Watermelon (*Citrullus lanatus*) Vegetative Growth as Affected by Nitrogen Fertilization and Soil Mulching

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Summary

Mulch type could have different impacts on crops, especially in changing the root zone temperature (RZT) and microclimate around plants. The aim of research was to determine nitrogen rate and mulch type impact on watermelon early vegetative growth and RZT in order to single out the combinations with the most intensive watermelon vegetative growth in Mediterranean conditions. The split-plot field experiment was conducted during two years and included additional nitrogen rates (0, 60, 120 and 180 kg N ha^{-1}) and mulches (black PE-film, straw, bare ground). The most intensive watermelon vegetative growth can be achieved without additional nitrogen fertilization, only by mulching the soil with black PE-film or with the least rate of additional nitrogen (60 kg N ha^{-1}) and straw mulch. Due to environmental conservation, especially in karst regions, these combinations should be preferred over the combination with large rate of additional nitrogen (120 kg N ha^{-1}) and bare soil which had the equal growth intensity. Positive effect of black PE-film is the result of the highest values of RZT, i.e., accumulated heat (growth degree days – GDD) during the six weeks after planting. Although the maximum and mean RZT and GDD values below the straw were lower than on the bare ground, the positive effect of straw on vegetative growth can be explained by higher minimum RZT and better nutrient availability and utilization, due to other benefits of mulching such as better maintance of soil moisture and structure.

Key words

Citrullus lanatus, microclimate, straw, PE-film, root zone temperature, growing degree days

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Introduction

Watermelon is grown all over the world at 3.5 million ha with production of a 117 million tons, most of which is in Asia (82.6%) and only 5.7% in Europe. China is the world's largest watermelon producer, followed by Turkey, Iran, USA and Egypt (FAOSTAT, 2018). According to Lešić et al. (2016) watermelon prefers dry, warm climate and is very sensitive to frost. Transplants can be planted in the field after temperatures reach 15 to 17°C, which means that the second half of April is the acceptable period for watermelon planting into fields for the region of southern Istria in Croatia.

Common agricultural practice for intensive watermelon production is based on soil mulching with black PE-film and fertirrigation. Straw mulch or bare ground is usually used in organic agriculture (Kasirajan and Ngouajio, 2012; Lu et al., 2003).

Nitrogen has a key role in all meristem functions, photosynthesis and protein synthesis in all plant organs because nitrate anion uptake enables leaf growth and photosynthesis through cell division, light reaction production and carbon dioxide assimilation (Lawlor, 2002). Studies by Goreta et al. (2005) and Cabello et al. (2011) show how nitrogen fertilization is necessary to obtain high crop yields, however, with an increase above optimal, production costs are raising but not the yield. There is a strong possibility of nitrogen leakage and ground water contamination (Gastal and Lemaire, 2002; Castellanos et al., 2013) especially in karst regions (Castellanos et al., 2013) like Istria. Fertirrigation is a widely used technology of vegetable production which provides water and nutrients necessary for plant growth (Elmstron et al., 1981; Brinen et al., 1979). Fertirrigation in rates corresponding to different phenophases is economical and respects watermelons indeterminate growth and different nitrogen requirements (Hartz and Hochmut, 1996; Goreta et al., 2005).

Effects of soil mulching with polyethylene (PE) mulches, especially with black PE-film, are higher early growth and yield, higher number of fruits and total yield (Lu et al., 2003; Soltani et al., 1995), also better water and mineral uptake and crops pest resistance (Lamont, 2005; Kasirajan and Ngouajio, 2012; Tarara, 2000). Depending on material characteristics, various polymer or plant mulches have different impacts on crops, which could be seen as effects on plants' microclimate (Lamont, 2005; Diaz-Pérez, 2010). The most influential microclimate factor is the root zone temperature (RZT), which rises under black PE-mulch (Diaz-Pérez, 2010), but decreases under straw mulches, compared to bare ground (Kar and Kumar, 2007). Enhanced RZT stimulates root growth, water and minerals uptake and results in a higher growth degree day's sum (Ruíz-Machuca et al., 2014; Diaz-Pérez, 2009).

