Responses of maize (*Zea mays* L.) roots to soil condition in an extreme growing season

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Abstract: Maize (*Zea mays* L.) covers the greatest area in Hungarian crop production relation. While tillage effects on soil condition and through the physical changes influence the depth and formation of the crop rooting. Maize root development was investigated in a long-term experiment on a Chernozem soil at the Experimental and Training Farm of the Szent István University (47°68'N, 19°60' E, 130 m a.s.l.) near the town Hatvan, Hungary. The objective was to compare mass and formation of the maize (*Zea mays* L.) roots in soils prepared by three different tillage systems. Methods of the primary tillage were suitable for conventional, soil remedying and the conservation principles that are ploughing (P, 30-32 cm), subsoiling (S, 40-45 cm) and tine tillage (T, 18—22 cm). The soil state was favourably loosened in the first three months, including at planting, then the soil became settled owing to the repeatedly, and often torrential rains. The maize roots has optimally grown in the first three months, and reached the maximal length, and later, probably due to the deterioration of the loosened state, it has not lengthened. The T treatment had the longest root (45.5 cm) and the highest root mass (8.84 t/ha) which differed significantly ($P<0.05$) from values obtained at the S and the P treatments. The results had particular importance in the contexts of the extreme growing season. Due to the soil condition assessments, more useful data were available to specify the effects of repeated rains on maize production.

Keywords: soil tillage, climate extreme, loosened soil layer, root biomass

Introduction

In Hungary the arable land covers 4,332 000 ha, and sowing area of maize covers about 1,150 000 ha (KSH, 2015). Three soil types are dominated in maize production, namely Luvisols, Chernozems and Vertisols (these together cover 70 % of the total area, Michéli et al., 2014). In Hungarian relation some 40 % of the total sown land is tilled by plough, 25 % by subsoilers and 22% by cultivators (Dekemati et al., 2016). A number of authors emphasised that damage caused by climate conditions could be diminished, however site adopted solutions are to be applied (Chen and Weil, 2011). Preserving damages on wet soils has become an acute issue during the autumnal primary tillage. Birkás (2008) calls attention to the maize requirements, including deeper loosened layer without compaction damage. Soil compaction is known to be a limited factor in the root development and moreover that restricts the water and/or nutrients uptake (Yaduvanshi and Ashwini, 2015). Soil tillage may a key factor in crop root development through improving physical factors that are water, aeration, temperature and penetration resistance (Dwyer et al., 1996, Kadžiené et al., 2011). Chen and Weil (2011) found that greater diameter of roots is more capable to penetrate compacted soil layer than roots with smaller diameter. Barber (1971) and Kovar et al. (1992) stated that different water regimes may influence on the root formation, therefore under various soil tillage methods root development can significantly be different. Birkás (2011) highlights the importance to use climate focused soil management with the primary goal of reducing climate-induced stresses through improving soil quality. The objective of this study was to compare mass and formation of the maize (*Zea mays* L.) roots in soils prepared by three different tillage systems. The hypothesis was that the deeper loosened layer may give the optimal conditions for maize root development.

Materials and methods

Maize root development was investigated in a long-term experiment on a Chernozem soil (WRB 2006) at the Experimental and Training Farm of the Szent István University (47°68'N, 19°60' E, 130 m a.s.l.) near the town Hatvan, Hungary. In this region, long-term yearly precipitation averages 580 mm (313 mm fall in the growing season). The measurements were conducted in year 2016, when amount of precipitation run to 731 mm, and from this 413 mm fell in the growing season. The experiment was arranged in a randomised block design with four replicates, and area of each plot is 2340 m^2 (13 m x 180 m). Six treatments are applied in the experiment (Birkás et al., 2015) however only three were selected for investigation. These treatments were suitable for conventional, soil remedying and the conservation principles that are ploughing (P, 30-32 cm), subsoiling (S, 40-45 cm) and tine tillage (T, 18-22 cm). Primary tillage was completed on 28th October, 2015, sowing on 8th April, 2016, and harvest on 24th October, 2016. Soil moisture content has exceeded the optimum (26m/m%) at the time of primary tillage causing unfavourable deformation in soil mainly at P treatment. There were no similar limiting factors at maize sowing. The maize cultivars (Limagrain 33.30 hybrid) corresponded to the site relation. The rate of fertilizer for maize met the requirements, that are N 120, P 90, and K 70 kg/ha. Samples to check soil condition – penetration resistance, moisture content, crumb' ratio – were taken in 30-day intervals in five replications. Impacts of the rain stress on soil condition were also surveyed. Shortly before the harvest three soil cores (30x30x50 cm) were taken per plot at three separate locations in four repetitions. Roots immediately cleaned from the soil and measured the length and then the biomass after air drying. The statistical evaluation was made by Microsoft Office Excel software package.

