https://doi.org/10.17221/106/2017-RAE

# Functional properties of blade tiller working tools

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**Abstract**

Pražan R., Hůla J., Kovaříček P., Čedík J., Gerndtová I., Vlášková M. (2018): Functional properties of blade tiller working tools. Res. Agr. Eng., 64: 63–69.

After the harvest of winter wheat, the tensile force, cross section of loosened soil and specific resistance of soil were measured on a loamy soil plot. During the comparative measurements, 3 blades were used with chisel width of 20 mm, 40 mm and 75 mm. In case of all blades, the measurements were carried out at the depth of 100, 200 and 300 mm. In the course of measurements, the standards of blades were attached in a measuring frame on six-component hinge with connected tensometric sensor. The selected blades were developed for a new type of tiller destined for primary cultivation of soil. Moreover, in case of a blade equipped by chisel there were used side wings of a width of 110, 150 and 200 mm for tillage into a depth of 100 mm. It was found that the width of blade chisels did not have a statistically significant effect on the values of specific resistance of soil during the soil tillage. At all widths of blade chisels, a trend of an increase in specific resistance of soil was recorded at growing recess into the soil.

**Keywords**: primary tillage of soil; depth of tillage; specific resistance of tillage

Blade tillers are widely used machines, especially for primary soil tillage in technologies of cultivation with ploughing and in practices of reduced soil tillage. Manufacturers of blade tillers aim at innovation of working tools in order to increase their service life, fulfilment of requirements for quality of work and achievement of favourable energy intensity of tillage. Kasisira and Plessis (2006) dealt with the relationship between the surface of cultivated soil profile, tensile force and parameters of chisel adjustment during the deeper tillage. An important parameter is the critical depth of tillage, which is related to the width of a tilling part of working tools, their spacing and soil properties, especially momentary soil moisture in tilled profile. The factors affecting the specific resistance of blade tillers were dealt by Hůla and Mayer (1995). The effect of soil tillage at higher working speed on the tensile force was studied by Linke (1993). A need to study the functions of a tiller equipped with solid standards is justified in a comparative study published by Anken et al. (1993). Kroulík (2004) mentions the importance of specific resistance for assessment of energy intensity of tiller working tools. Quality of soil cultivation can be evaluated according to size representation of soil aggregates, quantity of plant residues on soil surface and roughness of soil surface. Arvidsson et al. (2004) and Arvidsson and Hillerström (2010) determined the effect of tillage depth on specific resistance of tillage as well as on the grade of soil friability.

Supported by "New generation of soil tillage machine" and project "Research and development of agricultural technologies, machines, energetics and building aimed at increase of competitiveness of Czech agriculture and protection of environment", Project No. TA04011200 and RO0617. This article was presented at the 10th International Scientific Conference of Central and Eastern European Institutes of Agricultural Engineering (CEE AgEng), September 14–15, 2017 in the premises of Research Institute of Agricultural Engineering p.r.i., Prague, Czech Republic.

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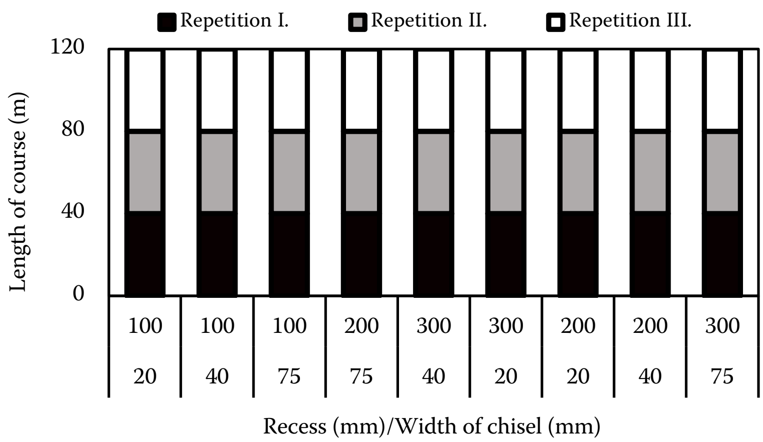


Fig. 1. Scheme of the measuring process of tillage mechanisms tensile resistance (Křinec, July 2015)

An important advantage of blade tillers is the possibility to influence the grade of incorporation of plant residues into the soil by selection of working tools – from almost total incorporation and mixture with topsoil up to leaving the plant biomass on soil surface while meeting the requirements for tillage of soil up to the demanded depth. This can control the soil erosion effects (Titi 2002).

