INFLUENCE OF DIFFERENT THRESHING SYSTEM DESIGN ON GRAIN DAMAGE

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Abstract. The aim of this work was to identify and compare how the threshing mechanism of combine harvesters affects damage on the grain. This comparison was based on field measurements, which took place in 2014 and 2015. The measurements were performed on two types of combine harvesters, with tangential (MF Cerea 7270 and Claas Lexion 580) and axial (Case AFS 9210 and NH CR 9080) threshing mechanisms. Winter wheat and spring barley grains were evaluated after threshing. It was found, that the more damaged grains were after the work of combine harvesters threshing with the tangential way. In average, combine harvesters with tangential threshing mechanism damaged 1.84 % of grain in comparison with axial combine harvesters 0.35 % of grain. The results showed that the axial threshing system of grain harvesters damaged the grain significantly lower in comparison with the tangential threshing mechanism. Higher germination ratio was determined on grains which were harvested with axial harvester threshers. Differences in germination of grains were not so high in the compared different threshing systems, it was 95.00-97.83 % by winter wheat and 93.75-96.75 % by spring barley.

Keywords: Claas, Case IH, New Holland, Massey Ferguson, combine harvester, grain, germination.

Introduction

Nowadays, combine harvesters are playing a crucial role in grain harvest. That is the reason that today they are very widespread in agricultural production companies as well as in service companies of agricultural machinery. Since 1938, when utilisation of a self-propelled combine harvester started [1], the combine harvesters have undergone development of structural elements, which resulted in increasing throughput materials through combine harvesters. Self-propelled harvesting combines are the key machines to realize performance in grain harvesting [2]. The last three decades of the development of combines was characterized by improvement of the productivity and efficiency – increase of the size and total weight of the machines and increasing productivity and efficiency [3].

The combine harvesters have also been evaluated according to a different concept of grain threshing and separation. Depending on the direction of the material flow through the threshing mechanisms the combine harvesters are described as tangential (direction of the flow in the tangent of the threshing drum) and axial (flow of material in the direction of the axis of the threshing-separating drum). According to Kumhála et al. [4] combine harvesters could be termed "conventional" and "unconventional". By the conventional combine harvesters they mean all the classic technological conceptions, using the tangential way of threshing and keyboard straw walkers. By the conventional combine harvesters they mean all the other machines that use axial rotational elements for both separation of grain or grain threshing and separation. The third group of combine harvesters has a tangential threshing system, but separation is equipped by an axial unit (one or two rotors), generally this system is known as hybrids. Rotary separators, both axial and tangential, appear better suited to handling stripped material than do straw walkers because their more aggressive action teases out the material and allows easier release of the grain [5].

Mechanical damage of seeds during harvesting and threshing, especially in naked cultivars, is one of the main factors decreasing the volume and quality of the yield [6]. Mechanical damage due to harvesting, handling, and other processes is an important factor that affects the seed quality [7]. Seed damage means lower grain value, reducing seed germination and increasing problems with storability of grain.

The causes which affect the mechanical damage of grain during harvest can be divided into the following four groups.

1. Technological quality setting and regulation of the combine harvester.
2. Structural differences of the threshing system and working mechanisms of the combine harvester.
3. Technical condition of the threshing mechanism and other parts of the combine harvester.
4. Physico-mechanical properties of the grain mass.

In the article evaluation of grain damages caused by different types of combine harvesters quipped by different systems of threshing and separation is described.

Materials and methods

Field measurements in order to determine the impact of construction on the threshing mechanism of grain damage were done in 2014 and 2015 seasons. In these years at harvest grain samples of winter wheat (*Triticum aestivum* L.), variety Meister and Potenzial and spring barley (*Hordeum vulare* L.*)*, variety Malz were collected. Harvesting took place in the Elbe lowlands, particularly in the fields around the village Popovice, which is located approximately 30 kilometres east of Prague in central Bohemia. This area is characterized by high quality soil and favourable climate conditions. These are important preconditions for achieving high yield. At each grain sampling there were optimal harvesting conditions. The parameters of the harvested fields and crops are in Table 1.

