POLYETHYLENE MULCHING EFFECTS ON SOIL PROPERTIES AND PHYSIOLOGICAL TRAITS IN TOMATO UNDER ECOLOGICAL CROP TECHNOLOGY

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Abstract

The aim of this study is to assess the influence of covering with black polyethylene mulch on soil properties and also over plant physiological behavior. Analyzed gas-exchange parameters were: soil net CO_2 exchange rate (NCER), soil respiration (Ce) and water humidity (W flux) as soil indicators and photosynthetic rate, transpiration, and stomatal conductance and also sugars leaf content as plant physiological indicators.

Plant material was Prekos tomato variety cultivated in protected organic system at The Vegetable Research and Development Station Bacau (SCDL Bacău). Our analysis showed that black plastic mulch on the soil surface favored soil compaction especially on the space between tomato plant rows. The strong soil compactness state was reflected by the high bulk density values and other indicators as smooth soil surface and the cracks networks. In variant with no black plastic cover, soil gas-exchange showed that net CO_2 exchange rate of was 7.94 µmol $m^{-2}s^{-1}$ and soil CO_2 flux as soil respiration was 77.4 µmol $m^{-2}s^{-1}$ both higher in comparison with black polyethylene covering variant. In variant with black plastic cover because of higher soil moisture under polyethylene the water flux between air and soil are increased. Photosynthesis registered a slight increase, having the value of 10 µmol $m^{-2}s^{-1}$ in flowering phenophase (June) and about 11 µmol $m^{-2}s^{-1}$ in ripening phenophase (July) in uncovered with polyethylene variant. During the studied period, the variant uncovered with black plastic (polyethylene) registered a small variation of the photosynthesis rate but a higher mean value than covered variant. Covered variant registered a higher value in the flowering phenophase and a smaller value in ripening stage.

Key words: polyethylene much, Prekos tomato variety, soil respiration, photosynthesis, sugar leaf

The use of plastics -- to cover greenhouses and high tunnels, as row covers, and for soil mulches – revaluated the horticultural practices. There is a wide variety of plastic mulch on the market that can reflect, absorb or transmit sunlight. Black plastic mulch increases soil temperatures about 5ºC at a depth of 2 inches compared to bare ground. Clear mulch is the most transparent to infrared radiation and warms the soil to the greatest extent of all plastic mulches, increasing daytime soil temperatures from about 7ºC to 13ºC at a depth of 2 inches. Infra-Red Transmitting (IRT) mulches warm the soil as intermediary between clear and black mulch. Highly reflective plastic mulches repel certain aphids. The main benefits of using plastic mulch include: increasing soil temperature, decreasing of water loss by direct evaporation, increased yield, reduced nutrient leaching and improved nutrient uptake, getting early production, ensure full control of weeds, ensure maintenance of a lower water content in soils from zone with high rainfall (Kasirajan S., Mathieu N., 2012).

Managing growth and development of an entire crop for optimum production involves the manipulation of environmental condition to obtain not only the maximum rate of photosynthesis under the given light conditions, but also the optimum balance of vegetative and generative growth of plants for sustained production and high yields (Portree J., 1996). The flux of CO_2 emitted from the soil surface to the atmosphere mainly originates from the respiration of roots as well as decomposition of root parts, soil organic matter and plant litter and is frequently used as an indicator of the "health" of that soil. Soil management practices, such as tillage intensity and method, the type of fertilizer used can have a great effect on CO_2 emissions. Some factors, which alter the resource availability, can be anticipated to influence carbohydrate partitioning in plants. The primary end products of photosynthesis are triose phosphates, which are rearranged into glucose-6-phosphate and used for the formation of starch as storage molecules or transported into the cytosol to form sucrose. In the source leaves, sucrose can be

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metabolized to its hexose products (i.e. glucosis and fructosis), it can be stored in the vacuole, or it can be transported through the phloem to the sink tissues (Osorio S. *et al*, 2014).

