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INFLUENCE OF THE DRIP IRRIGATION AND PLASTIC MULCH ON THE WATER DISTRIBUTION AND COMPACTNESS STATE OF GREENHOUSES SOIL WITH MEDIUM TEXTURE

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Abstract

The goal of our investigation is to established the influence of the drip irrigation associate with plastic mulch on the state of soil compactness, especially on the surface of the ground on the paths. In present, the aspect of soil surface (smooth or rough), the presence of small irregularities, the rill on the paths, the cracks formation after water evaporation and soil drying are the most useful indicators for farmers in order to assess soil degradation by compaction. To all these indicators, we added hysteresis of soil-water characteristic curves as indicator of compactness state of soil and quality yield. Hysteresis behavior of water is a soil characteristic curve and can be used by engineers in charge with design of irrigation system to avoid the negative effects of drip irrigation associate with plastic mulch technology. For avoid the soil degradation from greenhouses or solarium, we proposed a set of indicators for farmers to achieve first steps of soil degradation and for improve the irrigation management.

Key words*: soil compactness, plastic mulch, water hysteresis, soil wetting pattern.*

INTRODUCTION

Due to the compulsory location imposed by the existence of water sources many greenhouses or solariums were placed on soils considered with a low capability but then through the application of land improvement works satisfactory results have obtained (Canarache, 1998).

The soil with first class capability in greenhouses must have in 0-50 cm layer a humus reserve higher than 300 t/ha, clay 12-20% (maximum 25%) contented, slightly acid reaction and a low content of soluble salts and sodium cations exchangeable capacity less than 5% (Florea et al., 1987).

Especially in greenhouse, it’s used drip irrigation method which presents many advantages in gardening as low water and energy consumption. In last years, drip irrigation is associated with plastic mulch method in order to have better horticulture results. The plastic mulch has the advantage that limited water loss by evaporation and maintained a higher temperature on soil surface. However, these cumulated methods cause rapid soil degradation by local compaction between plant rows (on paths) and a high salinization at the wetting front was observed (Filipov et al., 2013).

Certainly, the soil degradation processes occur even in soils belongs to first class capability from greenhouses but using plastic mulch increase the compaction of the soil. The soil compaction on paths between rows of plants is pronounced by water circulation in soil, but, also, in the small space between ground and plastic wrap. In greenhouses or solariums water is provided by drip irrigation and water circulation has certain peculiarities. In soil wetting pattern, the wetting front is move downward in coarse texture soil (sandy) and extends horizontally in fine texture soil (clay) (Filipov & Bodale, 2018). For a soil with medium texture (loam-clay), as in our case, the wetting pattern in profile of soil is circular (Figure 1b).

We are study the soil degradation based on complex approach that take into account soil characteristics observation, physical properties determination in lab and, also, by simulations.

The simulations of soil water characterization curves (SWCC) is useful method for understanding the water movement in different types of soils. SWCC is described by water potential in soil at given water content (Hong et al., 2016), where the water content (θ) is define as the ratio of water volume to total volume of soil. The main soil water characterization curves are wetting and drying curves.

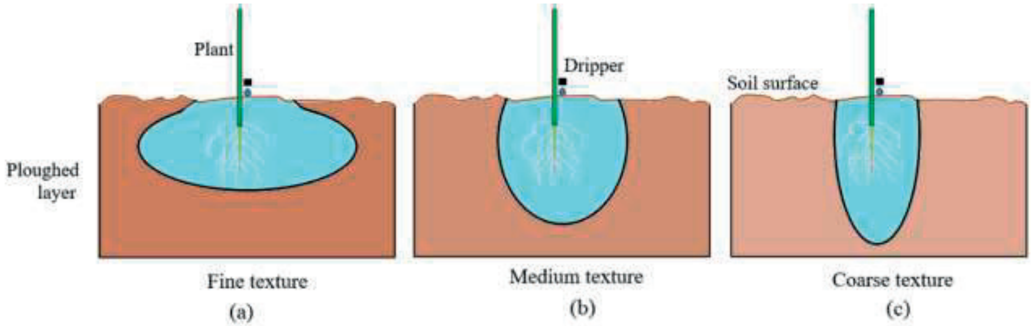

Figure 1. Wetting pattern in ploughed layer of soil with different textures: (a) for fine, (b) for medium and (c) for coarse textures of soil

