Operational effects of implements on crop residues in soil tillage operations

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ABSTRACT: After spring barley harvest the operational effects of tillers and seed drill on spring barley residues were evaluated in two variants of cultural operations. Generally low values of soil surface coverage by crop residues after cultural operations were performed document that soil tillage and sowing did not comply with the criteria for conservation technologies – the coverage of soil surface by crop residues was lower by 30% after all cultural operations. After silage maize harvest we determined the weight of maize crop residues and coverage of soil surface by these residues after shallow tillage by a disk tiller when nine variants of the operating mode of the tiller were used. Obviously, the change in the operating mode of the tiller was able to influence the coverage of soil surface by maize residues. The evaluation of the operational effects of disc tiller on crop residues indicated some restraints of the use of this group of implements for conservation (erosion-control) technologies of soil tillage.

Keywords: soil tillage; crop residues; quality of tiller operation

In the Czech Republic more than a half of the arable land area is potentially exposed to water erosion. To decrease damage caused by water erosion to the land resource it is urgent to reduce the action of kinetic energy of raindrops on the soil surface, to increase water infiltration into soil, to reduce the tractive force of water on sloping lands and to drain the surface runoff away without risk (Janeček et al. 2002). Purposeful utilisation of crop residues and catch crop biomass for the protection of soil surface from adverse effects of mainly intensive rains is a part of conservation technologies. Hanna et al. (1995) reported a significant contribution of covering at least a part of the soil surface by plant residues (20 to 30%) to a reduction in water erosion by 50 to 90% compared to the soil surface without plant residues. A positive measure in areas with rainfall deficit is to decrease water evaporation from soil if a part of the soil surface is covered by plant biomass (Baumhard, Jones 2002).

The evaluation of operational effects of soil tillers on crop residues is aimed at the acquisition of background data for the choice of implements suitable for soil conservation technologies with marked erosion-control effects. The choice of suitable implements from the aspect of the mechanism of their effects on soil and on plant biomass is a part of proposals of efficient cultural erosion-control measures.

Hůla et al. (1998) evaluated a possibility of using the image analysis for the assessment of soil surface coverage by plant biomass and calculated the relations between the coverage of soil surface by plant residues and plant residue weight on the soil surface after selected operations of soil tillage. Currently, the image analysis is commonly used to evaluate the coverage of soil surface by plant biomass.

The objective of measurements and evaluations was to assess the quality of operation of some implements from the aspect of their suitability for erosion-control technologies of soil tillage.

MATERIAL AND METHODS

The quality of tiller work was evaluated immediately after the respective operations were done. The coverage of soil surface by plant residues was evaluated and the weight of crop residues on the soil surface was determined. The method of image analysis was used to measure the coverage of soil surface by plant residues.

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After spring barley harvest with a New Holland TX 68 harvester-thresher in 2003 the operational effects of implements on spring barley residues were evaluated in two variants of operations done in one field. Barley straw was crushed during harvest and spread in the field.

Variant **A**

– skimming with Preciser 6000 disc tiller to a depth of 80 mm (D1),
– second loosening with Preciser 6000 disc tiller to a depth of 120 mm (D2),
– winter wheat sowing with Överum Multi Jet seed drill to a depth of 50 mm (S).

Variant **B**

– skimming with Preciser 6000 disc tiller to a depth of 80 mm (D1),
– second loosening with ROSS Farmer tine tiller to a depth of 120 mm (T2),
– winter wheat sowing with Överum Multi Jet seed drill to a depth of 50 mm (S).

The second loosening was performed after the emergence of weeds and self-seeded grain of forecrop. Soil type in the field: loamy soil.

On the same farm in the field after silage maize harvest the operational effects of disc tiller on silage maize residues were evaluated at shallow tillage in 2003. The field was divided into nine parcels; on each parcel tillage was done with Preciser 6000 Classic Line disc tiller where different angles of the plane of disc rotation with the direction of tiller pass, different operating depth and operating speed were set. In the front gangs of the tiller three angles were set while the values 10.3° and 17.1° were the extreme positions of the front gangs. The standard angle (15°) of the plane of disc rotation with the direction of tiller pass was set in the rear gangs (Table 1). Soil type in the field: loamy soil.