The aim of the measurements of functional properties of working tools was to compare the blades with different width of chisels and a blade with side wings, destined for a new type of blade tiller in terms of transversal profile of tillage, tensile force and specific resistance of tillage.

## MATERIAL AND METHODS

In the flat part of a plot after harvest of winter wheat, a measuring area of 120 × 120 m was selected. The soil surface was covered with stubble and spread cereal straw. Direction of the measuring passages was chosen upright to the direction of sowing. The length of a measuring section for one repetition was derived from the spacing of track interrows – 36 m. For every chisel and depth of tillage, one measuring passage with continuous recordings of the measured parameters on the whole measuring section was recorded. Three repetitions with the length of a section of 33 m were carried out afterwards in data recordings. Individual passages were carried out in parallel in the same direction. The width of the marked area enabled to realize up to 30 measuring passages. The test passages for the purpose of verification of chisels recess were carried out outside this area. The sequence of the measuring passages with the mentioned widths of working tools and recess into the soil is shown in the scheme (Fig. 1).

Before the measurement of tensile resistance, the penetration resistance of soil was measured by a penetrometer PEN-70 (Czech University of Life Sciences Prague, Czech Republic). The measurements were carried out in the diagonal direction of the measured area, with 30 repetitions in total. In the corresponding trajectory Kopecky´s rollers were used for determination of the physical state of soil (6 repetitions, length of 25 m), with a depth from 50 mm up to 300 mm, graduated in intervals of 50 mm. From the soil layers of 0–150 mm and 150–300 mm average samples of soil were withdrawn for determination of grain size by means of a groove probe in intervals of 50 mm up to the depth of 0.40 m; average samples from 3 sticks were used for determination of soil moisture established by the gravimetric method.

Characteristics of soil on the plot selected to measurement were as follows: loamy soil (content of particles < 0.01 mm, 32.1%), content of combustible carbon: in the depth 0–150 mm, 2.2%, in depth 150–300 mm, 2.0%; total porosity of topsoil before tillage: 100 mm, 37.2% vol.; 150 mm, 34.5% vol.; 200 mm, 32.5% vol.; 250 mm, 32.8% vol.; 300 mm, 32.2% vol.

The values of soil porosity show compacted soil in the profile up to 300 mm.

Mechanical properties of soil before tillage express the penetration resistance (Fig. 2). From this graph, a considerable increase of soil resistance is obvious in direction towards the depth. It relates to the previous multiannual cultivation of soil into the depth of 150–200 mm without ploughing, and to lower momentary soil moisture in the depth of 150–300 mm than in surface layer of topsoil (Fig. 3).

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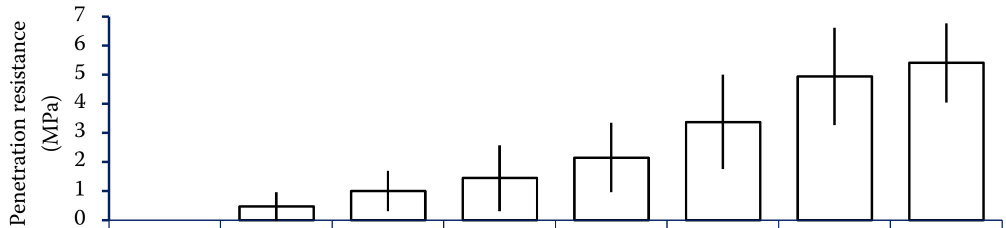


| | 0 | 40 | 80 | 120 | 160 | 200 | 240 | 280 |
|---|---|---|---|---|---|---|---|---|
| □ Average | 0 | 0.465 | 1.006 | 1.444 | 2.156 | 3.382 | 4.944 | 5.410 |
| Max | 0 | 0.956 | 1.698 | 2.583 | 3.345 | 5.006 | 6.628 | 6.770 |
| Min | 0 | −0.026 | 0.314 | 0.306 | 0.967 | 1.758 | 3.260 | 4.050 |

Depth (mm)

Fig. 2. Penetration resistance of topsoil before tillage

**Machine set for the measurement of tensile resistance of tillage mechanisms**. For the measurement of horizontal component of tensile resistance, a measuring frame was used with suspension of six components for attachment of one test piece with evaluated working tools. The measuring frame was suspended on a three-point suspension of tractor CASE III JX 1100U with afterload of the front axle by weight of 270 kg (6 × 45 kg), tyres used on the front axle were 340/85 R24 TM 600 PIRELLI, and on the rear axle it was 420/85 R34 TM 600 PIRELLI.