Sucrose as disaccharides compound is relatively a stable molecule (it is transported between different plant organs and even stored for long periods) when compared with monosaccharides, which are promptly metabolized and are seldom transported between cells or accumulated.

Our investigations concern to the influence of black plastic mulch on soil properties and on the physiological parameters in Prekos tomato variety cultivated in protected spaces under organic technology.

MATERIAL AND METHOD

The experimental design deployed soil chambers connected to an infra-red CO_2 gas analyzer. Physiological features analyzed by portable photosynthesis system (LCi, ADC Bioscientific) were such as: photosynthetic rate (µmol CO_2 m^{-2} s^{-1}), transpiration (mmol H_2O m^{-2} s^{-1}), and stomatal conductance (mmol m^{-2} s^{-1}). The representative soil type is Cambic Cernozem after Romanian System of Soil Taxonomy or Haplic Chernozems after WRBS. The physio-chemical properties of investigated soil were represented in tables below (*table 1, table 2*).

Table 1

Soil size particle of the Cambic Cernozems

Depth cm	Size particle (%)				Texture
	0.2÷2 mm	0.02÷ 0.2mm	0.02÷ 0.002mm	<0.002 mm	
0-25	0.5	44.6	27.2	27.7	Medium loam
20-33	0.8	43.1	30.6	25.5	
33-56	0.7	45.6	29.5	24.2	
56-90	1.0	50.8	26.9	21.3	

Table 2

The characteristics of analyzed soils

Depth cm	BD_r[1)] g/cm^3	BD_{pr}[2)] g/cm^3	BD_{ipr}[3)] g/cm^3	PD_{ipr}[4)] g/cm^3	PD_{ipr}[5)] g/cm^3
0-5	1.34	1.23	1.44	1.48	1.69
10-15	1.34	1.21	1.42	1.46	1.67
20-25	1.34	1.49	1.52	1.74	1.77
30-35	1.36	1.53	1.55	1.76	1.79
40-45	1.36	1.48	1.50	1.71	1.73

[1)]Bulk density of restricting rooting; [2)] Bulk density the plants rows areal;[3)] Bulk density on the interval between plants rows; [4)] Packing density on the plant rows [5)] Packing density of soil from middle interval between plants rows

Plant material consists by young leaf, exposed in sun. It was analysed two variants: soil covered with black plastic polyethylene and un uncovered variant at the experimental design placed in The Vegetable Research and Development Station Bacau. Samples from Prekos tomato variety cultivated in protected organic system, were collected on June (in flowering phenophase) and July (in ripening phenophase) 2008.

Sugars leaf analysis of dried plant material was extracted by Bertrand method combined with method Borel. Results were expressed as g % of dry matter. Measurements of soil gas-exchange parameters regarding soil respiration (Ce), water flux (W flux) and net CO_2 exchange rate (NCER) were undertaken with a soil chamber of portable photosynthesis system.

RESULTS AND DISCUSSIONS

Soil gas-exchange showed that net CO_2 exchange rate (NCER) of 7.94 µmol $m^{-2}s^{-1}$ and soil respiration (Ce) of 77.4 µmol $m^{-2}s^{-1}$ are both higher in variant of which are not covered with black plastic mulch in comparison with values obtained at variant covered with black plastic mulch. Black plastic polyethylene variant registered a light smaller value of 73.85 µmol $m^{-2}s^{-1}$ for soil respiration and a value of 7.58 µmol $m^{-2}s^{-1}$ for net CO_2 exchange rate (NCER) (*figure 1*).

These higher values of soil respiration and respectively, soil efflux exchange rate for CO_2 (NCER) are implying of an increases of micro-organisms activity in case of uncovered soil with plastic mulch. In covered variant with black plastic was observed the increasing of soil moisture represented by the W flux (vapors) of water between air and soil (*figure 1*). In generally, the highest CO_2 exchange rate was registered in organically managed fields, because of using organic amendments like manure, crop residues (Acatrinei L., Călugăr A., 2010, Feizienė *et. al*, 2008).

