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Cucumber (*Cucumis sativus*, L.) water use efficiency (WUE) under plastic mulch and drip irrigation

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ABSTRACT

To study the effect of two types of plastic mulch (transparent and black) with drip irrigation on water requirement and Cucumber (*Cucumis sativus*, L.) yield, in addition to their effect on Maturity time. Trials were carried out at Teezen Research Station, Hama Agricultural Research Center, GCSAR, Syria, during 2009–2010 growing seasons using complete randomized block design with three replicates. Soil characteristics were followed too because they reflect the effects of plastic mulch. Treatments were transparent mulched drip irrigation (DI + TM), black mulched drip irrigation (DI + BM), drip irrigation without mulching (DI) and surface furrow irrigation (SI). The results of the study indicated that (DI + TM) treatment excelled all other treatments at yield and water use efficiency (WUE), where its yield was 63.9 t ha^{-1}, and (WUE) was 0.262 t ha^{-1} mm^{-1}, while (DI + BM) treatment produced 57.9 t ha^{-1}, with a (WUE) of 0.238 t ha^{-1} mm^{-1}. However cucumber yield and WUE declined in the remaining treatments of no mulch (DI) and (SI) to reach 44.1 t ha^{-1} with 0.153 t ha^{-1} mm^{-1} and 37.7 t ha^{-1} with 0.056 t ha^{-1} mm^{-1}, respectively. The results showed that (DI + TM) treatment gave the highest soil temperature and moisture during both of the seasons in comparison to (DI + BM). This enhanced its vegetative growth and almost doubled its productivity compared to the SI treatment.

1. Introduction

Cucumber demands high temperatures and soil moisture for satisfactory yield, and under unfavorable climatic conditions, several problems may occur, such as the reduction of female flowers (Cantliffe, 1981), delay in fruit growth (Liebig, 1981; Marcelis and Baan Hofman-Eijer, 1993; Medany et al., 1999) and mineral disorders – (Bakker and Sonneveld, 1988). Therefore, planting is usually made in the spring-summer season when the weather conditions are favorable for plants growth and high yield could be achieved.

Syria has abundant land resources but the irrigation water supply is much less for adequately exploiting the soil potentials. This calls for adoption of advanced irrigation methods such as drip irrigation for effective use and management of the limited water resources.

Irrigation is an important limiting factor of crop yield, because it is associated with many factors of plant environment, which influence growth and development. Availability of adequate amount of moisture at critical stages of plant growth not only optimizes the metabolic process in plant cells but also increases the effectiveness of the mineral nutrients applied to the crop. Consequently any degree of water stress may produce deleterious effects on growth and yield of the crop (Saif et al., 2003). Surface irrigation method is most widely used all over the world (Mustafa et al., 2003).

In Syria cucumber is generally grown under conventional surface irrigation method too. In this method, the major proportion of irrigation water is lost by surface evaporation, deep percolation and other loses, resulting in lower irrigation efficiencies. Moreover, there is a tendency of farmers to apply excess water when it is available (Jain et al., 2000). Under limited water supply conditions farmers tend to increase irrigation interval, which creates water stress resulting in low yields and poor quality.

Drip irrigation, with its ability to provide small and frequent water applications directly in the vicinity of the plant root zone has attracted interest because of decreased water requirement and possible increase in production (Darwish et al., 2003; Janat, 2003). As the world increasingly becomes dependent on the production of irrigated lands, irrigated agriculture faces serious challenges that threaten its suitability. It is prudent to make efficient use of water and bring more area under irrigation through available water resources. This can be achieved by introducing advanced methods

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Table 1
Some selected soil chemical and physical properties.

Depth (cm)	pH 1:5	EC (dS m^{-1})	Avail-P (mg/kg)	Avail-K (mg/kg)	Mineral-N (mg/kg)	$CaCO_3$%	OM%	Sand%	Silt%	Clay%	Soil texture
0–30	7.8	0.22	9.5	507.5	2.97	5.66	0.77	14	15	71	Clay (Vertisol)
30–60	7.8	0.21	5.3	350	3.28	5.44	0.59	13	16	71	

P, phosphorus; K, potassium; N, nitrogen.

of irrigation and improved water management practices (Zaman et al., 2001). Among the water management practices for increasing water use efficiency WUE one of them is mulching. Any material spread on the surface of soil to protect it from solar radiation or evaporation is called mulch. Different types of materials like wheat straw, rice straw, plastic film, grass, wood, sand etc. are used as mulches. They moderate soil temperature and increase water infiltration during intensive rain (Gajri et al., 1994; Khurshid et al., 2006).

A large number of experiments have been conducted to study the effect of drip irrigation and plastic mulch on yield improvement of many crops in different agro-climatic region and soil condition. About 20–60% higher yields were obtained with drip irrigation in some studies (Sivanappan et al., 1974), while in other studies yield was reported to be slightly lower or equal to that of conventional irrigation (Doss and Evans, 1980) along with reduction in irrigation requirement of 30–60%.

Cucumber is also suited to drip irrigation in combination with plastic mulch, but little work has been done to study the effects of drip irrigation and plastic mulch on crop yield and WUE of cucumber in semiarid lands of Syria. The present investigation was planned to determine the effects of drip irrigation and plastic mulch on cucumber yield and WUE, in addition to their effects on the fate of water in the soil section.