Table 1

Basic parameters of crops and fields harvested in seasons 2014 and 2015

Season	**2014**		**2015**	
Crop	Winter wheat	Spring barley	Winter wheat	Spring barley
Variety	Meister	Malz	Meister	Malz
Harvest	2.8.2014	22.7.2014	27.7.2015	23.7.2015
Size of field, ha	51.42	30.04	28.38	94.50
Grain moisture, %	15	13	14	12
Yield, t·ha^{-1}	7.9	5.5	8.0	7.0

On the field a group of four combine harvesters worked together. The tangential method of threshing was represented by the harvesters Massey Ferguson Cerea 7278 and Claas Lexion 580. Representatives of the axial threshing system were Case AFS 9210 and New Holland CR 9080. Due to the possibility of repetition of the measurement the harvester settings and adjustment were according to the default setting, which is offered in onboard computer. This setting is recommended by the manufacturer of the combine to achieve an optimum result during harvest.

Each evaluated combine harvester worked till the grain tank was full. After it, when discharging the grains the representative sample weighing about 5 kg was collected in a plastic container. Thus, the samples were then examined and compared in terms of two parameters. The first parameter was the amount of mechanically damaged grains contained in the laboratory sample. The second examined parameter was threshed grain germination ratio.

Weighed quantities of damaged grains of individual measurements using the formula (1) are expressed as a percentage. The average percentages for individual types of combines and crop for both reporting seasons was calculated using the formula (2).

$$y_i = \frac{a}{b_i} \cdot 100, \tag{1}$$

where y_i – amount of damaged grains contained in the laboratory sample, %;
a – weight of the laboratory sample, g;
b – weight of damaged grains, g;
i – expresses the number of measurements; i = 1; 2; 3, ... 10.

$$z = \frac{1}{10} \cdot \sum_{i=1}^{10} y_i , \tag{2}$$

z – average number of damaged grains, %.

Germination of grains was determined according to ČSN 46 1011-13 regulations. The essence of this test is to soak the exact number of grains for a set time in hydrogen peroxide solution. Three measurements were performed for each sample from the individual collected sample from each combine harvester. Into two beakers 200 grains were counted, which were potted by 200 ml of 0.75 % hydrogen peroxide solution (5 ml of 30 % hydrogen peroxide with distilled water to 200 ml total volume of solution). The beakers were placed in a dark box which prevents the access of day light. After 48 hours the beakers were removed from the box and the solution was decanted through a sieve. To the beakers again 200 ml of fresh 0.75 % hydrogen peroxide solution were poured and the beakers were repeatedly placed in the dark box, now for 24 hours. After elapsing this time period the solution was removed from each beaker and the grains were transferred to laboratory trays. Here were non-germinated grains selected. It was the grains which did not exhibit obvious growth of roots and sprouts. The germinated grains were calculated using formula 3 and 4. For germination test only grain without visible mechanical damage is used.

$$x_i = \frac{(200 - n_1) + (200 - n_2)}{400} \cdot 100, \tag{3}$$

where x_i – germination of grains, %;
n_1 – number of sprouted grains in the first beaker, pcs;
n_2 – number of germinated grains in the second beaker, pcs;
i – expresses the number of measurements; i = 1; 2; 3.

$$k = \frac{1}{3} \cdot \sum_{i=1}^{3} x_i, \tag{4}$$

where k – average germination of grains, %.

Results and discussion

The results of mechanically damaged grains are shown in Fig. 1 and Fig. 2. There is statistically significant difference between the tangential and axial threshing system in the number of damaged grains. The tangential threshing system is more aggressive and it causes a higher level of mechanical damaging of grains.