The analyzed soil has a medium loam texture. The content of clay ranged in depth between 21.3 to 27.7% at particle < 0.002 %. The values of bulk density of restricting rooting for soil with medium loam texture, has a low amplitude and ranged between 1.34 g/cm^3 and 1.36 g/cm^3 (Filipov F., 2013). Soil layers under ploughed layer have values of bulk density higher than density of restricting rooting. Values of packing density ranged between 1.46 g/cm^3 up to 1.79 g/cm^3. Limit packing density value of 1.4 g/cm^3 separate non-compacted soil and moderately compacted soil from strong compacted (1.79 g/cm^3). Compactness state of soil from plants rows is not uniform, small surfaces with low compact soil alternated with those in which the soil is moderately compact. Local soil compaction on plant lines is due to frequently pressure for performing agricultural work and repeated harvesting tomatoes (Filipov F. *et al*, 2001).

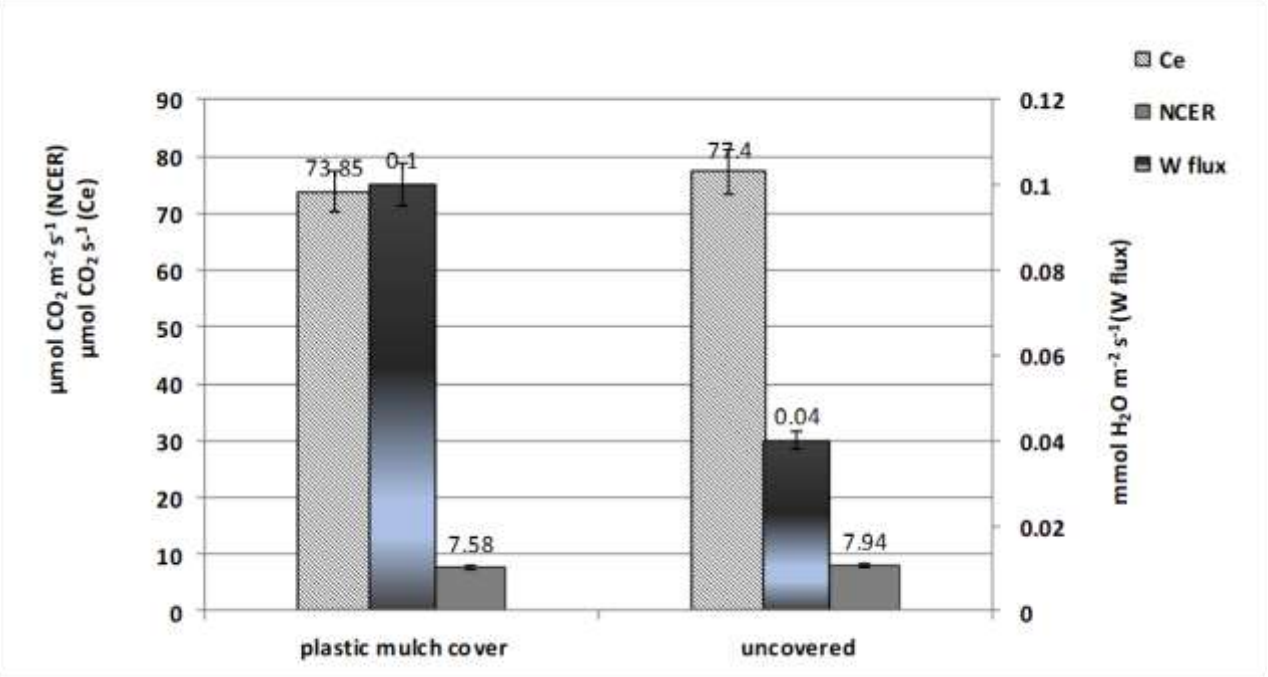

Figure 1 **Variation of soil net CO_2 exchange rate (NCER), soil respiration (Ce) and Water flux exchange (W flux) in analyzed variants**

