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Polyethylene Mulches and Drip Irrigation Increase Growth and Yield in Watermelon (*Citrullus lanatus* L.)

D. Romic, J. Borosic, M. Poljak and M. Romic
(University of Zagreb, Faculty of Agriculture, Zagreb, Croatia)

Summary

A 2-year study was carried out in the Vrana Valley in the Mediterranean part of Croatia to evaluate the effects of application of different mulching materials (black polyethylene film, clear photodegradable polyethylene film and paper biodegradable cellulose mulch) and irrigation systems (drip and micro irrigation) in watermelon (*Citrullus lanatus* L.) cultivation. Mean daily soil temperatures were converted to heat units (HU) on each treatment and the research confirmed that mulching of soil with polyethylene materials raises the soil temperature. Early in the season, during the first five weeks of watermelon growth soil mulched with clear film was the warmest, its temperature being significantly higher than in other treatments. Mulching with polyethylene materials enabled an earlier harvest compared to the control and paper, which was naturally due to more rapid initial plant growth. The highest watermelon yields were achieved on black film and drip irrigation (104.5 tons per hectare in 1995 and 79 tons per hectare in 1996). Clear film held its mulching function during first five weeks of the growing season in both years. Paper reduced soil temperature that resulted in lower soil temperature, slower plant growth and later harvest in comparison with polyethylene mulch treatments. Regarding the irrigation system applied, the higher yields were achieved with drip irrigation in both trial years.

Zusammenfassung

Verbesserung von Wachstum und Ertrag durch Polyethylen-Mulchfolien und Tröpfchenbewässerung bei Wassermelonen (*Citrullus lanatus* L.) Die zweijährige Untersuchung wurde im Vrana-Tal im kroatischen Mittelmeerraum zum Zweck der Auswertung von Aus- und Nachwirkungen der Verwendung von verschiedenen Mulchmaterialien (schwarzer Polyethylenfilm, lichtabbaubare Polyethylen-Klarsichtsfolie, biologisch abbaubarer Zellstoffmulch) und Bewässerungssystemen (Tröpfchen- und Mikrobewässerung) beim Anbau von Wassermelonen (*Citrullus lanatus* L.) durchgeführt. Die Bodentemperaturen wurden zu Tagesmittelwerten verdichtet. Diese wurden in Wärmeeinheiten (HU) umgerechnet, wobei die Basistemperatur 12.8 C ° betrug. Während der ersten fünf Wochen der Kultur erwies sich der mit Klarsichtsfolie gemulchte Boden als der wärmste; seine Temperatur war wesentlich höher als bei den anderen Verfahren. Die Bodenbedeckung mit Polyethylen-Kunststoffen erbrachte im Vergleich zum Kontroll- verfahren und zur Papiermulch eine frühere Ernte, was natürlich die Folge eines schnelleren initialen Pflanzenwachstums war. Die höchsten Wassermelonenerträge wurden bei Verwerdung von schwarzer Polyethylenfolie und bei Tröpfchenbewässerung (104.5 t ha^{-1} im Jahre 1995 sowie 79 t ha^{-1} im Jahre 1996) erzielt. Die Polyethylen-Klarsichtsfolie behielt während beider Versuchsjahre ihre Mulchfunktion. Durch den Einsatz von Zellulosemulch (Papier) wurde die Bodentemperatur im Vergleich zu den Varianten erniedrigt, wodurch das Wachstum verlangsamt und der Erntebeginn verzögert wurde. Im Hinblick auf das angewendete Bewässerungssystem wurden durch Tröpfchenbewässerung in beiden Versuchsjahren höhere Erträge erzielt.

