THE DISTRIBUTION QUALITY OF PLANT RESIDUES AFTER HARVEST BY DIFFERENT COMBINE HARVESTERS

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Nowadays, conservation technologies play an important role in plant production all around the world. 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 significantly influence the next plant germination and growth, especially when they are unevenly placed on the field surface. Today's modern combine harvesters are able to crush and distribute all plant residues quite evenly with satisfactory results but all their mechanisms have to be properly set and sometimes some small improvements have to be done. This paper concerns with evaluation of the husk and straw distribution quality on two very common combine harvesters – Case IH and John Deere. It is very interesting to compare two completely different systems of threshing and crop residues distributing. The measurement was carried out on serially manufactured machines without any change on them and with a small improvement on distribution mechanisms.

straw crushing; combine harvesters; conservation tillage; plant remains; distribution pattern

INTRODUCTION

Conservation tillage technologies where ploughing by a mouldboard plough is replaced by tillers and shallow soil loosening is increasingly used as a soil treatment. 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, 1998), it can be said that all possible negative effects (effects on next plant seed germination, shedding growth, rodents 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 a distribution regularity of plant residues left on the field surface after combine harvester passage). Furthermore, negative effects can be minimized by appropriate technology and application time and, last but not least, by tools used for skimming, seedbed preparation and seeding (Kumhála et al., 2000). From the previous crop harvest point of view, it has been revealed that cross irregularity of husk and straw distribution is a very significant point for the start of the next crop planting.

The main subject of this article is the observation of the husk and straw distribution pattern by axial and tangential combine harvesters in real operation. Furthermore, the effect of the plant residues' irregular on-surface placement after harvest on residues placement in soil profile after treatment by a shovel tiller.

MATERIAL AND METHOD

Crushing mechanisms of combine harvesters have to ensure good quality of straw crushing (90% of particles must be shorter than 80 mm) (Kumhála et al., 2002) and the crushed straw and other organic remains (husk, 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 of crop residues crushed and distributed on a field surface. This 6 m long strip corresponded with machine's working width and was divided into 0.5 m intervals. Then, all plant residues were collected from 0.1 m^2 area, which was considered as an "interval sample". Grain losses were separated from each sample and their placement across combine harvester working width was evaluated.

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 2266 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 (distribution pattern).

Combine harvester **John Deere 2266** was with engine power 199 kW; 5.90 m header width; 660 mm threshing drum diameter and 1670 mm width; total concave area 1.08 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 of 196 kW engine power; 5.9 m header width; rotor placed longitudinally; 762 mm rotor diameter; 2970 mm rotor length; total cleaning area 5.12 m^2; standard straw chopper and two disc chaff-straw distributor mounted.

In total, 3 variants were measured, namely: standard combine harvester Case IH without any change, combine harvester Case IH with the husk distributor's improvement and John Deere 2266 with the standard chaff distributor mounted.

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

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

Measurement conditions:

- **oil rape harvest** – combine harvester setting by manufacturer recommendations, working speed 5–8 $km.h^{-1}$, grain moisture 9%, straw moisture 15%, yield 2.7 $t.ha^{-1}$, 52 plants per 1 m^2.
- **winter wheat harvest** – combine harvester setting by manufacturer's recommendations, working speed 4,5–7 $km.h^{-1}$, grain moisture 14%, straw moisture 16%, yield 4,8 $t.ha^{-1}$, 550 plants per 1 m^2.

The measurement of husk and straw distribution quality on CASE IH combine harvesters was also carried out in 1999. It was our first measurement without any change on straw and husk distributor for gaining a general idea about this problem (Kvíz, 2000).

Our husk spreader improvement consisted in elongation of husk distributor's discs shafts by 20 cm. Due to this, the rotation surface of discs was lower, and more small straw particles and husk coming from sieves could fall down onto discs and could be therefore distributed more evenly. The design and detailed description of straw and husk distributors, including our improved variant, has been explained in previous papers (Kumhála et al., 2002).

