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Comparison of two sowing systems for CTF using commercially available machinery

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Abstract. The crop establishment belongs to crucial technology operations. The quality of sowing is the basis for obtaining efficiency of production. Controlled Traffic Farming (CTF) is a technology which prevents excessive soil compaction and minimizes compacted area to the smallest possible area of permanent traffic lanes (PTL). There were two sowing systems compared, namely row and band sowing when growing winter barley. Sowing parameters as well as all other field operations were identical for both compared systems. Measurements were conducted at an experimental field on non-compacted and traffic lane areas where CTF system was introduced in 2009, with 64% of compacted and 36% of non-compacted soil. Six crop parameters were analysed. Generally, it can be concluded that the band sowing performed better in yield (by 9.3% in non-compacted area; by 3.8% in traffic lane), ear number (by 5.2% in non-compacted area; by 10.1% in traffic lane) and grain number (by 6.3% in non-compacted area; by 8.1% in traffic lane) as well as crop height (by 6.6% in non-compacted area; and by 2.4% in traffic lane). The only parameter performing worse was TGW with decrease of 6.6% in non-compacted area and decrease 2.8% in traffic lane for band system. Differences in number of grain per ear were negligible.

Key words: band sowing, drill, CTF, soil compaction, cereals.

INTRODUCTION

Controlled Traffic Farming (CTF) system currently belongs to modern methods that are progressively becoming part of the efficient management of crop production in precision farming (Rataj et al., 2014).

The essence of this system is to concentrate the individual machinery paths into one trajectory with respect to the integer multiples of the working width of individual machines, in order to reduce the trafficked area and consequently improve growing condition compared to RTF (Random Traffic Farming) system. The reason for putting this system into practice is a long-term trend in continuously increasing size and especially weight of agricultural machinery (Kutzbach, 2000).

Chaiman (2015), Goodwin et al. (2015), Kroulík et al. (2011), Kumhála et al. (2013) and others state, that the primary effect of implementing the CTF system is to improve soil structure. According to the quoted authors this system can be used as a long-term tool to prevent soil compaction. As a result of the decreasing soil compaction, the pore volume and water infiltration capacity are increased, and the soil bulk density is decreased (Kovář et al. 2016; Chyba et al. 2017). Improvement of these physical-mechanical properties of the soil is subsequently reflected in the increase of crop yields.

Vermeulen et al. (2010) states, that within CTF system, besides the above benefits, there is also a more effective use of agricultural machinery. Consolidated tracks allow access to the field even in wetter soil conditions. There is a decrease in energy intensity, a lower number of operations, shallower cultivation, and lower tractor power requirement.

The CTF system is closely associated with conservation tillage systems eventually direct drilling. CTF creates two zones: non-trafficked crop beds and cropped or non-cropped traffic lanes (Chamen, 2015). This system can be established also with ordinary machinery without special adjustment, with different percentage proportion of non-trafficked area up to 68% (Gutu, 2015).

If the farmer decides to seed the CTF trafficked lanes, it is necessary to increase intensity of soil preparation and seeding requirements. This is required, because these lanes are caused by centralized traffic of all machinery during the growing season and the soil is more compacted then soil located in non-trafficked areas (Arslan et al., 2015, Kroulík et al. 2016).

Alternatively, it is possible to use special seed drills (combined seed drills with soil preparation or seed drill for direct drilling), that are able to place seed into the required depth evenly over the entire working width, including compacted CTF traffic lanes.

The aim of this work was to compare differences between two seeding systems in CTF technology through selected crop parameters with emphasis on different intensity of soil compaction.

MATERIALS AND METHODS

Experiment design

In 2010, a long-term field experiment was launched with the technology of Controlled Traffic Farming (CTF) at Slovak University of Agriculture in Kolíňany, Slovakia. This technology is used on a 16 ha field. Soil texture class on top (0–35 cm) is silty loam (51% silt, 30% sand, 19% clay) – analyses were conducted based on Slovak standards (Hrivňáková et al., 2011). Type of CTF system is 6 m OutTrack (64% non-compacted soil, 36% compacted soil). Commercially available machinery with standard wheel spacing were used for work operations – as they were supplied by the manufacturer. Field was cultivated within soil conservation tillage (without ploughing) up to depth of 15 cm. More detailed information can be found in other publications (e.g. Goodwin et al., 2015; Galambošová et al., 2017; Barát et al., 2017).