Key words. mulch – irrigation – growth – yield – watermelon

Introduction

Mulching materials are widely applied in the production of vegetable crops in different climatic regions. Mulches are well known for modifying the energy and water balance at the surface of soils and creating more favourable conditions for plant growth. Direct effects involve increased soil temperature (FARIAS-LARIOS et al. 1994), prevention of weed development (BOROSIC et al. 1998), control of soil-borne pathogens, and reduced insect/pest populations (FARIAS-LARIOS and OROZCO-SANTOS 1997). Favourable microclimatic conditions created by mulching can ensure, among other things, higher yields, products of better quality or/and earliness, as well as a more cost-effective production. In horticultural practices, however, different mulches are used, and depending on their characteristics, different materials have different effects. In temperate climates, black and clear mulches are used for increasing soil temperature in spring plantings, which enhances growth and earliness (Borosic et al. 1998). Black polyethylene mulch is an enduring and impermeable material that, besides raising soil temperature, also prevents weed growth and protects the bed from nutrient leaching (Schmidt and Worthington 1998; Romic et al. 2002). By increasing soil temperature, clear film influences a faster growth of crops (Farias-Larios et al. 1994). Use of photodegradable clear film eliminates the costs of gathering residues at the end of the growing season. Paper mulch would also have the advantage of decomposing into the soil, contributing to a reduction in waste, compared with the black polyethylene mulch (Brault et al. 2002).

Application of different irrigation systems, providing also fertigation, in combination with mulching can create ecologically desirable conditions for maximum yields of vegetables and, from the aspect of sustainable agriculture, can contribute to a more economical use of water, decreased nutrient leaching from the soil and thereby reduced fertiliser requirements (Farias-Larios and Orozco-Santos 1997; Bowen and Frey 2002; Romic et al. 2002). Owing to its ecological characteristics regarding the climate, soil and water reserves, the Mediterranean region is especially suitable for the application of mulching and fertigation and, therefore, the objective of this research was to set up a field trial to determine how the application of different mulching materials influenced: (i) soil temperature and accumulation of heat units in soil; (ii) growth and earliness of watermelon; and (iii) yield achieved under two irrigation systems (micro and drip).

Materials and Methods

Study site

A field trial was set up in the Vrana Valley in the Mediterranean part of Croatia (43 ° 57 ' N, 15 ° 30 ' E). From the geomorphological point of view, the region is a typical cryptodepression in karst environment formed by tectonic activities. Mean annual precipitation (1978–1996) amounts to 913 mm, and the mean monthly temperature ranges from 7 °C (January) to 23 °C (June). Annual Penman-Montheith reference evapotranspiration amounts to 1037 mm, the highest of 164 mm occurring in July. Climatic conditions are favorable for the field crop production throughout the year. The most of about 5000 ha of land are used for the field vegetable production, along with irrigation as an obligatory growing measure. Experimental plots were adjacent to commercial vegetable fields, with soil classified as Gleysol hydroameliorated (FAO 1990), of uniform physico-chemical characteristics (pH = 7.5, organic matter content 6.6 %, clay content 25 %). The meteorological station where climatic parameters required for the trial control were measured was located in the immediate vicinity of the experimental field.

Experimental layout

A field trial was carried out in two vegetational sesons of watermelon growing, in 1995 and 1996 on 1 ha trial plot. The trial was laid out as a split-plot design with three replicates. The main plot consisted of two treatments: drip irrigation and micro irrigation. The subplots contained four treatments: mulching with black polyethylene film, 0.04 mm thick; clear photodegradable polyethylene film, 0.013 mm thick; paper as biodegradable cellulose mulch, beige-coloured, and a control plot without mulch.

Watermelon (*Citrullus lanatus* L.) transplants, cv. Red Star, were grown in plastic greenhouses, in polystyrene containers (100 cm^3) filled with substrate Brill Erden 4. After acclimatisation, the transplants were planted on 5 and 6 May 1995 and 3 May 1996.

Basic fertilisation of 24 kg ha^{-1} of nitrogen, 34 kg ha^{-1} of phosphorus and 65 kg ha^{-1} of potassium as well as 40 tons per ha of ripe stable cow manure with 18.2 % dry matter were broadcast and incorporated in 1995. In 1996, basic fertilisation with 16 kg ha^{-1} N, 23 kg ha^{-1} P and 43 kg ha^{-1} K of compound NPK fertilizer as well as 20 t ha^{-1} of cow manure were broadcast and incorporated. Soil insecticide Dursban G-7.5 (active ingredient chlorpyrifos) was incorporated into soil before planting. Immediately after beds were formed herbicide Treflan EC 48 % (active ingredient trifluralin) was applied to the plots mulched with clear film and to the control without mulch.