2. Materials and methods

The field experiments were carried out during two successive growth seasons of 2009 and 2010, at Teezen research station, Agricultural Research Center, Hama, Syria. The site was located at 307 altitude, 35.1° N latitude and 36.5° E longitude. Where the summers are dry and hot, while winters are cold.

The soil of the experimental plot can be classified as red clay Vertisol with bulk density in the upper 30 cm of 1.15 g/cm^3 and the under layer till 60 cm was 1.17 g/cm^3.

Composite soil samples (0–30 and 30–60 cm) were collected before planting indicated that pH was 7.8, and available phosphorus were poor, while it had rich content of available potassium. Some physical and chemical soil properties are given in Table 1.

Cucumber seed (*Cucumis sativus*, L., “F1 Hybrid prince”) were sown manually in holes on June 10th 2009–2010, on one side of each furrow by keeping row-to-row and plant-to-plant distance 1.5 m and 40 cm, respectively.

The layout of the experiment was a completely randomized block design with three replications for each of the four treatments tested, [transparent mulched drip irrigation (DI + TM), black mulched drip irrigation (DI + BM), drip irrigation without mulching (DI) and surface furrow irrigation without mulch (SI)] as shown in (Fig. 1).

The experimental area was 4800 m^2, divided into three blocks. Each block consisted of four plots, 4.5 m × 40 m each. A border of three meter separated both the blocks and plots. Each plot had three rows, 1.5 m apart and 40 m long, In order to prevent the water in any one plot from affecting its neighboring plots. In both growing seasons, moldboard plow and disk harrow were used for tillage operations and a furrower was used for making furrows (40 m long, 75 cm wide and 50 cm deep) in the SI treatment. Soil moisture was determined using neutron probe (Troxler, 4300) for depth below 15 cm. Neutron probe was calibrated in the field by correlating neutron probe count ratio with volumetric water content measured by gravimetric method and bulk density.

A 125 cm neutron probe tubes were installed near the center of each plot between two plants and distanced 15, 30, 45, 60 and 75 cm from irrigation line. Moisture readings were taken at 15 cm depth intervals before and after each irrigation for determination of change in soil water storage and deep water percolation which below the root zone over time.

SURFER 8 software was used to graph the readings after obtaining the calibration curve. Irrigation scheduling was based on the calibrated neutron probe readings, whereas irrigation was applied at 85% of field capacity according to the effective roots distribution zone.

Gross water requirement (IR_g) for each plot was controlled by the special valve set for that plot, and the exact amounts used were read on a flow meter. The net irrigation requirement (IR_n) must replenish the actual crop evapotranspiration water (ETa), as rainfall and other components of the water balance. The gross irrigation requirements (IR_g) must increase the (IR_n), in order to compensate the irrigation efficiency and to leach salts:

$$\mathrm{IR_g} = \frac{\mathrm{IR_n}}{\mathrm{Ea}(1 - \mathrm{LR})}.$$

where Ea: irrigation efficiency coefficient (smaller than 1) and expresses the ratio: water stored in the crop root zone to be used by the crop/applied water (Jitan, 2012).LR: minimum amount of leaching needed to control salts with drip irrigation which equals to zero in study region.

ETa (mm/day), was estimated using the following form of the water balance equation (Castilla, 1990; Burba and Verma, 2005; Simonne and Dukes, 2010):

$$\mathrm{ETa} = \frac{\sum D(\theta_{\mathrm{Vi}} - \theta_{\mathrm{Vf}})}{\mathrm{days}}$$

where $(\theta_{vi} - \theta_{vf})$: is the change in volumetric soil water content between two measurement dates, D (mm): is the thickness of soil layer.

Data were calculated as the sum of the daily evaporation from class-A open-pan installed nearby the experimental plots. Reference crop evapotranspiration (ET_0) values were calculated based on FAO Penman–Monteith method. The crop coefficient, K_c for cucumber was basically determined by the ratio of the crop ET_c to the reference ET_0, whereas: $K_c = ET_c/ET_0$ (FAO, 1998).

The irrigation was carried out by a drip system of key Clipped emitters (4 l/h) spaced 40 cm apart, by each plant, on 16 mm (ID) laterals, one per row of cucumber. The emitters operate at a pressure of 100 KPa, which was controlled with bypass arrangement.

The used plastic mulch was black polyethylene (40 μm) for (DI + BM), and clear transparent polyethylene (100 μm) for (DI + TM).

