INFLUENCE OF SOIL COMPACTION ON GROWTH OF SPRING BARLEY

Marek BARÁT[1], Miroslav MACÁK[1], Vladimír RATAJ[1], Jana GALAMBOŠOVÁ[1], Róbert LÁMOŠ[1]

[1]Institute of Agricultural Engineering, Transport and Bioenergetics, Faculty of Engineering, Slovak University of Agriculture in Nitra, Tr. A. Hlinku 2, 949 76 Nitra, Slovak Republic

Abstract
Soil compaction made with traffic by agricultural machinery can be one of the factors limiting crop yields. In any case, some cultivated crops are more sensitive to excessive soil compaction, such as spring barley (Hordeum Vulgare). In this research, the development and growth of spring barley was monitored in a field where a long-term CTF (Controlled Traffic Farming) is established. The RTF (Random Traffic Farming), is simulated using three areas, that are passed once a year by tractor wheels. The results show that soil compaction affected the emergence of barley, while fewer plants were emerged per square meter on compacted soil, however, these plants formed similar number of tillers (on average 2.92 - 3.02 stems in different degrees of soil compaction). The number of ears was lowest in 1x trafficked soil and in multiple-times trafficked soil (501 and 509 ears per m^2), while in non-compacted soil it was higher (572 ears per m^2). Grain yield was highest on non-trafficked soil with CTF system - 5.23 $t.ha^{-1}$.

Key words: *Controlled Traffic Farming; spring barley; soil compaction.*

INTRODUCTION

Modern agricultural production has brought an increase in the power and weight of tractors used in crop production. Since 1966, the weight of agricultural tractors has increased by 300% (*Kumhála, et al., 2013*), while *Keller et al. (2019)* found, that the load on the wheels of harvesting machines increased by up to six-times from year 1960. Some research shows, that first or second pass of a heavy tractor has a negative effect on the growth of cultivated crops (*Pytka & Szymaniak, 2004; Sakai et al., 2008; etc.*), but *Schjonning et al. (2016)* state, that only multiple passes have a negative impact. Increased soil compaction reduces soil porosity, restricts root growth of cultivated crops, thereby reducing water and fertilizer use (*Reintam & Kuht, 2012*) and increasing the risk of water erosion.
It has been found that in conventional tillage system, 88% of the soil surface is trafficked in one year, with minimal tillage the trafficked area is reduced to 65% (*Kumhála, et al., 2013; Rataj, et al., 2014*). *Kroulík et al. (2009)* states similar numbers, and calculated that up to 145,6 % of area can be trafficked repeatedly in conventional tillage. CTF (Controlled Traffic Farming) is a technology that organizes the movement and tracks of machines into permanent lines, thus reducing the trafficked area to a minimum. CTF technology has a positive effect on the reduction of soil compaction, while it is suitable in combination with No-Till and Min-Till technologies, as it is not possible to use a plough when using CTF (*Antille, et al., 2019*).
Some plants tolerate compacted soil conditions better, some worse (*Orzech, et al, 2021; Arvidsson & Håkansson, 2014*). Barley is more sensitive crop for soil compaction, as it prefer porous soil, it restrics the growth of roots in compacted soil (*Bingham, et al., 2009; Mulholland, et al., 1996; Willatt, 1986*). For this reason, the effect of negative soil compaction will be more significant.
The aim of this article is to monitor the impact of soil compaction and CTF traffic management on growth and yield of spring barley sown with zero tillage technology.

MATERIALS AND METHODS

Spring barley (Hordeum Vulgare, variety IS Maltigo) was seeded by direct drilling technology on an 16 hectares experimental field with a long-term experiment with CTF (Control Traffic Farming), which was established in 2009. The crop rotation on this field includes cereals, peas, corn and oilseed rape. The field is located in the University farm in Kolíňany, which belongs to Slovak University of Agriculture in Nitra.
The OutTrack CTF system with a 6 m module is implemented to organize the traffic of machines without additional modifications to the machinery. For the simulation of RTF (Random Traffic Farming), three

areas are set in the field, which are trafficked by tractor wheel once a year, while they are placed perpendicular to the standard CTF tillage direction. There are 18 monitoring points on the experimental field, and it is possible to obtain data from different degrees of soil compaction:

- A – non-compacted soil (non-trafficked soil since the beginning of the experiment - since 2009)
- B – 1x annually compacted soil
- C – multiple-times compacted soil (permanent lines for machinery traffic)

For the purposes of this experiment, a spring barley crop was established in 2021 by direct drilling after the corn harvest. The soil surface was covered with a large amount of corn crop residues left after the harvest, which caused lower crop emergence.