The possibility of using direct seed drill with breaker tines for band sowing in CTF system was studied in comparison with row sowing system during one-year experiment in growing season 2016–2017.

It was necessary to respect the long-term experiment during setting up a sampling layout, especially direction of CTF track lanes and simulated RTF strips on the research field.

To solve the established aim of this paper, 18 monitoring points were designated, of which 9 points were located in three RTF strips (see Fig. 1). The RTF strips are areas trafficked wheel by wheel once a year with tractor John Deere 8230 (tire pressure 2.0 bar), perpendicularly to the direction of CTF.

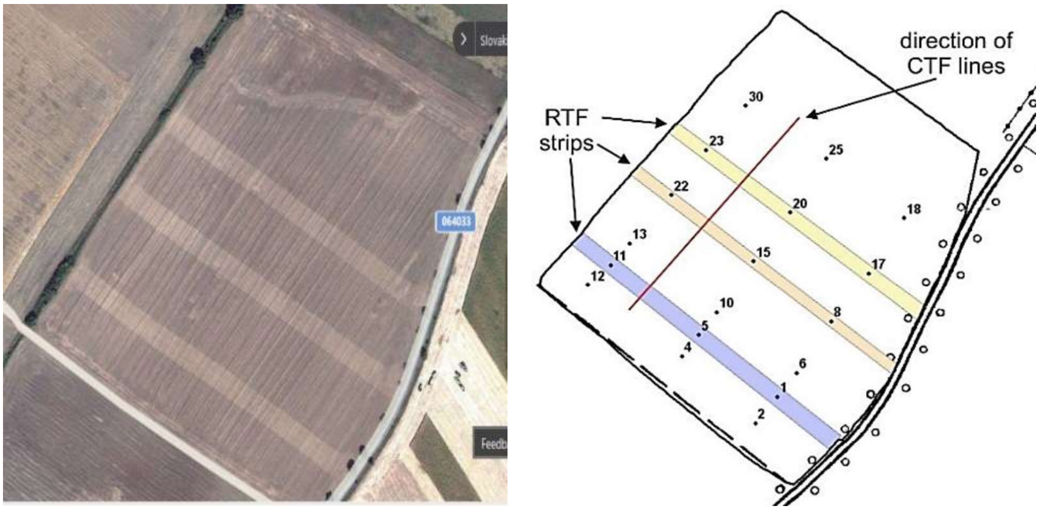

Figure 1. Satellite image showing 1x passed compacted area for RTF simulation, direction of CTF lanes and monitoring points (no. 1– 0) sampling layout.

The resulting matrix of experiment was based on 4 zones marked A, B, C, D, which represented areas with 4 different compaction intensities. The least compacted soil was in zone A, the most compacted in zone D. The soil compaction intensity was measured as a penetration resistance in the vertical axis, with a device manufactured by Eijlkelkamp. The values of penetration resistance (Fig. 2) show different intensity of soil compaction, as well as the depth of long-term soil cultivation.

The seeding was carried out alternately in the direction of CTF lanes – two passes with standard row seed drill, and two passes with combined direct drill for band sowing (see Fig. 3). The four treatments (zones A, B, C, D), from within which measurements were taken, were denoted as shown in Fig. 4. The samples were taken from each monitoring point in three replications in each zone. Each sample consisteds of crops cut nearly above ground from 1 m^2 area. Together 12 samples (6 from row sowing and 6 form band sowing area) were taken in each monitoring point with the mentioned process (see Fig. 3).

