The measurement of plant residues distribution quality after harvest by conventional and axial combine harvesters

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ABSTRACT

This paper concerns the evaluation of the husk and straw distribution quality measurement on different commonly used combine harvesters. The plant residues can significantly influence the next plant germination and growth, especially when they are unevenly placed on the field surface. The experiments were realised during the harvesting season in years 2001, 2002 and 2003. All machines were evaluated under normal operational conditions by winter wheat and oil rape harvest. For plant residues distribution quality evaluation the Christiansen's coefficient was calculated. The most important outcome from the measurement is that the distribution pattern of husk and straw depends on instantaneous material feed rate through the harvester. The higher material feed rate the worse regularity of husk and straw distribution. Axial combine harvesters break up straw more intensively then tangential combine harvesters. Straw crushers on tangential combine harvesters are therefore more loaded and need more attention from the crushing and distribution quality point of view. On the contrary, on axial combine harvesters most material goes on cleaning sieves and more attention should be paid to this small particles distribution.

Keywords: combine harvesters; straw crushing; plant remains; distribution quality

Conservation tillage (or no tillage) systems with their modifications are increasingly being introduced under an economic pressure also into areas with less favourable soil and climatic conditions of the Czech Republic.

Besides the advantages of the application of this kind of soil cultivation, there are some problems and risks arising, which are not significant when ploughing is applied. It is typical for shallow soil tillage that all plant residues are left on the soil surface or in the treated (tilled) upper soil layer. The plant residues can play an important role by the next plant cultivation. Based on lots of research (Johnson 1988, Ball and Robertson 1990), it can be said that all possible negative effects (effects on next plant seed germination, grain losses growth, rhodents spreading) can be eliminated or at least minimized as early as when the preceding crop is harvested (the minimum height of a stubble-field, maximum length of crushed straw particles up to 5 cm and good regularity of plant residues left on the field surface after combine harvester passage). Furthermore, negative effects can be minimized by an appropriate technology and its application time.

The decomposition of the primary organic matter in the soil is an important and frequently discussed problem of conservation tillage systems. If the post-harvest residues and organic manure are shallow-incorporated into the soil or if they are partly left near the soil surface, there arise considerations about organic matter accumulation in the upper soil layer after long time omission of tillage and about the insufficient decomposition of organic matter to produce humus after shallow incorporation (Horáček et al. 2001).

On the other hand, the agricultural enterprises specialized in cereals growing do not usually have livestock production or cattle breading. Thus, cereals straw remains in the field is a main source of essential organic matter supplied to the soil.

Procházková et al. (2003) says that a great number of researches have been engaged in the effects evaluation of straw incorporation into soil on consecutive crop yields and changes in the soil environment. These results show that straw manuring, particularly combined with shallow soil tillage, often generates problems associated with the proper crop establishment. Furthermore, straw can inhibit the germination, emergence and initial growth of consecutive crops. The inhibition mostly comprises physical and biochemical effects (water consumption for straw decomposition, phytotoxic substances released from straw or produced by its degradation).

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Such problems are more frequent under drier conditions and by growing winter cereals because there is a short period between straw incorporation into soil and seeding. Annual straw manuring at repeated cereals growing usually leads to an abundant soil supply with organic matter. Both deficient and excessive supply of organic matter into soil can adversely affect the quality of the soil environment and grown crops.

According to the described results it has been revealed, from the previous crop harvest point of view, that the cross irregularity of husk and straw distribution is a very significant point for the start of the next crop planting. Kvíz et al. (2003) measured the distribution quality of plant residues after harvest by different combine harvesters under normal operational conditions on two different plants, winter wheat and oil rape during one harvesting season. One from the outcomes of these measurements was that the irregularity of crop residues' distribution was always increasing with increasing feed rate of combine harvester.

This article concerning the husk and straw distribution cross irregularity follows up with the measurement mentioned above.

The main subject of this article is the observation of the husk and straw distribution cross irregularity on axial and tangential combine harvesters in a real operation during three consequent harvesting seasons.

MATERIAL AND METHODS

Crushing mechanisms of combine harvesters have to ensure a good quality of straw crushing (90% of all particles must be shorter than 80 mm) (Kumhála et al. 2002) and the crushed straw and other organic remains (husks, weed seeds, grain losses etc.) have to be evenly distributed along the working width of the machine.