The image analysis was applied to evaluate the coverage of soil surface by plant residues. After the cultural operations were done, images of the soil surface were collected with digital camera. In the course of computer processing coloured image was gradually transformed by means of software functions into black and white image where the white colour designated plant residues and the black colour designated soil surface. A function was used that defined the number of white and black pixels in the image and calculated their percentage proportions. The coverage of soil surface by plant residues was expressed in this way.

RESULTS AND DISCUSSION

Fig. 1 illustrates the relationship between the coverage of soil surface by spring barley residues and their weight after the operations soil tillage and sowing in variant **A** were done. The results for variant **B** are represented in Fig. 2. The graphs document an increase in the weight of crop residues influenced by an increase in the coverage of soil surface by crop residues. The distribution of crop residues on the soil surface was homogeneous, accumulation of plant residues were sporadic. Figs. 3 and 4 show the coverage of soil surface by spring barley residues in Box and Whisker Plot allowing the visual comparison of data sets.

In variant **A** statistical processing of data by analysis of variance did not demonstrate any sta-

Table 1. Operating mode of disc tiller in nine variants of soil tillage, weight and coverage of soil surface by maize residues

Variant of measurement	Operating mode of tiller			Maize residues	
	angle (°)	operating depth (mm)	operating speed (km/h)	average weight (g/m^2)	average coverage (%)
1	13.7	70	12	74.6	11.1
2	13.7	70	9	54.3	10.8
3	13.7	70	6	77.5	13.8
4	13.7	100	12	74.6	8.0
5	17.1	100	12	36.4	7.6
6	17.1	70	12	45.2	14.4
7	10.3	70	12	45.7	10.6
8	10.3	100	12	20.2	11.9
9	13.7	70	12	71.5	4.7
Before tillage				173.9	24.3

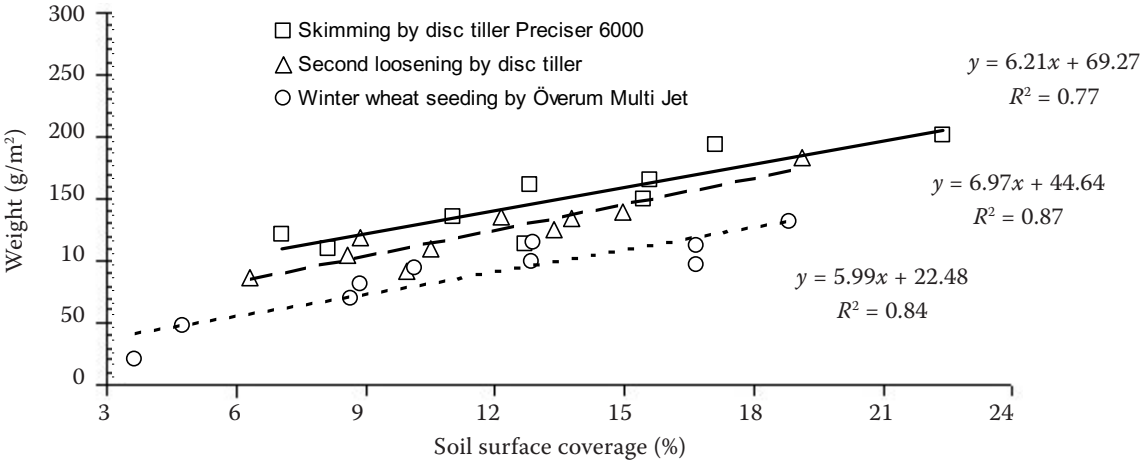

Fig. 1. Relationship between the coverage of soil surface by spring barley residues and their weight after cultural operations in variant **A**

tistically significant differences between cultural operations in the soil coverage by crop residues. In variant **B** a statistically significant difference was found between soil coverage by crop residues after the second loosening with tine tiller and soil coverage after sowing with seed drill. Generally low values of soil surface coverage by crop residues after the operations document that soil tillage and sowing did not comply with criteria for conservation technologies – the coverage of soil surface by crop residues was lower than 30%.