The main trial plot consisted of three beds, 50 m long, which were formed with a ridge rotary cultivator before planting. The distance between the centers of two ditches of a bed was 145 cm. The middle bed was used as the sampling plot in order to avoid margin effects.

A single line of drip irrigation tape with 50 cm spaced emitters (Netafim, Israel) was laid in the center of each bed prepared for planting transplants. Installation of mulching materials and the drip irrigation system, as well as planting of transplants were all done in one passage of a tractor-drawn planter and film layer (Maas, MOD 140). In micro irrigation, a lateral pipe was laid in the middle of the central plot, on which micro sprinklers Hadar 7110 (Naan, Israel) were installed at a 4-m spacing. The plants were planted in 1.0-m spaced rows.

Topdressing was applied through fertigation with liquid compound mineral fertiliser. A total of 85 kg ha^{-1} of nitrogen in 1995 and 98 kg ha^{-1} of nitrogen in 1996 was applied by fertigation according to the Hochmuth model (Hochmuth 1992). Nutrient inputs were the same for all treatments.

Irrigation frequency was governed by soil moisture dynamics measured electrometrically on a daily basis with gypsum resistance blocks (Soilmoisture meter Model 5910A used, manufactured by Soilmoisture Equipment Corp., Santa Barbara, Calif., USA), which were tested and installed at a 0.20-m depth, in each trial treatment in three replications. Irrigation was started when the average soil moisture in all treatments was approximately equal to 70 % of available water. The amount of water applied was measured with a flowmeter and equal quantities of water were added in each irrigation system regardless of the mulching materials used. Drip irrigation added 273 mm and micro irrigation 336 mm of water in 1995. In 1996, 326 mm of water was added with drip irrigation, and 406 mm with micro irrigation. Differences in the quantities of added water resulted from the amounts and distribution of precipitation during the growing seasons in trial years. The EC value of irrigation water, measured conductometrically, varied between 1.4 and 1.7 dS m^{-1}, pH from 7.5 to 7.8, and temperature between 19 and 22 °C.

Soil temperatures were measured using the geothermometers installed at 10-cm soil depth in each trial treatment. Temperature readings of the mulched and unmulched soil were measured daily at 7:00, 14:00 and 21:00 hours over the period from 8 May to 25 July 1995 and from 12 May to 22 July 1996. Mean daily soil temperatures were converted to heat units (HU) with a base of 12.8 °C using the formula: HU=mean daily temperature (°C)–12.8 (MAYNARD and HOCHMUTH 1997). Among for the other vegetable crops, base temperature of 12.8 °C are used for HU calculation for watermelon as well (SCHMIDT and WORTHINGTON 1998). Namely, watermelon is warm-season crop, and could be classified as very tender according to the adaptation to field temperatures. At the temperature of 15 °C, watermelon growth might be reduced, whereas the temperatures lower than 10 °C are markedly depressive.

Sampling and analysis

Plant growth parameters and yield were measured during the growing seasons. Thus, the number of vines, the length of the longest vine, and the number of leaves was determined on 20 plants of the sampling plot on 3 June 1995 and 4 June 1996. Yield of marketable watermelons was determined on the sampling plot, too. The first harvest in 1995 took place on 26 July and there were 5 harvests in all until 18 August. The first of the three harvests in 1996 was on 23 July and the last one on 9 August.

The soil temperature data were analysed using the Tukey's HSD test at $p<0.05$ and the Tukey-Kramer test for mean separation using the SAS System 6.12 software (SAS Institute Inc. 1989). The Tukey-Kramer test was applied when there was not the same number of data in both years of investigation. The yield data were analysed using two factor randomized complete block design with LSD test at $p<0.05$ for mean separation.

Results

Following variables referred to the effect of mulch, irrigation and mulch and irrigation interactions: soil temperature dynamics and accumulated heat units, plant growth parameters (number of leaves and vines, and the longest vine), and yield. The results will be outline in that order.

