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Effects of Mulching and Irrigation in Bell Pepper (*Capsicum annuum* L.) Growing in Mediterranean Part of Croatia

J. BOROŠIĆ [1]
D. ROMIĆ [2]
F. TOMIĆ [2]
Ivanka ŽUTIĆ [1]
Ž. KLAČIĆ [2]

SUMMARY

The Mediterranean part of Croatia is known for its vegetable production, but also for shortage of irrigation water in the warmest period of the year. Introduction of mulching films and drip irrigation represent an improvement in pepper production. The research involved three mulch types (black PE-film, transparent photodegradable PE-film, paper) and two irrigation systems (drip and sprinkler). The two-years field trial was set up according to the split-plot design in three replications in the Vrana valley near Biograd, as very known vegetable production area.

The mean decade soil temperatures, at a 10 cm depth, in May and June, were by 1.5 to 4.5°C higher under black film, and by 1 to 2°C lower under paper, in relation to soil temperatures without mulching.

Depending on the mulch type and irrigation method, eight weeks after planting, the plants were up to 91% higher in 1995 and up to 29% higher in 1996 than green pepper grown without mulching but under sprinkler irrigation. At same time in both years, the smallest number of fruits were set per plant in the crop without mulching and irrigated by sprinkling.

In comparison with the conventional pepper growing method, the yield of marketable fruits grown by other methods was 14 to 89% higher in 1995, and 30 to 99% in 1996.

In the first two harvest weeks, in PE-film mulching treatments, the yields of up to 128% achieved in 1995 and up to 115% in 1996 were higher than the total yield for the whole harvest period in treatments involving conventional bell pepper production.

KEY WORDS

bell pepper *(Capsicum annuum* L.*)*, mulching, irrigation, plant height, fruit setting, yield

[1] Vegetable Crops Department
[2] Department of Soil Amelioration
Faculty of Agriculture University of Zagreb
Svetošimunska cesta 25, 10000 Zagreb, Croatia

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Učinak malčiranja i navodnjavanja u uzgoju paprike (*Capsicum annuum* L.) u sredozemnom području Hrvatske

J. BOROŠIĆ [1]
D. ROMIĆ [2]
F. TOMIĆ [2]
Ivanka ŽUTIĆ [1]
Ž. KLAČIĆ [2]

SAŽETAK

Sredozemno područje Hrvatske je poznato po proizvodnji povrća, ali i nedostatku vode za navodnjavanje u toplom i suhom razdoblju godine. Korištenje filmova za malčiranje tla i navodnjavanje kapanjem su zahvati koji predstavljaju unapređenje u uzgoju paprike. Provedeno je istraživanje s tri vrste malča (crni PE-film, prozirni fotorazgradljivi PE-film, papir) i dva sustava navodnjavanja (kapanje i kišenje). Poljski pokus je bio postavljen po split-plot metodi u tri ponavljanja, na području Vrane kraj Biograda, kao jednom od u nas najpoznatijem području uzgoja povrća za tržište.

Srednje dekadne temperature tla na 10 cm dubine u mjesecu svibnju i lipnju ispod crnog filma bile su za 1.5 do 4.5 ^{0}C više, a ispod papira za 1 do 2 ^{0}C niže u odnosu na temperature tla bez malčiranja.

Ovisno o vrsti malča i metodi navodnjavanja, osam tjedana poslije sadnje visina je biljaka bila do 91% veća u 1995., a do 29% veća u 1996. od visine biljaka bez malčiranja i uz navodnjavanje kišenjem. Istovremeno u obje godine u usjevu bez malča i uz navodnjavanje kišenjem formirano je manji broj plodova po biljci.

U odnosu na uobičajenu tehnologiju uzgoja paprike prinos je tržnih plodova pri ostalim načinima tehnologije bio za 14 do 89% veći u 1995. i za 30 do 99% veći u 1996. godini.

U prva dva tjedna berbe pri malčiranju tla PE-filmovima ostvaren je do 128% veći prinos u 1995. i do 115% veći prinos u 1996. od ukupnog prinosa pri uobičajenoj tehnologiji uzgoja paprike.