Table 1 shows the values of weight of maize residues and soil surface coverage by these residues after shallow tillage with disc tiller when 9 variants of the operating mode of the tiller were used. Visual information on data sets of soil surface coverage by crop residues is presented in Box and Whisker Plot (Fig. 5).

Kolmogorov-Smirnov test of normal distribution in Statistica software was used for statistical processing of data on the coverage of soil surface by maize residues. The test indicated the value $p > 0.05$ for the given data set. Based on this fact it was possible to accept the hypothesis H_0 and to state the normal distribution of data.

Data homoscedasticity is another assumption for the application of analysis of variance. This test is also called check of homogeneity of variance and Cochran's and Bartlett's tests are applied for this purpose:

Cochran's test: 0.319060

Bartlett's test: 34.37584

$p = 0.000077$

The assumption of homogeneity of variance was not fulfilled because the value p for the given data set was smaller than the significance level $\alpha = 0.05$.

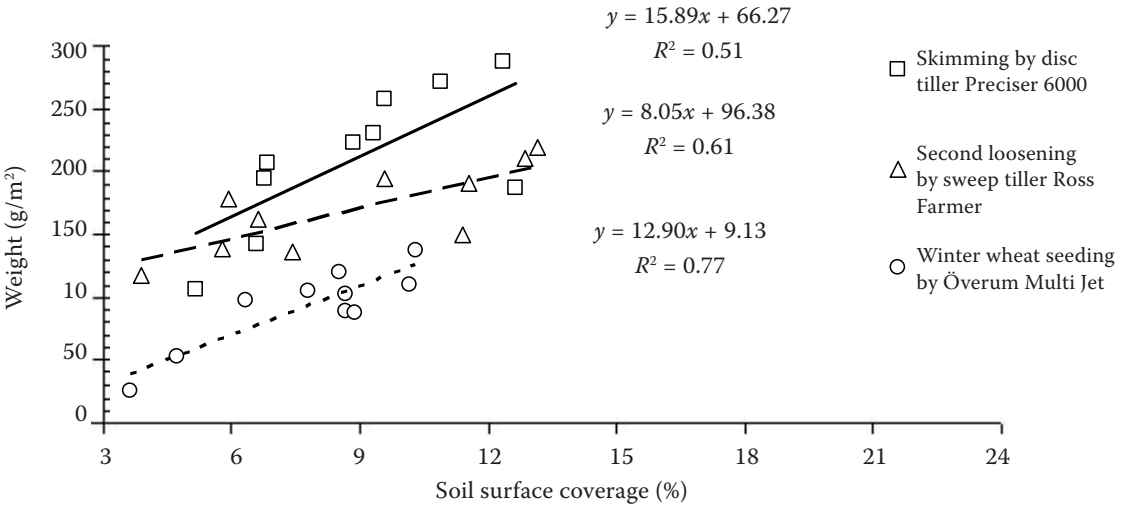

Fig. 2. Relationship between the coverage of soil surface by spring barley residues and their weight after cultural operations in variant **B**

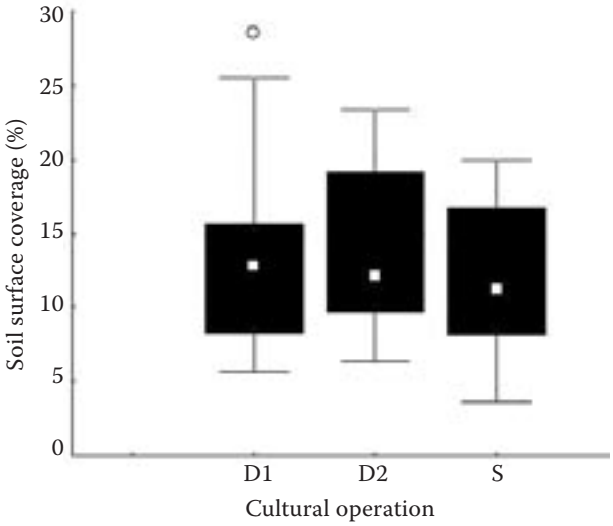

Fig. 3. Coverage of soil surface by spring barley residues after cultural operations – variant **A**