The aim of this research was to determine nitrogen rate and mulch type impact on watermelon early vegetative growth and RZT, in order to single out the combinations with the most intensive watermelon vegetative growth in Mediterranean conditions.

Materials and methods

Two-year field trial was set up in Valtura (44°52'52.7"N; 13°53'52.8"E), south Istria as two factorial experiment according to split–plot scheme with three replications. The first factor was additional nitrogen rate: 0 – control, 60, 120 and 180 kg N ha^{-1} and the second factor was mulch type: bare ground, straw and black PE-film. Each trial plot had three rows of 10 watermelon plants and the middle row was used for analysis of all vegetative growth parameters and microclimate measurements. Fertilization was based on the results of chemical soil analysis (pH 6.06 in KCl, humus 2.49%, N 0.26%, P_2O_5 11.2 mg 100 g^{-1} soil and K_2O 37.5 mg 100 g^{-1} soil) and standard watermelon yield (40 to 45 t ha^{-1}). Basic mineral fertilization (42 kg N ha^{-1}, 84 kg P_2O_5 ha^{-1} and 126 kg K_2O ha^{-1}) has been conducted before planting with a mineral fertilizer NPK 7-14-21 (Petrokemija, Kutina, Croatia). Stated additionally nitrogen rates were added by nine fertirrigation ratios respecting the nitrogen uptake needs for different watermelon phenophases (Hartz and Hochmuth, 1996).

Vegetative growth parameters (main vine length, diameter and number of leaves, number of secondary vines longer than 2.5 cm) were analyzed in the field 3, 4 and 6 weeks after transplantation (WAT) in 2010 and 4 and 6 WAT in 2011.

Root zone temperature (RZT) was measured with temperature sensors placed under mulches, 5 cm below the soil surface, in each treatment in two replications. Sensors connected to data loggers (HOBO U12 Temperature Data Logger U12-006, Onset Computer Company, Bourne, MA, USA), gathered temperature data every 10 minutes from planting during the observed vegetative growth period. Daily minimum, maximum and mean RZT were calculated from obtained data. Growing degree days (GDD), as a way of assigning a heat value to each day of vegetative period, was calculated using Growing Degree Days software Hobo Pro (Onset Computer Company, Bourne, MA, USA). Growing degrees is defined as the mean daily RZT of bare soil and soil underneath mulches, above base temperature for watermelon accumulated on a daily bases over a period of 42 days after planting. Base temperature represents biological minimum which is 15°C for watermelon according to Lešić et al. (2016) and Wien (1997).

Analysis of variance (ANOVA) with random effects was conducted on all vegetative growth data, while ANOVA with fixed effects was conducted for temperature data, using STASTISTICA version 10 (StatSoft, Inc.). Following significant F-test ($p \leq 0.05$) the difference among mean values was tested with Fisher LSD test.

Results and discussion

In both years, different nitrogen rates did not affect watermelons vegetative growth parameters observed in this study (Table 1 and 2). It is possible that additional nitrate fertilization had no effect on watermelon vegetative growth due to soil well enriched with nitrogen (0.26%) as a result of abundant nitrate fertilization on Valtura experimental field. In other studies, positive effect of higher nitrogen rates on watermelon (Maluki et al., 2016, Goreta et al., 2005), cucumber (Tanemura et al., 2008) and melon (Cabello et al., 2011) vine growth was observed.

In 2010 soil mulching had a significant effect on main vine length at 3, 4 and 6 WAT, and on main vine diameter at 3 and 4 WAT (Table 1). Mulching also affected main vine leaf number at 3 and 6 WAT and secondary vine number at 6 WAT 2010 (Table 1). By contrast, in 2011 there was no significant effect of mulch on vegetative growth parameters, except main vine leaf number at 4 and 6 WAT and secondary vine number at 4 WAT (Table 2). In both years, black PE-film achieved the highest values of parameters, significantly higher than the other mulch types (Table 1 and 2). Those results are consistent with well-known positive effects of black PE-mulch on vegetative growth (Lamont, 2005; Tarara, 2000). It increased leaf number and dry weight of watermelon (Ibarra-Jiménez, 2005), bell pepper (Canul-Tun et al., 2017) and potato (Ibarra-Jiménez et al., 2011). Also, black PE-film increased