***Used measuring devices and aids***: tensometric sensing unit, measuring computer PC104 with evaluation unit, evaluation software „ANALYSIS", mechanical profile graph, stakes, measure tape, clinometer, stop watch.

***Requirements for measuremen***
- 3 widths of working chisels – 20, 40, 75 mm;
- for every width of chisel three recesses into soil were selected – 100, 200, 300 mm;
- in case of chisel of the width of 75 mm, also the measurement with „wings" was carried out, with widths of 110, 150 and 210 mm, under the same recess of 100 mm;
- travel speed of tractor for all measurements was between 10 and 12 km/h.

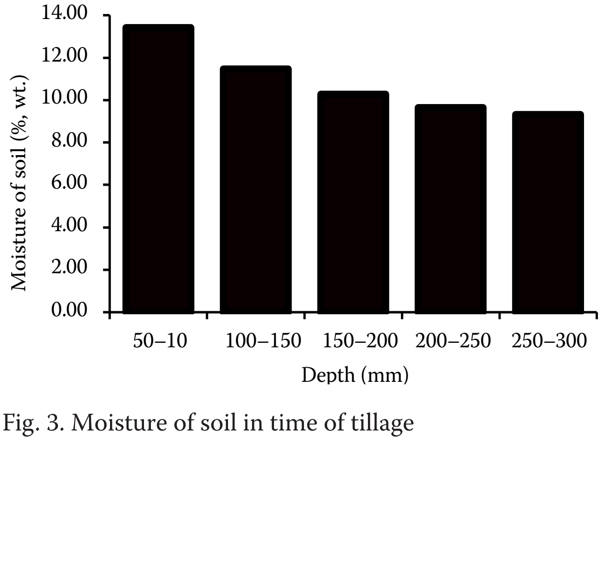


Fig. 3. Moisture of soil in time of tillage

For every chisel and recess, average depth of tillage was measured – 6 measurements for each repetition of the measuring track.

**Evaluation of the cultivated profile of soil**. In the direction perpendicular to the direction of machine set passage, a profile graph, width of 1.3 m, was placed after exposure of bottom of chisel groove. By means of wire finders, the profile of cultivated bottom was marked in a table and photographed. From the photograph of the marked profile, the area of cultivated land was determined

Contents of areas of tilled transversal profiles were calculated by means of the Simpson's method of numerical integration (Čermák, Hlavička 2008); calculation was carried out using the Excel programme.

Specific resistance of the working tools was calculated according to the following relation:

$$k_k = \frac{F_r}{S} \qquad \text{(kPa)}$$

where: $k_k$ – specific resistance of soil during tillage (kPa); $F_r$ – tensile resistance of blade (kN); $S$ – area of transversal profile of cultivated soil (m$^2$)

The aim of this experiment was to evaluate the parameters of soil tillage and its energy intensity at the use of three tillage blades with various width of chisel and at tillage into three different depths of topsoil. For the measurement and evaluation, 3 blades were selected; they were developed for a new type of tiller for primary cultivation of soil.

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Fig. 4. Tillage mechanism with simple chisel (left), tillage mechanism with chisel, width of 75 mm and side wings (right)

Table 1. Statistical significance of differences in the area of a tilled transversal profile

| Width of chisel | Adjusted depth of cultivation | | |
|---|---|---|---|
| | 100 mm | 200 mm | 300 mm |
| 20 mm | b C | b B | b A |
| 40 mm | b C | a B | a A |
| 75 mm | a B | a A | FAILURE |

small letters – statistical significance of differences between the values in columns (for various widths of chisels in the same depth mentioned in the heading of each column); HSD = 0.0075; 0.0058; 0.006; capital letters – statistical significance of differences between the values in lines (for various depths of tillage at the same width of chisels mentioned in the heading of each line); HSD = 0.0054; 0.0046; 0.0092; differences between averages marked by the same letter are statistically insignificant

