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# THE IMPACT OF SOIL STRUCTURE ON SOYBEAN NODOLATION

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**Keywords: soybean, micromorphology, soybean nodules, porosity.**

## ABSTRACT

*The aim of the paper was to emphasize the impact of soil structure on soybean nodulation, at micromorphological scale, showing the influence of soil fauna activity on the porosity genesis and evolution, as environment for the development of soya plant roots and of nodules containing Rhizobium bacteria. The researchers have been performed in the Eastern part of the Romanian Plain. The results showed that the compaction of Apt horizon of the Chernozem from Dâlga strongly influenced the soybean nodulation. The number of the nodules containing Rhizobium bacteria and developed on the root hairs of soya plants was significantly lower and their size significantly smaller, comparing to the surface Ap horizon. The researchers also outlined that the activity of the macro- and mezofauna (the soil structure architects) had a major influence on soybean nodulation.*

## INTRODUCTION

Many studies have been performed concerning the influence of soil structure on soybean development, but the relationship between "soil structure architects" (macro- and mezofauna) and the development of soybean roots, as well as the nodules containing *Rhizobium* bacteria (developed on the root hairs of soya plants) was less studied.

Good soil structure means the presence of aggregation which has positive benefits for plant growth; these benefits arise from the wider range of pore sizes which result from aggregation (Gardner et al., 1999).

The image analysis performed on oriented soil thin sections with the help of an image-analyzing computer, allowed to measures and characterizes porosity by their shape and size.

The shape factors (perimeter$^2$/4π*aria) afford the division of pores into different shape classes such as: regular (more or less rounded) pores (with shape factor 1-2); irregular pores (with shape factor 2-5); and elongated pores (with shape factor > 5).

These classes correspond broadly to the classes defined by Bouma et al. (1977) and Pagliai (1988).

According to the image analysis data Pagliai (1988) and Pagliai et al. (1995) showed that a soil is dense (compact) when the total porosity is less than 0.10 $m^2m^{-2}$, moderately porous when the total porosity ranges from 0.10 to 0.25 $m^2m^{-2}$, porous when it ranges from 0.25 to 0.40 $m^2m^{-2}$, and extremely porous over 0.40 $m^2m^{-2}$.

The aim of the study is to emphasize the impact of soil structure on soybean nodulation, at micromorphological scale, showing the influence of soil fauna activity on the porosity genesis and evolution, as environment for the development of soya plant roots and of nodules containing *Rhizobium* bacteria (developed on the root hairs of soya plants).

## MATERIAL AND METHOD

The studied area is located in the Eastern part of the Romanian Plain, in the central part of the Southern Baragan Plain, in Dâlga region, on Typic Chernozem (according to SRTS-2012) formed in loess like deposits.

The climate is temperate continental, with an average annual temperature of 10.8°C and an average annual precipitation of 480 mm, while evapotranspiration reaches 700 mm, and De Martonne aridity index is 23.

The bioclimatic zone is steppe, with the specific vegetation, characterized by the dominance of *Festuca valesiaca* association with *Cleistogenes serotonin, Artemisia austriaca, Stipa capillata, Agropiron* sp. At present, the natural vegetation has been replaced by crops with mezoxerofile weeds as: *Echinocloa crus-gali, Cynodon dactylon, Agropyron cristatum, Agropyron repens, Bromus arvensis, Cirsium arvense, Solanum nigrum, Matricaria chamomilla, Convolvulus arvensis.*

The soil profile were described in the field and sampled (from each pedogenetic horizon), for particle size distribution, pH, CEC, $V_{8.3}$% (disturbed samples) and micromorphological (undisturbed samples) analyses, according to RISSA Methodology-1987.

For the micromorphological research, undisturbed soil samples were air drayed and impregnated with epoxidic resins. After hardening, oriented thin sections (25 - 30 µm) have been made from each sample and studied after words with Documator (20 X) and optical microscope (50 - 100 X) in PPL and XPL. The terminology used for micromorphological description was according to Bullock et al. (1985).

Image analysis has been performed on soil thin sections with the help of an image-analyzing computer (PC-IMAGE software produced by "Foster Findlay Associates" – London). The instrument was adjusted to measure pores greater than 50 µm. The pores have been measured by their shape, which is expressed by the shape factor (perimeter$^2$/4$\pi$*aria).

## RESULTS AND DISCUSSIONS

The porosity was measured by the aim of image analysis, in order to characterize, at micromorphological level, the pore space as environment for soybean roots and as habitat for the rhizobia bacteria which developed in soya root nodules.