Table 1. Effect of nitrogen rate (0, 60, 120 and 180 kg N ha^{-1}) and mulch (bare ground, straw and black PE-film) on watermelon vegetative growth parameters at 3, 4 and 6 weeks after transplanting (WAT) in 2010

WAT[1]	Main vine									Secondary vine number		
	Length (cm)			Diameter (mm)			Leaf number					
	3	4	6	3	4	6	3	4	6	3	4	6
Fertilization												
0	9.4	44.6	115.6	5.3	7.2	8.2	5.6	9.1	16.4	0.4	3.9	7.4
60	9.2	47.1	118.7	5.3	7.1	8.7	5.7	9.6	16.8	0.3	3.2	7.4
120	10.0	54.9	140.7	5.7	7.3	9.3	5.9	9.8	18.7	0.3	4.7	8.9
180	10.0	48.2	124.4	5.3	7.1	8.1	6.1	9.9	17.3	0.4	4.0	7.8
Mulch												
Bare ground	7.9 b[4]	44.3 ab	116.4 b	5.2 b	6.7 b	8.6	5.3 b	9.1	16.5 b	0.3	3.3	7.2 b
Straw	8.7 b	39.9 b	106.9 b	5.1 b	6.9 b	8.1	5.3 b	8.8	15.6 b	0.3	3.0	7.0 b
Black PE-film	12.5 a	61.9 a	151.2 a	6.0 a	8.0 a	9.2	6.8 a	10.8	19.8 a	0.7	5.5	9.5 a
ANOVA[2]												
Fertilization	NS[3]	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Mulch	*	*	**	*	**	NS	*	NS	**	NS	NS	*
Fertilization×Mulch	***	***	***	NS	***	***	***	***	***	***	***	***

[1]Weeks after transplantation; [2]Mixed models ANOVA with random effects; [3]NS – no significant difference, *** - significant mean difference for $p \le 0.001$, ** - significant mean difference for $p \le 0.01$, * - significant mean difference for $p \le 0.05$; [4]Different letters within column denote significant differences between mean values based on Fisher LSD multiple comparison tests, for $p \le 0.05$.

Table 2. Effect of nitrogen rate (0, 60, 120 and 180 kg N ha^{-1}) and mulch (bare ground, straw and black PE-film) on watermelon vegetative growth parameters at 4, 6 and 8 weeks after transplanting (WAT) in 2011

WAT[1]	Main vine									Secondary vine number		
	Length (cm)			Diameter (mm)			Leaf number					
	4	6	8	4	6	8	4	6	8	4	6	8
Fertilization												
0	16.9	89.1	141.8	5.1	7.6	9.6	6.0	13.1	18.3	0.9	4.8	7.1
60	26.0	107.6	173.6	6.2	8.6	11.6	7.9	14.6	20.4	1.8	5.3	7.9
120	23.1	104.8	172.0	6.1	8.1	11.9	7.3	15.1	21.9	1.7	5.7	8.4
180	30.0	110.2	170.8	6.0	8.3	11.9	8.0	14.7	20.1	1.8	6.0	8.7
Mulch												
Bare ground	17.2	86.1	151.4	5.2	7.3	10.5	6.7 b[4]	13.8 b	20.8	1.3 b	4.4	7.3
Straw	21.2	95.8	171.7	5.8	7.8	11.3	6.7 b	13.7 b	20.9	1.1 b	5.3	8.9
Black PE-film	33.7	126.9	170.5	6.6	9.3	11.9	8.7 a	15.6 a	18.9	2.2 a	6.7	7.9
ANOVA[2]												
Fertilization	NS[3]	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Mulch	NS	NS	NS	NS	NS	NS	*	*	NS	*	NS	NS
Fertilization×Mulch	***	**	NS	*	*	NS	***	**	NS	***	*	NS

[1]Weeks after transplantation; [2]Mixed models ANOVA with random effects; [3]NS – no significant difference, *** - significant mean difference for $p \le 0.001$, ** - significant mean difference for $p \le 0.01$, * - significant mean difference for $p \le 0.05$; [4]Different letters within column denote significant differences between mean values based on Fisher LSD multiple comparison tests, for $p \le 0.05$.

leaf area and melon vine length (Alenazi et al., 2015) as well as broccoli total biomass and shoot dry matter (Diaz-Pérez, 2009).