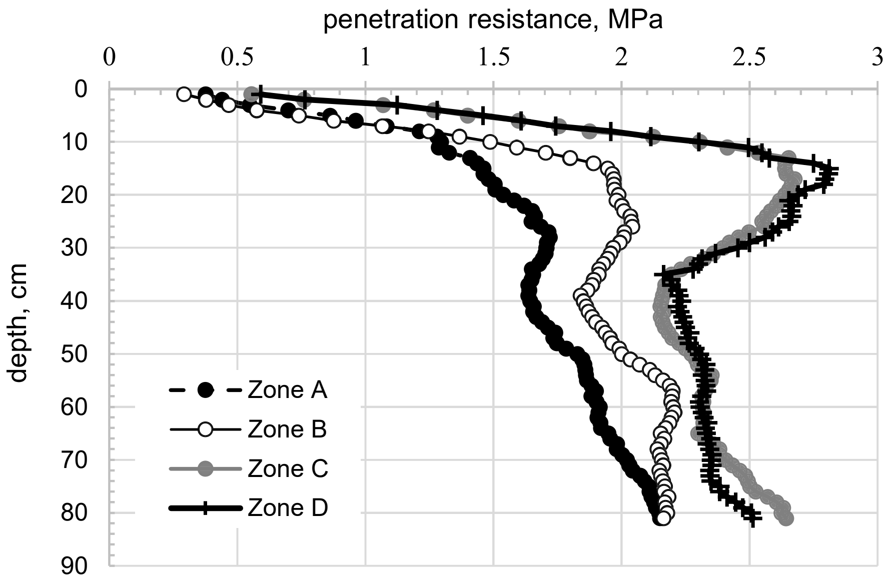

Figure 2. Intensity of soil compaction in experimental zones represented by vertical penetration resistance (measured in 2015).

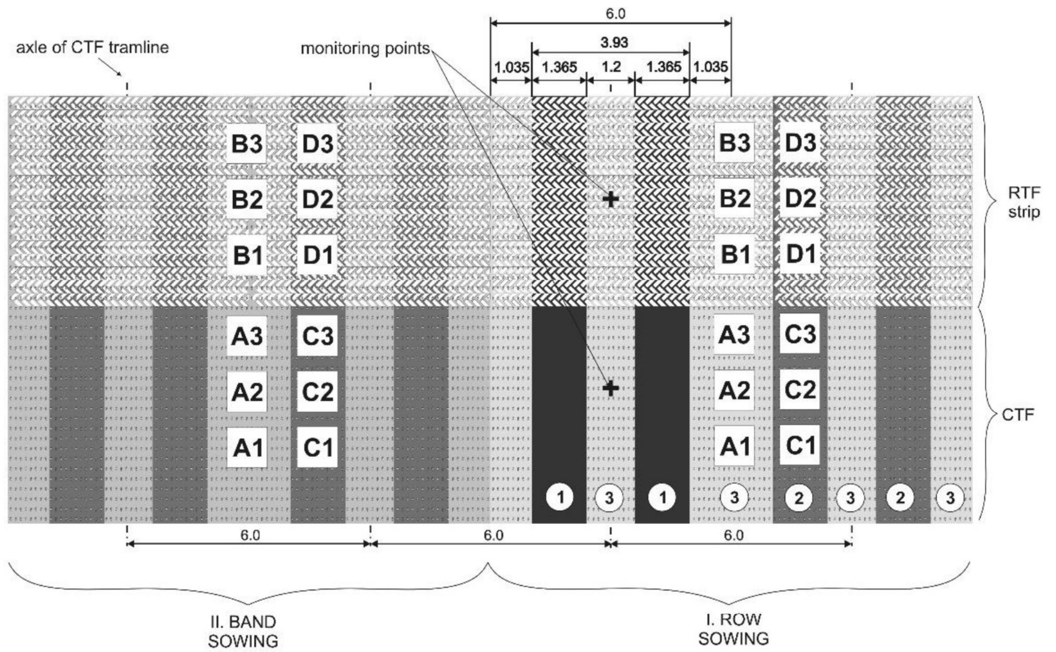

Figure 3. Experiment design – example of taking yield sampling layout on two monitoring points; 1 – non-cropped multiple-trafficked lanes – sprayer lanes (each 24 m), 2 – cropped multiple-trafficked lanes (location of samples: C1, C2, C3 and samples D1, D2, D3 in RTF strip), 3 – non-trafficked crop beds (location of samples A1, A2, A3); and one pass trafficked crop beds (location samples B1, B2, B3 in RTF strip), (the values given in the picture are t in meters).