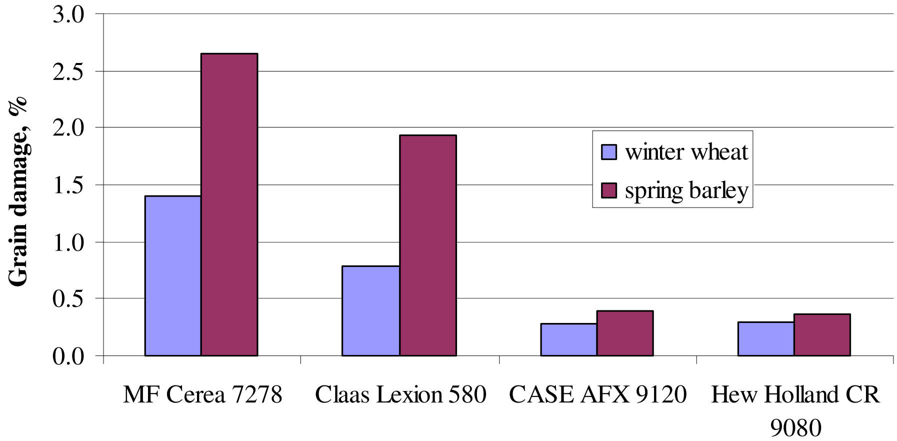

Fig. 1. **Average amount of damaged grains harvested in 2014**

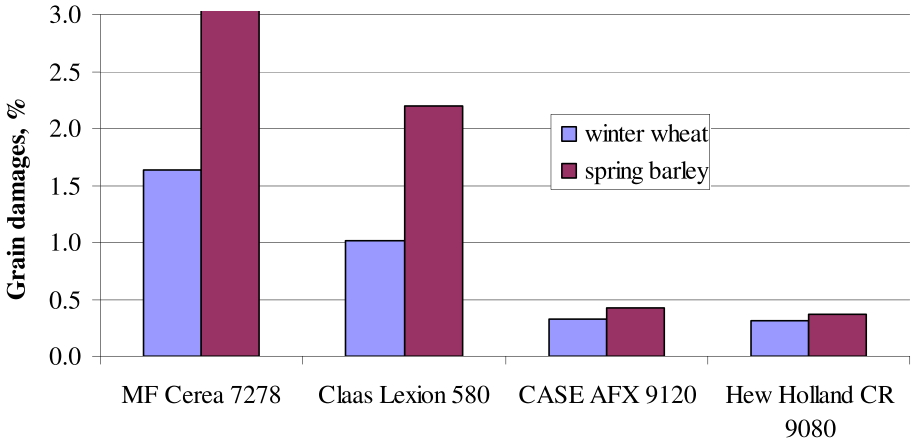

Fig. 2. **Average amount of damaged grains harvested in 2015**

The axial system works more gently and grain is less mechanically destroyed. There is the second interesting investigation that different crops have also influence on the level of mechanical damage. From this point of view is possible to say that spring barley is more sensitive to mechanical damage caused by the tangential threshing system. There is statistically significant difference on the chosen level of relevance ($\alpha = 0.05$). There is no significant difference between wheat and barley by using the axial threshing mechanism (Fig. 3). For evaluation STATISTICA software was used, tools ANOVA.

The field measurement in terms of the amount of damaged grains showed that the combine harvester based on the tangential threshing mechanism was damaging the grain more than the axial combine harvester, with a fairly significant difference. The average value of the amount of damaged grains of spring barley at the combine harvester Massey Ferguson 7278 Cerea was in the season 2014 of 2.65 %. At the combine harvester Claas Lexion 580, the amount of damaged grains was 1.93 %. By measurement of axial combine harvesters considerably lower values were measured.