Interaction between nitrogen rate and mulch type for all vegetative growth parameters was statistically significant at 3, 4 and 6 WAT in 2010 except for main vine diameter at 3 WAT 2010 (Table 1). Interaction in 2011 affected all growth parameters at 4 and 6 WAT, but not at 8 WAT (Table 2). Table 3 shows that in 2010 at 3 WAT, watermelon plants at combination 0 kg N ha^{-1} × black PE-film (0×PE) had the longest main vine, which significantly differed from all other treatments except 180 kg ha^{-1} × black PE-film (180×PE). Combination 60 kg N ha^{-1} × straw (60×S) had the same effect as combinations with higher nitrogen rates, 180×PE and 120 kg N ha^{-1} × bare ground (120×BG). This effect could be explained with the capacity of straw to preserve soil moisture. Studies of Liu et al. (2014) confirm that mulching with PE-films and straw prevents evapotranspiration. Liang et al. (2011) and Mu and Fang (2015) stated that straw mulch better preserves soil moisture than PE mulch and bare ground. Similar was observed by Qin et al. (2015) comparing the effects of straw, plastic and bare ground on maize and wheat yield, nitrogen and water use efficiency. They suggested that mulching increases all parameters compared to bare ground and it can close yield gap caused by the low nutrient input. In 4 WAT 2010, earlier explained interaction effect was even more obvious, since 0×PE, 180×PE, 60×S and 120×BG did not significantly differ in strong positive effect on main vine length (Table 3). Combination 180×PE had significantly higher value of this parameter, compared to all other mentioned treatments. Also, in 6 WAT 2010 similar interaction effect was confirmed, considering that combinations 0×PE, 60×PE, 180×PE, 60×S, 120×S and 120×BG did not significantly differ in their strong positive effect on main

Table 3. Multiple comparison tests of nitrogen fertilization and mulch interactions effects on watermelon main vine length, 2010, 2011

N (kg ha^{-1})	Mulch	Main vine length (cm)				
		2010			2011	
		3 WAT[1]	4 WAT	6 WAT	4 WAT	6 WAT
0	Bare ground	5.8 ef[2]	41.0 cd	117.0 bc	7.3 c	57.0 c
	Straw	5.9 ef	14.3 e	50.7 d	9.3 c	72.7 c
	Black PE-film	16.6 a	78.3 ab	179.0 a	34.0 b	137.7 ab
60	Bare ground	5.6 f	16.3 e	51.3 d	11.7 c	44.7 c
	Straw	13.4 bc	66.3 ab	157.3 ab	41.3 b	141.3 ab
	Black PE-film	8.8 de	58.7 bc	147.3 ab	25.0 b	136.7 ab
120	Bare ground	12.7 c	75.7 ab	176.7 a	35.3 b	154.0 a
	Straw	9.1 d	60.3 bc	155.7 ab	22.7 bc	84.7 bc
	Black PE-film	8.3 def	28.7 de	89.7 cd	11.3 c	75.7 c
180	Bare ground	7.7 def	44.0 cd	120.7 bc	14.3 c	88.7 bc
	Straw	6.2 def	18.7 e	64.0 d	11.3 c	84.3 bc
	Black PE-film	16.0 ab	82.0 a	188.7 a	64.3 a	157.7 a

[1]Weeks after transplantation; [2]Different letters within column denote significant differences between mean values based on Fisher LSD multiple comparison tests, for p ≤ 0.05.