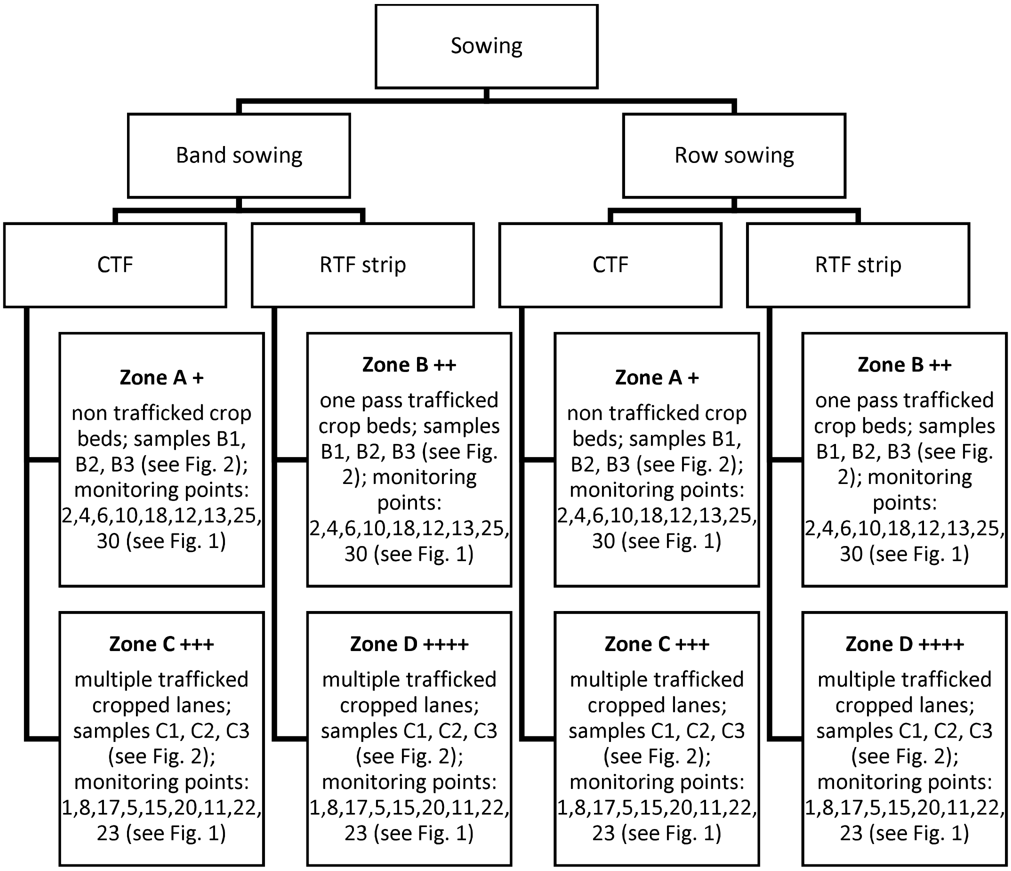

Figure 4. Matrix of experiment variants ('+' represents intensity of soil compaction from low + to high level ++++).

Seasonal and long-term experiment conditions

Within agricultural production processes on experimental field, conservation tillage is used together with growing crops as cereals, oil seed rape, and corn. Temperature and rainfall in the 2016/2017 growing season and long-term averages are shown in Fig. 5.

In one-season experimental assignment it was hypothesized, that the 6 crop parameters could be increased using the band sowing system in comparison to the row sowing system in different soil compaction zones specified in CTF system. Experiment conditions and all seasonal agrotechnical operations, were same for both sowing systems.

Row sowing was done by John Deere 8100 tractor and Lemken Solitair 9 universal seed drill with conventional row spacing of 12.5 cm. Band sowing was established by Kirovec K7484 tractor and Claydon Hybrid T6 combined direct seed drill with partial soil tillage, with band spacing of 30 cm (15 cm seed band + 15 cm free band without seed). The depth of breaker tines was set to 15 cm to keep the cultivation depth the same for both systems. Type of the seed, parameters of sowing and used drills are showed in Table 1.

