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Employment characteristics of tine cultivators at deeper soil loosening

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Abstract

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The work quality of selected tine cultivators that are suitable equally for deeper soil cultivation has been evaluated. The following implements were tested in a stubble field: Köckerling Vario 570, Simba Solo 450, Horsch Terrano 5 FX, Strom Finisher Mega 8000, Farmet Turbulent 450, Kverneland CLC 430, Väderstad TopDown 400. The cultivator evaluation criteria were the following: quantity of plant residues left on the soil surface, size distribution of clods, transverse elevation profile of the soil surface, elevation profile of the furrow bottom, cultivation depth, unit fuel consumption, travel reduction ratio, work-rate, and unit draft of a cultivator. All of the cultivators were equipped mainly with tine tools, followed further on by disc tools and either by levelling or by crumbling tools. Plant residues were well worked into the soil by Väderstad and Farmet cultivators. Horsch, Kverneland and Väderstad cultivators showed good crumbling effect. The highest work speed was reached by tractors with Strom and Horsch implements.

Keywords: clod size; cultivation depth; deeper cultivation; plant residues; tine cultivator; unit draft

New structural designs of farm implements and tools enable extensive use of various ways of reduced-tillage technologies of soil cultivation, soil preparation and sowing. Nowadays, there is a wide range of farm implements and lines intended for reduced-tillage technology that makes it possible to accommodate the selection of a technological process to particular conditions, thus ensuring quality crop stand establishment.

Field trials focused on work quality comparison of farm implements are not frequent, and those carried out by an independent institution, and thus impartial, are almost rare (Šařec, Šařec 2011). Therefore, no relevant references are at hand. More attention is given to working tool design than to the final implements. This, however, enables to predict draught of the implements (Sahu, Raheman 2006). The draught force required to pull an implement is of great importance, since it determines fuel consumption and the tractor power required. For a given tractor size, reducing the draught force per metre working width means that the implement size or working speed can be increased, leading to higher work rate and decreased timeliness costs. There are clear differences in specific draught between the different tine and share types (Arvidsson, Hillerström 2010). Draught also increases with depth of operation at an increasing rate (Manuwa 2009). Minimising the draught force though it is not the main issue because reducing the magnitude of the

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specific resistance (draught force/disturbance) is much more significant as it is a better indicator of overall tillage efficiency (Godwin 2007).

Most of the seven tested cultivators were regular tine cultivators suitable in general for deeper soil movement to 0.15 to up to 0.25 m depth. The cultivators Horsch Terrano 5 FX (Horsch Maschinen GmbH, Schwandorf, Germany) and Farmet Turbulent 450 (Farmet a.s., Česká Skalice, Czech Republic) consisted of a tine section, of levelling discs, and of a rear roller or packer. The cultivator Väderstad TopDown 400 (Väderstad-Verken AB, Väderstad, Sweden) was in addition equipped with a front disc section. The cultivator Köckerling Vario 570 (Köckerling GmbH & Co. KG, Verl, Germany) was composed of tines followed by a rear roller. The cultivator Kverneland CLC 430 (Kverneland Group, Klepp, Norway) was composed of tines also in front, but followed by two rear disc gangs. The cultivator Strom Finisher Mega 8000 (Strom Export s.r.o., Prague, Czech Republic) could be viewed as an exception, because it was constructed for the working depths up to 20 cm at most, and was described by the manufacturer as a disc-tine cultivator. It was composed of front disc gangs, tines, a drag and a rear roller. Finally, the cultivator Simba Solo 450 (Simba International Ltd., Sleaford, UK) was labelled by its manufacturer as a disc cultivator since it consisted of front disc gangs, loosening tines (TerraGrip 250 mm), rear disc gangs (both front and rear 0.7 m in diameter) and a rear roller.

MATERIAL AND METHODS

The aim was to evaluate the work characteristics of various manufacturers' tine cultivators performing a deeper soil cultivation of stubble to the depths exceeding 0.15 m.