The straw and husk distribution quality was observed after each passage of a combine harvester in 6 m wide strip where the crop residues should have been distributed on a field surface. This 6 m wide strip corresponded with the machine's working width and was divided into 0.5 m intervals. Then, all plant residues were collected from 0.1 m^2 area.

The measurement of a husk and straw distribution pattern was carried out on Case IH 2188 combine harvester with an axial threshing system and on John Deere 2264 with a conventional tangential threshing system. Thereby, it was possible to compare two completely different systems of threshing process and to observe a possible influence on straw and husk distribution quality.

Combine harvester John Deere 2266 was equipped with 199 kW engine power; 5.9 m header in width; 660 mm threshing drum in diameter and 1670 mm in width; total concave area 5.83 m^2; total straw walkers area 7.67 m^2; total sieves area 5.83 m^2; standard straw chopper equipped; twin vane-disc chaff distributor mounted (JD equipment retrofitting).

Combine harvester Case IH 2188 was with 196 kW engine power; 5.9 m header in width; rotor placed longitudinally; 762 mm rotor in diameter; 2970 mm rotor in length; total cleaning area 5.12 m^2; standard straw chopper and two disc chaff-straw distributor mounted. For the measurements Case IH combine harvester with the husk distributor's improvement (described by Kumhála et al. 2002) was used in all cases.

The number of repetitions by each measurement variant was three at minimum. It means we had 12 interval samples from one combine passage with three or more repetitions.

Our experiments were realised during the harvesting season in July and August in years 2001, 2002 and 2003. All measurements were carried out at Ing. Zdeněk Kvíz's farm in Bratřínov village in the field called Za Chadimou and Struha. The samples were being taken under normal operational conditions and therefore represent common machine setting, forward speed and harvested plant state suitable for optimal harvest.

Measurement conditions

Oil rape harvest – combine harvester setting by the manufacturer recommendations, working speed 5–8 km/h, grain moisture 9%, straw moisture 15%. The average yield was different during harvesting years and varied from 1.1 t/ha (2003) to 2.7 t/ha (2001). In 2002, the measurement on oil rape was not carried out because of the very difficult harvesting conditions after the floods in the Czech Republic.

Winter wheat harvest – combine harvester setting by manufacturer recommendations, working speed 4.5–7 km/h, grain moisture 14%, straw moisture 16%, average yield varied from 2.7 t/ha (2003) to 4.8 t/ha (2001).

The measurement of husk and straw distribution quality on Case IH combine harvester was also carried out in 1999 (Kvíz et al. 2003). It was the first measurement for gaining a general idea about this problem.

For plant residues' distribution quality evaluation the Christiansen's coefficient was used. This coefficient determines a percentage deviation of each measurement from all measurements' arithmetic mean. When these deviations are small the value of Christiansen's coefficient is close to 1 (100%) and *vice versa*. The coefficient is calculated using following formula:

$$C_u = \left[1 - \left(\sum_{i=1}^{n} |i_{si} - i_m| / n \cdot i_m\right)\right]$$

where: i_{si} – weight of an i interval sample (g)
i_m – arithmetic mean of i_{si} values (g)
n – number of samples

This coefficient is accepted by various standards (ASAE 1983, ČSN 11 0046) and is frequently used for evaluation water distribution uniformity of irrigators etc.

RESULTS AND DISCUSSION

For every measurement the Christiansen's coefficient was counted separately for husk and for straw remains. It was assumed that the distribution quality of crop remains would depend also on their immediate amount so the Christiansen's coefficient was calculated in dependence on the total observed weight of the straw and/or husk per square meter in one measurement (composed of 12 interval samples) as well.

These values were processed separately for oil rape and winter wheat, each time for straw and husks separately and for both evaluated combine harvesters. Graphical evaluation of our measurement was carried out by means of MS Excel charts. It was decided to use the range of Christiansen's coefficient in the interval from 0 to 1 (it means not in %) for charting.