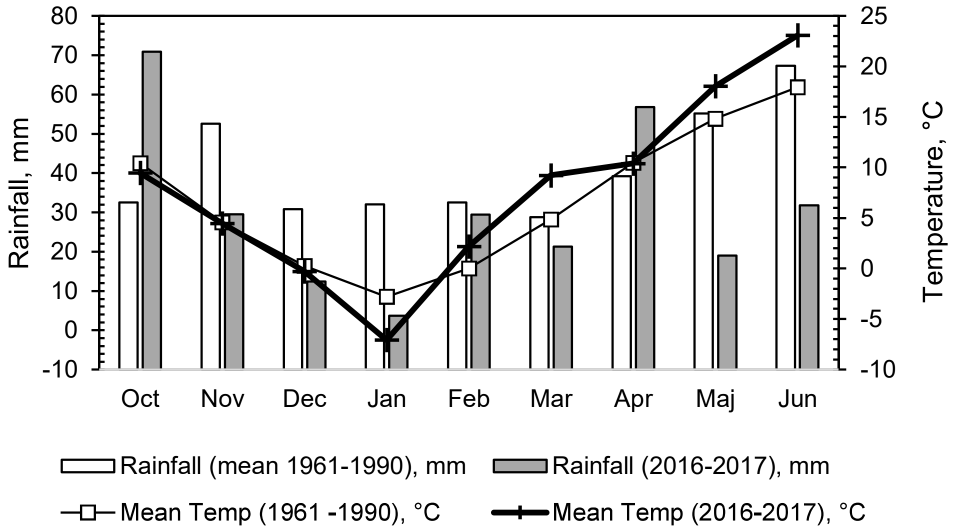

Figure 5. Rainfall represented monthly as sum of precipitations and monthly means of air temperature records for Kolíňany, Slovakia (Slovak University of Agriculture in Nitra, 2017).

Table 1. Parameters of seed, sowing and used drills

Parameter	SEED	
Botanical name	Hordeum vulgare L. (winter barley)	
Variety	WINTMALT	
Generation	C1	
Seed disinfectant	Lamardor 400 FS	
Certified by	Central Control and Testing Institute in Agriculture – Slovakia	
Parameter	DRILLS	
	Lemken Solitair 9	Claydon Hybrid T6
Swath width, m	6	6
Number of sowing tines, pcs	48	19
Seed row/band spacing, cm	12.5	15
Weight, kg	1,600	6,500
Front breaker tines, pcs	NA	19
Maximum depth of breaker tines, mm	NA	300
Parameter	SOWING	
	row sowing	band sowing
Sowing rate, kgha^{-1}	220	220
Depth of sowing, mm	30–40	30–40
Depth of breaker tines, mm	NA	150

Note: NA – not available.

The following six parameters were analysed: ear number, yield, TGW – Thousand Grain Weight, crop height, grain number per 1 m^2, grain number per ear. Yield and TGW were recalculated to uniform moisture content 14%.

Parameters were determined using the methodology contained in the following standards – STN EN ISO 520, STN EN ISO 24333/AC, STN EN ISO 712, STN 46 1025. Pairwise comparison of monitored sowing systems was carried out according to *Fisher's LSD test* (Least Significant Difference) statistical method.

RESULTS AND DISCUSSION

The assessment of band and row sowing systems was carried out in the CTF experimental field. The aim was to find out, if there is a statistically significant difference between the band and row sowing system with respect to 6 crop parameters. Calculated mean values and their standard deviations of measured crop parameters are shown in Table 2. Final results of *Fisher's LSD test* for all measured parameters are shown in Table 3.

Table 2. Means and standard deviations of crop parameters recorded for row and band sowing system, ($n = 9$; each value was calculated as the average of the area of 3 m^2)