Fertilizers were applied according to soil test results and Ministry of Agric. and Agra. Reform (MAAR) recommended levels of N (250 kg ha^{-1}), P (150 kg ha^{-1}) and K (350 kg ha^{-1}) as urea (46% N), triple supper phosphate (46% TSP) and K_2SO_4 (46% SOP), respectively, using Dosatron injector in drip system, or manually spreading immediately before irrigation for SI treatment. All other

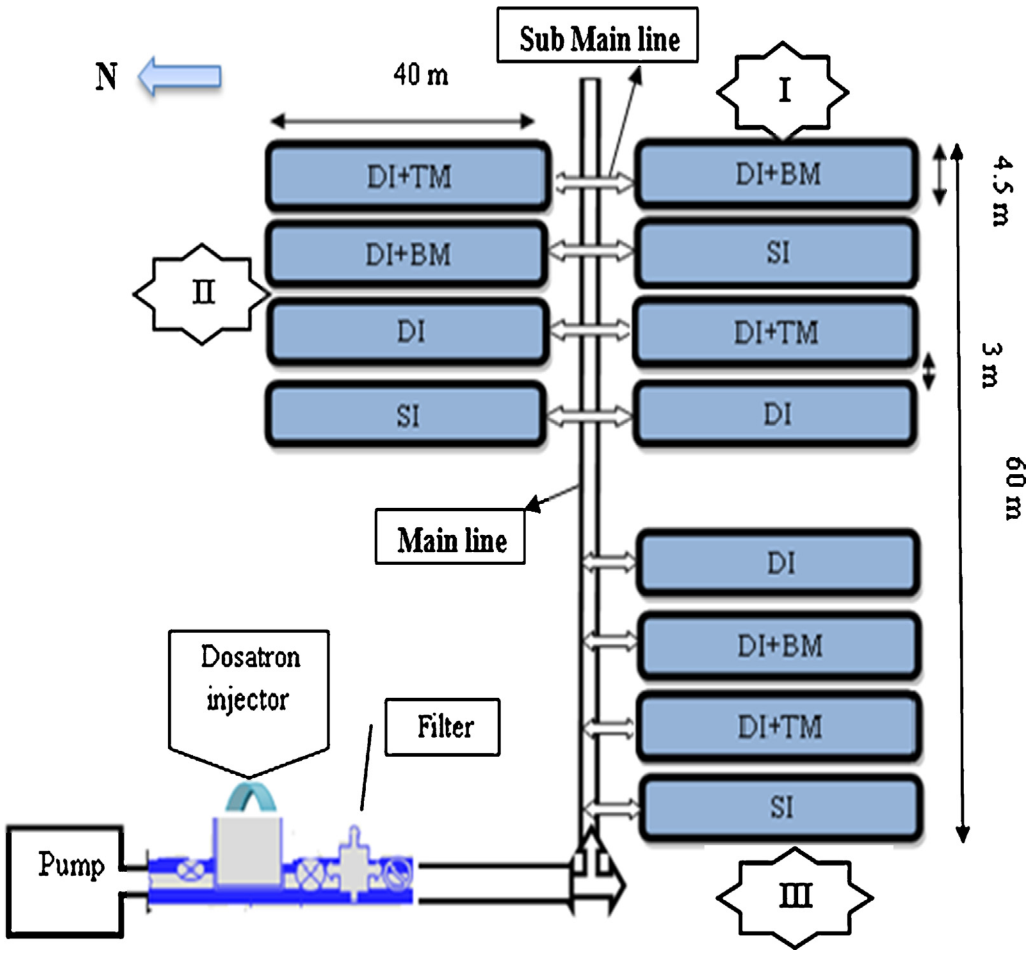

Fig. 1. Layout of cucumber experiment and irrigation system at Teezen research station, Hama, Syria.

Table 2
Irrigation interval, Da (days); net irrigation requirements, IR_n (mm); gross irrigation requirements, IR_g (mm), and number of irrigations, *N*, for the study treatments, as average during months of the both of growing seasons (June 10 until September 10).

Treatment	DI + TM			DI + BM			DI			SI		
Month	Da	IR_n	IR_g	Da	IR_n	IR_g	Da	IR_n	IR_g	Da	IR_n	IR_g
June	5	3.8	4.1	6	3.5	3.9	4	4.1	4.5	6	20.7	49.8
		3.7	4.0		3.9	4.2		3.7	4.1		19.2	40.9
		3.9	4.2					3.8	4.1			
		4.0	4.3		3.8	4.1		4.2	4.6		22.1	41.2
	$N=4$			$N=3$			$N=5$	3.6	3.9	$N=3$		
July	4	5.3	5.8	5	5.2	5.6	4	3.9	4.2	6	17.3	43.6
		5.0	5.4		5.3	5.6		5.2	5.6		16.2	40.1
		14.6	15.8		5.5	5.9		5.6	6.0		19.8	40.9
		14.6	16.2		14.0	15.3		5.7	6.1		32.4	48.8
		13.8	14.9		14.6	16.0		13.8	14.8			
		18.5	20.2		14.9	16.2		14.0	15.4		33.8	52.1
	$N=7$	17.8	19.0	$N=6$			$N=7$	14.6	15.7	$N=5$		
August	5	16.8	18.0	4	16.8	18.1	3	18.6	20.2	6	31.2	51.6
		16.5	17.8		16.5	18.2		18.2	19.6		35.4	53.6
		17.5	19.0		17.5	19.0		16.5	17.6		32.4	56.1
		18.2	19.4		17.8	19.6		16.2	17.8		30.0	45.0
		18.8	20.5		16.2	17.6		17.8	19.4			
					17.8	19.4		14.9	16.3			
		14.9	16.5					15.5	17.1		29.4	51.7
					15.8	16.9		15.8	17.4			
	$N=6$			$N=7$			$N=9$	17.8	19.2	$N=5$		
September		17.2	18.5	5	17.5	19.2	4	15.2	16.8	7	33.0	56.1
	$N=1$			$N=2$	17.5	19.2	$N=2$	17.5	19.2	$N=1$		
Total	$N=18$	224.9	243.6	$N=18$	224.1	244	$N=23$	265.8	289.4	$N=14$	372.8	671.5