Soil temperature

The highest average soil temperature for the entire watermelon growing period in the two research years, significantly higher than the temperatures in other trial treatments, was recorded under black mulch (Table 1). No significant difference was determined between the average soil temperature on the control plot and in the treatment with clear mulch. The significantly lowest average temperature as much as 1.7 °C lower than in the control was recorded under paper, indicating that paper film showed an effect of temperature insulation.

However, early in the season, during the first five weeks of watermelon growth (until 4 June when the measurements of plant growth parameters started in both years), the plant cover over the mulch was sparse, soil mulched with clear film was the warmest, and consequently its temperatures were significantly higher than in other treatments. Degradation process of the clear film started approximately at the time when the measurement of vegetative growth parameters started. Hence, the mentioned mulch effects of the clear film gradually disappeared in the remaining part of the growing season, which was reflected in the same average soil temperature in the control and in the clear film treatment for the entire growing period. The degradation process started with vertical bursting on the stretched bed margins. After the clear film was degraded, the soil temperature in this treatment was lower than in the control, which could be attributed to the lusher vegetational cover. Larger differences in soil temperature were recorded at the beginning of the growing season; however, with the progress of the season, the plant canopy covered the mulch and temperatures under the mulches became more uniform in all trial treatments.

Table 1. Two-year average soil temperatures at 10-cm depth under different mulching materials during the watermelon growing period (1995-1996).

Treatment	Soil temperature (°C)	
	Entire growing period*	Period until 4 June**
Black film	24.3 a	21.2 b
Clear film	22.4 b	22.2 a
Paper	20.6 c	18.3 d
Control	22.3 b	19.4 c

* Mean values with the same letter in the column are not significantly different ($p<0.05$) according to Tukey's test.

** Mean values with the same letter in the column are not significantly different according to the Tukey-Kramer test.

Heat units

Transformation of the mean daily soil temperature rendered data on the HU accumulated in soil. From the onset of measurement to 4 June 1995, the soil mulched with clear film accumulated 239.2 HU, which is 20 HU more than the soil mulched with black film (Fig. 1). The control treatment accumulated 146 HU in the same period, or 16 HU more than soil mulched with paper. However, in the period from the onset of soil temperature measurement to the first harvest (26 July 1995) most HU were accumulated under black film (936 HU), which is 177 HU more than in the control, and 294 HU more than under paper. Similar relations were determined also in 1996. In the period until 4 June, most HU (214) were accumulated under clear film, which is 25 HU more than under black film, 44 HU more than in the control, and 55 HU more than under paper (Fig. 2). Before the commencement of the first harvest, most HU were accumulated under black film (801 HU), and the least under paper (536 HU), as much as 138 HU less than in the control. Considerable differences in HU accumulated in particular trial years were caused by different weather conditions and different duration of measurements.

Number of leaves and vines, and the longest vine

Measurements of the parameters of plant growth: the number of leaves, the number of vines, and the longest