Table 4. Multiple comparison tests of nitrogen fertilization and mulch interactions effects on watermelon main vine diameter, 2010, 2011

N (kg ha^{-1})	Mulch	Main vine diameter (cm)				
		2010			2011	
		3 WAT[1]	4 WAT	6 WAT	4 WAT	6 WAT
0	Bare ground	5.0 bc[4]	6.7 cdef	8.3 bcd	4.0 d	6.7 cd
	Straw	5.0 bc	6.3 def	6.7 e	5.0 cd	6.7 cd
	Black PE-film	6.0 ab	8.7 ab	9.7 b	6.3 abc	9.3 abc
60	Bare ground	5.0 bc	5.7 f	7.0 de	5.0 cd	5.7 d
	Straw	5.7 abc	8.0 abc	9.7 b	6.7 abc	10.0 ab
	Black PE-film	5.3 bc	7.7 abcd	9.7 b	7.0 ab	10.0 ab
120	Bare ground	6.0 ab	8.0 abc	11.3 a	6.7 abc	10.0 ab
	Straw	5.0 bc	7.3 bcde	9.0 bc	6.3 abc	7.3 bcd
	Black PE-film	6.0 ab	6.7 cdef	7.7 cde	5.3 bcd	7.0 bcd
180	Bare ground	4.7 c	6.3 def	7.7 cde	5.0 cd	7.0 bcd
	Straw	4.7 c	6.0 ef	7.0 de	5.3 bcd	7.3 bcd
	Black PE-film	6.7 a	9.0 a	9.7 b	7.7 a	10.7 a

[1]Weeks after transplantation; [2]Different letters within column denote significant differences between mean values based on Fisher LSD multiple comparison tests, for p ≤ 0.05

vine length (Table 3). In 4 WAT 2011, combination 180×PE differed from all other treatments due to higher value of main vine length, while in 6 WAT 2011 it also had the longest main vine, but statistically equal to the combinations 0×PE, 60×PE, 60×S and 120×BG (Table 3). In both years interactions related to bare ground indicated that nitrogen rate of 120 kg N ha^{-1} resulted with the longest main vine, compared to the highest or lower nitrogen rate.

Observing the interaction effect on main vine diameter (Table 4) in 3 WAT 2010, it was obvious that combination 180×PE was again at statistically higher level than other combinations except 0×PE, 120×PE, 60×S and 120×BG. In 4 WAT 2010 interaction effect was similar, due to the black PE-film at 180 kg N ha^{-1}, which had the greatest main vine diameter, statistically equal to the values of combinations 0×PE, 60×PE, 60×S and 120×BG. According to the achieved main vine diameter values, straw and bare ground at 180 kg N ha^{-1} belong to the lowest statistical rank as well as the straw at 0 and bare ground at 60 kg N ha^{-1}. This can be explained by the possibility that in soil well enriched with nitrogen, the plant growth had already reached the highest level so additional high nitrogen rate (180 kg N ha^{-1}) had no positive effect on this parameter. The same explanation can also be applied for similar data of other researched vegetative growth parameters. In 4 and 6 WAT 2011 interaction effect on main vine diameter was similar because the combination 180×PE obtained the greatest main vine diameter without the statistical differences amongst values of combinations 0×PE, 60×PE, 60×S and 120×BG and additionally 120×S in 4 WAT.

Table 5 shows interaction effect on the watermelon main vine leaves number. In 3 WAT 2010 combination 180×PE had the highest number of leaves per main vine that did not differ from combinations 0×PE and 60×S. In 4 and 6 WAT 2010 the same combinations (0×PE, 60×PE, 180×PE, 60×S, 120×S and 120×BG) belonged to the rank with the highest number of leaves of watermelon main vine and combinations 120×PE and 180×BG additionally in 6 WAT. Also, in 4 and 6 WAT 2011 combination 180×PE had the highest number of leaves per main vine, which was statistically equal to values of combinations 120×BG and 60×S and combinations 0×PE and 60×PE in 6 WAT.