Barley growth was monitored in two growth stages at different degrees of soil compaction, as follows:

- End of tillering (BBCH 29-30) – Plants were taken up, and all tillers and stems on individual plants were counted. Subsequently, the number of plants per meter squared, the current number of stems per meter squared (main stem with tillers), and the average number of stems per plant were determined.
- Before harvesting – The plants were cut above the ground. The number of ears per meter squared, thousand kernel weight, grain moisture and yield (converted to tons per hectare) were determined.

RESULTS AND DISCUSSION

The crop developed differently on all intensities of soil compaction through the whole season. The crop was established by direct drilling into corn stubble, which caused lower emergence. The number of plants also depended on the degree of soil compaction, with an average of 270 plants per m^2 emerged in the non-trafficked soil. In compacted soil, the number of emerged plants was even smaller, 204 plants per m^2 in 1x trafficked soil and 222 plants per m^2 in multiple-times trafficked soil.

During the first measurement, the number of stems per m^2 on the non-trafficked soil in experimental field was 788 stems per m^2. Once a year trafficked soil and multiple-times trafficked soil had similar number of tillers as non-compacted soil (average 2.92 - 3.02 stems per plant), but due to the smaller number of emerged plants in those areas there was a lower number of stems per m^2, resulting in lower current stand density.

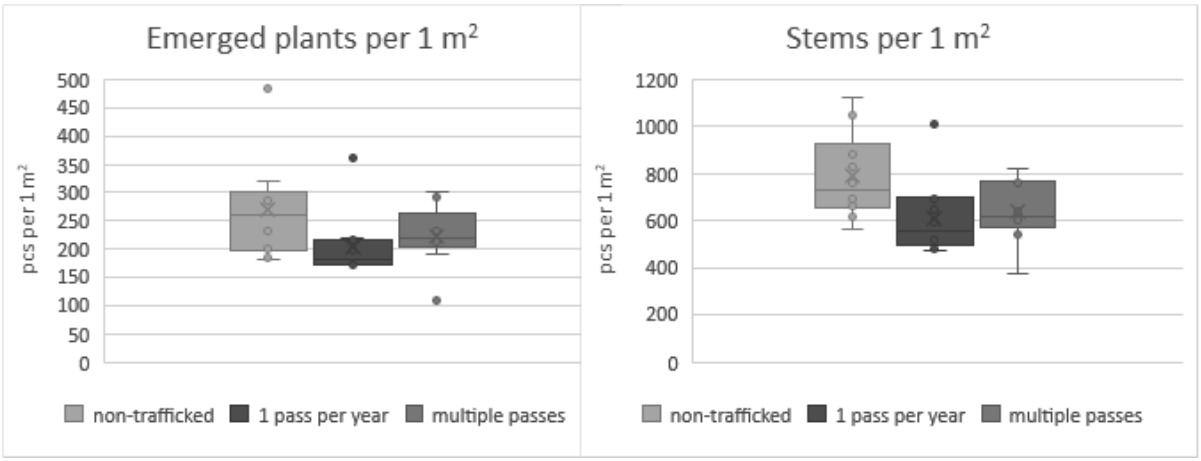

Fig. 1 Average number of emerged plants per 1 m^2 (Left) and average number of stems per 1 m^2 (right)

The second measurement of the stand took place just before the crop was harvested. It was found that the final number of productive ears in the area was lower than the number of stems found in the first measurement. The stand density relatively to the intensity of soil compaction was unchanged, where the highest density was on average 572 ears per m^2 in non-trafficked soil. 1x trafficked soil and multiple-times trafficked soil had approximately the same number of ears (on average 501 and 509 ears per m^2).

