum. It passes faster through the concave. This, as it is known, contributes to reducing the losses of the combine threshing machine. Therefore, it can be concluded that it is expedient grain pre-threshing by the header working units before the cut-off material enters the feeder house conveyor.

The grain threshing process occurs from the moment when the fingers of the header reel begin to interact with the stem. The degree of grain separation from the mass that the header is transporting depends on many factors: the technical and technological characteristics of the harvesting method, the phase of the crop growth, its humidity, maturity, variety, dynamic components of the effect on plants, and others.

Indicators of seed quality depend on many factors *(Fiscus D. et al, 1971; Tarasenko A., 2014)*. They include: 1) the physical and mechanical properties of the technological material, which is processed by threshing, determined by the moisture content of the grain and not the grain part, the ratio of the mass of grain and straw, the shape and structure of the grains, varietal characteristics and other properties; 2) factors associated with the construction of grain harvesting machines and equipment for post-harvest grain processing (types and parameters of working bodies, their arrangement); 3) technological regulations and operating conditions of the main mechanisms of the combine, especially the threshing separating device (drum speed, threshing gaps, feeding); 4) technical condition of the parts (wear of pests, planks, screws, scrapers, etc.).

Present mechanisms used for harvesting grain do not completely prevent seed damage. It should be noted that the level of seed damage depends significantly on humidity *(Zielinski A. and Mos M., 2009)*. Experiments have shown that if the humidity is more than 25%, the injuries are quite significant and can completely damage the germ. With increasing humidity, damage to the seeds increases. For all cereal crops, the optimum moisture for collection is 16-17% *(Derevyanko D., 2011; Shahbazi F. et al, 2012; Szwed G. and Lukaszuk J., 2007).*

It should be noted that the share of grains with macro-damage (crushed, flattened and compressed with damage to the germ or a separate part of the grain) is about 3-5%. The number of grains with micro-damages (damaged shell, hidden internal defects – scratches, dents, cracks, etc.) reaches a level of 50-80% or more (*Baker K. et al, 1986)*. Based on the studies of results of the TSS type influence on the micro-damage of grain, it was established that in an axial-rotor combine, an increase in the rotor speed from 520 rpm to 810 rpm results in a corresponding growth micro-damage of seeds from 25-30% to 45-50%. In the drum-walker combine, the increase in the drum rotation frequency from 700-760 rpm to 820 rpm leads to a corresponding growth of micro-damage of seeds from 37-38% to 41-44%.

MATERIALS AND METHODS

The conducted research aimed to determine the influence of working units, technological operations and technological processes on the indexes of seed quality (micro-damage).

To achieve this purpose, the following tasks were accomplished:

- to determine the quality losses (micro-damages) of wheat seeds separated by the preliminary threshing device in conditions of sequential setting in it of the developed and manufactured: intermediate threshing drum without additional slats (smooth drum) of threshing drum with a rasp bar under the drum; threshing drum with two additional slats (tooth-like profiles with a height of the bar 20 mm, 30 mm and smooth slats) of the intermediate threshing drum with four additional slats (tooth-like profiles with a height of the bar 20 mm, 30 mm and smooth slats) compared to the standard header;
- to determine the level of micro-damages accumulation for the combine's bunker grain as a result of the entire technological cycle of threshing;
- to determine the effect of the throughput of the combine on the quality of grain, separated by a pre-threshing device.

We have developed a preliminary threshing device for grain located in a feeder house of a combine harvester KZS 9-1 "Slavutich". The basis of the device for preliminary threshing of bread mass in the combine harvester was an intermediate thrashing drum and a deck installed below it (Fig. 1). Kherson machine-building plant manufactures the family of KSZ 9-1 "Slavutich" Ukrainian grain harvesters.

Experimental research was carried out on the experimental field of the National Scientific Centre "Institute of Agriculture Engineering and Electrification", sown with winter wheat of Mironovskaya 61, according to standard methods *(Dospehov B., 2014; Vedenyapin G., 1973).* The yield of the field was 5.5 t/ha.

According to the study plan each sample was taken from a combine harvester stone trap which is located in front of the main threshing drum. This mass, which accumulated there, was a mixture of grain separated from the ear, uncoated grain into a spikelet, chaff and straw. Accumulated mass in a stone trap was placed in specially prepared packages beforehand by signing them.