The field trial took place at the farm Agro Slatiny a.s., Slatiny, Czech Republic during five days from the September 3–7, 2010. The experiment was accomplished by staff members and postgraduate students of the Department of Machinery Utilization, Faculty of Engineering, Czech University of Life Sciences Prague, Czech Republic. The tine cultivators were tested when tilling trial lots of stubble in the same field. Due to precipitations that changed the work conditions, the individual cultivators had to be towed by different tractors. Each of the cultivators in question made two passes, the second one in a particular angle to the first one, in the following variants (Table 1).

Table 1. Field trial variants and basic characteristics of used machinery

Variant	Pass	Tractor	Engine power (HP)	Cultivator	Working width (m)
0			stubble field prior to soil cultivation		
I	1st	Challenger	330	Köckerling Vario 570	5.7
II	2nd	Challenger	330	Köckerling Vario 570	5.7
III	1st	Case Magnum 310	310	Simba Solo 450	4.5
IV	2nd	Case Magnum 310	310	Simba Solo 450	4.5
V	1st	JD 8530	350	Horsch Terrano 5 FX	5
VI	2nd	JD 8530	350	Horsch Terrano 5 FX	5
VII	1st	Fendt 930 Vario TMS	300	Strom Finisher Mega 8000	6
VIII	2nd	Fendt 930 Vario TMS	300	Strom Finisher Mega 8000	6
IX	1st	Challenger	330	Farmet Turbulent 450	4.5
X	2nd	Challenger	330	Farmet Turbulent 450	4.5
XI	1st	Fendt 924 Vario	240	Kverneland CLC 430	4.3
XII	2nd	Fendt 924 Vario	240	Kverneland CLC 430	4.3
XIII	1st	Fendt 924 Vario	240	Väderstad TopDown 400	4
XIV	2nd	Fendt 924 Vario	240	Väderstad TopDown 400	4

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Fig. 1. Measurement of clod size distribution by screens of various sizes

Before, during or after each pass of the cultivators, the following variables were measured or monitored:

– soil moisture content (%),
– quantity of plant residues/m^2,
– clod size distribution (measured by screens of various sizes (Fig. 1),
– soil penetration resistance (MPa) (measured by the apparatus PX 70; Czech University of Life Sciences, Prague, Czech Republic),
– soil bulk density (g/cm^3) and porosity (%),
– field speed (km/h),
– travel reduction ratio,
– cultivation depth (m) and its evenness,
– unit draft of a cultivator (N/cm^2) (measured by a special three-point hitch frame (Fig. 2),

Fig. 2. Special three-point hitch frame measuring draft of a cultivator

Fig. 3. Elevation profile measurement using a laser profilometer

– elevation profile of the furrow bottom (measured using a laser profilometer – custom made using laser sensor Banner LT3; Czech University of Life Sciences, Prague, Czech Republic) (Fig. 3) – prior to each measurement, the tilled soil down to the furrow bottom was removed in a stretch 1.64 m. wide and crosswise to the direction of cultivation in order to carry out the measurement.

For each item measured, at least four samples were taken, and their average was evaluated.

RESULTS AND DISCUSSION

Every day of the field trials, there were numerous rainfalls from 1 to 5 mm. This made the measurements more difficult, and affected particularly the travel reduction ratio (slip) of the tractors, and also the sieving of soil when investigating the clod size distribution.

Characteristics of work conditions

The trial field was stubble after the harvest of winter wheat whose straw had been gathered. Stubble height varied between 0.080 and 0.192 m. Soil porosity ranged from 47.4 to 48.6% by volume (the average being 47.9%), soil bulk density from 1.38 to 1.58 g/cm^3 (the average 1.46 g/cm^3), and the soil moisture ranged from 16.3 to 17.8% by weight (the average 17.2%).