Table 5. Multiple comparison tests of nitrogen fertilization and mulch interactions effects on watermelon main vine leaf number, 2010, 2011

N (kg ha^{-1})	Mulch	Main vine leaf number (cm)				
		2010			2011	
		3 WAT[1]	4 WAT	6 WAT	4 WAT	6 WAT
0	Bare ground	5.0 def[2]	8.7 cd	16.7 bcd	3.7 g	11.7 de
	Straw	4.0 ef	6.0 e	11.0 e	5.0 fg	11.7 de
	Black PE-film	7.7 ab	12.7 a	21.7 a	9.3 bcd	16.0 abcd
60	Bare ground	3.7 f	6.7 de	12.3 de	5.7 efg	9.7 e
	Straw	7.0 abc	11.0 abc	18.7 ab	10.0 abc	17.0 abc
	Black PE-film	6.3 bcd	11.0 abc	19.3 ab	8.0 cde	17.0 abc
120	Bare ground	6.3 bcd	11.0 abc	19.7 ab	11.0 ab	20.3 a
	Straw	6.0 cd	11.0 abc	19.3 ab	6.7 def	13.7 bcde
	Black PE-film	5.3 de	7.3 de	17.0 abcd	4.3 fg	11.3 de
180	Bare ground	6.0 cd	10.0 bc	17.3 abc	6.3 efg	13.7 bcde
	Straw	4.3 ef	7.3 de	13.3 cde	5.0 fg	12.3 cde
	Black PE-film	8.0 a	12.3 ab	21.3 ab	12.7 a	18.0 ab

[1]Weeks after transplantation; [2]Different letters within column denote significant differences between mean values based on Fisher LSD multiple comparison tests, for $p \leq 0.05$.

Table 6. Multiple comparison tests of nitrogen fertilization and mulch interactions effects on watermelon secondary vine number, 2010, 2011

N (kg ha^{-1})	Mulch	Secondary vine number				
		2010			2011	
		3 WAT[1]	4 WAT	6 WAT	4 WAT	6 WAT
0	Bare ground	0.0 b[2]	2.3 cd	7.0 bcd	0.3 f	2.7 de
	Straw	0.0 b	1.3 cd	3.7 de	0.0 f	4.3 cde
	Black PE-film	1.3 a	8.0 a	11.7 a	2.3 bcd	7.3 abc
60	Bare ground	0.0 b	0.3 d	2.7 e	0.7 ef	2.0 e
	Straw	1.0 a	6.0 ab	10.7 ab	2.7 abc	8.0 abc
	Black PE-film	0.0 b	3.3 bc	9.0 abc	2.0 bcde	6.0 abcd
120	Bare ground	1.0 a	8.0 a	12.0 a	3.3 ab	8.3 ab
	Straw	0.0 b	3.7 bc	9.3 abc	1.3 cdef	4.3 cde
	Black PE-film	0.0 b	2.3 cd	5.3 cde	0.3 f	4.3 cde
180	Bare ground	0.0 b	2.7 cd	7.0 bcd	1.0 def	4.7 bcde
	Straw	0.0 b	1.0 cd	4.3 de	0.3 f	4.7 cde
	Black PE-film	1.3 a	8.3 a	12.0 a	4.0 a	9.0 a

[1]Weeks after transplantation; [2]Different letters within column denote significant differences between mean values based on Fisher LSD multiple comparison tests, for $p \leq 0.05$.

Interaction effect on watermelons' secondary vine number is shown in Table 6. In 3 WAT 2010 combinations 0×PE, 180×PE, 60×S and 120×BG had statistically equal secondary vines number, significantly higher than other combinations. In 4 and 6 WAT 2010 the rank with the highest number of secondary vines had the same combinations (0×PE, 180×PE, 60×S and 120×BG) and combinations 60×PE and 120×S additionally in 6 WAT. In 4 and 6 WAT 2011, as recorded for the main vine leaf number, combination 180×PE had the highest secondary vines' number, which was statistically equal to values of combinations 120×BG and 60×S and additionally combinations 0×PE and 60×PE in 6 WAT. Secondary vine number in both years, similarly to other vegetative parameter, had the highest values at wide range of nitrogen fertilization on PE-film, and also on straw when mulched with 60 kg N ha^{-1} but bare grown achieves the same number of secondary wines at higher nitrogen fertilization, 120 kg N ha^{-1} This again indicates, how either mulching with PE-film at low or no additional nitrogen will achieve the best vegetative early growth, the same as straw mulching with 60 kg N ha^{-1} or bare ground with higher nitrogen levels as 120 kg N ha^{-1}.