Experimental research was carried out on the preliminary threshing device of a grain combine KZS 9-1. The research program was designed to test an intermediate cylindrical beater with pull-out pins (serial header) in comparison with the following developed and manufactured designs of a preliminary thresher device (a 330 mm cylindrical toothed-blade drum) of an experimental header. These are: a header with a threshing drum without additional slats (smooth drum); a header with an intermediate threshing drum and a rasp bar under it; header with an intermediate threshing drum with two additional slats (tooth-like profiles of a 20 mm, 30 mm slat height and a smooth bar); header with an intermediate threshing drum with four additional (tooth-like profiles of a 20 mm, 30 mm height and a smooth bar). A steel corner (measuring 45 x 45) was used as the slats, one side of which was attached to the side surface of the drum. On the other side of the corner, a tooth-shaped profile was cut in the form of equilateral triangles 20 mm high and 30 mm high.

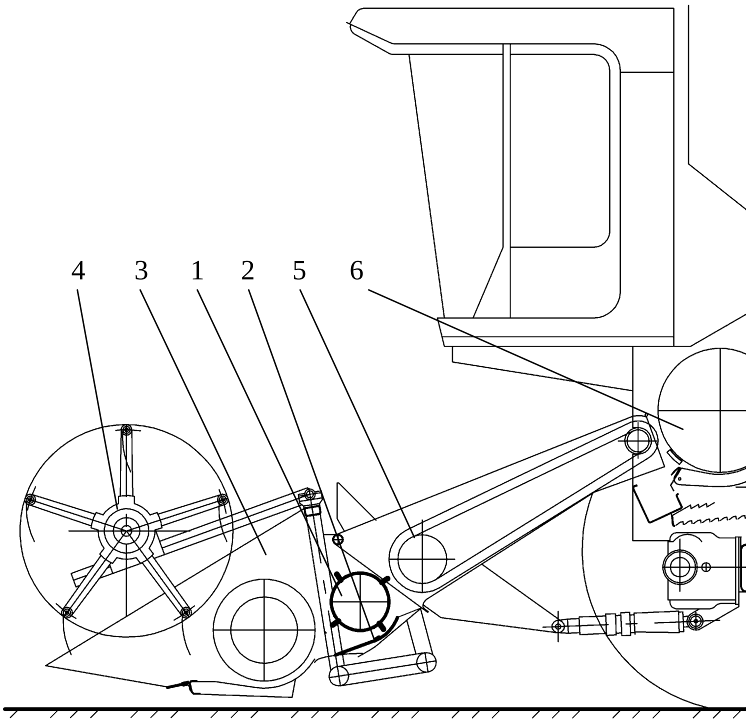

Fig. 1 - General view scheme of a combine harvester header with a device for preliminary grain threshing:
1 − a tooth and spatulate shaped thrashing drum; 2 − a deck; 3 − a header; 4 − a reel; 5 – an inclined chamber conveyor; 6 – threshing-separation system of combine harvester

The methodology of the research included the selection of a site with a uniform and aligned stand of grain. Studies were conducted at four speeds of movement of the combine in three replications. The speed of the combine varied within 0.56-1.67 m/s.

When conducting experiments, we determined the length and area of the experimental plot, the time it took for the combine to pass through the experimental plot, the speed of the combine.

Processing of research results was carried out under laboratory conditions. The mass of the separated grain, the mass of not separated grain and the total mass of the grain in the GSM were determined in the laboratory according to the results of the disassembly of samples taken in the field.

Throughput was determined according to dependencies (1), (2):

$$q = \frac{B \cdot v \cdot Q}{360}, \tag{1}$$

$$Q = Q_G + Q_G \cdot \beta \tag{2}$$

q is the throughput, [kg/s];
B – width of the header, [m];
v – speed of the combine, [km/h]

Q – yield of grain and straw, [t/ha];

Q_G – grain yield, [kg/ha]*;*

β – proportion of straw by weight relative to grain yield.

Estimation of germination and germination energy was carried out according to the ISTA technique *(ISTA Documents, 2011)* and methods of national standard. To determine the germination energy and seed germination, 4 samples of 100 seeds were formed from each sample tested. After that, the seeds were put on 3 layers of moistened filter paper with special vessels (cup of Koch, Petri), which were placed in a dark place. The germination energy was determined by the number of similar seeds 3 days after the germination began, the seed germination was determined after 7 days.

After the term of germination and the end of all calculations, all identified seedlings are divided into three groups according to the quality of germination: a) normally germinated; b) not germinated; c) not sprouting.