Soil porosity is an exchangeable parameter in Chernozems, as a result of a very high biodiversity and a very high biological activity. The ingestion of soil material and the transport from a horizon to another (bioturbation) generate and renewed permanently soil aggregates and pore space. In these conditions, the pores are mainly biological (biopores) and have two important characteristics: they are abundant and interconnected (feature that reflects their continuity and allows water circulation and air exchange between soil and atmosphere).

Although soil porosity is a dynamic parameter, the combination of image analysis with micromorphological observation on thin sections, can give an adequate image of the physical status of the soil.

Image analysis of the pore distribution, characterized by their shape and size, showed clear differences between the studied horizons (Ap and Apt) of the Chernozem root active layer (Fig. 1 a and 2 a), as well as the differences between the pore genesis (reflected by their shape – Fig. 1 b and 2 b).

In the surface Ap horizon, the total porosity (< 100 - > 1000 µm) was 0.23 $m^2m^{-2}$, dominated by the pores with 200-300 µm equivalent pore diameter (Fig. 1 a). Among them, elongated pores were the most frequent, followed by the regular and the irregular pores.

In the case of the size class of 100-200 µm (equivalent pore diameter), the proportion of the different type of pores was relatively balanced, except for the irregular pores which was lower. The irregular pores became dominant in the size class of 400 - 500 µm and 500 - 1000 µm respectively (Fig. 1 a).