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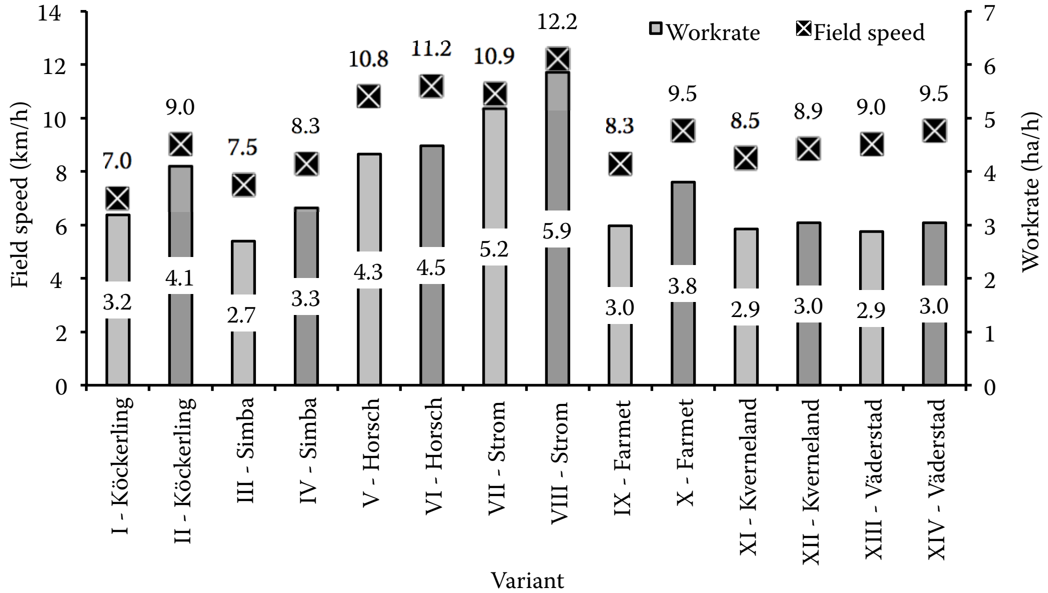

Fig. 4. Field speeds and work rates of tractors and cultivators tested

Tine cultivators' work characteristics

The required field speed was set down to 10 km/h. Only the tractors with Horsch and Strom cultivators managed to adhere to this speed (Fig. 4). The other cultivators worked at a speed ranging from 7.0 to 9.5 km/h. The reasons were either an insufficient drawbar power or a significant travel reduction ratio (slip).

The work rates shown in Fig. 4 were calculated using working widths of the cultivators and their field speeds. The field efficiency of 0.8 was considered for all of the sets of tractors and cultivators. The highest work rate was attained by the set with the cultivator Strom, followed then by the sets with the Horsch and Köckerling cultivators.

The required working depth of the cultivators was set down to 0.15 to up to 0.20 m. Most of the