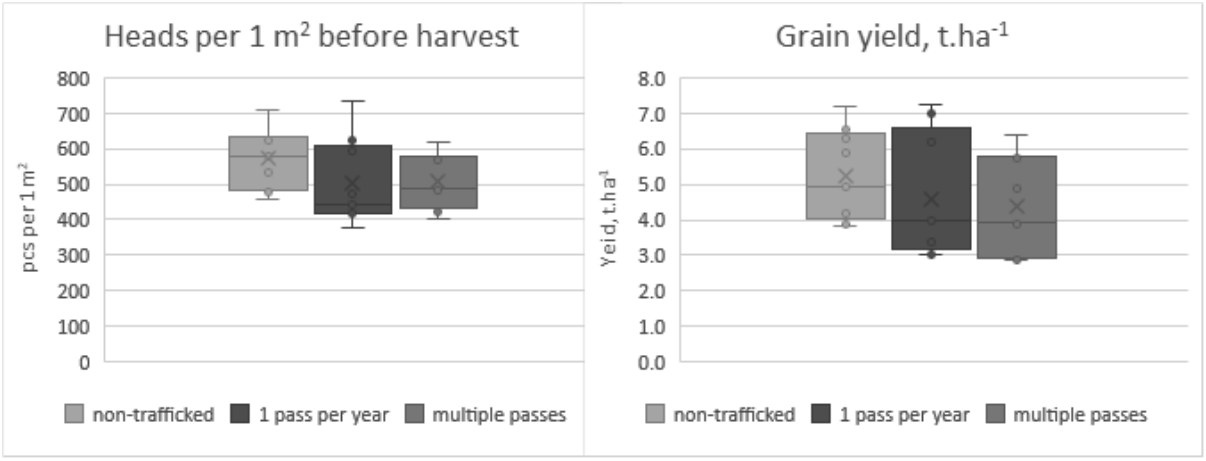

Fig. 2 Average number of heads per 1 m^2 before harvest (Left) and average barley grain yield (right)

The final grain yield was affected by TKW (Thousand Kernel Weight) only slightly. It was found that the TKW was similar in different degrees of soil compaction (54.3 g for non-trafficked soil, up to 53.7 g for multiple-times trafficked soil). Relatively similar TKW on compacted soil may be the result of lower stand density.

These parameters had a significant effect on the grain yield at harvest. The highest yield was on non-trafficked soil with an average 5.23 $t.ha^{-1}$. The average yield in 1x trafficked soil was 4.58 $t.ha^{-1}$ and in multiple-times trafficked soil 4.37 $t.ha^{-1}$. All of the above parameters in the experimental field with different soil compaction intensity are shown in Tab. 1.

Based on those results it can be concluded, that even the first pass of agricultural machinery has a negative effect on barley growth and yield. Similar results were reported by *Pytka & Szymaniak (2004); Sakai et al. (2008)*; etc. It was also proved that barley is a sensitive crop on soil compaction, as reported by *Bingham et al. (2009)*, etc.

Tab. 1 Crop stand parameters and yield parameters of spring barley in experimental field

	MEASUREMENT 1			MEASUREMENT 2		
Traffic intensity (relates to soil compaction)	Number of plants per m^2	Number of stems (main stem + tillers) per m^2	Number of stems (main stem + tillers) per plant	Number of ears per m^2 before harvest	Thousand kernel weight, g	Grain yield, $t.ha^{-1}$
Non-trafficked	270	788	3.00	572	54.3	5.23
1x trafficked per year	204	613	3.02	501	54.1	4.58
Permanent track line	222	637	2.92	509	53.7	4.37

CONCLUSIONS

Soil compaction has a negative effect on the growth and yield of cultivated crops. Spring barley sown by direct drilling after the corn harvest had low number of emerged plants per m^2, while it was even less on the compacted soil. CTF system minimizes soil compaction by organizing the movement of machines on permanent track lines, thus creating areas with non-trafficked and non-compacted soil. It was found that the spring barley crop was better in this non-compacted soil, which was also reflected in the yield, where the average grain yield in non-trafficked soil was 5.23 $t.ha^{-1}$. That was more than 4.58 $t.ha^{-1}$ and 4.37 $t.ha^{-1}$ on average in area with one annual machinery pass and multiple passes of agricultural machinery wheels.

This experiment shows that the CTF system can also be used in soil-conservation tillage technologies with a system of direct drilling and that one yearly pass of tractor has a significant effect on grain yield of spring barley.