Results and discussion

The precipitation was 57% higher in the growing season compared to the multi-year average. In May, there was a day when 46 mm of rain fell, coupled a hail aggravating the situation. Moreover, intense rainfalls had repeatedly occurred during summer. Monthly amount of precipitation (Table 1.) was less unfavourable than intensity and distribution of rains which proved to be more extreme.

Table 1. Monthly amount of precipitation in the growing season (Hatvan, 2016)

	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	**Dec**
mm	**-**	**-**	**-**	**21**	**106**	**44**	**107**	**55**	**47.5**	**33**	**-**	**-**

Due to the abundant rains soils has continuously settled. Values of the soil penetration resistance were quite low at the sowing time (≤1.8MPa) at both treatments. These values had doubled (~3.7MPa) till the harvest time at same soil moisture content (31-30 m/m% in average of the 0-60 cm soil layer). Authors previously stated that tillage affects the development of roots (e.g. Barber, 1971). As Unger and Kaspar (1994) noted, soil compaction is a limiting factor of the root growth, and the climate extremities, through soil state deterioration are also modifying factors. Soil state measurements gave real information to the evaluation of maize rooting. The former pan compacted layer had really extended at the P treatment, and for this reason, depth of the rooting was the shortest (34 cm). The loosened state had fairly remained at the T treatment consequently depth of the

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rooting (47 cm) surpassed the depth of the tillage. Values of the deviation were low at the treatments where soil state remained (T) or worsened (P) to the same extent (Table 2.). The length of the maize root was found to be unequal at the S treatment, similarly to the uneven loosened state.

Table 2. Values of root length

Treatments	1. repetition	2. Repetition	3. Repetition	4. Repetition	Average (cm)	Deviation
Tine tillage	47	46	46	44	45.75	1.26
Ploughing	34	36	37	35	35	1.29
Subsoiling	39	41	40	44	41	2.16

The difference between dry root biomass at different soil tillage and soil condition could be proven statistically ($P < 0.001$, Figure 1.). Highest (8.8 t/ha) dry root biomass was measured in tine tilled (T) soil, and the lowest (7.2 t/ha) in the subsoiled (S) treatment. These favourable effects were confirmed by yield data (no discussed in this paper), too.

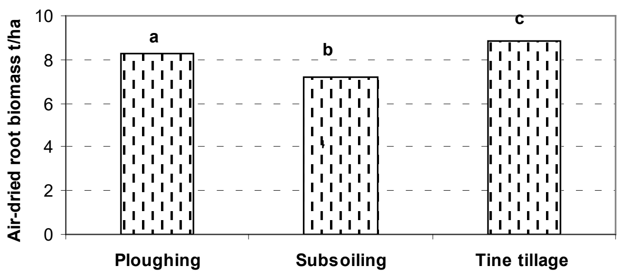

Figure 1. Dry root biomass of maize at different tillage treatments in year 2016

Note: $LSD_{0\cdot05}$: 0.848 t/ha

According to the publications concerned, depth and quality of tillage are important primary factors of the root formation (Bennie and Botha, 1986; Unger and Kaspar, 1994). However, as Dekemati et al. (2016) highlighted, that the consequences of a rainy growing season can really be unpredictable.