KLJUČNE RIJEČI

paprika (*Capsicum annuum* L.), malčiranje tla, navodnjavanje, visina biljaka, zametanje plodova, prinos

[1] Zavod za povrćarstvo
[2] Zavod za melioracije
Agronomski fakultet Sveučilišta u Zagrebu
Svetošimunska 25, 10000 Zagreb, Hrvatska

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INTRODUCTION

The Vrana valley is a typical vegetable production area in Croatia. Due to agroecological factors, vegetable growing in this area is not feasible without irrigation. The conventional pepper production method in the Vrana valley is without mulching and under sprinkler irrigation.

The available quantities of good quality water are limited, first of all owing to the salinity of Vrana Lake water (Romić, 1995). For this reason, a research project for introduction of vegetable growing methods aimed at saving water and reducing contamination of both underground and surface waters is in progress (Romić et al, 1996). This paper presents part of the research results, which refer to bell pepper *(Capsicum annuum* L.*)* grown using an irrigation system with reduced water consumption and soil mulching.

MATERIALS AND METHODS

In 1995 and 1996, a two-factor field trial with bell pepper cv. Istra F_1 was carried out at the agricultural plant Vrana near Biograd in the Mediterranean part of Croatia, according to the split-plot design in three replications. The main plots involved two treatments: drip irrigation and sprinkler irrigation. The subplots involved four treatments: mulching with black polyethylene (PE) film, 0.04 mm thick; photodegradable transparent PE-film, 0.013 mm thick; biodegradable paper; and without mulch (control).

The experiment was laid out on a soil of light texture (25% clay), high organic matter content (5.8% humus), and 12.6 mg P_2O_5 and 25 mg K_2O per 100 g soil. Ploughing in of some 20 t/ha of ripe manure (20% dry matter) and a 24 kg/ha N, 78 kg/ha P_2O_5 and 78 kg/ha K_2O as a mineral fertilizer was applied on the whole experimental plot.

The main plot consisted of three beds of 50 m length each. The middle bed was used to determine the growth and yield component parameters. Immediately before beds were formed, herbicide Treflan EC 48% (2.4 l/ha) was applied on plots mulched with photodegradable film and on those without mulching.

Pepper seedlings were pricked out into polystyrene trays with cells of about 50 cm each. Seedlings were planted in the phase of 4 to 5 true leaves. The planting took place on 3 and 4 May 1995, resp. on 1 and 2 May 1996. Two rows of peppers were planted in a bed, with a 70 cm row spacing. Spacing between the plants in a row was 35 cm.

The overall bed width was 145 cm. The forming of beds, laying of pipes for drip irrigation, laying of films, planting of seedlings were all performed mechanically. For drip irrigation, the pipes were laid so that there was a 30 cm distance between drippers. A pipe for sprinkler irrigation was laid on the middle bed of the trial plot, with 4 m spaced microsprinklers.

Top dressing was aplied with liquid mineral fertilizer ($N:P_2O_5:K_2O$) in the ratio 7:5:9 according to a modified programme for Florida, USA (Hochmuth, 1994). In the growing period, 1.6 kg N/ha was aplied per day.

Soil temperatures were measured daily at 7, 14 and 21 hours at a depth of 10 cm. During the growing period, the increase of vegetative plant parts and the appearance of generative pepper plant part were determined twice.

The total yield and fruit yield in the first two harvest weeks were determined from the middle bed.

Significance of the differences between yields of different pepper growing practices were tested by the F-test applying the analysis of variance.

RESULTS

Soil temperatures

Mean decade soil temperatures, at a 10 cm depth without mulching, ranged from 16.5 to 20.3°C in May, and 20.5 to 23.5°C in June, depending on the year. At the same time in May, the mean decade soil temperatures, at a 10 cm depth under transparent film, were by 2.5 to 4.5°C higher, but under paper by about 1°C lower than on soil without mulching (Table 1).
In June, the mean decade soil temperatures, at a 10 cm depth, under black film were by 1.5 to 4.5°C higher, and under paper by 1 to 2°C lower than on beds without mulching, depending on the year (Table 1). In June, the differences were small, or none at all, between soil temperatures in treatments without mulching and soil temperatures in those mulched with photodegradable film because the film was mostly degraded. As a matter of fact, under the transparent film "the greenhouse effect" was felt for a relatively short period, owing to its fast photodegradation.