Oil rape

The results of distribution quality evaluation for the oil rape harvest appears in the charts on Figure 1 (straw distribution) and Figure 2 (husk distribution). It follows from presented charts that the measurement for oil rape were realised during two harvesting seasons only (2001 and 2003). The measurement in the harvesting season 2002 was not possible to realise because of problems

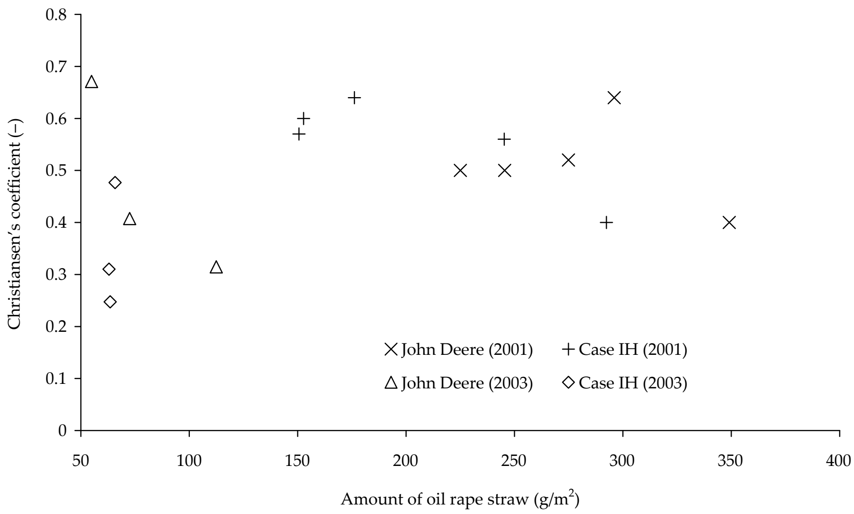

Figure 1. Dependence of Christiansen's coefficient value on amount of oil rape straw

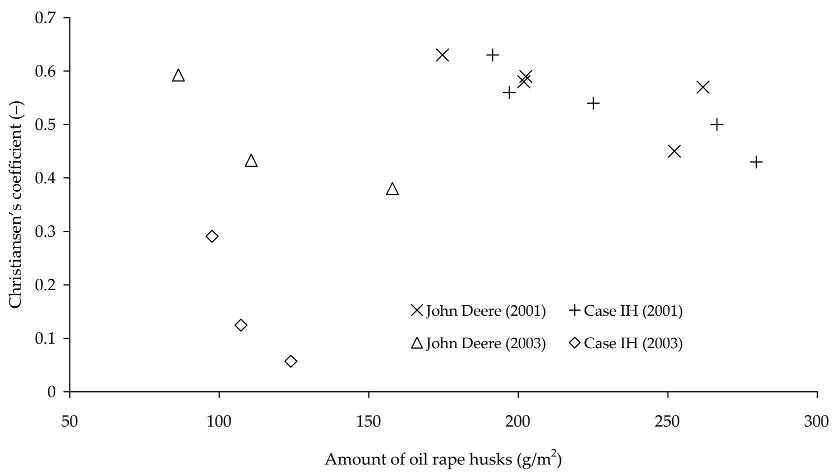

Figure 2. Dependence of Christiansen's coefficient value on amount of oil rape husks

connected with floods during summertime in the Czech Republic.

It is evident from both charts that the amount of harvested material per square meter was considerably higher during the measurements carried out in 2001 in comparison with the measurements from 2003. It was caused by a small amount of precipitations during the summer period of this year. In consequence of this fact the oil rape yield was relatively low in this year (fluctuated around average value of 1 t/ha) and the amount of plant residues was smaller as well. As opposed to the season 2001 the conditions for oil rape production were relatively favourable and the average yield from the tested fields fluctuated around 2.7 t/ha. The amount of plant residues was also higher in this year for that reason.

Another finding was that the amount of straw seems to be higher for John Deere combine harvester than for Case IH combine and on the other hand the amount of husks and other small particles seems to be higher for Case IH than for John Deere. This fact can bear on different threshing system of evaluated machines. The cleaning sieves on axial combine harvesters (Case IH) gather more small plant particles in comparison with conventional tangential harvesters (John Deere). These particles flow from threshing process where material stays longer in the space between the threshing drum and concave by using an axial threshing system. Because of the axial threshing system, straw is therefore more broken up than by using tangential threshing system.

According to the evaluation of the dependence of straw distribution quality on straw weight per square meter (Figure 1) it is possible to derive the following statements. The regularity of oil rape straw distribution seems to be decreasing when the amount of straw increases. It follows especially from the measurement carried out in 2001. Unfortunately it is difficult to underlay this finding by a statistical evaluation because of the small number of measurements, which was caused by a very demanding measuring method, time-consuming samples taking and difficult situation during normal operational harvesting conditions. The *R*-Squared value for linear regression were found $R^2 = 0.68$ for Case IH and $R^2 = 0.1$ only for John Deere. The situation in 2003 was worse then in 2001, the dispersion of measured values was relatively high and all measurements were carried out with almost the same amount of straw. From John Deere measurements it is possible to derive the same conclusion described above in 2001.