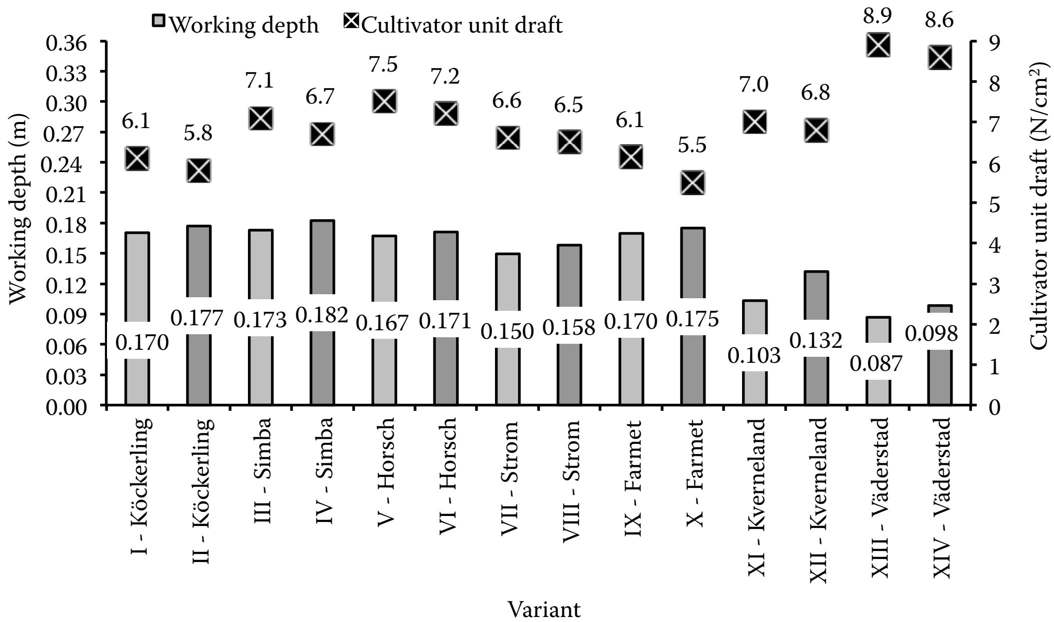

Fig. 5. Working depths and unit drafts of the cultivators tested

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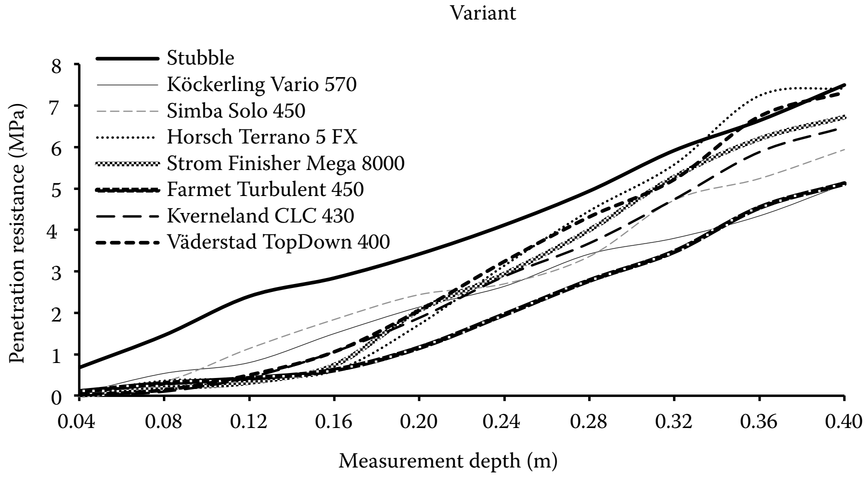

Fig. 6. Average values of soil penetration resistance for stubble and for the variants after the first pass of the cultivators tested

sets of tractors and cultivators succeeded to adhere to this depth (Fig. 5). The cultivators Strom and particularly Kverneland and Väderstad were exceptions because of considerable travel reduction ratios (slips) of the respective tractors.

The lowest draft per square centimetre (Fig. 5) was measured in the case of the Farmet and Köckerling cultivators equipped with chisel shaped tools. On the other hand, the cultivator Väderstad demonstrated the highest unit draft.

As Fig. 6 shows, the highest values of soil penetration resistance were revealed on stubble, particularly at depths up to 0.32 m. After the first pass, values of soil penetration resistance to the depth up to 0.20 m did not differ distinctly between the cultivators. Yet at the depths from 0.36 to 0.40 m, the differences among the cultivators increased. The lowest values were determined in the case of the cultivators equipped with chisel shaped shares, i.e. in the case of Farmet and Köckerling, whereas the highest resistance was reached in the case of the cultivators with goose-foot shaped shares or similar, i.e. in the case of Horsch and Väderstad.