Another negative effect is due to deficiency of carbon dioxide exchange from air to soil on dry and warm days, and to the soil gradually compacted among plants rows and to the moderately to strong compacted soil under ploughed horizon. The negative influence of black plastic mulch on soil quality can easily be noticed after harvesting and removing the plants debris and the black foil. Strong compaction of the soil between the plant rows is evidenced by the decrease of the surface land level after diminishing of soil porosity. Another morphological indicator of the compact soil is the smooth surface without any roughness. As a result of gradual drying of the soil between the plants rows a network of cracks is developed.

In condition which the soil was not covered with polyethylene mulch, plant gas exchange parameters have increased from flowering stage to ripening stage of Prekos tomato variety. Thus, photosynthesis rate showed the value of 10 µmol $m^{-2}s^{-1}$ in flowering phenophase (June) and about 11 µmol $m^{-2}s^{-1}$ in ripening phenophase (July). Transpiration registered a smaller variation during analyzed period, the value was 2.82 mmol $m^{-2}s^{-1}$ in June and 3.2 mmol $m^{-2}s^{-1}$ in July. Stomatal conductance with a value of 1 mmol $m^{-2}s^{-1}$ in June which was 5 times higher than that registered in June of 0.2 mmol $m^{-2}s^{-1}$ was increased at once with transpiration (*figure 2*). Stomatal behavior, generally, controls the volume of CO_2 entering the intercellular air spaces of the leaf for photosynthesis, playing a key role in water lost through transpiration. Some climate factors from polytunnels such as air temperature, CO_2 concentration, photoperiod, radiation level, relative humidity, diurnal fluctuations in water potential (moisture extremes) can affect physiological behavior of plant from protected spaces (solariums and greenhouses). Some investigations revealed that the black plastic mulch could induces in hot summer days some physiological disturbance easily seen by farmers as rolled leaves of tomatoes (Barden *et al*, 1987).

In condition with black polyethylene mulch, photosynthesis rate was higher in June when registered a value of 13 µmol $m^{-2}s^{-1}$ than that registered in July which was approximative 6 µmol $m^{-2}s^{-1}$. The transpiration was registered close value in both analyzed months, around 3.5 mmol $m^{-2}m^{-1}$. Stomatal conductance registered on July a value of 0.45 mmol $m^{-2}s^{-1}$, being almost two-folded than value of 0.21 mmol $m^{-2}s^{-1}$ registered on June (*figure 3*). In previous work we observed that an increasing of internal concentration of CO_2 (Ci) in gas-exchange chamber and apparition of photorespiration in tomato variety due to stomatal closure.