For the quality of husks and other plant remains distribution it is possible to derive, from Figure 2, almost the same conclusion like in the case of straw distribution quality evaluation. The *R*-Squared values for the linear regression are better for the measurements from 2001 than in the case of straw evaluation ($R^2 = 0.86$ for Case IH and $R^2 = 0.51$ for John Deere).

The distribution uniformity is comparable for both evaluated machines in the case of higher material amount. If the amount of material is smaller the results of Christiansen's coefficient are better for John Deere combine harvester in both cases (straw and husks). It is necessary to add here that worse uniformity of relatively small amount of plant residues does not have to play so important role like in the case of high amount of plant residues.

Winter wheat

The results from winter wheat measurement are in the charts in Figures 3 and 4. It was possible to compare the quality of plant remains distribution for both machines during all three years in this case. As follows from these charts, the amount of plant remains was the highest in 2001. This situation is similar to the case of oil rape. Both years (2002 and 2003) were not favourable for winter wheat production from the weather point of view. The average yield of wheat fluctuated around 2.7 t/ha in 2002 and around 3.3 t/ha in 2003 only in comparison with the relatively favourable year 2001 (average yield 4.8 t/ha). The amount of winter wheat plant remains was smaller as well which can be seen in Figures 3 and 4.

The amount of straw (Figure 3) was almost the same for both machines in 2001 and 2003 but in 2002 the higher amount of straw were observed after the John Deere combine harvester passage. The amount of husk and other small remains was higher after John Deere in 2001 and 2002 (Figure 4). It can be derived from this fact that in 2002 John Deere combine harvester worked on the better crop than Case IH. It could also explain the worse distribution quality especially of husks and also the straw of the John Deere in this year. Since the distribution quality was worse for both machines it is possible to explain this by less favourable working conditions during these measurements or by different setting of combine harvesters.

The dependence of distribution quality on distributed material amount seems to be similar to the case of oil rape harvest: the higher amount of plant residues the worse regularity of distribution. This finding follows especially from the measurements carried out in 2001 (average $R^2 = 0.72$), but the same trends (not so significant) are possible to observe in 2002 and 2003.

The most important outcome from the presented measurement of combine harvesters husk distributors' work quality is that cross irregularity of husk

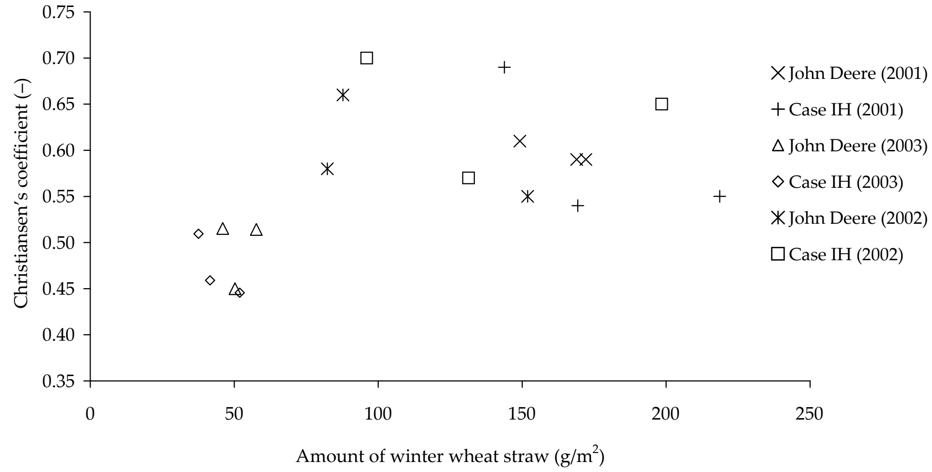

Figure 3. Dependence of Christiansen's coefficient value on amount of winter wheat straw