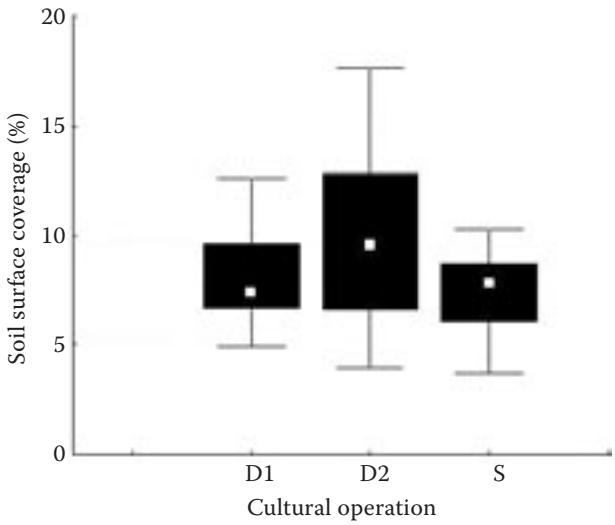

Fig. 4. Coverage of soil surface by spring barley residues after cultural operations – variant **B**

Therefore logarithmic transformation was applied according to the formula:

$$X_{new} = log\ x_{original} \quad (1)$$

After transformation the sets were tested by Cochran's and Bartlett's tests again:
Cochran's test: 0.222275
Bartlett's test: 9.773253
p = 0.369152

The assumption of homogeneity of variance was fulfilled in this case. After the assumption of homogeneity of variance was fulfilled, analysis of variance was done. Statistical significance of differences in mean values was tested in the sets and the results are shown in Table 2. It is indicated between what variants the difference in the values of soil surface coverage was statistically significant.

Kolmogorov-Smirnov test of normal distribution in Statistica software was used to check normal dis-

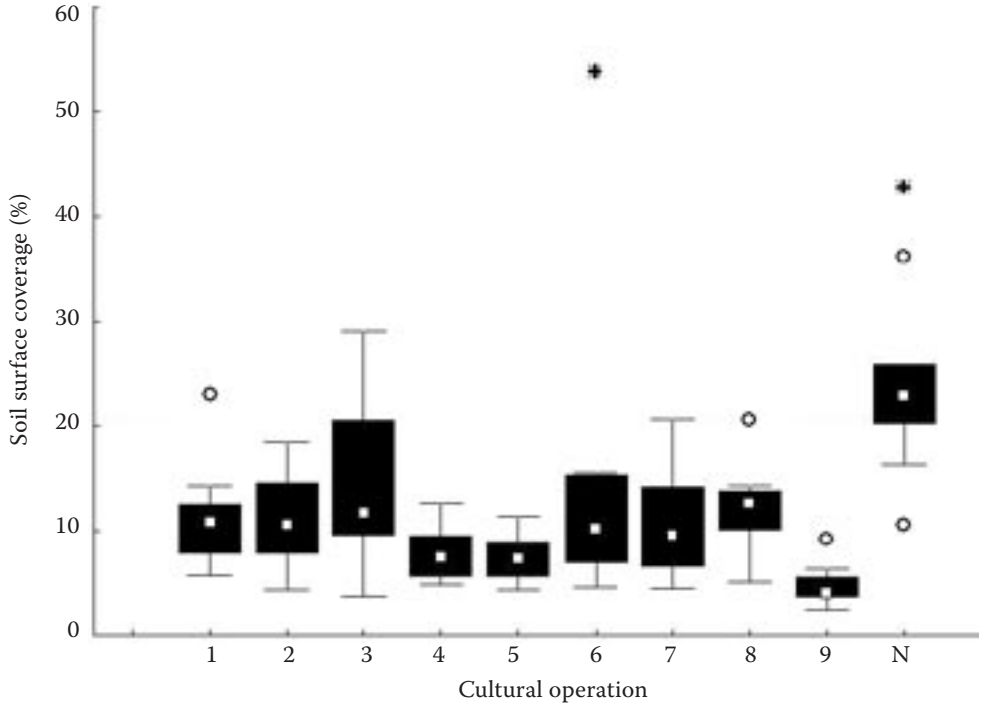

Fig. 5. Coverage of soil surface by maize residues in nine variants of tillage by a disc tiller and on untreated soil (N)