The germination and germination energy was determined in percent. Based on the results of the analysis, the arithmetic mean of the results of determining the similarity of all four analyzed samples was taken. Investigation of the germination and germination energy was also carried out for wheat seeds, which were seized in different places of the combine harvester after passing through the whole threshing cycle. The main goal of these studies is to determine the influence of working units, technological operations and technological processes on the indicators of seed quality.

Grain damage at threshing, separation and transportation was determined in accordance with methods for seeds testing. During the research, the amount of damaged wheat seeds in the total mass was assessed, which affects the technological properties of the seeds as a raw material for further processing.

The micro-injury investigation was carried out for wheat seeds taken from different locations of the combine harvester as a result of the threshing cycle.

The processing of experimental results was carried out taking into account the methods of regression analysis. The approximation of the experimental dependencies by the mathematical model was performed using the least squares method using the statistical software package STATISTIKA-6.5. Checking the adequacy of mathematical models was carried out using the elements of variance analysis using the Fisher criterion at a confidence level of 0.95.

RESULTS

There were taken samples of grain from the grain harvester hopper to assess the impact level on seeds of the working units of the entire threshing technological cycle (experimental header).

Based on the results of the conducted investigations, it was established that the arithmetic mean value of the germination energy of the grain harvested by the serial header, as well as the experimental samples (header with a rasp bar under the drum, a header with a smooth drum, a header with a drum that contains two slats, a header with a drum with four slats) was in the range of 88-98% (Figure 2). It should be noted that the speed of the combine harvester did not significantly affect grain quality indicators. This is due to the fact that the experiments were carried out under conditions of a sufficiently high grain yield (5.5 tons/ha) and the grain harvester capacity was 8-10 kg/s.

Micro-damages were assessed according to the following indices: damage to the grain shell; damage to the germ; whole seed.

The average index of damage to the grain shell in the serial header was 10.5%, in the experimental header with a rasp bar under the drum – 9.5%, in header with two additional slats on the drum – 7.25%, header with 4 additional slats on the drum – 10.25%; header without bars on the drum – 11.25%. The highest level of damage to the shell of the grain is installed in the header, without slats on the drum – 11.25% (Figure 3). This is due to the fact that, because of the lack of slats on the drum (smooth drum), the duration of the interaction of the free grain separated from the GSM with the moving layer of mass fed will be greater. Grain-straw mass will slide over the layer of separated grain. Note that in the absence of slats on the drum, the residence time and thickness of the grain layer will be higher than in the designs with slats. This causes a multiple dynamic effect of the GSM (fluctuations in the thickness of the layer, both GSM and separated grain) on the layer of separated grain, which leads to an increase in the index of damage to the grain shell.