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

$$C_u = 100 \cdot \left[1 - \left(\sum_{i=1}^{n} \left| i_{si} - i_m \right| / n \cdot i_m\right)\right] \qquad [\%]$$

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

After harvest, the plot of land was broken up by a shovel tiller. The rate of infestation with growing grain losses plants was determined by the image analysis in fixed rows.

By the plant residues placement evaluation after skimming the same place in rows were observed. The sample of crop residues after skimming consisted of two parts; firstly crop residues remained on the field surface, and secondly, within treated profile (under soil surface).

RESULTS AND DISCUSSION

Distribution regularity

For every measurement 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 Christiansen's coefficient was calculated in dependence on the total weight of a sample.

These values were processed separately for oil rape and winter wheat, each time for straw and husk and for all three variants of evaluated combine harvesters. Graphical evaluation of our measurement was carried out by means of MS Excel charts.

In all cases and variants, it was found out that the irregularity of crop residues' distribution was always decreasing with increasing feed rate of combine harvester (mass going through the harvester). This fact was proved both for straw (Fig. 1) and for husk (Fig. 2) by winter wheat harvest and for oil rape as well. The more material was harvested the worse Christiansen's coefficient was calculated. There is a total weight of plant remains from one combine harvester passage (sum of all interval samples) on the X-axis and there are Christiansen's coefficient values on the Y-axis. The presented charts are for winter wheat only.

The cleaning sieves on axial combine harvesters (CASE) gather more small plant particles in comparison with conventional tangential harvesters (John Deere). These particles flow from a threshing process where harvested material stays a particular time in the space between the threshing drum and concave. Because of the axial threshing system, harvested material stays longer in the threshing space and straw is therefore much more treated and broken up than by using tangential threshing system.

This reality was shown by oil rape harvest where the straw, very easy to break off, was not crushed so much in tangential threshing system. This resulted in better husk distribution on tangential combine harvester with mounted distributor because there were not so many small particles on the sieves going into the distributor.

There is the opposite situation in distribution of oil rape straw. Because a great amount of oil rape straw is going into the crusher, the distribution plate is overloaded, the distribution quality is declining and is worse than on axial combine harvesters.

The improvement on axial combine harvesters consists in elongation of husk and straw distributor shaft by

