International Symposium “Root Research and Applications”
RootRAP, 2–4 September 2009, Boku – Vienna, Austria

Soil compaction and root growth controlling factors in cropland, semi-arid of South Bulgaria

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ABSTRACT

Soil compaction is recognized as an important problem in cropland. The main objective of this study was to evaluate soil factors controlling root development of maize grown on field with subsoil compaction in semi-arid area of South Bulgaria. Two treatments were examined: deep loosening in combination with drainage and control without meliorations (control). Root observations to 1 m depth were made on vertical and horizontal planes covered with 2 x 2 cm grid mesh at silking. For analysis of root spatial pattern, the variance: mean ratio (VMR) test was also applied. Results for root densities expressed as dry mass and proportions of “full” squares consisting at leas one root were similar in the topsoil, but significantly higher in the subsoil of the meliorated plot showing deeper root allocation there. The control plot had more squares with numerous roots at the top- subsoil boundary owing to grouping of roots in pores and cracks. The horizontal planes in the control generally consisted less “full” squares, showing larger soil areas without roots and great distances for water and nutrient transmission. Consequently, an inhibited water extraction from subsoil, a delay in crop ontogenesis and less biomass production was established during the observed period. The VMR test at small (2 cm) scale was close to 1 only in the topsoil of the meliorated plot indicating lack of clusters. At all other positions and scales examined, the VMR’s were considerably higher than 1 showing different levels of clustering. The strongest positive correlation was found between the root data and the soil hydraulic conductivity, which can be used as an indicator for root distribution.
KEYWORDS: Maize, Soil compaction, Root density and spatial distribution patterns, Semi-arid climate

INTRODUCTION

Soil compaction, occurring naturally or induced by anthropogenic activities, is often established in agricultural areas of Bulgaria. As a result, many cultivated soils are characterized by pore structure of the arable layer, and 5 % of them are prone to surface waterlogging (Dilkova et al., 1998). In such soils root development suffers due to increased mechanical resistance against root penetration, inhibited water, nutrient and oxygen supply. The main task was to evaluate factors limiting root distribution of maize (*Zea mays L.)* grown on compacted soils under semi-arid climate condition of South Bulgaria. A specific task was compare effects of amelioration practices against subsoil compaction on soil characteristics and thus on the root and plant growth and uptake. To achieve this, root density and spatial distribution pattern, crop biomass production, water uptake and relevant soil parameter were measured.

METHODS AND MATERIAL

The study was conducted at the experimental field of “N. Pushkarov” Institute of Soil Science in Thracian lowland, Southeast Bulgaria. Maize was grown on two 90 m^2 plots, one with deep loosening applied to 0.6 m depth in combination with drainage and one without meliorations against subsoil compaction. The soil is Dystrict Planosol, clay loam to clay, with high degree of textural differentiation, prone to surface acidification and waterlogging. The climate is continental-Mediterranean with mean annual temperature of 12^{o}C, annual precipitation of 600 mm and long periods of drought in late summer. Plant growth and soil water monitoring were conducted; soil parameters were measured at the experimental start and during the root observation. Root growth was examined using soil profile method shortly after silking (Himmelbauer, 2001). In each plot, 2 vertical planes to 1 m depth and 3 superposed horizontal planes intersecting top- and subsoil layers at 13, 26 and 50 cm were dug, smoothed and covered with 2 x 2 cm grid mesh. Root contacts were mapped and density indexes were obtained, accounting for the presence and the absence of roots in each square following Tardieu (1988). For vertical profiles, these indexes were also related to root mass density taking soil monoliths from different positions with a face one grid square. Summary statistics, analysis of variance, and correlation analyses were conducted to find out the relations between root and soil parameters. In addition, for analysis of root distribution pattern a Variance/ Mean Ratio (VMR) test was used (Grieg Smith, 1983).

RESULTS AND DISCUSSIONS

At the time of root observation, an apparently deeper allocation of the maize roots was observed in the meliorated than in the control plot. Root densities, expressed as dry mass and proportion of "full" squares, consisting at least one visible root, were similar in the topsoil of both plots, but significantly higher in the subsoil of the meliorated one. On the other site, the control plot had more squares with lots of roots, especially at the top- subsoil boundary, indicating root grouping in areas with low penetration resistance like pores and cracks. A bulk density of 1.6 g cm^{-3}, hydraulic conductivities below 2 cm d^{-1} and air-filled porosity of only 3.4 to 6% were measured there. All horizontal maps in the control consisted less "full" squares with large areas without roots and great distances for water and nutrient transmission in the soil. Due to clustering and inter-roots competition, the water extraction in the subsoil was limited, which apparently inhibited the maize growth during the observed period. As a result, a delay in the ontogenesis and less biomass production was established in the control plot. The VMR test at a small (2 cm) scale was close to 1 only in the topsoil of the meliorated plot indicating lack of clustering. At all other positions and scales examined up to 10 cm, the VMR' values were considerably higher than 1 showing different levels of root clustering. A strong correlation of the measured root parameters with soil hydraulic conductivity, weaker with available soil water, significant but negative with clay content, pH and bulk density and insignificant with porosity data were estimated (Correlation table).

Table Coefficients of correlation between different root and soil parameters

	Depth cm	**Bulk density**(1) g/cm^3	**Available Water** vol.%	**Hydraulic conduct.**(2) cm/d	**Porosity Total** vol.%	**Porosity Air-filled**(1) vol.%	**pH**	**Clay** %	**RMD** mg/cm^3	**Index>0** % Sq	**Index>4** % Sq
RMD, mg/cm^3	**-0,910**	**-0,590**	**0,557**	**0,785**	0,061	0,300	**-0,755**	**-0,744**	1		
Index>0, % Sq	**-0,947**	**-0,624**	0,414	**0,682**	0,184	0,323	**-0,873**	**-0,750**	**0,961**	1	
Index>4, % Sq	**-0,779**	-0,484	**0,644**	**0,811**	-0,079	0,235	**-0,558**	**-0,655**	**0,954**	**0,837**	1

(1) Parameters measured at filed capacity level, and (2) at saturation, RMD- root mass density, percentage of squares (Sq) consisting at least one root (i.e. Index >0) and a lot of roots (i.e. Index > 4). Coefficients in bold show statistically significant correlations.

ACNOWLEDGEMENT

The authors thank the ÖFG, MOEL-Plus-Förderungsprogramm for the 6 month fellowship of Dr. M. Himmelbauer at "N. Poushkarov" Institute of Soil Science and Agroecology, Sofia, Bulgaria.

REFERENCES

Dilkova, R., E. Filcheva, G. Kerchev, M. Kercheva (1998): Humus peculiarities of the virgin surface waterlogged soils. In Congres Mondial de Sci. du sol, 16e, Montpellier, France, 20-26 aout 1998. Resumes. Vol. 1, Symp. N 18, p.378

Grieg Smith, P. (1983): Quantitative Plant Ecology. Univ. of Calif. Press, Berkeley, p. 347.

Himmelbauer M.L. (2001): Study of root growth in the field. Soil Science, Agrochemistry and Ecology, 4-6: 179-181

Tardieu F. (1988): Analysis of the spatial variability of maize root density I. Effect of wheel compaction on the spatial arrangement of roots Plant and Soil 107, 259-266