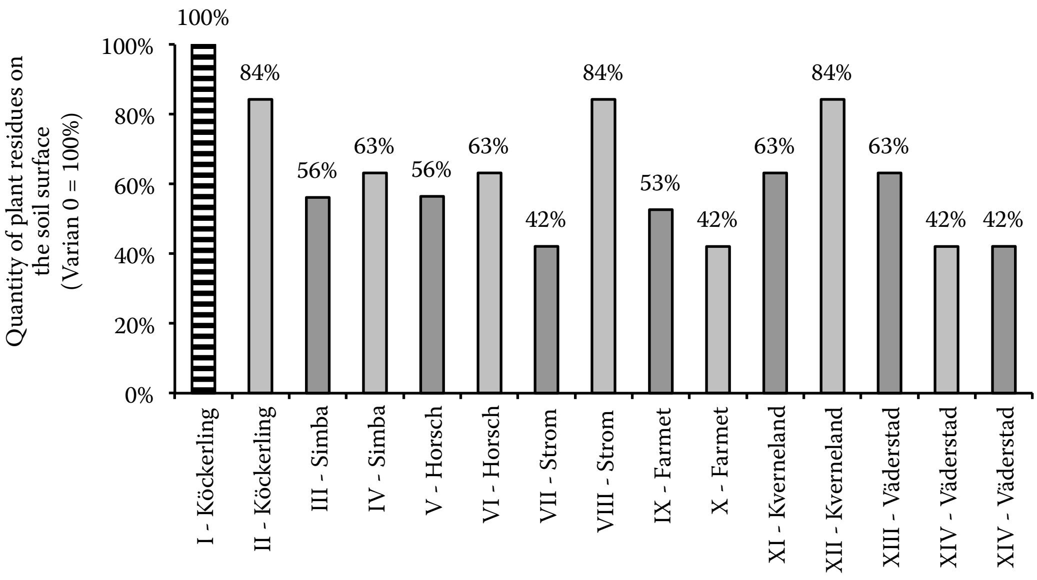

Fig. 7. Relative quantity of plant residues on the soil surface (value of variant 0, i.e. 0.76 kg/m^2, considered as 100%)

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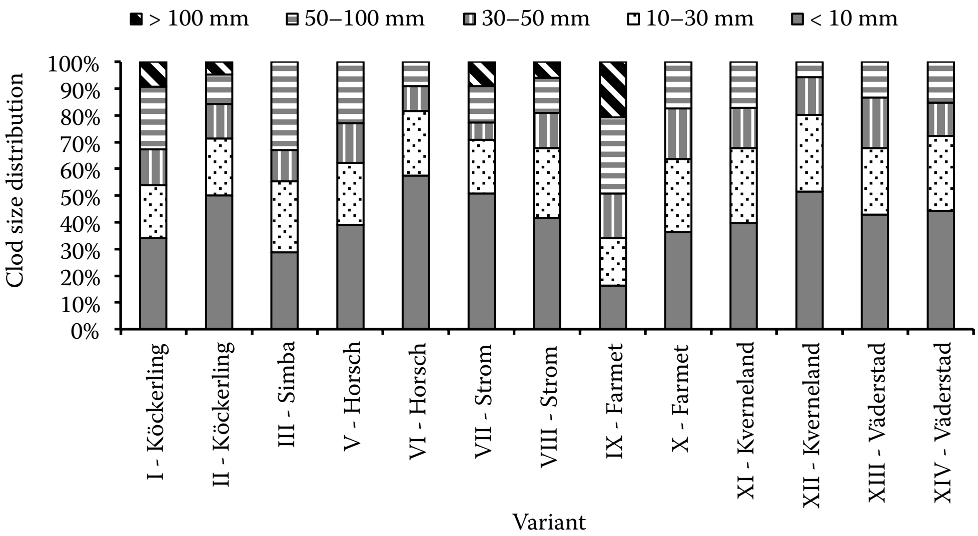

Fig. 8. Relative size distribution of soil clods by weight

The largest fraction of plant residues left on the soil surface (Fig. 7) was measured after the first pass of the cultivators Kverneland, Köckerling, and Strom. On the other hand, the cultivators Väderstad and Farmet showed good capacity in embedding plant residues. After the second pass, plant residues were well embedded again by the cultivator Väderstad, and equally by the cultivator Horsch. Farmet demonstrated slightly higher quantity of plant residues left on the soil surface than after the first pass.