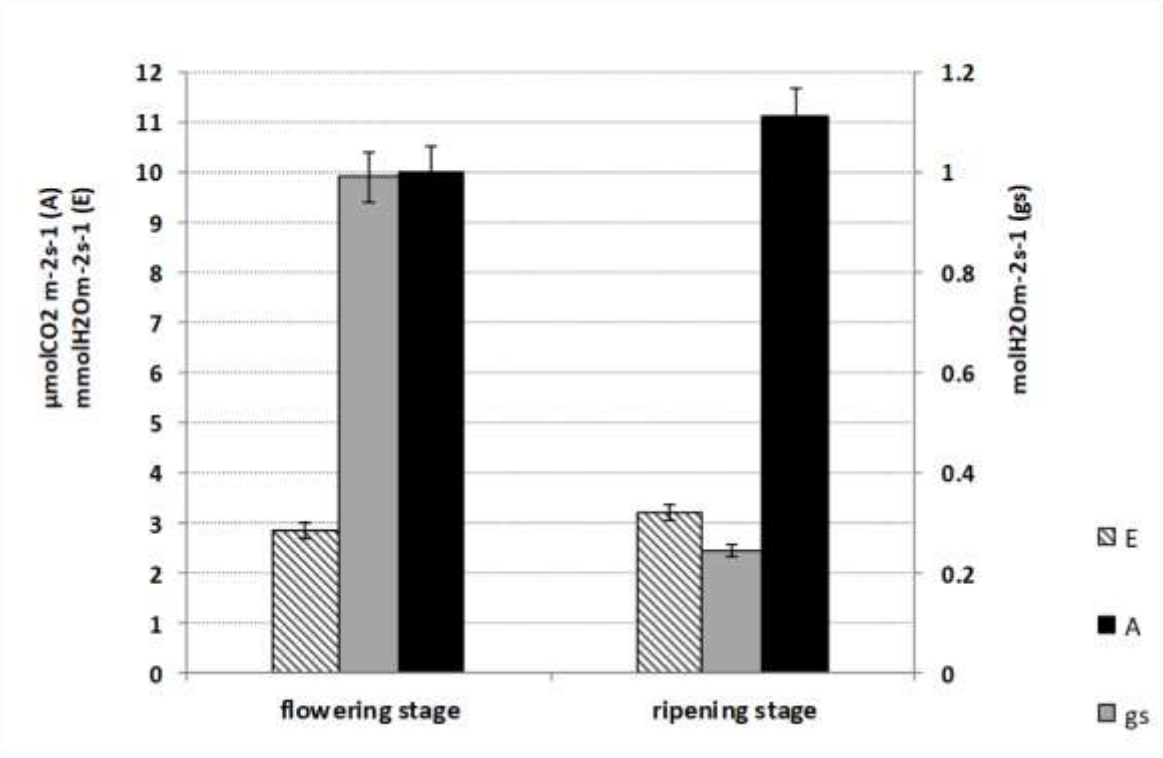

Figure 2 **Graphic representation of gas-exchange parameters (A-photosynthesis rate, E-transpiration, gs - stomatal conductance) in Prekos tomato in uncovered black polyethylene variant**

Fast rate of photosynthesis in early morning increased the accumulation of carbohydrates in tomato leaves is followed by the apparition of photorespiration process observed later in the morning (Acatrinei L., 2009, 2010). It was observed that delaying ventilation in greenhouses to conserve CO_2 resulted in higher temperatures over 30 °C. It well known that in higher temperatures (over 25°C), net photosynthesis begins to decline and the supplementation of CO_2 above this temperature is not considered rentable. Hence, the reduction of transpiration may cause insufficient cooling, and heat damage to the leaves under conditions of intense light (Nederhoff E.M., 1988).