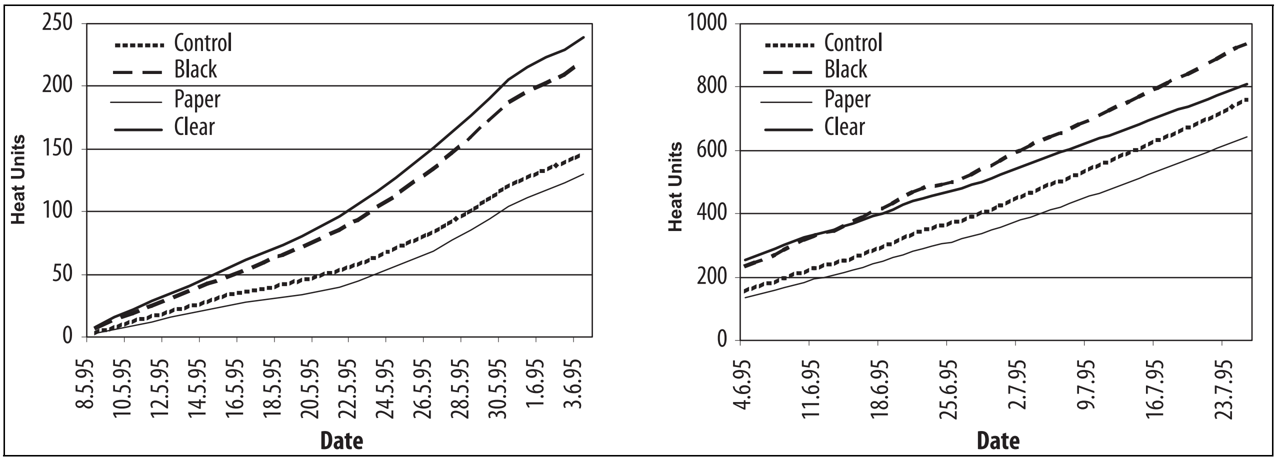

Fig. 1 Accumulated heat units 10 cm deep in the soil on different trial treatments in 1995 (plot split into two periods).

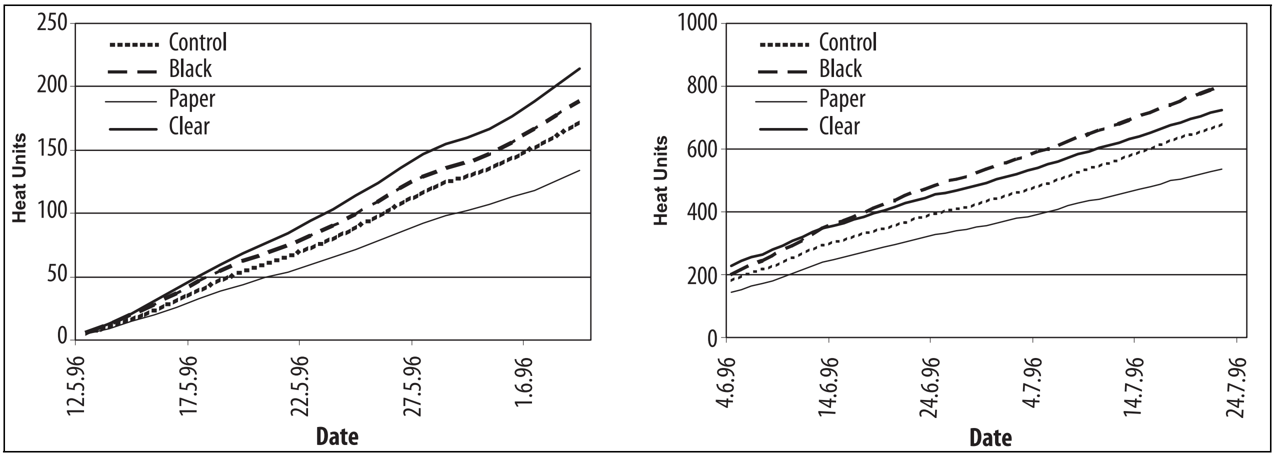

Fig. 2 Accumulated heat units 10 cm deep in the soil on different trial treatments in 1996 (plot split into two periods).

vine, were started 29 days after planting in 1995, and 33 days after planting in 1996 (Table 2).

The number of leaves on the longest shoot was significantly higher ($p<0.05$) on polyethylene films than in other treatments in both trial years. Significantly ($p<0.05$) largest number of leaves developed on clear film in 1995, and on black film in 1996 than in other treatments (Table 2). The smallest number of leaves in both trial

Table 2. Number of leaves and vines and the longest vine (cm) in trial treatments at 29 and 33 vegetation days in 1995 and 1996, respectively.

Treatment	Number of leaves* per plant	Number of vines* per plant	Longest vine*
	29 days of vegetation in 1995		
Black film	5.28 b	0.97	13.33
Clear film	7.55 a	1.68	18.58
Paper	0.03 c	0.0	0.0
Control	1.25 c	0.02	0.18
LSD 0.05**	1.78	–	–
	33 days of vegetation in 1996		
Black film	37.04 a	5.71 a	74.71 a
Clear film	25.80 b	4.30 b	61.55 b
Paper	7.54 d	0.64 d	10.23 d
Control	13.07 c	2.03 c	29.04 c
LSD 0.05	5.16	0.77	12.09

*Mean values with the same letter in each column are not significantly different ($p<0.05$).