The wetting and drying processes has a hysteresis behavior cause by a sum of factors as irregular space geometry, different contact angles at the upward and downward of water, the entrapped air inside the soil, shrinking and swelling of pores and thermal effects (Bodale & Stancu, 2020; Nimmo, 2006; Ward et al., 2000). The hysteresis is characterized by a relative large difference between the main drying and wetting soil water retention curves (Bodale & Stancu, 2020).

The infiltration is the move downward of water from the soil surface inside the soil due gravity and diffusion. The wetting pattern depends by hydraulic properties of soils. For example, in sandy soil deep infiltration is favorite, instead in clay the horizontal infiltration is dominate.

In Green-Ampt model (Witelski, 1998) the horizontal infiltration is describe by below equation:

$$\frac{\partial \theta}{\partial t} = \frac{\partial}{\partial x} D \frac{\partial \theta}{\partial z} \quad (1),$$

where: D is water diffusion in the soil; $\partial\theta/\partial t$ is infiltration rate; x is distance on horizontal direction; z is the deep. Water diffusion in the soil depends by soil hydraulic conductivity (K) that in clay is 0.03 cm/h.

MATERIALS AND METHODS

The study of soil degradation in gardens, greenhouses and solariums was performed on field observations, laboratory determinations and SWCC simulations.

The investigations were conducted in some high plastic tunnels from Vegetable Research Stations in the Eastern part of Romania, especially from Bacau, Targu Frumos and Spataresti greenhouses. In present study, the representative soil type is *Cambic Cernozem* in Romanian System of Soil Taxonomy (Florea, 2012) or *Haplic Chernozems* in World References Base of Soil Resources (FAO, 2015). On the other side, from geological point of view, the soils from this study were developed as alluvial deposits or like loess deposits.

In order to highlight the associated effect of soil mulching with plastic foil and drip irrigation was initiated a study of pedo-morfological indicators in both variants; without and with plastic mulch film. Some pedo-morfological indicators such as the aspect of soil surface (smooth or rough), the presence of small irregularities, the rill on the paths, the cracks formation after water evaporation and soil drying are useful indicators for approximate assessment of the compactness state of soil.

In the field, we sampled undisturbed samples from 10 to 10 cm up to the depth of 50 cm in order to analyzed the bulk density, instead the size particles were determined in the laboratory on crushed soil samples from profiles.

Theoretical approach was used to simulate the wetting and drying water retention curves in aggregated and compacted samples. These soil proprieties were described by a set of analytical solution of van Genuchten-Mualem equation (Arrey et al., 2017):

$$\theta(h)=\begin{cases}\theta_r+\dfrac{\theta_s-\theta_r}{[1+|\alpha h|^n]^{1-1/n}}, & h<0\\ \theta_s, & h\geq 0\end{cases} \quad (2),$$

where: θ_s is saturated water content; θ_r - residual water content; h - pressure head; α - air trapped coefficient; n - pore size distribution. The simulated results of soil water retention curves and pedological aspects were used to determine the soil degradation.

RESULTS AND DISCUSSIONS

The crops with (1) and without (2) plastic mulch film (Figure 2) were analyzed. In Figure 2, (a) and (c) were used to note the plants rows, respectively (b) and (d) for the intervals between plants rows (paths).