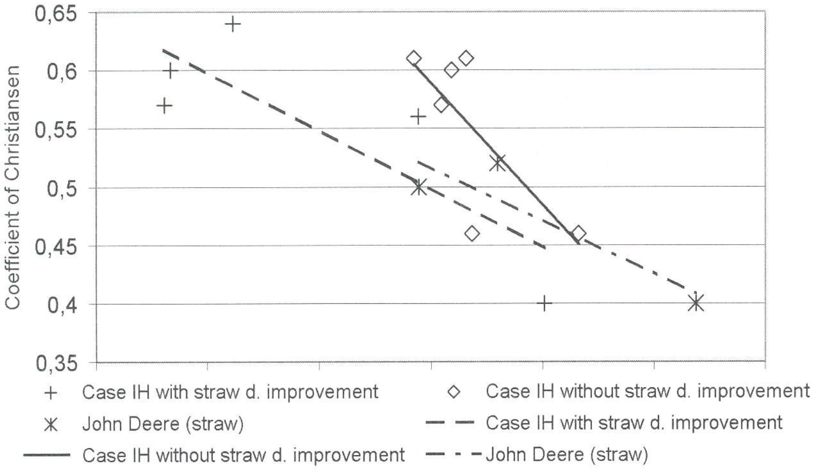

Fig. 1. Straw distribution uniformity evaluation during wheat harvest

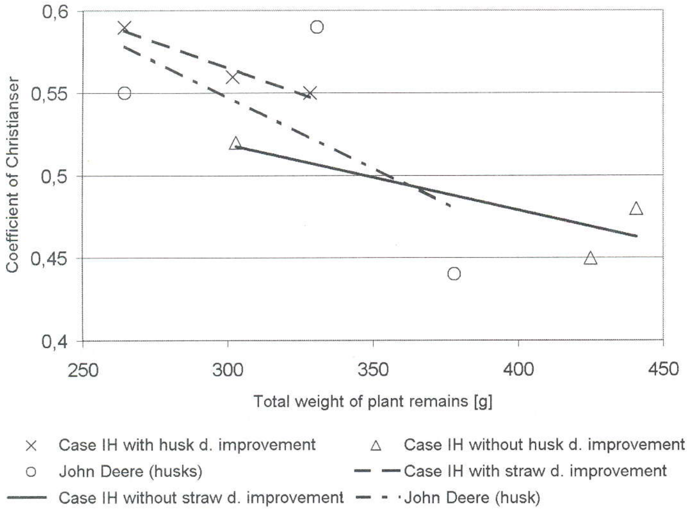

Fig. 2. Husk distribution uniformity evaluation during wheat harvest

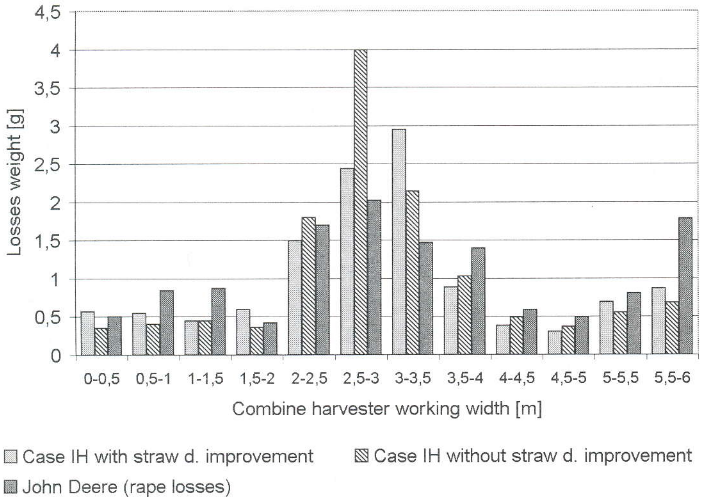

Fig. 3. Grain losses distribution during rape harvest

20 cm. This has had a very significant effect on husk and straw distribution quality by winter wheat harvest. This change could be highly recommended. By oil rape harvest the effect on distribution quality was not very significant.

Grain losses

In conservation tillage technologies, the grain losses placement is a very important point and especially by oil rape harvest. The distribution quality of grain losses was evaluated by means of bar charts. Fig. 3 shows a distribution of oil rape grains after combine harvester passage.

The variant without any change had the worst distribution. The vast majority of grains remained in the middle strip after combine harvester passage. When using the change of distributor's shaft on CASE or tangential John Deere combine harvester, the regularity of distribution was better. Because of the fact that grains are heavier

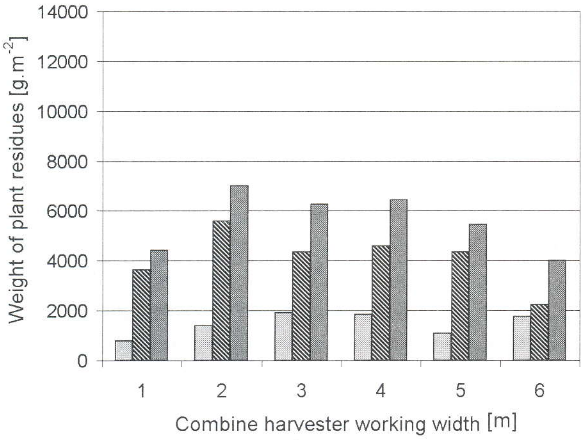

Fig. 4. Plant residue's distribution after skimming (combine harvester John Deere). Columns from left: surface, profile, together

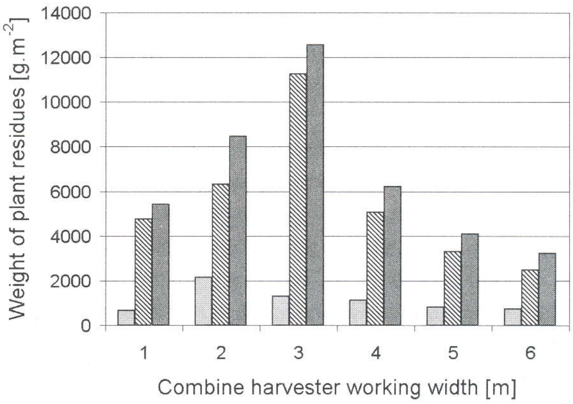

Fig. 5. Plant residue's distribution after skimming (combine harvester Case IH without straw distributor improving). Columns from left: surface, profile, together

than plant remains, they are given more kinetic energy and therefore they reach sides of the combine harvester passage. It is shown in charts.