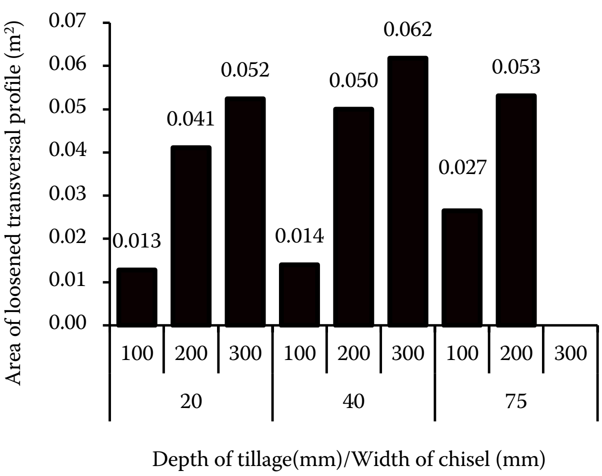


Fig. 5. Area of loosened transversal profile of soil at different depths of tillage and widths of blade chisels

## RESULTS AND DISCUSSION

The area of loosened transversal profile of soil is one of the indicators of suitability for the selection of blades. Average values from three measurements are mentioned in the graph in Fig. 5. Table 1 shows the results of statistical evaluation of loosened area profile of soil during the tillage with blades equipped by chisels with various widths and with different depth of tillage.

Dependence of area of loosened transversal profile on blade width at three depths of tillage is expressed by graph in Fig. 6. With increasing width of blade chisels, the area loosened transversal profile of soil at all three depths of tillage increases as well. To express the dependence, linear model of function was chosen.

Tensile force during the tillage considerably increased with growing depth of tillage, as it is illustrated on graph in Fig. 7. Statistical significance of differences of tensile force at different widths of blades and different depths of tillage is shown in Table 2.

For the selection of blades that can be mounted on a newly developed tiller, it is very important to evaluate the specific resistance during the tillage. Average values of specific resistance of soils are expressed in the graph in Fig. 8. Statistical significance of differences between specific resistance of soil at different widths of chisels and different depths of tillage is expressed in Table 3. In case of 75 mm-wide blades, the measurement at the greatest recess was not finished (failure caused by overload of blade standard suspension).

From the results of measurements, it is obvious that for the medium-deep tillage into the depth un-

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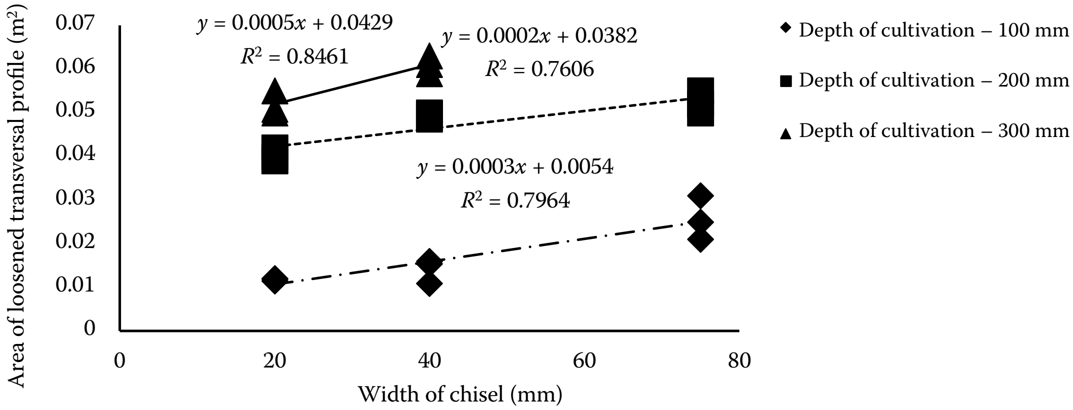


Fig. 6. Dependence of area of loosened transversal profile on the width of blade chisels