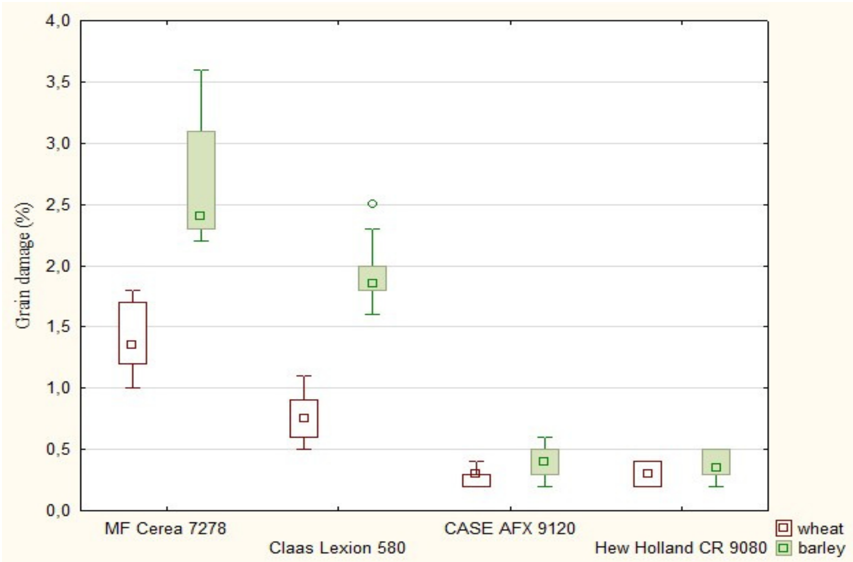

Fig. 3. **Results of ANOVA evaluation of grain damage**

At the combine harvester Case AFS 9120 there was an average amount of damaged grains 0.39 % and at New Holland CR 9080 the value was only 0.37 %. The amount of damaged grains of winter wheat compared with spring barley was for combine harvesters based on tangential threshing mechanism about 50 % lower. For axial combines the average value of damaged grains of winter wheat was 0.29 %. A slight increase was found in the amount of damaged grains in the season 2015, at all compared combine harvesters and crops compared the year before. It could be probably due to lower moister content of grain. By lower moister content grain is more sensitive to the mechanical damaging.