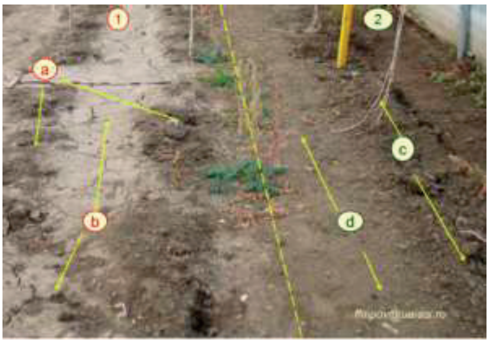

Figure 2. The surface of ground after harvested in Bacau plastic tunnel: (1) is the ground surface after plastic mulch film was used; (a) represents where the rows of plants were; (b) was the interval between plants rows (paths); (2) is the soil surface without plastic mulch film; (c) rows of plants; (d) paths

From pedological point of view, soil compactness state is evidenced by some aspects of soil surface such as the presence of cracks on the smooth surface. The cracks can be seen on rows that were covered with (1) plastic foil (a from Figure 2), also, for covered rows a more pronounced convexities were observed on paths between plants rows (b from Figure 2) than when no foil was used. In garden layouts without plastic mulch film (2) can be seen the greater surface roughness (c from Figure 2) and the absence of the convexity on the interspace between plants rows (d from Figure 2).

Compactness state of soil with medium texture is also evidenced by the distribution of plant roots. The presence of compacted layer, described by plowpan, does not allow penetration of plant roots (Figure 3A-1). In this case, a slows water infiltration occur and favors accumulation of excess water at the base of ploughed layer. In the plowpan there are only few roots, especially on the earthworm channels (Figure 3A-2) or on the path of the cracks (Figure 3B) formed by soil drying. The difference between clod of strong compacted and slight compacted was evidenced (Figures 3C and 3D).

The soil samples, from 0 to 90 cm depths, analyzed in laboratory had medium loam texture with a content of clay range between 21.3% and 27.7%. The soil layers under ploughed layer had values of bulk density higher than density of restricting rooting. Values of packing density range were between 1.46 g/cm^3 up to 1.79 g/cm^3. The limit of packing density value was 1.4 g/cm^3 to separate non-compacted soil by moderately compacted soil and 1.7 g/cm to separate moderately by strong compacted soils.

The aspect of the upper part of soil profile is shown in Figure 4. The lateral development of roots plant (1 from Figure 4) is due to high state of plowpan compactness which prevents the penetration of plant roots or allows roots to penetrate only in the cracks resulted after soil drying (2 from Figure 4). Also, in the strong compacted layer, roots were found (3 from Figure 4).