Table 2. Statistical significance of differences between the variants of tillage with disc tiller after maize silage harvest (coverage of soil surface)

Variant	2	3	4	5	6	7	8	9	N
1	–	–	–	–	–	–	–	+	+
2		–	–	–	–	–	–	+	+
3			–	–	–	–	–	+	–
4				–	–	–	–	–	+
5					–	–	–	–	+
6						–	–	+	+
7							–	+	+
8								+	+
9									+

N – before soil tillage, + statistically significant difference (α = 0.05)

tribution of data from the evaluation of maize residue weight on the soil surface. The test indicated the value $p > 0.05$ for the given set of data. Based on this fact it was possible to accept the hypothesis H_0 and to state the normal distribution of data.

Data homoscedasticity is another assumption for the application of analysis of variance. Cochran's and Bartlett's tests were used:
Cochran's test: 0.284541
Bartlett's test: 9.728626
$p = 0.372898$

The assumption of homogeneity of variance was fulfilled. The analysis did not indicate any statistically significant differences between the sets of data on maize residue weight.

The evaluation of operational effects of disc tiller on maize residue weight when different setting of its implements was used proved that a change in the operating mode of the tiller might influence the coverage of soil surface by maize residues. But the evaluation of maize residue weight on the soil surface did not show any statistically significant differences between the variants.

The overall evaluation of results indicated that the tested disc tiller incorporated a relatively high amount of crop residues into soil. It confirmed some constraints of the use of this group of implements for conservation (erosion-control) tillage. As the hazard of water erosion of soil is highest in the period of torrential rains (April–October), it is very urgent to use technologies and implements that enable to make use of protective functions of crop residues on the soil surface during soil tillage and sowing in summer and spring. Wischmeier and Smith (1978) developed the theory of C-factor (factor of canopy cover), and our recommendation is in agreement with this theory.

Disc tillers are suitable for minimum tillage because their area capacity is high at shallow tillage. Tine tillers fitted with sweeps appear more suitable for conditions with higher requirements for soil protection from water erosion.

The evaluation of operational effects of implements on crop residues during tillage and sowing contributes to the acquisition of background data for the calculation of soil losses caused by erosion at particular sites. Currently the Revised Universal Soil Loss Equation (RUSLE) is used for these calculations (Janeček et al. 2002).

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Působení strojů na posklizňové zbytky plodin v pracovních operacích zpracování půdy

ABSTRAKT: Po sklizni jarního ječmene bylo hodnoceno působení kypřičů a secího stroje na posklizňové zbytky jarního ječmene ve dvou variantách pracovních postupů. Celkově nízké hodnoty pokryvnosti povrchu půdy posklizňovými zbytky po jednotlivých pracovních operacích ukazují, že zpracování půdy a setí nesplňovalo kritéria pro půdoochranné technologie – pokryvnost povrchu půdy posklizňovými zbytky byla po všech pracovních operacích nižší než 30 %. Po sklizni kukuřice na siláž byly zjištěny hodnoty hmotnosti posklizňových zbytků kukuřice a pokryvnosti povrchu půdy těmito zbytky po mělkém kypření půdy talířovým kypřičem, kdy bylo zvoleno 9 variant pracovního režimu kypřiče. Ukázalo se, že změnou pracovního režimu kypřiče je možné ovlivnit pokryvnost povrchu půdy posklizňovými zbytky kukuřice. Výsledky hodnocení vlivu talířového kypřiče na posklizňové zbytky ukazují na omezenou použitelnost této skupiny strojů pro protierozní technologie zpracování půdy.

Klíčová slova: zpracování půdy; posklizňové zbytky; kvalita práce kypřičů

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