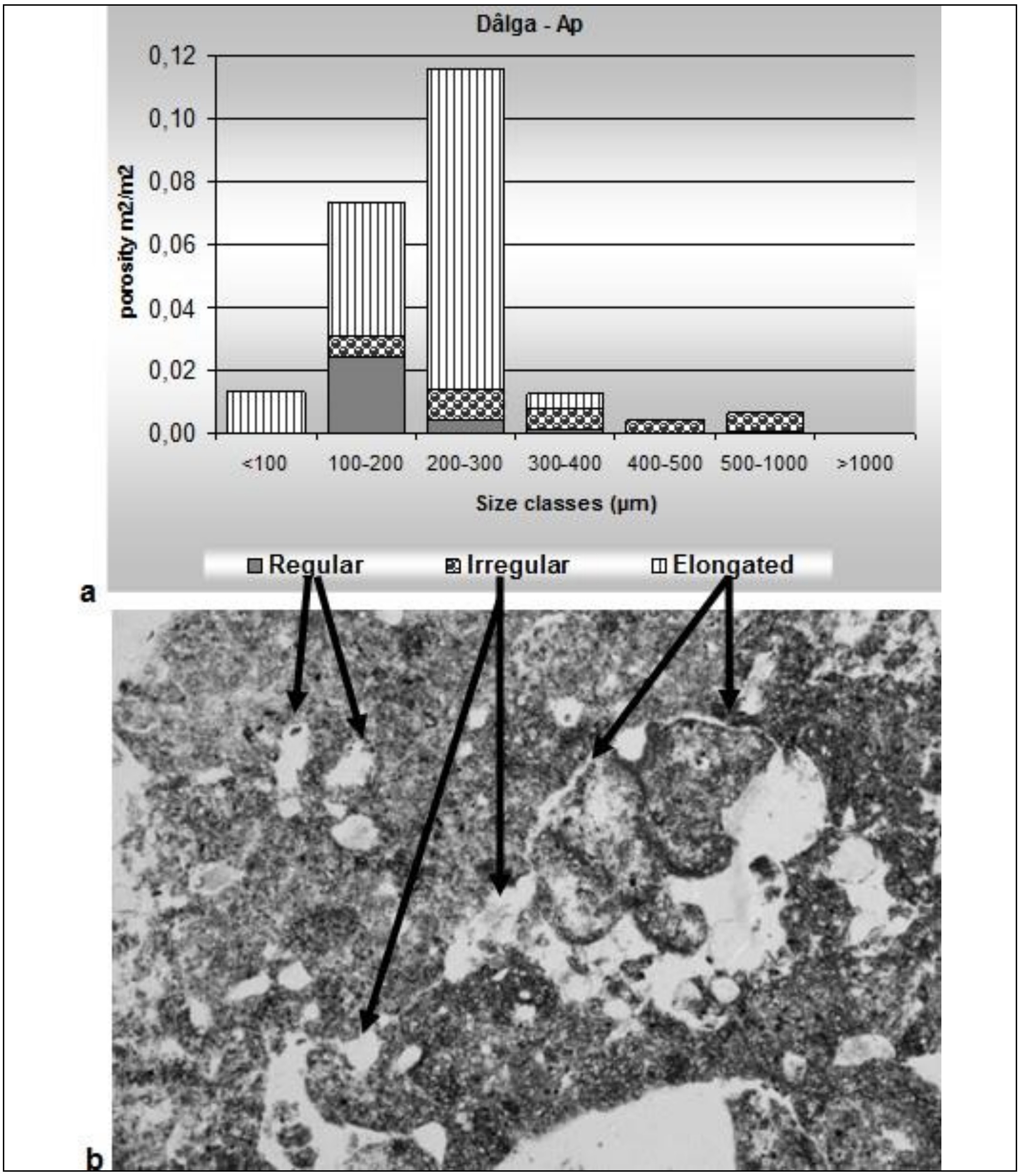

**Fig. 1. *Ap horizon. (a) Image analyze: soil porosity according to their shape and size; (b) Thin sections: pores generated by biological activity (reflected by their shape).***

As shown in figure 1 b, the irregular pores become dominant in the areas with collapsed chambers and channels (burrows) filled with coprolites (casts) generated by macrofauna (earthworm) activity and partially integrated in soil matrix. Irregular pores are also the vughs (voids with the irregular walls) generated by mezofauna activity.

The regular pores (with rounded shape) are generated mainly by soya plant roots growth and also by mezofauna burrowing.

Elongated pores are formed by cracks (generated by the physico-mechanical processes) and by fine semicircular fissures which delimitate the biological pedofeatures from the surrounding matrix (Fig. 1).

The thin section image (Fig. 1 b) reveals that the porosity of the upper Ap horizon is mostly biological and relatively well preserved, even in the conditions of a tilled layer.

In the Apt horizon of the Chernozem from Dâlga, more compacted comparing to the upper Ap horizon, the total porosity (< 100 - > 1000 µm) slightly decreases at 0.21 $m^2m^{-2}$.

According to Pagliai (1988) and Pagliai et al. (1995) the total porosity data showed that the soil in both horizons (Ap and Apt) is moderately porous.

As in the Ap horizon, the total porosity of Apt is dominated by the pores belonging to the size classes of 200-300 µm and 100-200 µm (Fig. 2 a).

The prevalence of the elongated pore is obvious (Fig. 2 b), being a characteristic for the compacted horizons.

In Apt, the large pores of 400 to >1000 µm are dominated by the presence of the irregular pores (Fig. 2 a).

