The Journal of Animal & Plant Sciences, 25(5): 2015, Page: 1398-1410
ISSN: 1018-7081

RESPONSE OF MUSKMELON CULTIVARS TO PLASTIC MULCH AND IRRIGATION REGIMES UNDER GREENHOUSE CONDITIONS

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ABSTRACT

Mulching and irrigation water management is among the vital practices that are being applied in commercial vegetable production. White-on-black plastic mulch in combination with four irrigation levels (40, 60, 80 and 100% based on crop evapotranspiration (ETc)) was applied to assess growth and yield responses of two F_1 muskmelon cultivars ('Velta' and 'Parana') under greenhouse conditions. Crop water productivity (water use efficiency, WUE and irrigation water use efficiency, IWUE) were also evaluated. Plastic mulch treatment resulted in higher plant height, leaf area, fruit number, early fruit yield, total yield and crop water productivity than non-mulch treatment. High and medium irrigation levels (100 and 80% ETc) enhanced plant height and leaf area and increased fruit number, early and total yield. On the other hand, low irrigation levels (40 and 60% ETc) decreased yield and increased WUE and IWUE. 'Velta' plants showed superior vegetative growth, higher crop yield, WUE and IWUE than 'Parana' plants. A higher crop production was observed with mulch and 100% ETc treatment for 'Velta' cultivar. However, higher WUE and IWUE values were found under mulch with the lowest irrigation level (40% ETc) for 'Velta' cultivar. Plastic mulch with 80% ETc water treatment was considered more suitable for optimizing WUE with no major yield reduction. For muskmelon yield enhancement with 20% saving in irrigation water, it is recommended to apply medium irrigation level (80% ETc) and plastic mulch under greenhouse conditions.

Key words: Muskmelon, white-on-black plastic mulch, crop yield, crop water productivity.

INTRODUCTION

Melon (*Cucumismelo* L.) is a worm season vegetable crop divided into two subspecies: *C. melo* ssp. *melo* and *C. melo* ssp. agrestis based on ovary pubescence (Kirkbride, 1993; McCreight*et al*., 2004). *C. melo* ssp. *melo* includes 11 types; of these three groups have economic importance as *cantalupensis* (cantaloupe), *reticulatus* (muskmelon) and *inodorus* (winter melon) (Szabo *et al*., 2008). Cantaloupe and muskmelon rank the third vital cultivated cucurbits worldwide after watermelon (*Citruluslanatus* Thunb.) and cucumber (*Cucumissativus* L.) crops (Nu˜nez-Palenius *et al*., 2008). Muskmelon is a beautiful colored, juicy, musky and delicious fruit that has nutritive and medicinal values (Milind and Kulwant, 2011).

In arid regions, protected cultivation has gained great interest since climate control and drip irrigation allow for increasing yield while saving water resources. Vertical growth of plants (trellising) in greenhouse can enhance available light interception, air movement and microclimates for each plant (Rodriguez *et al*., 2007) which results in higher yield than under field conditions.

Mulching is one of the management practices that can be used for increasing WUE (Rashidi and Keshavarzpour, 2011). Mainly, there are three major colors of plastic mulch used in commercial vegetable production: i.e., black, clear and white (or white-on-black) reflective mulches. The black mulch is being the dominant color used for vegetables (Gordon *et al*., 2010; Hochmuth *et al*., 2012). White or coextruded white-on-black mulch can cause a slightly lower soil temperature in comparison with bare soil because the mulch absorbs less radiant energy and it reflects back into the plant canopy most of the incoming solar radiation (Ham *et al*., 1993; Lamont, 2005). This kind of mulch is recommended when lower soil temperatures are desirable for sowing vegetables, particularly in summer production under warmer arid regions compared with black plastic mulch (Gordon *et al*., 2010). Generally, the benefits of mulch in the production of vegetable crops are well established (De Pascale *et al*., 2011). Use of mulches has many advantages such as reducing nutrient leaching, decreasing soil evaporation, increasing soil moisture conservation and controlling weeds (Lamont, 2005; Kumar and Lal, 2012). In turn, rapid and uniform crop soil coverage leads to high and uniform yield (De Pascale *et al*., 2011). Earlier harvests are also among the most important benefits of plastic mulch application as a result of the increase in soil temperature (Ban *et al*., 2009; Hochmuth *et al*., 2012).

Irrigation water management through drip irrigation system greatly affects growth, yield and yield components of muskmelon. Hartz (1997); Leskovar *et al*. (2001) indicated that using drip irrigation can improve plant growth, increase fruit size and marketable yield, and may also leads to early fruit yield of muskmelon. It is generally accepted that muskmelon production are highly influenced by total applied irrigation water (Fabiero *et al*., 2002). Irrigation studies have shown that muskmelon is sensitive to water stress (Zeng *et al*., 2009; Li *et al*., 2012). Low water amount leads to smaller fruits, and low fruits number and yield (Kirnak *et al*., 2005; Long *et al*., 2006; Dogan *et al*., 2008). Therefore, supplying the optimum amount of water to muskmelon plants is essential for maximum yield and conserving water (Ahmadi-Mirabad *et al*., 2014).