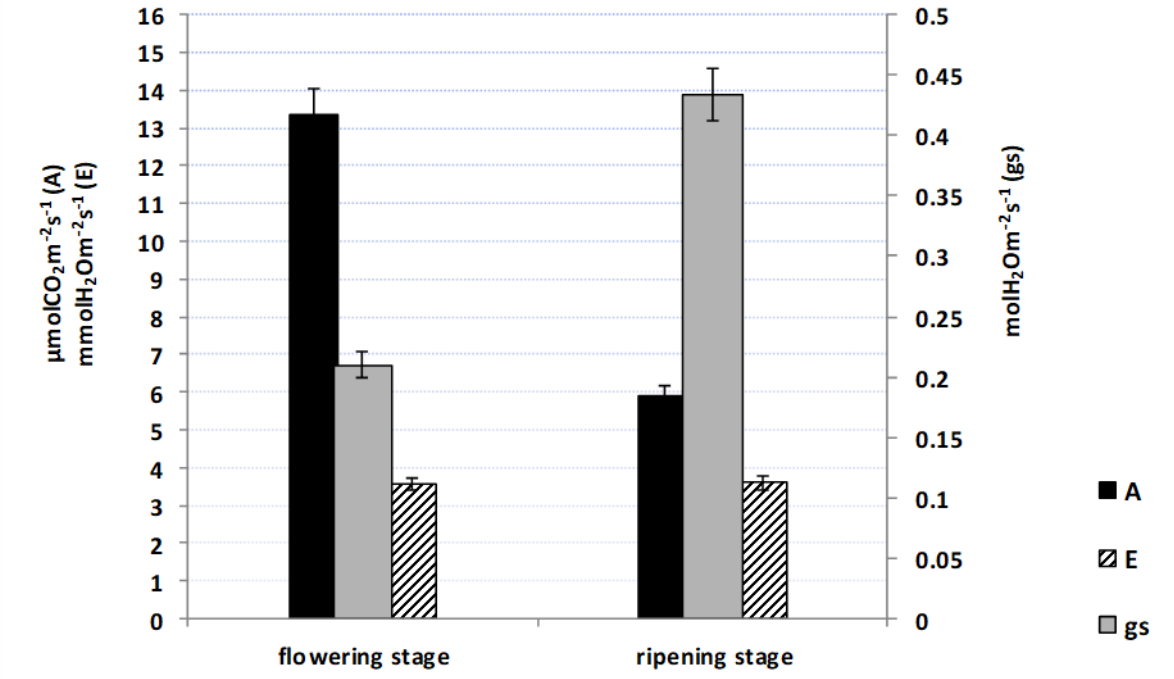

Figure 3 **Graphic representation of gas-exchange parameters (A-photosynthesis rate, E-transpiration, gs - stomatal conductance) in tomato varieties in condition with black polyethylene mulch**

In young plants, carbon dioxide may increase sugar translocation in the roots and movement of nitrogen towards the development of new roots. Carbohydrates are accumulated in the vegetative or early reproductive phase (Osorio S. *et al*, 2014). Sugars leaf registered different accumulation in analyzed plots. During studied vegetation stage, the accumulation of carbohydrates increased and thus, on July was registered higher amount of mono-, di- and polysaccharides on each analyzed variant (with black polyethylene mulch and without black polyethylene mulch) (*figure 4*). In variant with black polyethylene mulch, were observed a reduced the accumulation of monosaccharides in June and respectively, in polysaccharides on July than in variant without black polyethylene mulch. Increased disaccharides in ripening stage were almost 1.16 higher in variant with black polyethylene cover being correlated with increasing photosynthesis rate observed at this variant. Polysaccharides which have a structural role for plants increased two times higher in variant without black polyethylene mulch in comparison with uncovered variant. Covering with black polyethylene were increased the photosynthesis rate, accumulation of monosaccharides and also disaccharides in a fast manner from flowering stage to the ripening stage of tomatoes. In some cases, sugar metabolism can be used as an indicator of the photosynthetic activity. The production of sugars in the mesophyll cells and their transport to guard cells may present a central role in the tight regulation of A-gs. Some researchers found correlation for sugars with A and also, with gs and provides further evidence for a role of sucrose (disaccharide) and its derivatives, glucose and fructose (monosaccharides), in connecting mesophyll and guard cells. There is evidence showing that disaccharide (sucrose) can act as an osmolyte and its accumulation in leaves inhibiting the uptake of monosaccharides from photosynthesis and also decreasing starch levels (Gago J. *et al*, 2016)