** Test was not applied on the data in column 2 and column 3, because no vines started to develop.

Table 3. Effect of irrigation and mulching on watermelon yield in 1995.

Irrigation	Treatment	Yield (t ha-1)					
		26 July	28 July	31 July	9 August	18 August	Total
Drip	Black film	16.4	35.1	37.2	12.9	3.0	104.6
	Clear film	14.5	22.9	22.5	20.4	3.9	84.2
	Paper	0.0	5.2	4.8	46.2	10.1	66.3
	Control	3.1	8.7	10.0	47.3	7.2	76.3
Micro	Black film	11.7	22.1	41.8	13.1	1.6	90.3
	Clear film	15.6	19.3	31.7	9.3	2.1	78.0
	Paper	0.0	0.0	4.3	41.0	10.4	55.7
	Control	0.7	3.8	13.7	45.4	4.8	68.4

years was recorded on paper. In 1996, five weeks after planting on the treatment with paper mulch, 7.54 leaves were developed, but on the control treatment 13.1 leaves. In 1995, no vines started to develop on paper 29 days after planting. The largest number of vines and the longest vine were determined on clear film. Differences in watermelon growth between different treatments could be related with soil temperatures, that is, accumulated heat units.

Yield

In 1995, watermelon harvest started on 26 July. There were 5 harvests in all, and the last one took place on 18 August (Table 3).

The highest watermelon yield in the first harvest of 1995 was achieved on black and clear film mulches regardless of the irrigation system. In the first three harvests under drip irrigation 85 % and 71 % of total yield was harvested on black film and on clear film, respectively. On the treatment with micro irrigation 84 % and 85 % of total yield was harvested on black film and on clear film, respectively. In the same period, regardless of the irrigation system, 8 % to 29 % of total yield was harvested on paper and in the control. The highest yields in the control and on paper were achieved 15 days later (9 August).

The highest total yield in 1995 (104.6 tons per hectare) was achieved with black film mulching and drip irrigation. Testing of the effect of films on watermelon yield revealed that a significantly ($p<0.05$) higher yield was achieved on black film compared to the other treatments (Fig. 3). The difference between the yield achieved on the treatment with clear film and the control was not statistically significant, as well as the difference in the yields achieved on the different irrigation systems in 1995.

There were three harvests in 1996 (Table 4). In the first harvest under drip irrigation 77 % and 54 % of total yield was harvested on black film and on clear film, respectively. On the treatment with micro irrigation 73 % and 52 % of total yield was harvested on black film and on clear film, respectively. In the same period there was no watermelon yield on the treatment with paper mulch and drip irrigation, and only 1 % with micro irrigation. On the control treatment with drip irrigation in the first harvest was achieved 15 % of the total yield, and 7 % with micro irrigation. Nine days after the first harvest, higher yields were harvested on paper and in the control. In 1996, the highest total yield (84 t ha^{-1}). was achieved with black film and drip irrigation.

Analysis of the differences between films revealed that there were statistically significant differences between black film and the other treatments, while the difference between other treatments was not statistically significant (Fig. 3). The difference in total yields between irrigation systems was statistically significant ($p<0.05$) in 1996.