Mulch type had major effect on the root zone temperature (RZT) and growing degree days (GDD) which shows Table 7. Maximum RZT under PE-film was statistically higher than under straw in 2010 and under straw and bare ground in 2011. Also, minimum RZT under PE-film was statistically higher than under straw and bare ground in 2011, while in 2010 it was equal with value under straw. PE-film also achieved higher mean RZT than under straw and bare ground in 2010 and straw in 2011. In regards to bare ground, straw had lower values of maximum RZT in both years and mean RZT in 2011, while in both years it had higher values of minimum RZT. This is in consistence with the study by Toth et al. (2008), when they concluded how soil temperature under straw mulch showed lower and more uniform daily temperature fluctuation compared to bare ground. The RZT increase as a result of mulching and its positive effect on growth parameters and yield was observed for broccoli (Diaz-Pérez, 2009), bell pepper (Diaz-Pérez, 2010) and tomato (Diaz-Pérez and Batal, 2002). In 2011 soil under PE-film and bare ground had statistically higher accumulated heat i.e. GDD during six weeks after transplanting than under straw. There were

Table 7. Daily maximum (MAX), minimum (MIN) and mean temperatures underneath the mulches and growing degree days ($GDD_{T=15°C}$), 2010, 2011

Mulch	Daily average root zone temperature (°C)[1]							
	2010				2011			
	MAX	MIN	MEAN	GDD Soil	MAX	MIN	MEAN	GDD Soil
Bare ground	25.4 a[2]	17.6 b	21.0 b	110	27.7 b	17.0 c	21.9 a	141 a
Straw	22.7 b	18.9 a	20.7 b	96	21.3 c	18.5 b	19.9 b	76 b
Black PE-film	25.8 a	19.3 a	22.4 a	131	26.0 a	20.1 a	23.0 a	143 a
ANOVA[3]	***	***	***	NS	***	***	***	***

[1]Average values of daily temperatures from transplanting until 6 WAT in years 2010 and 2011; [2]ANOVA with fixed effects, *** - significant mean difference for $p \le 0.001$; [3] Different letters within column denote significant differences between mean values based on Fisher LSD multiple comparison tests, for $p \le 0.05$.

no statistical differences in GDD between researched mulch types in 2010, but relative highest value was achieved under PE-film and relative lowest under straw.

Conclusion

The positive effect of soil mulching with black PE-film on early vegetative growth of watermelon was confirmed by statistically relevant interactions with 60 kg N ha^{-1} for most performed analyses of the researched parameters, and especially with 0 and 180 kg N ha^{-1} due to established positive interactions in all analyses of all parameters. The same strong effect was achieved by combinations of straw with 60 kg N ha^{-1} and bare ground with 120 kg N ha^{-1}. Therefore, the most intensive watermelon vegetative growth can be achieved without additional nitrogen fertilization, only by soil mulching with black PE-film or with the least rate of additional nitrogen (60 kg N ha^{-1}) and straw mulch. Due to environmental conservation, especially in karst regions, these combinations should be preferred over the combination with large rate of additional nitrogen (120 kg N ha^{-1}) and bare soil. Achieving the highest intensity of vegetative growth without or with minimal additional nitrogen fertilization, same as with high nitrogen dose, is a consequence of the positive effect of soil mulching on root zone temperature as a main factor of root growth, and also on soil moisture and structure. Positive effect of black PE-film is a result of highest values of RZT, i.e., accumulated heat (growing degree days – GDD) during the six weeks after planting. Although the maximum and mean RZT and GDD values below the straw were lower than on the bare ground, the positive effect of straw on vegetative growth can be explained by higher minimum RZT and better nutrient availability and utilization, due to other benefits of mulching such as better maintance of soil moisture and structure.

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