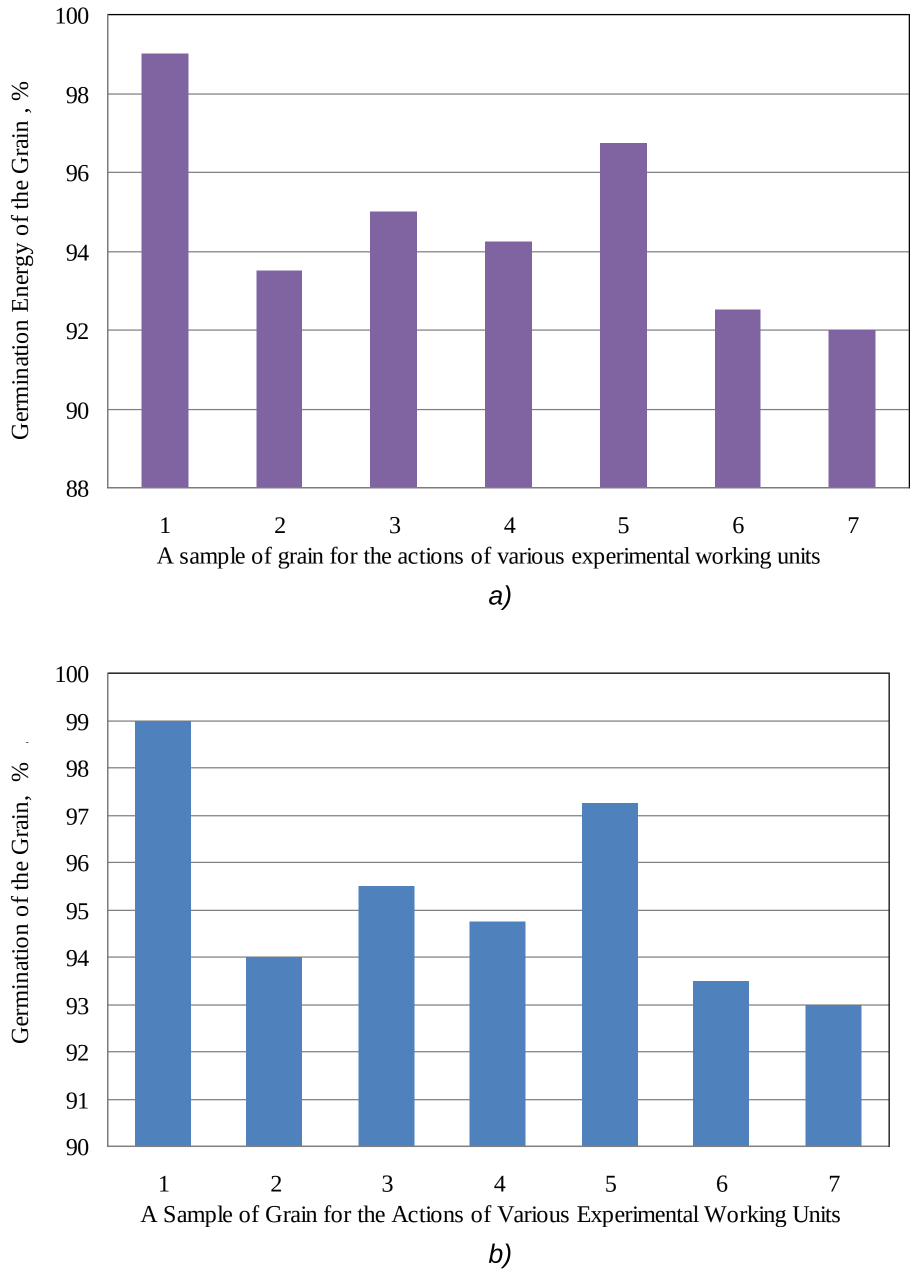

Fig.2 - Research results diagram of the germination energy *(a)* and the wheat grain germination *(b)* separated by the preliminary threshing device under the conditions of successive setting of experimental working units:
1 - non-threshed grain; 2 - the establishment of rasp bar under the drum; 3 - smooth drum; 4 - a drum with two slats; 5 - a drum with four slats; 6 - grain from the feeder house of the serial header; 7 - grain from the combine's hopper

The least indicator of damage to the grain shell is installed in the header with two additional slats on the drum – 7.25%. The value of the average grain damage factor in the serial and experimental header with 4 additional slats on the drum was approximately the same. The results for determining the level of damage to the grain shell are shown in Fig. 3.

It should be noted that there was certain deterioration in the transport function of the feeder house in the course of the research on experimental samples of the header (header with a rasp bar under the drum, a header with a smooth drum, a header with a drum that contains two slats). It was caused by the fact that experiments at the planned high levels of combine speeds were not realized, because the increase in speed led to the formation of mass that was ejected from the feeder house and accumulated from the outside. Due to this, the operator reduced the speed of the harvester's movement in order to stabilize the transportation function and ensure that the mass formed above the camera enters the feeder house.

Fig. 3 - Research results diagram of the grain micro-damage of wheat grain separated by the preliminary threshing device under the conditions of successive setting of experimental working units:
1 - grain from the feeder house of the serial header; 2 - the establishment of rasp bar under the drum; 3 - smooth drum; 4 - a drum with two slats and 30mm tooth height; 5 - a drum with two slats and 20mm tooth height; 6 - a drum with two smooth slats; 7 - a drum with four slats and 30mm tooth height; 8 - a drum with four slats and 20mm tooth height; 9 - a drum with four smooth slats; 10 - grain from the combine's hopper

The effect of the combine throughput on wheat seeds quality indicators was determined in order to establish the most rational operation modes of the combine with the header, containing the proposed design of the preliminary threshing device.

It was established that each of the considered devices of the previous grain threshing is characterized by a different value of the throughput level, according to which the injury of the grain will be minimal (Fig. 4).