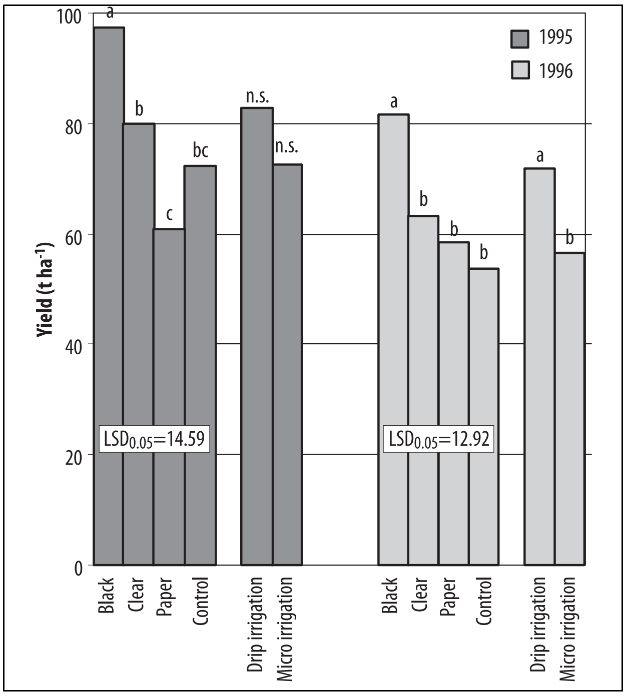

Fig. 3 Effect of mulching and irrigation on yield of watermelon.

According to determined effects of measured variables (mulch and irrigation) and their interactions on the watermelon yield, in both years of trial the mulch effect was evident (Table 5), along with the highest yield achieved on the black mulch treatment. Regarding the irrigation system, in one of two years of trial drip irrigation resulted in higher yield as compared to micro irrigation. However, the interaction between the irrigation system and type of mulch did not show significant differences in the yield achieved.

Discussion

This study showed that different mulches have different effects on soil temperature, growth and development, earliness, and the total yield of watermelon. The

Table 4. Effect of irrigation and mulching on watermelon yield in 1996.

Irrigation	Treatment	Yield (t ha^{-1})			
		23 July	2 August	9 August	Total
Drip	Black film	65.1	17.7	1.3	84.1
	Clear film	34.5	24.9	4.5	63.9
	Paper	0.0	51.0	21.3	72.3
	Control	10.3	46.6	10.2	67.1
Micro	Black film	57.5	19.2	2.3	79.0
	Clear film	32.6	25.1	4.7	62.4
	Paper	0.5	28.8	15.5	44.8
	Control	2.7	28.2	9.3	40.2

Table 5. Abbreviated table of analysis of variance for watermelon yield.

Year	Source	Sum of Squares	Degrees of freedom	Mean square	F-value
1995	Replication	1008.4	2	504.2	3.63
	Irrigation (A)	626.3	1	626.3	4.51
	Mulch (B)	4225.3	3	1408.4	10.14
	Interaction (AB)	36.1	3	12.0	0.09
	Error	1943.0	14	138.8	
1996	Replication	234.8	2	117.4	1.08
	Irrigation (A)	1395.9	1	1395.9	12.82
	Mulch (B)	2675.2	3	891.7	8.19
	Interaction (AB)	861.7	3	287.2	2.64
	Error	1524.5	14	108.9	

highest watermelon yields were achieved on black film, which creates conditions favoring the growth and development by modifying the energy and water balance on the soil surface and thereby the yield of watermelon. Black polyethylene film absorbs and radiates solar energy. HAM et al. (1993) established that, under laboratory conditions, black film absorbs 95.8 % of short-wave global irradiance with a transmittance of 0.7 %. Part of the energy absorbed by black film, depending on a number of factors, can be ceded to the soil by conduction. Contrary to black film, clear film absorbs 4.9 % of short-wave global irradiance with a transmittance of 84.5 %. In growing agricultural crops under field conditions, clear film, laid on the soil surface or not more than 2 cm above it and depending on the method of seedbed cultivation, is usually covered with condensed water, which is transparent for the incoming short-wave irradiation and retains the outgoing long-wave irradiation, resulting in higher soil temperatures. Clear mulch is thus more effective than black and white mulches in increasing soil temperatures and enhancing growth of crops, because most of the solar energy is directly transmitted to the soil and a large portion of the terrestrial radiation is blocked by the polyethylene (FARIAS-LARIOS and OROZCO-SANTOS 1997). In this research higher soil temperatures under polymer materials were also recorded in the first few weeks of the growing season.