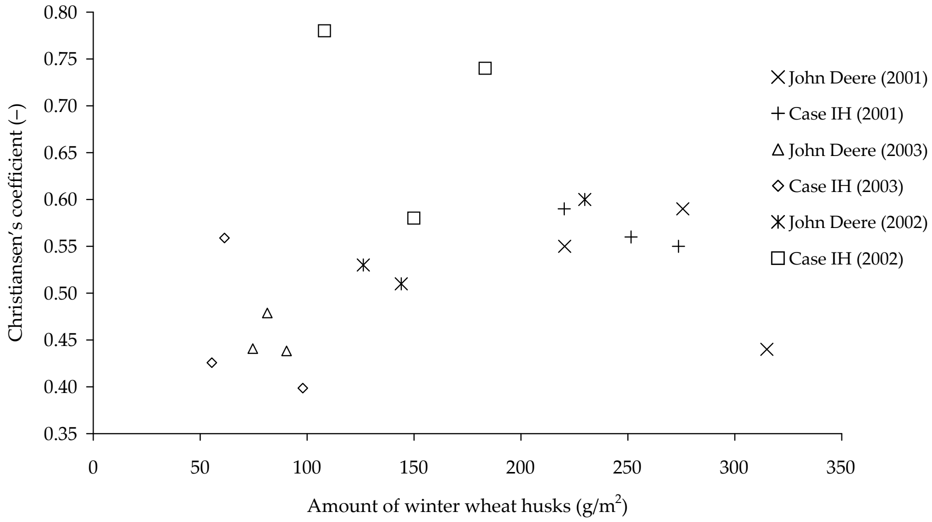

Figure 4. Dependence of Christiansen's coefficient value on amount of winter wheat husks

and straw distribution very probably depends on the instantaneous amount of harvested material. The more amount of material, the worse regularity of husk, and straw distribution. From a practical point of view it can be recommended to pay an adequate attention to this problem especially when using conservation tillage and when the preceding crop had a high yield and high amount of crop residues.

All kinds of straw choppers on combine harvesters have optional settings for deflection blades and it is largely possible to set the angle of husk spreader as well. It is becoming necessary to set not only the threshing and cleaning mechanisms on combine harvesters but also husk and straw distribution mechanisms.

Axial combine harvesters, thanks to their technological process of threshing, break up straw more intensively than tangential combine harvesters. Straw crushers on tangential combine harvesters are therefore more loaded and need more attention to be paid to from the crushing and distribution quality point of view. On the contrary, on axial combine harvesters most material goes on cleaning sieves and more attention should be paid to this small particles distribution.

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ABSTRAKT

Hodnocení rovnoměrnosti rozptylu rostlinných zbytků po sklizni konvenčními a axiálními sklízecími mlátičkami

Rostlinné zbytky mohou významně ovlivnit vzcházení a růst následně pěstované plodiny především v případě používání půdoochranných technologií. Toto riziko se zvětšuje zejména při jejich nerovnoměrném rozhozu po povrchu pozemku. Příspěvek hodnotí rovnoměrnost rozptylu slámy a plev u běžně používaných axiálních (Case IH) a tangenciálních (John Deere) sklízecích mlátiček. Pokusy proběhly ve třech po sobě následujících sklizňových sezonách v letech 2001 až 2003, a sice na sériově vyráběných strojích seřízených podle údajů výrobce, za běžných sklizňových podmínek při sklizni ozimé řepky a ozimé pšenice. Pro vyhodnocení rovnoměrnosti rozptylu posklizňových zbytků byl použit Christiansenův koeficient. Rovnoměrnost rozhozu rostlinných zbytků se zhoršuje s jejich zvětšujícím se množstvím, což platí především pro sklizeň výnosných porostů. Z praktického hlediska je vhodné věnovat v případě aplikace půdoochranných technologií odpovídající pozornost nejen kvalitě samotné sklizně, ale rovněž rozhoru rostlinných zbytků. Pracovní nástroje drtičů slámy i rozmetadel plev je třeba přizpůsobovat měnícím se sklizňovým podmínkám stejně tak jako ostatní pracovní mechanismy sklízecí mlátičky. Axiální sklízecí mlátičky rozrušují slámu více než sklízecí mlátičky tangenciální. Drtiče slámy na tangenciálních sklízecích mlátičkách jsou proto více zatěžovány a jejich seřízení je třeba rovněž věnovat odpovídající pozornost. Naproti tomu u sklízecích mlátiček axiálních přichází více materiálu na síta a v důsledku toho jsou více zatěžována rozmetadla plev.

Klíčová slova: sklízecí mlátičky; drcení a rozmetání slámy; rostlinné zbytky; rovnoměrnost rozptylu

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