Heat accumulation was lower under black film while paper acted as thermal insulator, so much so that soil heating was prevented, which had however a negative effect at the beginning of the growing period (May, June) when the mean decade soil temperatures at a 10 cm depth without mulching were below of 20°C.

Shoot height

Four and eight weeks after planting, the average pepper shoot in 1995 was higher when the soil was mulched with black or transparent film, and irrigated by sprinkling or dripping, as a result of increased soil temperature (Table 2). Compared to the pepper shoot height achieved without mulching and with sprinkler irrigation, the shoot was by 28 to 68% and 13 to 91% higher four weeks resp. eight weeks after planting, depending on the type of mulching and irrigation method used.

A somewhat smaller influence of mulching on pepper growth was observed in 1996. Five weeks after planting, pepper plants grown under black or transparent PE-film

mulching were up to 37% and eight weeks after planting up to 29% higher than plants grown without mulching and under sprinkler irrigation (conventional pepper production).

Fruit setting

Mulching and drip irrigation influenced faster pepper fruit setting (Table 3). In both years, eight weeks after planting, the smallest number of fruits, longer than 1 cm, was recorded in the treatment without mulching but irrigated by sprinkling (0.3 resp. 0.2 fruits per plant). Sprinkler irrigation and the use of PE-mulching (black and transparent film) brought about 2 to 5.5 times more fruits. Drip irrigation without mulching increased the number of fruits by about 4.5 times in both years, while black and transparent mulching about 5 times in 1995, and by 11 to 13 times in 1996.

Yield of marketable fruits

In 1995, harvesting of pepper started on 20 July and lasted until 5 October at 10 to 15 day intervals, or as many as 21 days between the one before the last and last harvest. In 1996, the harvest was of shorter duration, from 24 July until 7 September, at intervals from 13 to 17 days. Due to labour shortage for harvesting, the intervals between two harvests were too long, so much so that a number of fruits changed colour and reached physiological maturity. Therefore, all fruits were divided into two groups: marketable and not for sale.

In 1995, the yield of marketable fruits ranged from 29.27 t/ha (without mulching, with sprinkler irrigation) to 55.37 t/ha (mulching with black film and drip irrigation). Compared to the conventional pepper growing method (without mulching with sprinkling), the yield of marketable fruits was by 14 to 89% higher relative to other growing methods (combination of mulching type and irrigation method), which is significant for all combinations with a 95% probability, except for paper mulching and sprinkler irrigation (Graph 1).

In comparison with conventional pepper growing methods, higher yield was achieved in 1996 with the use of all types of mulching and drip irrigation, even with black film and sprinkler irrigation (30 to 99%). However, only the yield of pepper under black film mulching and with drip irrigation differed significantly (probability 95%) from the yield obtained by the conventional growing method.

By applying drip irrigation instead of sprinkling, an average increase of pepper yield of 26% was achieved

Table 1. Mean decade soil temperatures (°C) at a 10 cm depth during the first two months of the pepper growing period