Reduced soil temperature is one of the major environmental effects of organic mulches (SCHMIDT and WORTHINGTON 1998). Paper, a material of organic origin used in this trial, acted as an insulator, which resulted in a lower soil temperature. Color has an important role as well. BRAULT et al. (2002) reported that lower soil temperature was recorded under the beige than under the black colored paper.

Accumulation of more heat units under black and clear films in this trial resulted in faster plant growth. Similar results were obtained by FARIAS-LARIOS et al. (1994) in cucumber production and by BOROSIC et al. (1998) in bell pepper growing. The faster growth of watermelon on clear film is related to higher accumulation of heat units in the initial weeks of growing. Since clear film is also photodegradable, it started to disintegrate after a few weeks and gradually lost the mulch function. Regardless of the herbicide applied, higher temperatures under clear film favored the development of weeds. Weeds were mechanically eradicated two times during the growing season, in the same way as in the control. Lower temperatures under paper resulted in slower growth and development of watermelon. BOROSIC et al. (1998) reported slower growth under paper mulch as well.

Mulching with polyethylene materials enabled an earlier harvest compared to the control and paper, which was naturally due to more rapid initial plant growth. Results of other authors also point to higher yields of watermelon in mulching with polyethylene films (BHELLA 1988; FARIAS-LARIOS and OROZCO-SANTOS 1997; SANDERS et al. 1999), but of other crops as well (FARIAS-LARIOS et al. 1994; ROBERTS and ANDERSON 1994; HODGES et al. 1995; BOROSIC et al. 1998). Fast growth on clear mulch led to earliness, but not to significantly higher yield. This could be a consequence of earlier photodegradation of materials as well as a high weed incidence. Still, this mulching material has considerable advantages in terms of reduced costs of post-harvest gathering. Paper is microbiologically degradable, but in comparison with clear film its degradation process is slower and did not start until the end of the watermelon-growing season. Film was left on part of the trial plot in order to determine the onset of its degradation. Degradation began in mid-September.

Besides its high heat requirements, watermelon is a demanding crop also from the aspect of water supply. Hence, its production in the Mediterranean and subtropical regions is hardly feasible without irrigation. Choice of the irrigation system depends on a number of factors such as, among others, the quantity and quality of water available for irrigation, production technology, and economic indicators. Generally, one of advantages of drip fertigation comparing with micro fertigation is in direct nutrient solution application into the root zone that might improve fertiliser application efficiency, but in irrigation with microsprinklers the nutrient solution is broadcast over the whole area. Soil moisture was maintained at approximately the same level in both irrigation systems throughout the trial. Nevertheless, in the second year of trial significantly ($p<0.05$) higher yield was achieved with drip irrigation. This could be for a number of reasons. One of the reasons could be attributed to the differences between the temperature of water and plant during the irrigation. In middle June of 1996, the highest daily temperature exceeded the value of 35 °C. Irrigation was usually carried out in the afternoon, when the differences in temperature were as many as 10 to 15 °C, which might cause a heat stress. It brought about the carbonate precipitation on the leaf surface that could also be reflected in yield reduction. BOROSIC at al. (1998) compared drip and micro irrigation systems in bell pepper production with different mulching materials and recorded higher yields in drip irrigation. Good interaction of water and nitrogen for watermelon yield was reported by PIER and DOERGE (1995), who achieved the highest yield with maintaining the soil water tension of 7.2 kPa and with a high nitrogen (N) rate of 336 kg ha^{-1}. According to DASBERG and OR (1999), the choice of the irrigation system was also reflected in the economic effect of reduced water consumption. In this trial, 20 % lower water consumption was determined in drip irrigation, which is in agreement with the effects reported by BHELLA (1988) for watermelon production.

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Addresses of authors: Dr. Davor Romic, Assist.Prof. (Corresponding author) and Dr. Marija Romic, Univ. of Zagreb, Faculty of Agriculture, Dept. of Amelioration, Svetosimunska 25, 10000 Zagreb, Croatia, Prof. Dr. Josip Borosic, Dept. of Vegetable Production and Dr. Milan Poljak, Assist.Prof., Dept. of Plant Nutrition, Svetosimunska 25, 10000 Zagreb, Croatia, , e-mail: dromic@agr.hr.