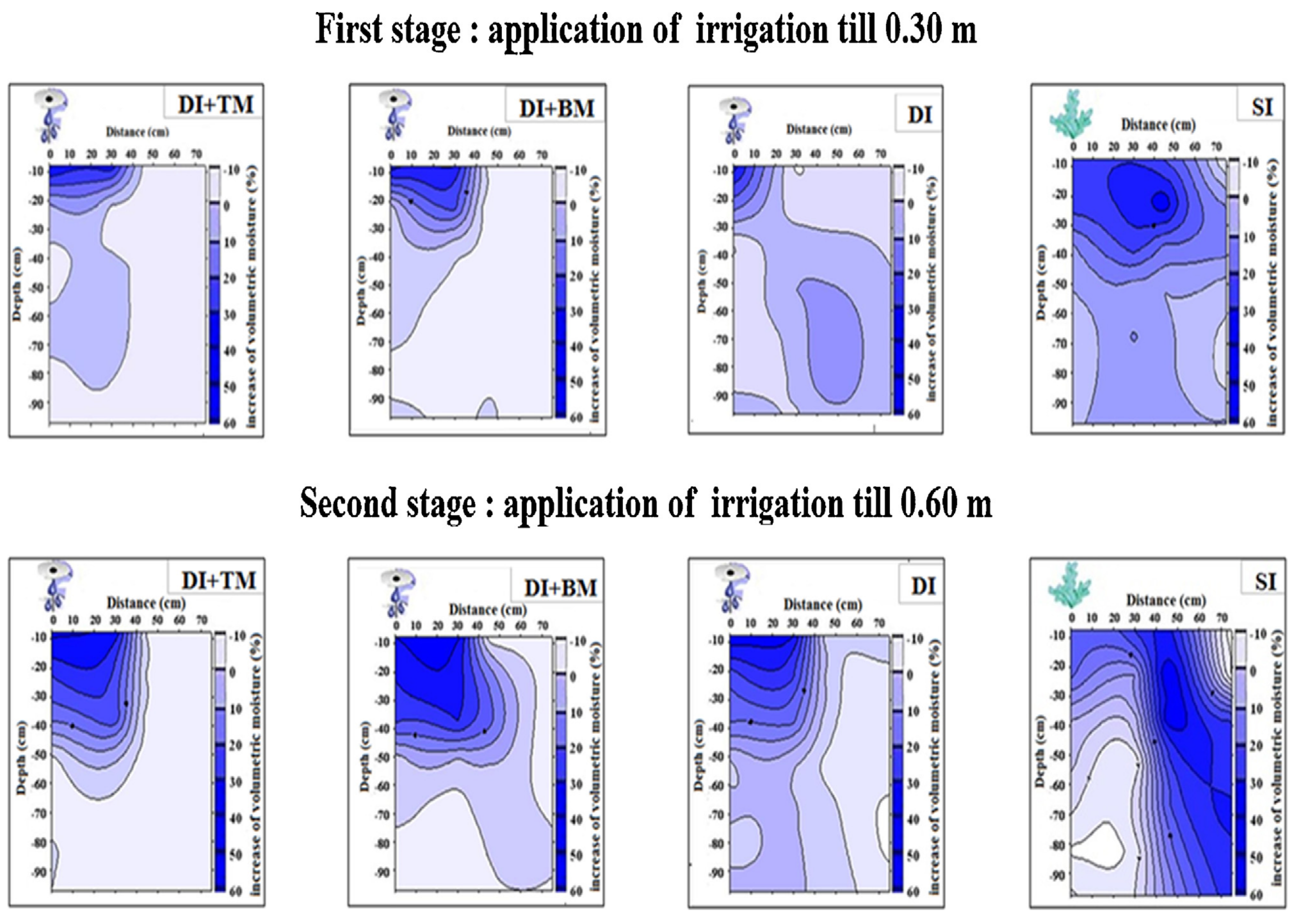

Fig. 2. Diagrams of water content in soil after drip irrigation such as (wetting bulb) compared with irrigation water distribution pattern after surface furrow irrigation.

necessary operations such as pest and weed controls were performed according to general local practices and recommendations.

Mercury thermometers were installed at the surface of soil, at the 5 cm soil depth and at the 10 cm soil depth in two replicates of each treatment, i.e., a total of 24 thermometers. Temperature was recorded from 10 June (planting date) till the end of the season. Measurements were taken each two hours of the day on two days a week. Air temperature was taken from a nearby weather station.