Further experience was gained in this rainy season. The higher soil moisture content at the time of primary tillage increased the production risk through soil state damage which were mostly visible, however less detectable by instrumental measurements. Kneading and puddling of the soil by plough are visible and the pan compaction is opened by profile excavation. Damaging the soil structure in wet soil by subsoiler is related to the tool design. In our case a moderated soil kneading occurred at subsoiling, however, the quality of the loosening was poorer compared to the loosening created by tine tillage. The favourable soil conditions at planting time gave minimal guarantees to prevent soil state deterioration in he given rainy season. As Birkás et al. (2015) and Dekemati et al. (2016) noted that there is a demand for the elaboration of methods suitable for conservation tillage of wet soils. The growing season in year 2016 was considered to be favourable in terms of the amount of precipitation. It may outline that the impact of the repeated rains, and the extreme distribution proved to be more harmful to the soil quality condition. Among the negative phenomena of the rainy season were the crumb deterioration, the siltation of the small soil particles, the

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leaching the small particles to the deeper soil layer (increasing the compaction risk) and the hard crust formation in the soil surface. In the viewpoint of the soil, damages caused in the rainy seasons require step-by-step remediation in the next seasons.

Conclusions

The unpredictable weather is considered to be much danger today, particularly for production of crops – mainly for maize – that are more sensitive to the climate induced soil condition deterioration during growing season. In our case, the experience gained in the long-term experiment give a chance to recognize the climate induced hazards in the future. The data were stated that the maize root may grow most favourably in soil prepared by less physical damages in the tillage season. This requirement fulfilled satisfactory by tine tillage. The dry root biomass may the highest at soil condition which has suffered the least deterioration in the rainy season. Less soil damage was realized by tine, when pan compaction occurrence was negligible. Soils will really be exposed to the climate stresses. Vulnerability of soils has already become an acute problem for agricultural production, and it will be even more complex problem in future decades.

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References

Barber, S. A. (1971). Effect of tillage practice on corn (*Zea mays* L.) root distribution and morphology. Agronomy Journal, 63: 5. 724-726. DOI: 10.2134/agronj1971.00021962006300050020x

Birkás, M. (2008): Enviromentally–sound adaptable tillage. Akadémiai Kiadó, Budapest. DOI: http://dx.doi.org/10.1556/AAgr.57.2009.1.11

Birkás, M. (2011): Tillage, impacts on soil and environment. In. Glinski J; Horabik J; Lipiec J. (Ed.) Encyclopedia of Agrophysics. Springer Dordrecht, pp. 903-906.

Birkás, M., Kisic, I., Mesic, M., Jug D., Kende Z. (2015): Climate induced soil deterioration and methods for mitigation. Agriculturae. Cons. Sci. 80: 1. 17-24.

Chen G., Weil, R.R. (2011). Root growth and yield of maize as affected by soil compaction and cover crops. Soil and Tillage Re*search* 117, 17-27. DOI: http://dx.doi.org/10.1016/j.still.2011.08.001

Dekemati, I., Radics, Z., Kende, Z., Birkás, M. (2016): Soil state assessment in Croatia and in Hungary – Similiarities and differences. Növénytermelés, 65 (Suppl.), 139-142.

Dwyer, L. M., Ma, B.L., Stewart, D.W., Hayhoe, H.N., Balchin, D., Culley, J.L.B., McGovern M. (1996): Root mass distribution under conventional and conservation tillage. Canadian J. of Soil Science, 76.1 23-28. DOI: 10.4141/cjps-2014-026

Kadžienė, G., Munkholm, L.J., Mutegi, J.K. (2011). Root growth conditions in the topsoil as affected by tillage intensity. Geoderma, 166.1. 66-73. DOI: http://dx.doi.org/10.1016/j.geoderma.2011.07.013

Kovar, J. L.,Barber, S.A., Kladicko, E.J., Griffith, D.R. (1992): Characterization of soil temperature, water content, and maize root distribution in two tillage systems. Soil and Tillage Research, 24.1. 11-27. DOI: http://dx.doi.org/10.1016/0167-1987(92)90069-N

KSH (2015): Agrárgazdasági Figyelő, 7.3.21 DOI: 10.7896/zsk.1501

Michéli, E., Fuchs, M., Láng, V., Szegi, T., Kele, G. (2014): Methods for modernizing the elements and structure of the Hungarian Soil Classification System. Agrokémia és Talajtan 63: 1. 67-78.

Unger, P. W., Kaspar, T.C. (1984): Soil compaction and root growth: a review. Agronomy Journal, 86. 5. 759-766.

Yaduvanshi, A., Ashwini R. (2015): Effect of Global Temperature Changes on Rainfall Fluctuations over River Basins Across Eastern Indo-Gangetic Plains. Aquatic Procedia, 4, 721-729. DOI: http://dx.doi.org/10.1016/j.aqpro.2015.02.093