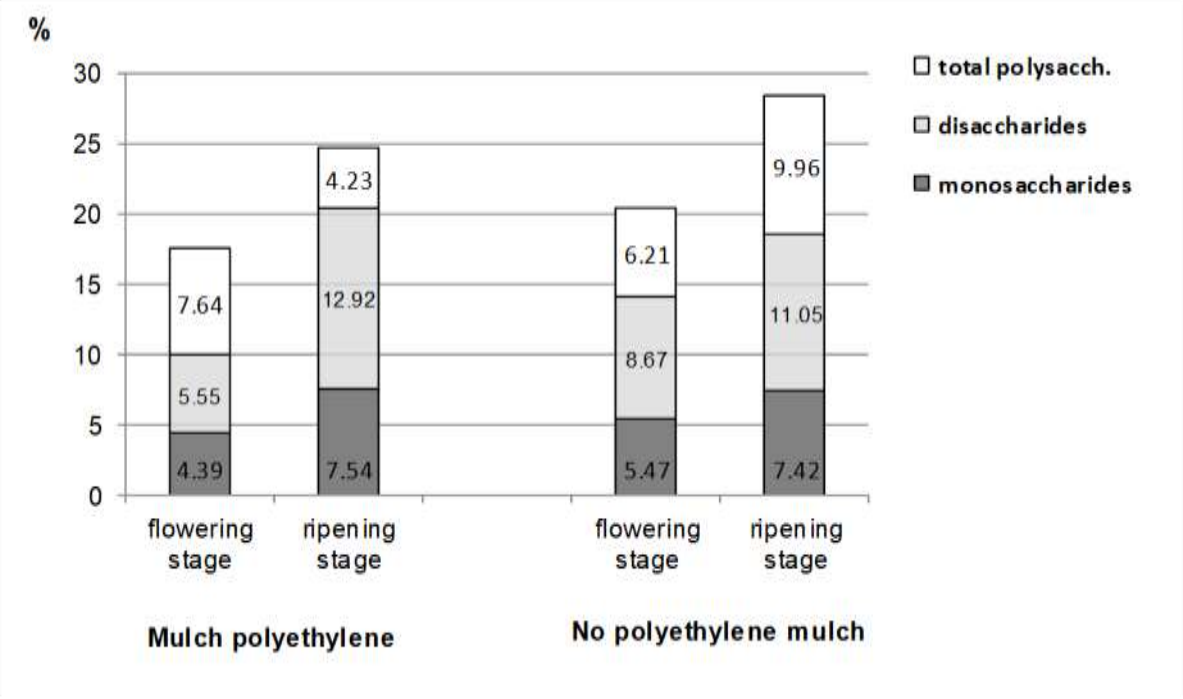

Figure 4 **Sugars leaf variation of tomato organic crop in different soil condition**

This observation is confirmed also by our results that shows in variant with black cover polyethylene on soil surface, the increasing stomatal conductance is linked with reduced photosynthesis rate and respectively, a higher disaccharides amount observed in ripening stage of Prekos variety. In that case, tomato plant registered an increased development and shortening the vegetation period due an increasing photosynthetic rate and a variable accumulation of sugars leaf. In uncovered variant, the photosynthesis rate is higher during the vegetation stage until fruit ripening and also, polysaccharides content is increased, leading to a slow rate of sugars accumulation.

CONCLUSIONS

This study analyzed the effects of black plastic on tomato physiological behavior, soil physical and physico-chemical features such as compaction, respiration and water flux with the

aim to provide a deeper insight on the cultivation of tomato planted in protected spaces with an organic technology. Black plastic mulch (polyethylene cover) on the entire surface of soil from high plastic tunnel provoked soil compaction, in the areas located between plants rows. Some indicators of strong compacted soil observed were: the smooth soil surface, the presence cracks after soil drying, distribution uniformity of plant roots associated with morphological type of structure and degree of structure development and are also an additional indicators of that phenomenon, soil compaction.

The results showed that plots without black plastic mulch has higher soil respiration because of the exchange flux between air and soil movement (soil respiration). The humidity revealed by water flux was higher in variant with black polyethylene cover. In the analyzed period, some foliar gas - exchange parameters (photosynthesis, transpiration rate) have increased from flowering stage to ripening stage in Prekos tomato variety at uncovered black polyethylene plot. In variant with black cover polyethylene on soil surface, the higher stomatal conductance is linked with reduced photosynthesis rate and respectively, a higher disaccharides amount. Sugars leaf fraction increased more higher from flowering until ripening stage in tomato fruit, in uncovered variant especially polysaccharides in correlation with maturation fruit at this stage and also sugars accumulation in fruit.

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