The yield ($t\,ha^{-1}$) from each plot was recorded in each pick, and the effectiveness of cucumber in using water during its complete growth period is generally described in terms of WUE and is expressed as the ratio of total crop yield to the total depth of water applied to crop including effective rainfall during its complete growth period (Steyn et al., 2000; Oweis, 2012): WUE = CY/WA, where WUE = water use efficiency, $t\,ha^{-1}\,mm^{-1}$. CY = total crop yield, $t\,ha^{-1}$. WA = total depth of water applied, mm. Data on cucumber yield and water use efficiency (WUE) were recorded by using standard procedures, and were statistically analyzed. Means were separated with the $LSD_{0.05}$ and $LSD_{0.01}$ using GenStat 7 program.

3. Results and discussion

3.1. Water applied

Before planting, 25 mm irrigation water was applied to all treatments to bring the soil water content in 0–60 cm soil depth up to level of field capacity.

Irrigation schedule were started measuring of soil water content by neutron probe. The maximum amount of water applied to the cucumber was 671.5 mm in the (SI) treatment while the minimum amount was 243.6 mm in the DI + TM treatment as average during both of growing seasons as shown in Table 2.

It was noted almost similar to net or gross irrigation requirements and also number of irrigations (N = 18) in the DI + TM and DI + BM treatments. While those parameters were high in non-mulched treatments to reach IR_n = 265.8 mm, IR_g = 289.4 mm and number of irrigations N = 23 for (DI) treatment.

These results are also in agreement with those of Tiwari et al. (2002), Samuel and Singh (2003), Ertek et al. (2006) and Zotarelli et al. (2009).

3.2. Water movement in the soil

The irrigation water was applied to compensate the water deficiency of the root zone soil (0.30 m) in the first stage and the root zone soil (0.60 m) after, according to FAO (1998) for cucumber effective roots distribution zone, and monitored in 0.30 depths increment to 0.90 m after irrigation for each treatment. Monitoring the soil water content in the drip irrigated plots revealed that infiltration below 0.90 m depths was negligible especially in mulched plots compared with that of SI plots.

Fig. 2 shows the soil water contents measured by Neutron probe before and after irrigation drawn by SURFER 8 software. These readings indicate that plastic mulching has a pronounced effect on drip irrigation effectiveness through the good estimation of wetting bulb's dimensions under the dripper and understanding its moisture changes in place and time, whereas the use of drip irrigation with plastic mulch reduced both of evaporation from soil surface

Table 3
Water applied, yield and water use efficiency (WUE) of different treatments (mean of 2009 and 2010).

Parameters	Treatments				F test	LSD[++]	
	DI + TM	DI + BM	DI	SI		.05	.01
Water applied (mm)	243.6	244	289.4	671.5			
Yield (t ha^{-1})	63.9	57.8	44.1	37.7	*	2.79	4.23
WUE (t ha^{-1} mm^{-1})	0.262	0.238	0.153	0.056	*	0.011	0.016

LSD[++]: The least significant difference.
* The significant difference at 1% level.

and water distribution area in soil away from the lines of irrigation, which has extreme effect on irrigation water distribution pattern, root distribution, efficiency of the fertilizers, water use and ultimately on the cucumber production quantity and quality, These results are also in agreement with those of ICARDA (2000) and Pawar et al. (2002).

Surface furrow irrigation reduces irrigation frequency from one irrigation every few days as drip system to one every week which reduced the productivity 17% compared with (DI) treatment, and attributed to the large ranges of soil moisture of the rooting zone. Similar data were reported by Wang et al. (2006). The results showed that the highest soil moisture values were recorded with transparent plastic mulch and black polyethylene mulch compared to bare soil. Generally, all mulches increased weekly measurements of soil moisture and water use efficiency. These results were agreed with those obtained by Farias-Larios et al. (1994a,b), Salman et al. (1991a) and Weber (2000). Therefore, the different types of mulch lead to increasing the soil moisture due to decreased of evaporation from soil surface compared to bare soil. So, mulches finding favorable soil environmental conditions and had a positive effect on growth of cucumber plants and contributed to increasing vegetative growth and yield.

Table 2 and Fig. 2 can help us to derive that applied drip irrigation effectiveness for DI + TM, DI + BM and DI was 92% while it decreases to 57% for SI. The percent of water use reduction was 64%, 65% and 57% for DI + TM, DI + BM and DI, respectively, compared with SI. These results are also in agreement with those of Louise et al. (1999), Patel and Patel (2001) and Ghorbani (2003).

Table 4
Actual evapotranspiration ETa (mm), and length of cucumber growth stages, Lg (days), as average in the both of growing seasons (Jun10 until Sep10).

ETa (mm) Lg (days)	DI + TM	DI + BM	DI	SI
Init. (L_{ini})	3	5	10	37
	3	5	10	11
Dev. (L_{dev})	31	31	34	99
	29	31	30	28
Mid. (L_{mid})	161	160	180	207
	51	47	43	44
Late. (L_{late})	18	18	22	30
	10	10	10	10
Total	213	214	246	373
	93	93	93	93

3.3. Water use efficiency (WUE) and yield

The present study shows the effects of drip irrigation and plastic mulch on crop water requirement and WUE. The results of the study indicated that DI + TM treatment markedly decreased the amounts of applied water in the order DI + TM ≤ DI + BM < DI < SI and increased WUE in the order DI + TM > DI + BM > DI > SI. The highest WUE (0.262 t ha^{-1} mm^{-1}) was obtained for the DI + TM treatment because this treatment consumed about 64% and 16% less water than the SI and DI treatments respectively, and produced comparatively higher yield.