The total amount of grain losses was higher on axial combine harvesters compared to tangential John Deere harvesters. It could be caused, however, by an improper setting of the cleaning mechanism on combine harvester. Nevertheless, this part of the measurement was not the main point.

Rate of infestation with weeds and seedlings grown from grain losses

Measured values of a rate of infestation with weeds and grown grain losses corresponded with husk and straw distribution measurement. The experiment has shown that it is sufficient to evaluate the distribution quality of grain losses according to image analysis. For more accurate evaluation it is better, however, to count the exact number of plant individuals grown from grain losses because it is difficult to determine the exact number of plants from the image analysis.

The regularity of grain losses distribution and especially further plant individuals grown is very important from the efficiency of a following chemical treatment point of view.

Plant residues' distribution after skimming

It can be seen on charts (Figs 4 and 5) that there are some noticeable differences in plant residue placement after skimming (carried out by shovel tiller Horsch Concorde CO8).

Two variants are compared on charts (Figs 4 and 5), namely John Deere with serial husk distributor mounted, and CASE IH without any husk distribution. It means, regarding regularity of straw distribution, the best and the worst measured variant. It follows from charts that the overall irregularity of plant residue distribution after harvest has no influence on on-field-surface part of plant remains. This on-surface part of residues consisted of straw and bigger particles and was minor one. The vast majority of plant residues were mixed into soil at shallow depth. This under-soil part of plant remains consisted mainly of husk and small straw particles. It turned out that the overall quality of husk and straw distribution corresponded with the amount of crop residues under-soil in treated profile (irregular distribution) whilst the on-surface crop residues were always very balanced. Consequently, this fact can deteriorate conditions for next plant germination and growth.

CONCLUSIONS

The most important outcome of the measurement of combine harvesters husk distributors' work quality is that the distribution pattern of husk and straw depends on instantaneous material feedrate through the harvester. The more 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 the high amount of crop residues.

All kinds of straw choppers on tangential combine harvesters have an 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 threshing and cleaning mechanisms on combine harvesters but also husk and straw distribution mechanisms.

The advantage of our change of distributor shaft on Case IH for better distribution quality was proved by the winter wheat harvest but was not significant for the oil rape harvest. 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 from the crushing quality point of view. On the contrary, on axial combine harvesters most material goes onto the cleaning sieves and more attention should be paid to this small particles distribution.

From the grain losses distribution point of view, according to our measurement, it can be stated, that machines with husk spreaders tend to spread heavier particles (in this case grains) to the sides of machine working width. By oil rape harvest, however, all measured combine harvesters had sufficient and very similar distribution pattern. The higher amount of grain losses was shown by winter wheat harvest on axial combine harvesters.

The measurement evaluation of infestation with weeds and plants growing from grain losses has shown that it corresponded with grain losses distribution on the field surface and the regularity was quite satisfactory. The placement of all plant residues after tillage was almost even on a field surface. Most small particles were mixed into soil when tilled and the placement of these particles corresponded with irregular distribution of all harvested plants' residues before tillage. To sum up this part of our research, the plant remains, mixed into soil after tillage, were placed as irregularly as they were before tillage. The plant remains left on the soil surface were placed more evenly, but the separation of small and big particles took place. The long and big particles stayed on the field surface and the majority of small ones were mixed into soil.

The mentioned irregularity of small plant remains in treated soil profile and so their great concentration at the particular place could affect next plant germination and growth. This problem presented here is becoming very important nowadays because more and more farmers are using conservation tillage systems on their fields and that is why it is necessary to pay a proper attention to do the best from this point of view.