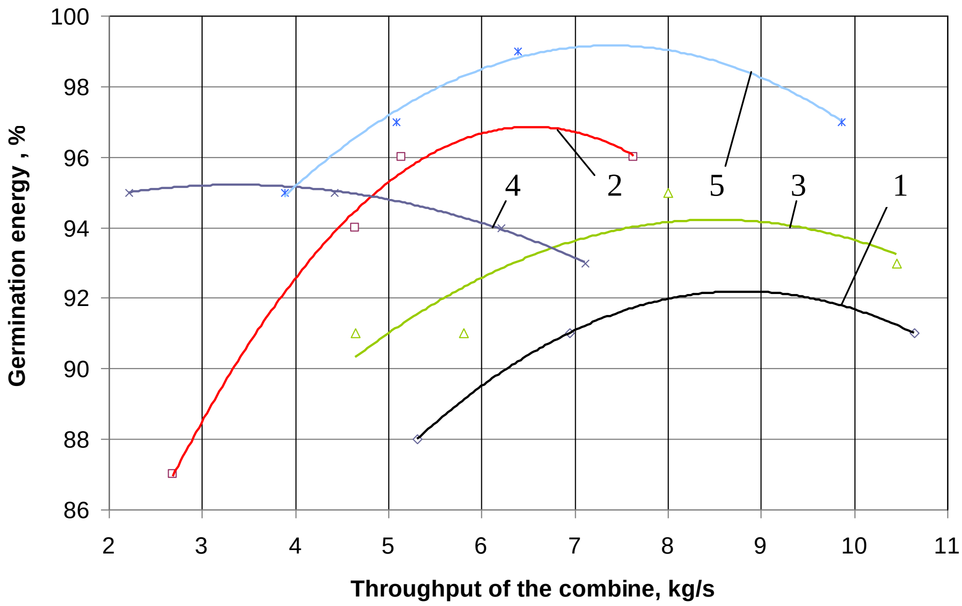

Fig. 4 - Experimental dependencies of grain germination energy on the combine throughput:
1 - serial harvester; 2 - a header with an intermediate threshing drum, which contains a bar under the drum; 3 - header with a smooth drum; 4- header with an intermediate threshing drum, which contains two additional strips; 5 - headers with an intermediate threshing drum, which contains four additional strips

According to the results of the conducted research, the highest germination energy level of the harvested grain was determined by a reaper, the drum of which contains four strips - 99% for loading the combine thresher at 7.5 kg/s.

Values of grain germination for all samples were studied and did not significantly differ from the arithmetic mean values of germination energy.

CONCLUSIONS

According to the results of the conducted investigation it was established that the arithmetic mean value of the germination energy of grain harvested by the serial header was 91-95%, for the header, which contains a rasp bar under the drum was 88-96%, for header with a smooth drum was 93-96%, for the header, the drum of which contains two bars was 93-95% and four bars was 95-98%. The arithmetic mean value of the germination energy of the non-threshed grain (from the sheaf) was 99%, and the grain from the combine harvester hopper was 92%.

The highest values of the grain germination energy are recorded in the header the drum of which contains four slats (95-98%). It was established that as a result of passing the grain through the entire technological chain of the combine, germination energy decreased by 1.13 - 1.15 times.

The values of the grain germination indices for all the samples investigated did not differ significantly from the arithmetic mean values of the germination energy indices.

It was found that the value of the indicator of the unharmed seed in header with a rasp bar under the drum was 86.75%. It was 86,5% for the serial header, 85.75% for the header with two additional slats on the drum (tooth profile, tooth height 30 mm), 83.75% for the header with four additional slats on the drum (tooth-shaped profile, tooth height 30 mm) and 82.5% for the header with no slats on the drum.

According to the integral index of micro-damage, the grain from the grain harvester's hopper had the most highest indicators - 19.5% (14% shell damage and 5.5% germ damage), which is 6.25% worse than in the header with a rasp bar under the drum, 6% more than in the serial header, 5.25% more than in the header with two additional slats on the drum (tooth profile, tooth height 30 mm) and 4.25% more than in the experimental header with four additional slats on the drum (tooth profile, height tooth 30 mm).

For the proposed options for preliminary threshing of grain, rational throughput values had been established, which corresponded to high levels of germination energy.

The highest germination energy level of the grain 99% was noted in the header, the drum of which contained four strips, according to the combine throughput 7.5 kg/s. The high level of grain germination energy for a serial header of 92% was noted at a combine throughput 8.5-9.5 kg/s. The maximum values of the grain germination energy were observed: for the header with a pre-threshing device with a bar under the drum at a throughput 6-7 kg/s; for a header with a smooth drum – 8-9 kg/s.

The level of the germination energy of the grain, which was collected after an experimental header with a pre-threshing drum with four slats, was 7% higher than grain in the serial header. A small decrease (1.0-1.5 kg/s) of the throughput of the combine was noted during the study.

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