Cultivators Horsch, Kverneland and Väderstad, generally those equipped with goose-foot shaped shares or similar, demonstrated good ability in breaking down the soil clods (Fig. 8). On the other hand, low crumbling effect was measured in the case of Farmet and Simba cultivators. The values for the Simba cultivator after the second pass could not be determined due to heavy precipitation.

Cultivators Kverneland, Strom, Väderstad and Simba provided good results in terms of evenness of the furrow bottom (Fig. 9). On the other hand, after the first pass of the cultivators Horsch Terrano 5 FX, Köckerling Vario 570 and Farmet Turbulent 450, the furrow bottom showed substantial ups and downs.

None of the cultivator proved to be the best or the worst in all of the monitored indicators. The outcomes also depend on the shape of tines, which may be changed within a given cultivator to bring the desired effect.

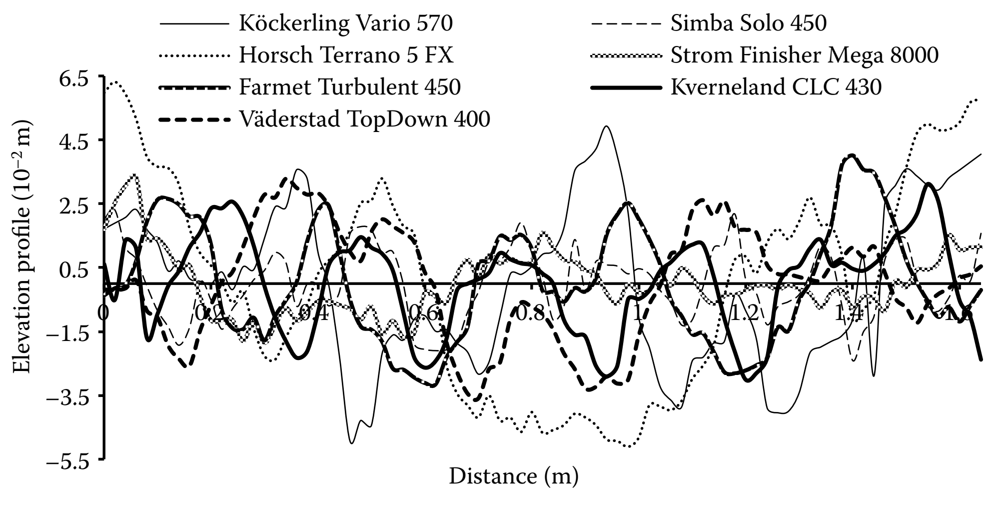

Fig. 9. Elevation profiles of the furrow bottom in the direction crosswise to the first pass of the cultivators tested

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CONCLUSION

The tractors with cultivators Strom Finisher Mega 8000 and Horsch Terrano 5 FX were able under the given conditions to attain the highest field speed as well as work rate. However, these conditions were not uniform due to changing precipitations, and due to various tractors used for drawing individual cultivators. That is partly why the required working depth, i.e. 0.15 to 0.20 m, could not be adhered to at all times.

Cultivators Farmet Turbulent 450 and Köckerling Vario 570, generally those equipped with chisel shaped tools, demonstrated the lowest values of unit draft.

The lowest values of soil penetration resistance below the cultivated profile were determined with the cultivators equipped with chisel shaped shares, i.e. in the case of Farmet and Köckerling.

Cultivators Väderstad TopDown 400 and Farmet Turbulent 450 showed good capacity in embedding plant residues.

Cultivators Horsch Terrano 5 FX, Kverneland CLC 430 and Väderstad TopDown 400, generally those equipped with goose-foot shaped shares or similar, demonstrated good ability in breaking down the soil clods.

Cultivators Kverneland CLC 430, Strom Finisher Mega 8000, Väderstad TopDown 400 and Simba Solo 450 provided good results in terms of evenness of the furrow bottom.

The authors recommend to loosen the beaten tracks and headlands prior to stubble cultivation, and to loosen the whole field prior to sowing employing the tested or similar cultivators.

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