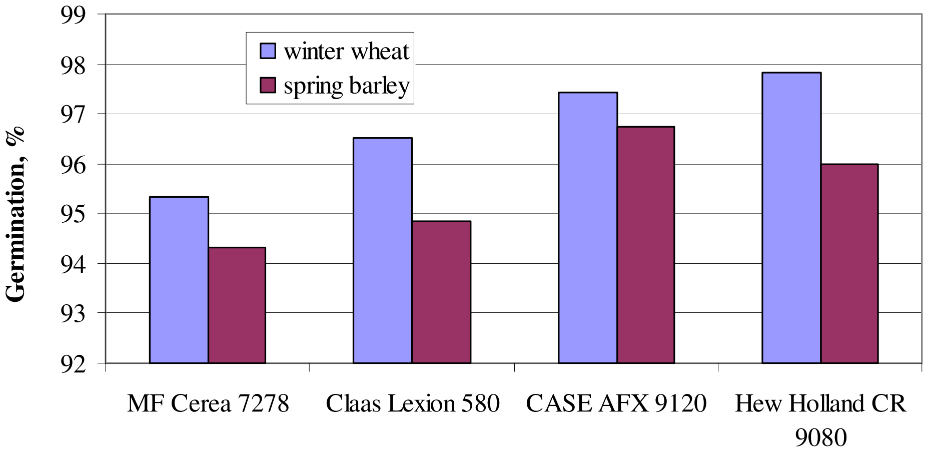

Fig. 4. **Average germination of grains harvested in 2014**

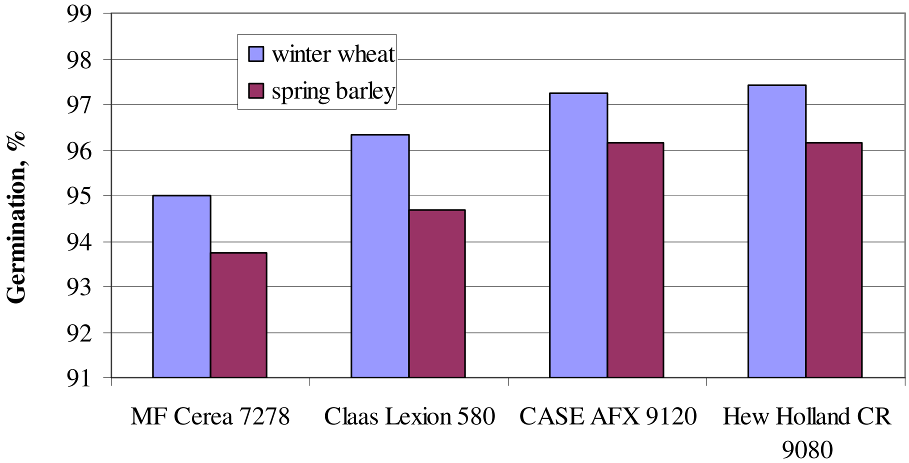

Fig. 5. **Average germination of grains harvested in 2015**

Lower average value of germination was measured in grains processed by the machine with a tangential threshing mechanism (Fig. 4. and Fig. 5). This verified and confirmed the results of previous measurements.

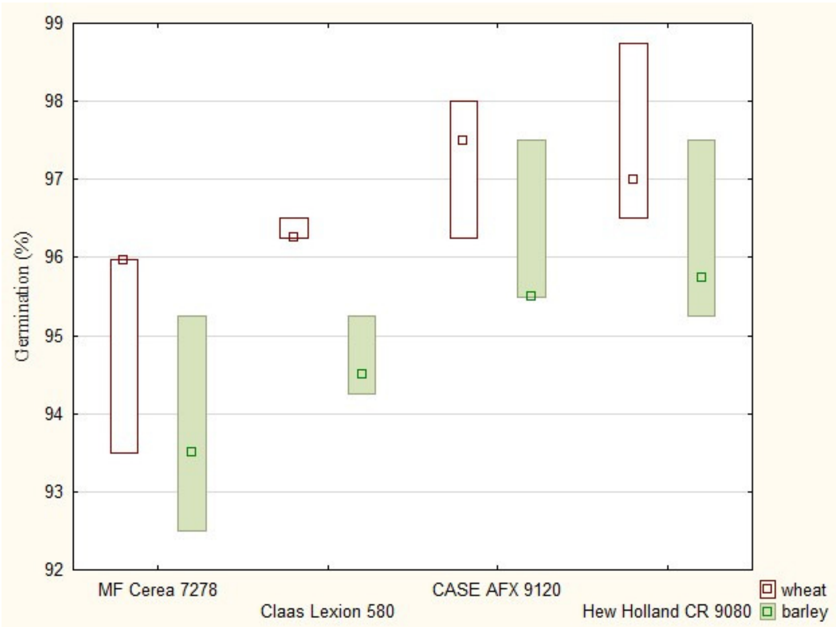

Fig. 6. **Results of ANOVA evaluation of grain germination**

The differences between the measured values of germination of grains are not as significant (Fig. 6) as differences in the measurement values of the first parameter (damage of grains). The lowest value of germination of grains of spring barley was 93.75 % and the highest 96.75 %. The lowest value of germination of winter wheat grains was 95.00 % and the highest 97.83 %. But there is statistically significant difference ($\alpha = 0.05$) between the axial and threshing system, too. The grains harvested by axial units have higher germination ratio.

Conclusions

1. The field experiment and followed up laboratory test confirm the hypotheses that the axial threshing system causes lower mechanical damaging of harvested grain (amount of damaged grains was 0.37-0.39 %) compared to the tangential threshing system (amount of damaged grains was 1.93-2.65 %).
2. The grains harvested by the axial threshing system have significantly higher germination ratio, more than 97 % (wheat) and more than 95 % (barley).

3. Indirectly the influence of grain moisture content on mechanical stability of grain is confirmed.
4. Recommended setting of the working mechanisms must be modified according to the actual and local condition.
5. Impact of the actual year weather on mechanical behavior of the grains may be expected.

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