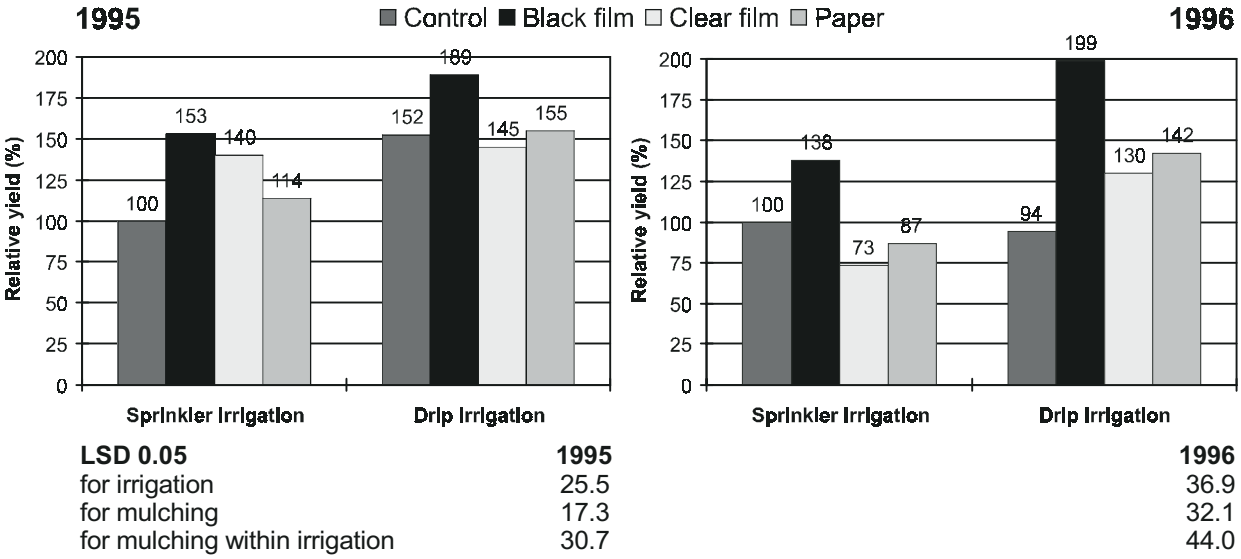
Mulches	1995					1996				
	May-Decade		June-Decade			May-Decade		June-Decade		
	II	III	I	II	III	II	III	I	II	III
Control	16.5	20.3	21.6	23.5	22.9	17.5	19.0	22.5	23.5	20.5
Black PE-film			25.1	26.2	24.6	20.5	19.1	27.0	26.1	22.2
Clear PE-film	19.4	24.7	23.6	23.1	22.5	20.3	21.3	24.1	21.6	18.9
Paper			20.2	21.4	21.6	17.6	18.0	21.8	22.0	19.6

Table 2. Pepper plant height (cm) some 4 and 8 weeks after planting in 1995, and 5 and 8 weeks after planting in 1996

Date	Sprinkler irrigation				Drip irrigation			
1995	Control	Black PE-film	Clear PE-film	Paper	Control	Black PE-film	Clear PE-film	Paper
June 2	5.6	9.4	9.2	8.0	7.1	9.2	9.1	7.1
June 28	16.2	22.2	25.6	18.2	26.9	30.9	29.7	22.1
1996								
June 5	7.0	8.3	7.2	7.1	7.1	9.6	8.0	7.0
June 25	18.7	22.4	18.6	15.1	17.3	24.2	21.5	17.1

Table 3. Number of pepper fruits of more than 1 cm length per plant, some 8 weeks after planting

Date	Sprinkler irrigation				Drip irrigation			
1995	Control	Black PE-film	Clear PE-film	Paper	Control	Black PE-film	Clear PE-film	Paper
June 28	0.3	0.7	1.6	0.4	1.4	1.5	1.6	0.4
1996								
June 25	0.2	1.1	0.4	0.2	0.9	2.6	2.3	0.6



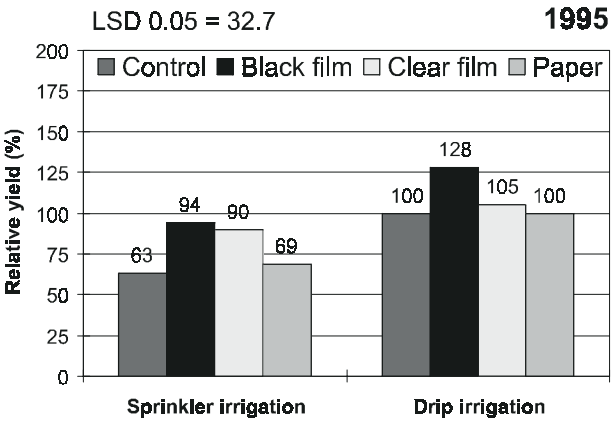
LSD 0.05	1995	1996
for irrigation	25.5	36.9
for mulching	17.3	32.1
for mulching within irrigation	30.7	44.0

Graph 1. Relative yield of marketable bell pepper fruits
(Total yield without mulching, but with sprinkler irrigation = 100)

in 1995, and of 42% in 1996, which was significant at the level of 95% probability for both years (Graph 1).