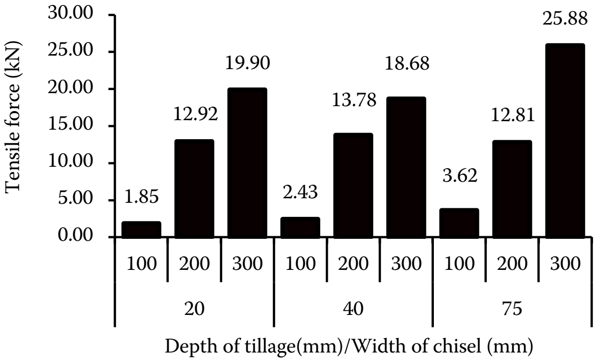


Fig. 7. Tensile force at different depths of tillage and widths of blade chisels

Table 3. Statistical significance of differences in specific resistance of tillage

| Width of chisel | Adjusted depth of cultivation | | |
|---|---|---|---|
| | 100 mm | 200 mm | 300 mm |
| 20 mm | a B | a A | a A |
| 40 mm | a B | a A | b A |
| 75 mm | a A | a A | FAILURE |

for small and capital letters explanation see Table 1; small letters HSD = 83.74; 133.20; 72.79; capital letters: HSD = 78.40; 92.35; 132.95; differences between averages marked by the same letter are statistically insignificant

der 200 mm, the suitable width of blade chisels is 75 or 40 mm. At this width of chisels, no statistically significant differences were determined in specific resistance of tillage into the same depth of soil. Measured high tensile force at blade chisel, width of 75 mm, at recess up to 300 mm is the reason for the use of these blades for medium-deep tillage up to the depth of 200 mm. Contrary to expectations, suitability of narrow chisels (20 mm) could not be confirmed for deeper tillage up to 300 mm.

Table 2. Statistical significance of tensile force differences

| Width of chisel | Adjusted depth of cultivation | | |
|---|---|---|---|
| | 100 mm | 200 mm | 300 mm |
| 20 mm | b C | a B | a A |
| 40 mm | b C | a B | ba A |
| 75 mm | a C | a B | a A |

for small and capital letters explanation see Table 1; small letters: HSD = 1.03; 5.78; 6.32; capital letters: HSD = 5.14; 4.66; 5.12; differences between averages marked by the same letter are statistically insignificant

At settings for the depth of tillage of 100 mm, using the blade with chisel, width of 75 mm, was compared to the same blade supplemented by side wings, when the total width of the working tools was 110, 150 and 200 mm. This measurement was aimed at the assessment of different variants of working tools for shallow tillage, in terms of param-

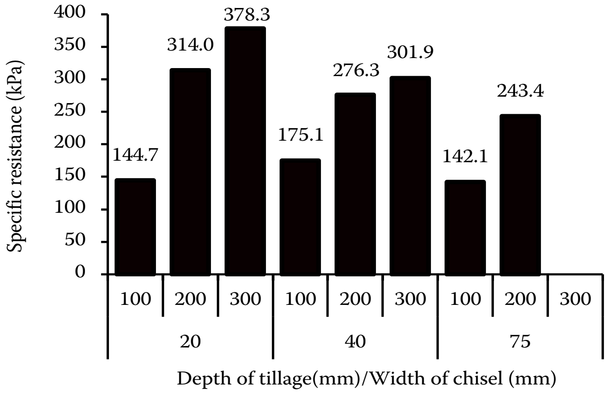


Fig. 8. Specific resistance at different depths of soil tillage and widths of blade chisels

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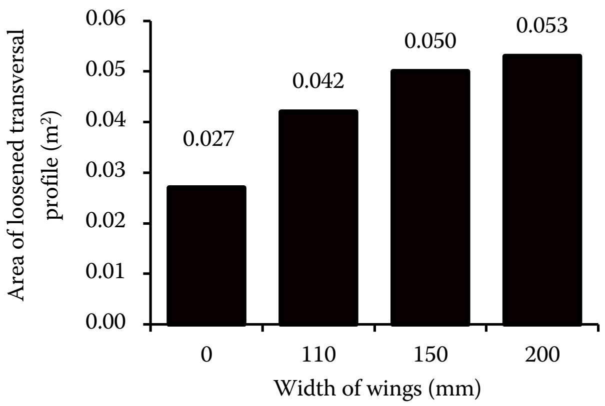


Fig. 9. Area of loosened transversal profile at different widths of wings in case of the blade equipped by chisel, width of 75 mm; differences between averages marked with the same letter are not statistically significant; HSD = 0.0077