Parameter	Zone	Row sowing, mean ± STD	Band sowing, mean ± STD	diff. between means of band and row sowing,	diff. between means of band and row sowing *, %
Ear number, pcs m^{-2}	A	913.6±180.1	961.3±118.2	47.7	5.2%
	B	806.5±108.3	1,040.4±155.9	233.9	29.0%
	C	884.9±105.0	974.7±98.7	89.8	10.1%
	D	845.6±79.9	993.3±106.4	147.7	17.5%
Yield (14%), t ha^{-1}	A	8.0±1.6	8.7±1.0	0.7	9.3%
	B	6.9±1.1	8.8±1.2	2.0	28.8%
	C	7.8±0.7	8.1±0.7	0.3	3.8%
	D	7.2±1.0	8.3±1.0	1.0	14.3%
TGW (14%), g	A	47.7±1.8	44.6±6.8	-3.1	-6.6%
	B	46.3±1.8	45.4±3.2	-0.9	-2.0%
	C	46.3±1.9	45.1±3.7	-1.3	-2.8%
	D	48.3±4.3	43.3±4.0	-5.0	-10.4%
Crop height, cm	A	78.1±4.9	83.3±3.0	5.1	6.6%
	B	76.1±6.2	83.2±4.8	7.1	9.3%
	C	82.8±4.4	84.9±2.0	2.0	2.4%
	D	77.0±5.3	82.4±3.0	5.3	6.9%
Grain number, pcs m^{-2}	A	16,987.7±3,497.3	18,055.7±2479.3	1,068.0	6.3%
	B	15,059.3±2,211.3	19,436.9±3618.5	4,377.6	29.1%
	C	16,547.1±1,970.8	17,893.5±1950.6	1,346.4	8.1%
	D	15,712.6±2,055.2	18,369.1±2717.7	2,656.5	16.9%
Grain number per ear, pcs/ear	A	18.6±0.7	18.8±1.5	0.2	1.3%
	B	18.7±0.8	18.6±1.3	-0.04	-0.2%
	C	18.8±1.4	18.4±1.1	-0.4	-2.1%
	D	18.6±1.6	18.4±1.1	-0.1	-0.7%

diff. = difference; STD = standard deviation; * row sowing is interpreted in calculation as 100% accounting basis; pcs = pieces.

Table 3. Differences between means and significance of pairwise comaprisons; asterisks indicate differences larger than *LSD* at $p < 0.1$ (*) *LSD* and $p < 0.05$ (**); ns = not significant

Crop parameter	Zone A	Zone B	Zone C	Zone D
Ear number pcs.m^{-2}	$LSD_{0.05}$ = 161.44 $LSD_{0.1}$ = 132.95	$LSD_{0.05}$ = 142.24 $LSD_{0.1}$ = 117.14	$LSD_{0.05}$ = 108.04 $LSD_{0.1}$ = 88.97	$LSD_{0.05}$ = 99.74 $LSD_{0.1}$ = 82.14
	47.70 ns	**233.93 ****	**89.78 ***	**147.70 ****
Yield, t ha^{-1}	$LSD_{0.05}$ = 1.45 $LSD_{0.1}$ = 1.19	$LSD_{0.05}$ = 1.25 $LSD_{0.1}$ = 1.03	$LSD_{0.05}$ = 0.73 $LSD_{0.1}$ = 0.60	$LSD_{0.05}$ = 1.08 $LSD_{0.1}$ = 0.89
	0.74 ns	**1.97 ****	**0.30 ns**	**1.04 ***
TGW, g	$LSD_{0.05}$ = 5.31 $LSD_{0.1}$ = 4.38	$LSD_{0.05}$ = 2.72 $LSD_{0.1}$ = 2.24	$LSD_{0.05}$ = 3.15 $LSD_{0.1}$ = 2.60	$LSD_{0.05}$ = 4.39 $LSD_{0.1}$ = 3.62
	-3.14 ns	**-0.92 ns**	**-1.28 ns**	**-5.05 ****
crop height, cm	$LSD_{0.05}$ = 4.27 $LSD_{0.1}$ = 3.52	$LSD_{0.05}$ = 5.86 $LSD_{0.1}$ = 4.82	$LSD_{0.05}$ = 3.60 $LSD_{0.1}$ = 2.96	$LSD_{0.05}$ = 4.55 $LSD_{0.1}$ = 3.75
	5.13 **	**7.09 ****	**2.03 ns**	**5.34 ****
Grain number pcs.m^{-2}	$LSD_{0.05}$ = 3,213.06 $LSD_{0.1}$ = 2,646.17	$LSD_{0.05}$ = 3,178.35 $LSD_{0.1}$ = 2,617.59	$LSD_{0.05}$ = 2,078.29 $LSD_{0.1}$ = 1,711.61	$LSD_{0.05}$ = 2,553.79 $LSD_{0.1}$ = 2,103.22
	1,068.00 ns	**4,377.59 ****	**1,346.39 ns**	**2,656.52 ****
Grain number per ear pcs/ear	$LSD_{0.05}$ = 1.26 $LSD_{0.1}$ = 1.04	$LSD_{0.05}$ = 1.16 $LSD_{0.1}$ = 0.96	$LSD_{0.05}$ = 1.30 $LSD_{0.1}$ = 1.07	$LSD_{0.05}$ = 1.50 $LSD_{0.1}$ = 1.23
	0.25 ns	**-0.04 ns**	**-0.40 ns**	**-0.14 ns**

The obtained differences between the average yields, the number of ears, the number of grain per 1 m^2 and the crop height were positive for the benefit of band sowing in each zone (A, B, C and D).