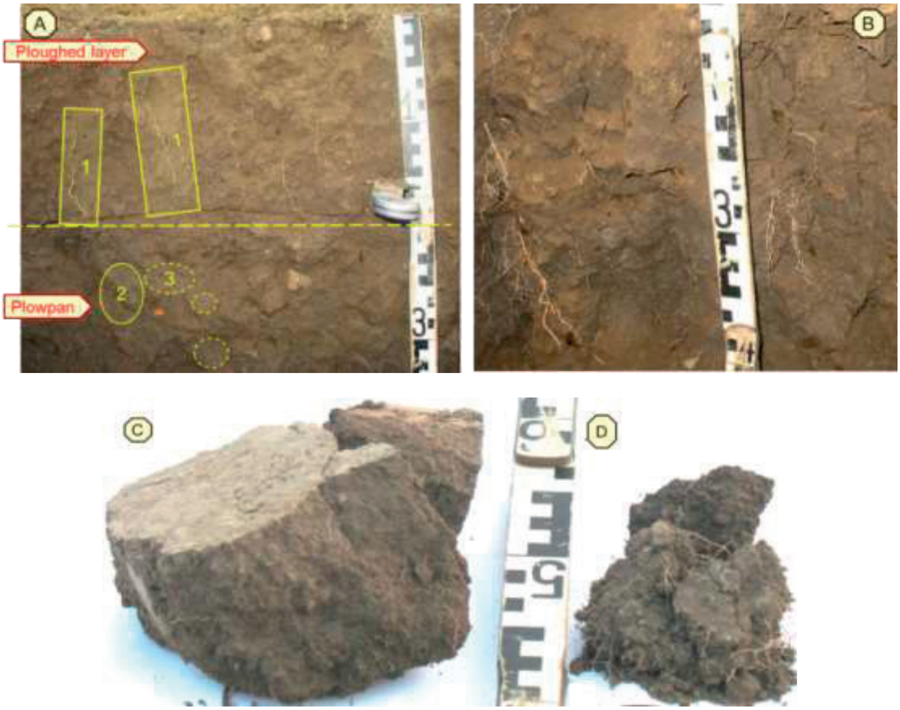

Figure 3. Soil profiles in Bacau plastic tunnel: A - Slight compacted soil in ploughed layer; the presence of plant roots (1) in the ploughed layer and locally earthworm channels (2) & (3) in the plowpan; B - Preferential root distribution in the areas that delineated by cracks; C - Compacted soil from paths; D - Slight compact soil on the plant rows

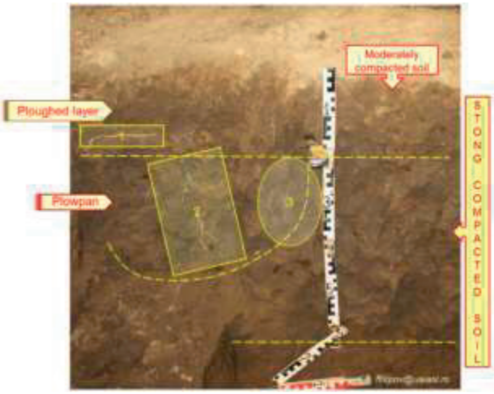

Figure 4. Compactness state of medium texture soil after harvested and removed the mulching foil in Bacau plastic tunnel: 1 - the preferential lateral development of the roots above the compact soil layer; 2 - preferential development of roots on the walls of fine cracks; 3 - inactive roots

In gardening, the water drops from drip irrigation fall on plants row under plastic foil (Figure 5). The wetting pattern shows a bulb in ploughed layer which elongated down in medium texture soil (loam). Furthermore, the plastic foil maintains a temperature higher that in air which favors evaporation of water from moisture surface (Croitoru et al., 2013). Especially in the night, water condense on plastic foil when the dew point is reached and the drops moisten the whole surface of the ground including the paths (Figure 5a). This moisten ant the traffic causes the compaction of ground surface on paths (Figure 5b).

The plowpan act as a barrier against move downward of water because there is a difference in capillarity. When the wetting front reaches at plowpan a lateral extension takes place (Figure 5b). This horizontal moisture under paths has major contributions on soil degradation.

We developed a model based on van Genuchten-Mualem equation which was able to simulated the wetting and drying curves in samples with different compaction (Arrey et al., 2017; Bodale & Stancu, 2020). The relationship between water content and potential by linear semi-logarithmic coordinate (Burton et al., 2015).