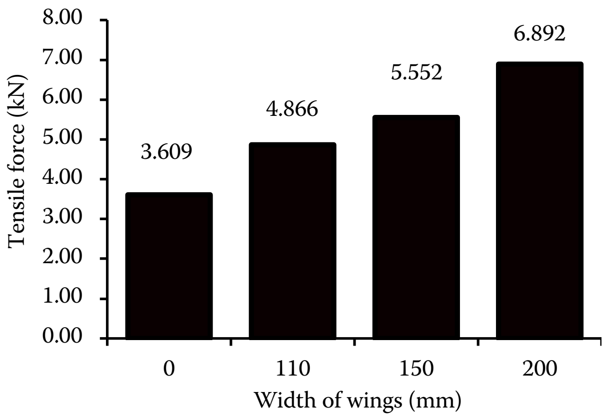


Fig. 10. Tensile force at different width of wings at blade with chisel, width of 75 mm; HSD = 2.22; differences between averages marked with the same letter are not statistically significant

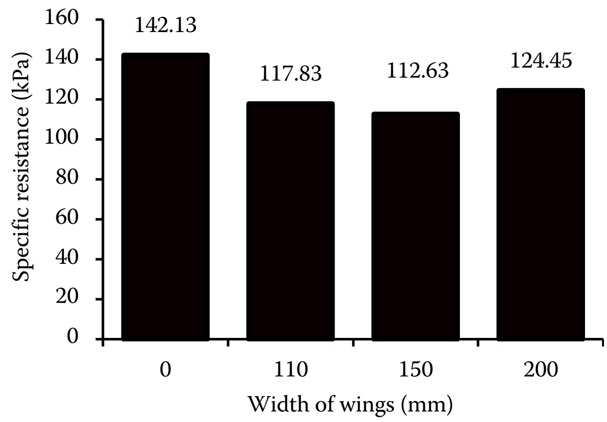


Fig. 11. Specific resistance of tillage using wings of different widths in case of the blade equipped by chisel, width of 75 mm; HSD = 85.94; differences between averages marked with the same letter are not statistically significant

eters of tillage and their energy intensity. Area of the loosened transversal profile of soil with marked statistical significance of differences between averages is shown in Fig. 9.

Values of tensile force incl. statistically significant differences between averages are shown in Fig. 10. Use of wings led to an increase of tensile force, this force was increasing with growing width of wings. Only the values in case of a blade without the wings and blade with wings of 200 mm of width differed from each other statistically significantly.

Average values of specific resistance of soil during the tillage by blade with chisel width of 75 mm with added side wings are shown in the graph in Fig. 11. Differences between averages were under the limit of statistical significance.

From the evaluation of advantages of side wings results that at the width of wings of 150 mm a favourable area of loosened profile of soil was found, with acceptable tensile force and the lowest specific resistance of tillage. However, it was also under the limit of statistical significance. Blades were equipped with a 75 mm-wide chisel, with side wings and width of 150 mm. As a suitable alternative for shallow tillage of soil, usually stubble ploughing and repeated shallow tillage can be recommended.

Majority of professional literature sources mentions that with increasing required depth of tillage, it is suitable to reduce the chisel width of blades. This finding was confirmed by realized measurement only in part. On the contrary, the suitability of blades equipped by side wings was confirmed for the purpose of shallow tillage and can be recommended.

Arvidsson and Hillerström (2010) found out a statistically non-conclusive increase of specific resistance of tillage with growing width of chisels. This trend was not confirmed in this study. On the contrary, the results confirmed increasing specific resistance of tillage with the growing depth.

## CONCLUSION

On the basis of the measurement results, it is possible to deduce the following conclusions:

– width of blade chisels had no statistically significant effect on the values of specific resistance of soil tillage;

– at all widths of blades the trend of increasing specific resistance with increasing recess of blades was recorded;

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– at the use of side wings at blade with the chisel width of 75 mm, it was found out that with increasing width of side wings the tensile force was increasing, whereas the specific resistance was not influenced by the use of side wings. For shallow tillage of soil it is possible to recommend a blade equipped by side wings with 150 mm of width.

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Received for publication October 24, 2017
Accepted after corrections March 15, 2018