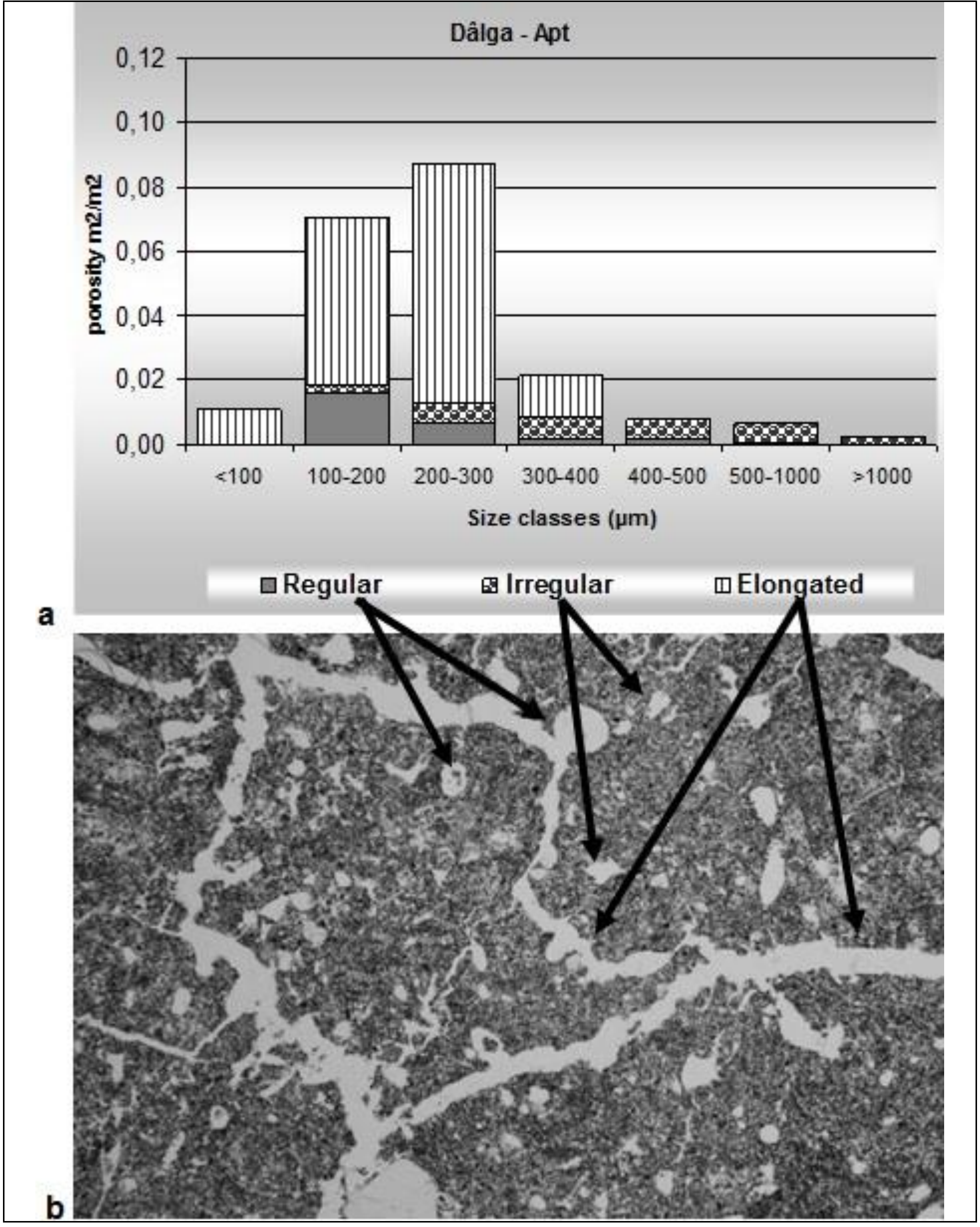

***Fig. 2. Apt horizon. (a) Image analyze: soil porosity according to their shape and size; (b) Thin sections: interpedal pores generated by phisico-mechanical processes and intrapedal pores generated by biological activity (reflected by their shape).***

The image of the thin sections (Fig. 2 b) showed a complex structure: a) with moderate to well developed subangular blocky structure; and b) crack structure with more or less interconnected elongated pores. The intrapedal voids are compound packing regular (rounded and ellipsoidal) and irregular pores (mainly irregular shaped vughs), as well as very fine fissures. The intrapedal porosity was generated by soil macro- and mezofauna and consists in collapsed channels filled with coprolites and partially to totally integrated in soil matrix, under the very active compaction process. The intrapedal vughy structure was generated mainly by the activity of coprophagous mezofauna.

Due to the compaction, which was the main process of the Apt horizon, the general tendency was to a close porosity and burrows disintegration (Răducu et al., 2002).

The soil from Dâlga was relatively well structured by the intense biological activity, which adds to the porous system generated by physico-mechanical processes, numerous and continuous bio-pores, which results in the development of abundant soya roots and further in an intense process of nodulation in the upper Ap horizon (Fig. 3).

***Fig. 3. Nodules on soybean root hairs.***

However, in Dâlga profile the compaction of Apt horizon strongly influenced the soybean nodulation: the number of the nodules containing *Rhizobium* bacteria (developed on the root hairs of soya plants) was significantly lower (Fig. 3), as well as their size which was smaller, comparing to those formed on the roots developed in the surface Ap horizon.

The total porosity of the active layer of the studied Chernozem (both Ap and Apt horizons) was the result of three main processes: a) spatial arrangement of aggregates, generated by tillage; b) physico-mechanical processes (of wetting and drying); and c) biological activity.

The issues outlined above emphasizes that the activity of the macro- and mezofauna (the soil structure architects) had a major influence on soybean nodulation.

## CONCLUSIONS

The researchers indicate a significant correlation between the soil porosity measurement by image analysis (according to their shape and size) and the thin section image showing the porosity generated by soil fauna (according to their shape).

The image analysis data of the total porosity showed that the soil in both horizons (Ap and Apt) was moderately porous (the total porosity in Ap is 0.23 $m^2m^{-2}$, while in Apt slightly decreased at 0.21 $m^2m^{-2}$).

The micromorphological observations on soil thin sections pointed out the dominance of the porosity generated by soil macro- and mezofauna (more preserved in Ap and more collapsed and integrated in Apt soil matrix under compacted processes).

The compaction of the Apt horizon strongly influenced the soybean nodulation of rhizobia: the number of the nodules formed on the root hairs was significantly lower (Fig. 3), as well as their size which was smaller (comparing to those formed on the roots developed in the surface Ap horizon).

The macro- and mezofauna (the soil structure architects) had a major influence on soybean nodulation.

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