The lowest WUE (0.056 t ha^{-1} mm^{-1}) realized for the SI treatment can be ascribed to the fact that the 175% more water was applied to this treatment than the DI + TM, while yield of the SI method was 59% of the DI + TM treatment. These results are also in agreement with those of Doss and Evans (1980), Drost and Hefelbower (2004), Kirnak and Demirtas (2006), Ngouajio et al. (2006) and Seyfi and Rashidi (2007). Results indicated that non-mulched treatments (DI and SI) received an average of 246 mm and 373 mm, respectively to produce 44.1 t ha^{-1} and 37.7 t ha^{-1} cucumber, respectively, whereas treatments with transparent and black plastic mulching consumed an average of 213 mm and 214 mm water, respectively and yielded average of 63.9 t ha^{-1} and 57.8 t ha^{-1}. These results support those of Wien et al. (1993), who showed that increased tomato growth and yield by polyethylene mulching is a consequence of enhanced root growth and nutrient uptake early in the season.

Statistical analyses using the *F*-test were carried out. LSD at .01 and .05 levels was also determined. As shown in Table 3, the results surely showed significant differences in yield and WUE between treatments at .01 level, whereas transparent mulch with drip irrigation exceeded all the treatments of the study in the order DI + TM > DI + BM > DI > SI. Similar data were reported by Diaz-Perez and Batal (2002), Simms et al. (2005) and Waterer et al. (2008).

3.4. Consumptive water use (actual crop evapotranspiration, ETa)

ETa (mm) for each treatment was calculated during various cucumber growth stages. It is noted that SI consumed more water than DI which in turn consumed more than DI + BM or DI + TM, which had similar values, as shown in Table 4. Similar data were reported by Battikhi and Ghawi (1987).

Table 5
Average monthly solar radiation, minimum and maximum temperature, rainfall, wind, evaporation from pan and ET_0 during both of experimental seasons.

Month	Solar (h/d)	Temp (°C)		Rainfall (mm)	Wind (m/s)	E_{pan} (mm)	ET_0[a] (mm)
		Max.	Min.				
Jun	13	33	22	0	2.2	214	152
July	13	35	26	0	3.2	323	248
Aug	12	35	25	0	1.9	273	199
Sep	11	32	23	0	1.9	73	52
Total seasonal						883	657

[a] FAO Penman–Monteith method, Jun. 10–30. . . Until Sep 10.

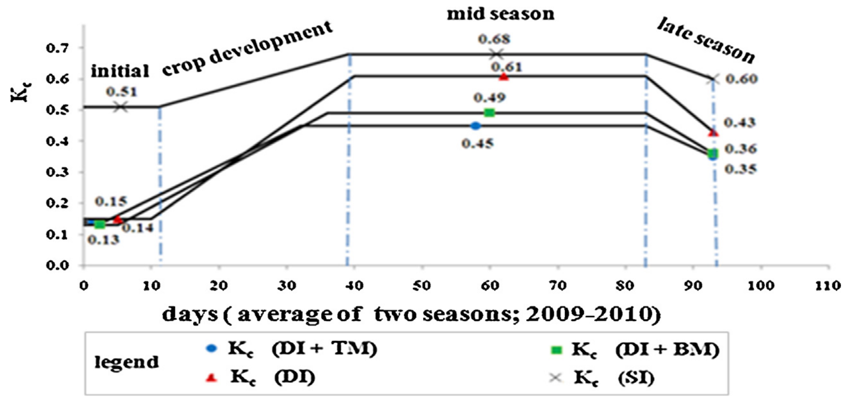

Fig. 3. Cucumber crop coefficient curves at Teezen research station, Hama.

It is also explained that drip irrigation system with plastic mulches (black and transparent) substantially prevent the evaporation from the soil surface. Associated with the reduction in evaporation is a general increase in transpiration from cucumber leaves caused by the transfer of both sensible and radiative heat from the surface of the plastic cover to adjacent vegetative leaves. Evaporation increased especially during the first weeks after transplanting where plants did not have enough canopies to shade the soil. Plastic mulches directly affect the microclimate around the plant by modifying the radiation budget (absorptivity vs. reflectivity) of the surface and decreasing the soil water loss. These results are also in agreement with those of Jenni et al. (2000), Orzolek (2000), Orzolek et al. (2003), El-Nemr (2006) and Korir et al. (2006). Table 5 shows the climatic data as average during both of experimental seasons. It also shows potential evaporation rates from class A pan which sets near field and reference crop evapotranspiration (ET_0) values were calculated based on FAO Penman–Monteith method.

It was noted that (ET_0) values reached the maximum value during July. And also Actual evapotranspiration (ETa) started to increase from the date of sowing till midseason stage and reached maximum in July and August then declined again at the end of mid and late season stages in September as shown in Table 4.