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Rovnoměrnost rozmetání posklizňových zbytků za různými typy sklízecích mlátiček.

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V posledních letech se ve světě i u nás v rostlinné produkci stále více prosazují technologie mělkého zpracování půdy bez orby, pro které se vžil název půdoochranné nebo také minimalizační technologie.

Podstata tohoto systému zpracování půdy spočívá v omezování hloubky zpracovávané vrstvy půdy na nezbytné minimum, což zkracuje pracovní čas potřebný pro přípravu půdy, a tím je možné snáze dodržet agrotechnické lhůty pro výsev plodin. Dále tento postup částečně šetří náklady, potřebu strojů i pracovních sil. Dlouhodobé pokusy ukázaly i zlepšení půdní struktury a snížení jejího předchozího utužení. Všechny zmiňované klady jsou uváděny ve srovnání se systémem s orbou.

Uplatňování půdoochranných technologií má však i svoje nevýhody, které se mnohdy ani při uplatňování systémů s orbou nevyskytovaly. Protože všechny rostlinné zbytky zůstávají na povrchu pozemku nebo jsou zapraveny do mělké hloubky zpracovávané vrstvy půdy (na rozdíl od orby, kde je všechen rostlinný materiál zaklopen hluboko na dno brázdy), mohou svou přítomností v blízkosti vysetého semene následné plodiny způsobovat určité problémy. Negativní stránkou potom může být rozšiřování některých plevelných druhů, především sveřepů, možnost ovlivnění vzcházení následné plodiny velikým množstvím rostlinných zbytků v blízkosti semene, retardace růstu rostliny způsobená rozkladem posklizňových zbytků a vysokou koncentrací látek vzniklých tímto rozkladem, v některých

obdobích zvýšené nároky na chemickou ochranu a nepřímo i možnost většího rozšíření hlodavců, kteří využívají rostlinné zbytky jako svoji ochranu.

Podle autorů Johnson (1988) a Ball, Robertson (1990) lze všechny tyto negativní vlivy odstranit nebo alespoň minimalizovat již při sklizni předplodiny a následnou volbou vhodných postupů a strojů pro podmítku, předseťovou přípravu půdy a setí.

Velice důležitou úlohu hraje při řešení tohoto problému sklízecí mlátička. Pokud by byl rostlinný materiál sklizený mlátičkou z určitého pracovního záběru vrácen na povrch pozemku, kvalitně podrcen a rovnoměrně rozprostřen, nastal by zcela přirozený případ koloběhu organické hmoty v přírodě, a to bez větších problémů. Realita při sklizni bývá však jiná. Sklízecí mlátička rozmetá posklizňové zbytky nerovnoměrně, a to tak, že uprostřed záběru mlátičky je soustředěna většina plev, úhrabků a rozdrcené slámy (Kvíz, 2000).

Určitou úpravou drtičů a správným seřízením rozmetacích mechanismů lze rovnoměrnost rozmetání zlepšit, což bylo měřením potvrzeno. Dále bylo zjištěno, že nerovnoměrně rozmetané rostlinné zbytky jsou po prvním zpracování půdy – po podmítce, zapraveny do půdy jen z části. Větší částice zůstávají na povrchu pozemku a jsou rozprostřeny rovnoměrně, avšak menší částice zapravené do zpracovaného profilu si nerovnoměrnost zachovávají. Z toho lze usuzovat, že v místech větší koncentrace rostlinných zbytků mohou nastat výše zmíněné problémy. Vliv nerovnoměrnosti rostlinných zbytků v půdě na následnou plodinu je v současnosti předmětem výzkumu a jeho výsledky doplní předkládanou práci později. Sleduje se vzcházivost následné plodiny, velikost porostu, počet jedinců při sklizni a výnos plodiny. Po ukončení této části experimentu bude možné stanovit míru ovlivnění růstu plodiny nerovnoměrně rozmístěnými zbytky předplodiny.

drcení slámy; rovnoměrnost rozmetání posklizňových zbytků; zpracování půdy; sklízecí mlátička

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