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REFERENCES

1. Antille, D.L., Peets, S., Galambošová, J., Botta, G.F., Rataj, V., Macák, M., Tullberg, J.N., Chamen, W.C.T., White, D.R., Misiewicz, P.A., Hargreaves, P.R., Bienvenido, J.F., & Godwin, R.J. (2019). Review: Soil compaction and controlled traffic farming in arable and grass cropping systems. In Agronomy Research, 17(3), 653–682. https://doi.org/10.15159/AR.19.133
2. Arvidsson, J., & Håkansson, I. (2014). Response of different crops to soil compaction – Short-term effects in Swedish field experiments. In *Soil & Tillage Research, 138*, 56-63. https://doi.org/10.1016/j.still.2013.12.006
3. Bingham, I.J., Rees, R.M., & Bengough, A.G. (2009). Influence of Soil Compaction on the Dynamics of Root Growth and Mortality in Spring Barley. *Internal Symposium "Root Research and Applications" RootRAP*. 2.
4. Keller, T., Sandin, M., Colombi, T., Horn, R., & Or, D. (2019). Historical increase in agricultural machinery weights enhanced soil stress levels and adversely affected soil functioning. In *Soil and Tillage Research, 194*. 104293. https://doi.org/10.1016/j.still.2019.104293
5. Kroulík, M., Kumhála, F., Hůla, J., & Honzík, I. (2009) The evaluation of agricultural machines field trafficking intensity for different soil tillage technologies. In *Soil and Tillage Research*, Vol. 105, Issue 1. 171-175. https://doi.org/10.1016/j.still.2009.07.004
6. Kumhála, F., Gutu, D., Hůla, J., Chyba, J., Kovaříček, P., Kroulík, M., Kvíz, Z., Mašek, J. & Vlášková, M. (2013). Technology of Controlled Traffic Farming on fields. *Certificated methodology*. 40. ISBN 978-80-213-2425-1. (in Czech).
7. Mulholland, B.J., Black, C.R., Taylor, I.B., Roberts, J.A., & Lenton, J.R. (1996). Effect of soil compaction on barley (Hordeum vulgare L.) growth – I. Possible role for ABA as a root-sourced chemical signal. In *Journal of Experimental Botany*. 297. Vol 47. 539-549.
8. Orzech, K., Wanic, M., Załuski, D. (2021). The Effects of Soil Compaction and Different Tillage Systems on the Bulk Density and Moisture Content of Soil and the Yields of Winter Oilseed Rape and Cereals. In *Agriculture*. 11(7). 666. https://doi.org/10.3390/agriculture11070666
9. Pytka, J., & Szymaniak, G. (2004). Investigations of stress state in soil under tractor tyres. In *Teka Komisji Morotyzacji I Energetyki Rolnictwa*. 04. 172-176.
10. Rataj, V., Galambošová, J., Macák, M. & Nozdrovický, L. (2014). Precision Agriculture: System – machines – experiences. 160 p. ISBN 978-80-86726-64-9. (in Slovak)
11. Reintam, E. & Kuht, J. (2012). Weed Responses to Soil Compaction and Crop Management. In *Weed Control*. 243-263. ISBN 978-953-51-0159-8.
12. Sakai, H., Nordfjell, T., Suadicani, K., Tabot, B., Ebbe, B. (2008). Soil Compaction on Forest Soils from Different Kinds of Tires and tracks and Possibility of Accurate Estimate. In *Croatian Journal of Forest Engineering*. 29(1). 15-27.
13. Schjonning, P., Lamandé, M., Munkholm, L. J., Lyngvig, H. S. & Nielsen, J. A. (2016). Soil precompression stress, penetration resistance and crop yields in relation to differently-trafficked, temperare-region sandy loam soils. In *Soil & Tillage Research*. 163. 298–308.
14. Willat, S.T. (1986). Root growth of winter barley in a soil compacted by the passage of tractors. In *Soil & Tillage Research*. Vol. 7, Issues 1-2. 41-50. https://doi.org/10.1016/0167-1987(86)90006-1

Corresponding author:

Ing. Marek Barát, PhD., Institute of Agricultural Engineering, Transport and Bioenergetics, Faculty of Engineering, Slovak University of Agriculture in Nitra, Tr. A. Hlinku 2, 949 76 Nitra, Slovak Republic, phone: +421 37 641 4355, e-mail: marek.barat@uniag.sk