3.5. Crop coefficient

The crop coefficient (K_c) values decreased by an average of 35% due to use drip irrigation with plastic mulch which reduced soil evaporation compared with non-mulched treatments (DI and SI), as shown in (Fig. 3). These results are in agreement with those of Safadi (1991), Vickers (2001) and Mata et al. (2002). Also when we compared it with cucumber crop coefficient values given in Allen et al. (1998), we noted that the K_c values almost similar to ones which were calculated in SI treatment.

3.6. Soil temperature

Soil temperature was measured at soil surface and two depths 5 and 10 cm, each 2 h, respectively during day, twice a week. The results are presented as average during both of seasons (Fig. 4). Average air temperatures were generally higher than soil temperatures which measured at depths of un-mulched treatments. It reached a minimum during both of the second and third quarters of June of 22 °C at 6 a.m., and 33 °C at 14 p.m. It increased to a maximum of 26 °C in the morning and 35 °C in the afternoon in July. Air temperatures remained higher than soil temperatures at all depths in previous treatments except in both of DI + TM and DI + BM treatments. The values of soil temperature with mulching are much higher than those of soil without mulching. This may be owing to mulching prevents cooling of the soil surface due to evaporation. The values of soil temperature under transparent mulch were higher than those under the black mulch. These transparent plastic mulch may permit warming of 6.4, 5.9 and 5.6 °C to a depths of 0 cm (soil surface), 5 cm and 10 cm, whereas black plastics permit warming of 3.1, 2.7 and 2.4 °C at the same previous depths compared to the treatments without mulching. Using mulch types (transparent and black) enhanced soil temperature.

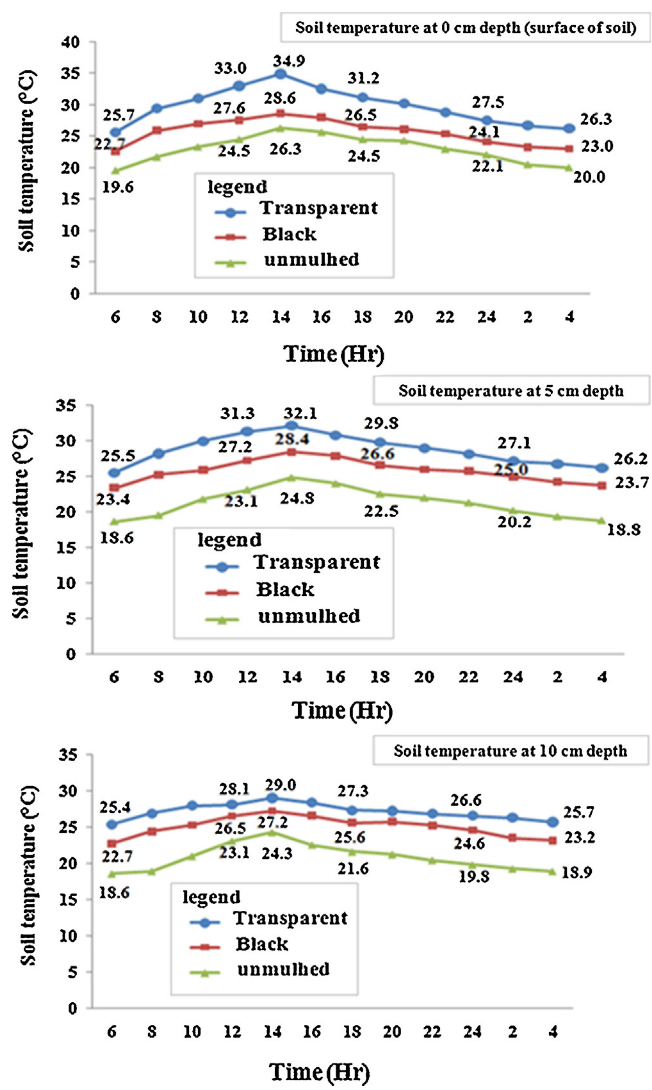

Fig. 4. Average of soil temperature under mulched and unmulched cucumber at the surface of soil and two depths 5 and 10 cm.

transparent plastic mulch increased soil temperature more than black mulch especially during the first weeks after transplanting where plants did not have enough canopies to shade the soil. The degree on contact between the mulch and soil, often quantified as a thermal contact resistance, can affect greatly the performance of mulch. If an air space is created between the plastic mulch and the soil by a rough soil surface, soil warming can be less effective than would be expected from particular mulch.

Sunlight passes through the transparent plastic and heats the soil. A layer of water underneath the plastic retains the radiant heat at night through what is known as a greenhouse effect. Black plastic mulch absorbs most of the sunlight and becomes greatly warmed, and little energy passes through to warm the soil. These results support those of Ham and Kluitenberg (1994), Waterer (1999, 2000), Tarara (2000), Lamont (2005) and Ngouajio and Ernest (2005) who showed that transparent mulch absorbs only 5% of short-wave radiation, reflects only 11%, but transmits 84% of short-wave radiation, whereas surface temperatures do not reach the levels found on black plastic due to their low absorption rates of short-wave radiation. That means that transparent plastics actually heat the soil by transmitting light to the soil surface rather than conducting heat like dark plastics. While differently Liakatas et al. (1986) and Ham et al. (1993) explained that laying transparent mulch loosely across the soil creates an insulating air gap between the mulch and soil that results in higher daytime temperatures under transparent plastic than black plastic mulch. Then, if clear plastic is laid tightly across the bed, its effects will be minimized and, in this situation, black plastic laid tightly across the bed would be more effective at heating the soil.