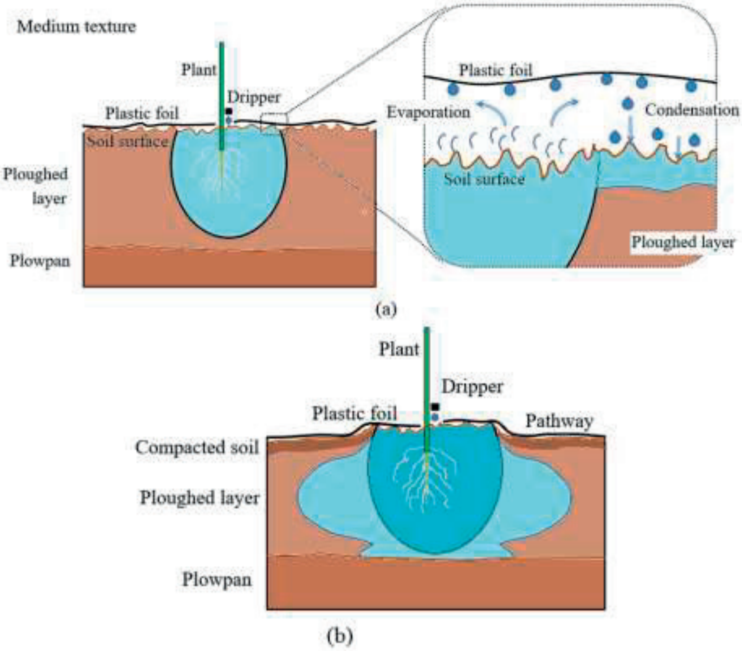

Figure 5. The wetting pattern in medium texture soil with plastic mulch. Evaporation and condensation of water under the plastic mulch foil (a). Lateral water movement caused by plowpan which favors the compaction of soil on paths between plants rows (b)

The simulation of hysteresis loop of aggregated soil from ploughed layer (Figure 6) showed a high water content than in compacted soil (Castendyk & Eary, 2009). This difference is given by variation of the capillary rise when water is move from one layer to another.

The field capacity point is almost the same for the two samples but the slopes of SWCCs of compacted soil decrease slower than aggregated soil. This variation makes difficult the identification of the residual water content point.

The quantity of the water content in aggregated soil is bigger than in compacted soil because the porosity decrease at compaction (Figure 6).

Available water for plant is more clearly defined in aggregated soil where find most of the plant roots.

The morphological indicators that can be used to evaluate the state of soil compactness are represented by the smoothness of the soil surface on the interval between rows of plants, the formation of cracks due to the decrease of soil moisture, the presence of small convexities in the central part of the interval between rows as a result of the decrease of the total porosity of the upper part of the soil, decreasing the frequency of plant roots and preferential distribution of roots on the faces of structural aggregates.

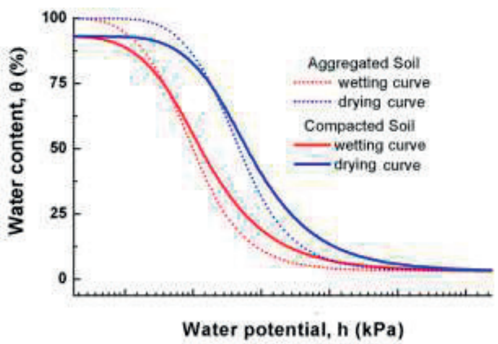

Figure 6. The water hysteresis loops aggregated and compacted soil. Wetting (red shapes) and drying (blue shapes) curves simulated for aggregated (dots line) and compacted soil (solid line)

The local compaction of the under ploughed layer is highlighted, during the growing season, by extending the width of the wet strip on the soil surface. This indicator could be used if the plastic foil does not cover the entire surface of the ground. The mentioned indicators can be easily observed by farmers and use to avoid the soil degradation.

Strong compactness of the soil in the area of the interval between plants rows allows us to recommend avoiding plastic mulch on the intervals between plant rows.

We recommend to use of plastic foil only on the row of plants. This will allow farmers to avoid oversized irrigation by following the wetting strips on the surface of the uncovered soil.

CONCLUSIONS

Plastic mulch on the entire surface of soil from high plastic tunnel favors soil compaction even using drip irrigation. Strong compactness of the soil in the area of the interval between plants rows allows us to recommend farmers to avoid plastic mulch over the whole surface of the plastic tunnel.

Indicators of strong compacted soil, easily distinguishable by farmers, are the smooth soil surface, the presence cracks after soil drying and the presence of pronounced convexity on paths between plants rows.

Plants roots distribution could be used as the additional indicators that confirm strong compactness of the soil.

The slopes of wetting and drying curves simulated for compacted soil decrease slowly which shows that plants extract harder water from compacted soil. In this case, the residual water content accentuates degradation of soil and should be taken into account as a technical indicator of compactness when design the irrigation systems.

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