Differences in ear number between band and row sowing system ranged from 5.2% to 29% (Table 2). The differences were significant ($p > 0.05$) in zone B and D, and in zone C (at $p > 0.1$). In zone A, the differences were not significant as is shown in Table 3. Based on this, it can be concluded that placing seed grain to strips, supported tillering of sown cereal (winter barley). Next factor which supported tillering, was the use of breaker tine placed before each seed coulter on combined drill. This breaker tine creates trench in the axis of the seeding strip. Working depth (15 cm) of breaker tine corresponds with maximum depth of soil tillage during season.

Increase of ear number influenced the grain number per 1 m^2 as well as yield. Differences in grain number per 1 m^2 ranged from 6.3% to 29.1%. The differences were significant ($p > 0.05$) in zone B and D. Differences in yield ranged from 3.8% to 28.8% and were significant ($p > 0.05$) in zone B and in zone D ($p > 0.1$).

The authors Chamen (2015) and Kroulík et al. (2011) state, that CTF system concentrates all machines passes to the track lanes. Soil compaction in these track lanes causes increase of soil bulk density (limit value ~ 1.45 t m^{-3}; Lhotský et al., 1991). On this basis, it can be concluded that plants have problems with root growth.

Therefore, for CTF systems, the potential to increase the yield, or to reduce the yield penalty, depends on the area ratio of permanent traffic lanes to permanent crop beds and on tillage intensity of cropped traffic lanes (Galambošová et al., 2017).

Based on this study, it is important to pay attention to the soil tillage and quality of sowing i.e. sowing depth, seed spacing in row or in band, mainly in cropped traffic lanes.

Although for band sowing no yield differences were obtained between cropped traffic lanes (zone C and D) and non-compacted soil (zone A), but this system seems to support tillering of growing cereal (winter barley) as it was found in other experimental zones where higher yields were obtained.

LSD test confirmed, that these yield differences were significant mostly in zones with higher level of soil compaction.

Based on this it can be concluded, that band sowing performed by combined direct seed drill with partial soil tillage is suitable way, to care for the cropped traffic lanes in the CTF system.

For band sowing, the higher values of crop height were recorded in all experimental zones. Mean values of this parameter ranged from 2.4% in zone C to 9.3% in zone B. The *LSD test* confirmed, that the differences in this parameter were significant ($p > 0.05$) in zones A, B, and D.

Means of TGW were lower for band sowing in all experimental zones. As stated above, the ear number was larger for band sowing than for row sowing. However, the grains in ears from band sowing were smaller then grains in ears cropped in row sowing zones.

Statistically significant differences of TGW ($p > 0.05$) were confirmed only in zone D, which represented the highest soil compaction.

Measured data do not show statistically significant differences between grain number per ear in band and row sowing.

CONCLUSIONS

Aim of this paper was to evaluate the band and row sowing carried out on soil with different intensity of compaction in the CTF system. The conditions during the experiment were the same for both sowing systems in each zone.

The yield of winter barley was higher at band sowing in all areas with different levels of traffic intensity. However, the differences in yield between the band and row sowing were significant mostly in zones with higher level of soil compaction. The basic influence on the higher yield in band sowing resulted from better tillering. Next factor was the use of breaker tine placed on combined drill before seed coulter.

Based on this knowledge, we can recommend band sowing performed by combined seed drill with partial soil tillage, as one of the possibilities to care for the cropped traffic lanes in the CTF system. The depth of breaker tine can vary, according to depth of the compacted soil pan. The depth of this compacted soil pan depends on the depth of soil tillage during the season or on some other factor.

If it is possible to adjust the depth of breaker tines individually, this depth could be different - e.g. in CTF system: lower or zero depth for non-trafficked areas and higher depth for cropped traffic lanes. Then we could use a tractor with lower power and cut down the tractor fuel consumption. Following this, we could predict, that the yields between cropped traffic lanes and non-compacted areas in the CTF system will be equivalent.

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