3.7. *Earlier production (precocity) and weed control*

Plastic mulches raise soil temperature in the planting bed which promotes faster crop development and earlier yields. Whereas germination dates for DI + TM, DI + BM, DI and SI were on June 13, 15, 20 and 21, respectively, maturity dates were on July 9, 13, 22 and 27 at the same previous arrangement. Also it is associated with the best vegetative growth and significantly increased productivity limits of (70%, 53% and 17%) for DI + TM, DI + BM and DI compared with the SI treatment. Increased yield could be largely attributed to the increase in soil temperature due to application of plastic mulch which resulted in an enhancement of soil environment around roots of cucumber plants, which led to increasing plant growth and, hence, increasing nutrients uptake. Hence, earlier production and higher total yield was obtained. These results were in line with those obtained by Wien and Menotti (1987) and Farias-Larios et al. (1994b). The results reported that the greatest total yield of cucumber plants was obtained with transparent polyethylene mulch followed by black polyethylene and then by drip irrigation without mulching. This effect was statistically significant in both seasons. The unmulched plots were hand-weeded four times over the growing season. No effort was made to control weeds in the mulched plots. Although, clear plastic mulch may result in an increase in soil temperature, the presence of light led to the disadvantage of weed growth, while the absence of light with black plastic did not allow photosynthesis of weeds under the film and therefore weed growth was suppressed. This result was in agreement with that found by Lamont (1999, 2001).

4. Conclusions

With growing water demand and increasing signs of water scarcity, there is an urgent need to achieve higher output per unit of water consumed. Fortunately, there is ample scope to improve crop water productivity, particularly in areas where yields are currently low. In the present study, effects of drip irrigation and plastic mulch on water applied and WUE was investigated. The results of the study indicated that DI + TM and DI + BM treatments markedly decreased water applied in the order of DI + TM < DI + BM < DI < SI and increased WUE in the order of DI + TM > DI + BM > DI > SI. The DI + TM treatment attained the highest WUE of 0.262 t ha^{-1} mm^{-1}. The lowest WUE (0.056 t ha^{-1} mm^{-1}) realized for the SI treatment These results are also in agreement with those of Jain et al. (2000), who concluded that drip irrigation and plastic mulch markedly affects applied water and water use efficiency. Reference crop evapotranspiration (ET_0) value was calculated based of Penman–Monteith method, which was recorded the maximum value during July. Actual evapotranspiration (ETa) started to increase from the date of sowing till Midseason stage and became maximum in July and August then again reduced in the last Maturity and harvest stage in September. The crop coefficient (K_c) values decreased by an average of 35% due to use drip irrigation with mulch. The percent of water use reduction was 65%, 64% and 57% for the transparent mulched drip irrigation, black mulched drip irrigation and no mulch drip irrigation, respectively compared to the furrow surface irrigation treatment.

Results also indicated that plastic mulch generally raised soil temperature, whereas transparent plastic mulch raised the limits of the soil temperature (6.4, 5.9 and 5.6) °C respectively at the surface of soil, at the 5 cm soil depth and at the 10 cm soil depth. While black plastic mulch raised the limits of the soil temperature (3.1, 2.7 and 2.4) °C respectively at the same previous soil depth, compared with both irrigation treatments without mulching, which enhanced Cucumber vegetative growth and significantly increased its productivity limits of (70%, 53% and 17%) for all drip irrigation treatments (transparent plastic mulch, black plastic mulch and without mulch), compared to the surface furrow irrigation treatment. whereas transparent plastic mulch raises soil temperature; however, black plastic is advantageous for weed control. As if there are benefits of plastic mulch, there are also some problems such as removing the plastic mulch after the cropping season is the biggest disadvantage. Little pieces of plastic can scatter across a field. Many landfills also will not accept plastic, and it is difficult to recycle. The cost of applying plastic mulch can be quite high both in terms of materials and equipment. With drip irrigation, managing plastic mulch is more intense. Wilting plants could mean a plugged drip line, while overly wet areas could mean rodent damage to the lines. Drip line problems are hard to evaluate when covered with mulch. Although that, we suggest popularization of these study to include other crops that more profit for farmers such squash, pepper and tomato, and hope use other many colors of plastic mulch and examination them effect on water use efficacy (WUE), and Potential to double-crop plastic mulch (see Waterer et al., 2008). We advise use organic mulch also such as rice, wheat and barley straws and do not advice use of plastic mulch on potatoes which planted in Autumn season because of high soil temperatures under plastic mulch will destroyed potato nodes (see Wang et al., 2004).

Last but not least, Drip irrigation significantly increased crop yield of Cucumber and improved WUE due to consumption of less water. However, integrated use of drip irrigation and plastic mulch was more appropriate and profitable. Therefore, drip irrigation in combination with plastic mulch especially (transparent mulch) was found to be more effective irrigation method in improving WUE and increasing crop yield of cucumber.

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