By the use of mulching materials, higher average pepper yields were achieved, by 7 to 36% in 1995, and 5 to 74% in 1996 in comparison with pepper yield without mulching. However, there were no significant differences in average yields between the mulching materials used in both years, except in comparison of black film with the other two materials and the control.

Observing the influence of mulching on average pepper yields in drip irrigation in both years, a significantly higher yield was obtained with black film mulching. In the sprinkler irrigation system in 1995, there were no significant differences in yields between black and transparent films, then transparent film and paper, and in 1996 between the control, transparent film and paper.



Graph 2. Relative yield of marketable bell pepper fruits in the first two harvest weeks (29.27 t/ha yield without mulching, but with sprinkler irrigation)

Yield of marketable fruits in the first two harvest weeks

Yield of marketable fruits in the first two harvest weeks is of utmost importance because of its higher selling price. In pepper growing without mulching and with sprinkler irrigation in the first two harvest weeks in 1995, an amount of 63% of marketable fruits out of the total yield (29.27 t/ha) was achieved. Mulching and drip irrigation played an important part with regard to yield because, in the first two harvest weeks, a yield from 69% (mulching with paper and irrigation by sprinkling) to 128% (mulching with black film and drip irrigation) was achieved out of the total yield of marketable fruits obtained by the conventional pepper growing practices (Graph 2).

In the first two harvest weeks in 1996, with drip irrigation and soil mulching (black and transparent film), a yield was achieved of 115%, resp. 85% of the total yield obtained in the whole harvest period in conventional production (sprinkling without mulching).

DISCUSSION

The data on soil temperature differences obtained under mulching materials, in comparison with unmulched soil, agree with published data (Yard, 1992; Taber, 1993; Castellane et al, 1994; Castilla et al, 1994; Siwek and Libik, 1994; Cavero et al, 1996). Higher soil temperature under transparent and black films caused a faster growth of plants. However, due to early photodegradation, the applied photodegradable film started to burst as early as five weeks later. For this reason, the initial growth of

plants on these plots was slowed down after two months, as compared to plant growth under mulching with black film, because most of the soil became bare. At the beginning of the growing period, the growth of pepper plants was of equal intensity with mulching with black and transparent films.

Much slower was the growth of pepper plants grown without mulching or with paper mulching, which has been confirmed by other authors (Cavero et al, 1996).

The intensity of pepper growth was the cause of an earlier or later appearance of flowers and fruits. Strongly developed plants had more fruits set per plant. The crop irrigated by dripping and mulching with PE-films had a several times higher number of fruits set per plant eight weeks after planting. This fact points to the possibility of earlier harvest and higher yield per unit area in the first part of harvest period, when the offer of peppers at the market is lower, but the prices are higher.

The mentioned more intensive vegetative growth and earlier appearance of pepper flowers and fruits rendered, under identical growing methods, also a higher total yield at harvest. Compared with the conventional cultivation method (without mulching, with sprinkler irrigation), the yield of marketable pepper fruits grown using PE-mulching and drip irrigation was significantly higher, 30 to 100%, depending on the method of growing and the year. Similar results were achieved with watermelon (Borošić et al, 1997). Also other authors report similar results on the increase of pepper yield when using mulching with PE-films and drip irrigation (López and Jiménez, 1992; Silvestri and Siviero, 1994).

Therefore, the use of polymer materials for mulching with drip irrigation is recommendable for the Mediterranean part of Croatia, because of faster initial plant growth, earlier formation of fruits, earlier start of harvest and greater total yield of peppers in comparison with the pepper production method used thus far.

CONCLUSIONS

On the basis of research results on mulching and irrigation effects in bell pepper growing the following conclusions have been brought:

- Higher soil temperatures under PE-films result in enhanced plan growth;
- More intensive pepper growth causes an earlier appearance of flowers and fruits as well as strongly developed plants have more fruits set;
- Soil mulching with PE-films results in earlier and higher yields. Compared with the conventional growing method, the yield of marketable pepper fruits grown using PE-mulching and drip irrigation is higher, 30 to 100%, depending on the year;
- The use of PE-materials for mulching with drip irrigation in pepper growing is recommendable for the Mediterranean part of Croatia.

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