It is becoming critically important to optimize WUE for agricultural use. This needs a change from maximizing productivity per unit of land area to maximizing productivity per unit of water consumed. In order to maximize WUE it is essential to save water and to encourage best crop growth (De Pascale *et al*., 2011). Cultural practices that increase WUE and decrease excessive amount of irrigation water are crucial. Thus, irrigation and mulching practices may contribute to improve crop water productivity and muskmelon production.

Limited studies are available on the effects of drip irrigation and plastic mulch on plant growth, yield and crop water productivity of selected vegetable crops. Therefore, the objective of the present study was to evaluate plant growth, crop yield and crop water productivity response of two muskmelon cultivars using white-on-black plastic mulch and irrigation regime treatments under greenhouse conditions.

MATERIALS AND METHODS

Site description: The study was carried out in fiberglass greenhouse at the Agricultural Research and Experimental Station, College of Food and Agricultural Sciences, King Saud University at Dirab (latitude: 24° 39' N and longitude: 46° 44' E), Riyadh, Saudi Arabia.

Plant materials: Two muskmelon (*Cucumismelo* var. reticulates) cultivars were tested: 'Velta' F_1 (round shape, medium netting with green flesh color) and 'Parana' F_1 (round shape, medium netting with white green flesh color) (RIJK ZWAAN, Netherland). The soil texture of the top 30 cm was sandy with 7.9 and 2.18 dS m^{-1} for pH and electrical conductivity (EC), respectively. Agricultural practices (i. e. fertilization, pests and diseases control) were performed as recommended (Kemble, 1996).

Direct seeding was conducted inside a fiberglass greenhouse on 3rd September 2011 and 5th of September 2012 during the two growing seasons of 2011/2012 and 2012/2013, respectively. The controlled conditions inside the greenhouse were adjusted for day/night temperature 26/18°C and relative humidity 70%, during the growing season. Harvest-ripe fruits were handpicked during December and continued until the middle of February, in both growing seasons.

Mulch treatments: White-on-black (non-transparent) polyethylene plastic-mulched (0.06 mm thick and 80 cm wide) was used for mulching while bare soil was selected as a control treatment. Some lines of raised beds (10.0 m long) were prepared and covered with white-on-black plastic mulch after setting up a drip irrigation system in each plot.

Irrigation level treatments: Four irrigation levels were applied: 100% ETc (control treatment), 80% ETc, 60% ETc and 40% ETc (water stress treatment). The EC value of irrigation water was 1.24 dS m^{-1}. Muskmelon plants were irrigated uniformly in the first two weeks for seed establishment to ensure good root system, and then all irrigation treatments started after this period. The total amounts of applied water were: 1200 for 40%, 1800 for 60%, 2400 for 80% and 3000 m^3 ha^{-1} for 100% based on pan evaporation (Allen *et al*., 1998).

Vegetative growth and crop yield traits: Plant growth traits and fruit yield were measured during the growing seasons. At day 65 after planting, (50% flowering), three plants from each experimental plot were sampled. Plant height and leaf area were recorded. The total leaf area was measured using a Portable Area Meter (LI-COR model 3000A). All fruits were harvested at the optimum ripening stage. Fruits number and weight for the first and second harvests were used to estimate early fruit yield (Ibarra *et al*., 2001). Fruits number and weight $plant^{-1}$ was measured to determine total crop yield.

Crop water productivity: Crop water productivity (WP) or water use efficiency (WUE) as indicated by Geerts and Raes (2009) is defined as the ratio of the weight of marketable yield (Yc) to the volume of water consumed by the crop ETc.WUE and irrigation water use efficiency (IWUE) have generally been employed to provide details about crop water productivity (Bozkurt and Mansuroğlu, 2011).

WUE (kg m^{-3}) was estimated according to Allen *et al*. (1998) as:

WP = Yc/ETc

Where, ETc attributes to water lost by evapotranspiration (ETc) during the crop cycle

IWUE was estimated according to Erdem*et al*. (2005) as:

$IWUE = (Y_1 - Y_{NI}) / I$

Where, Y_1 is the total yield of irrigation treatments (t ha^{-1}),

Y_{NI} is the total yield of 100% ETc control treatment (t ha^{-1}) and

I is the amount of irrigation water (m^3 ha^{-1}).

Experimental design and statistical analysis: The experimental design was split-split-plot system in randomized complete blocks with three replications. Mulch treatments were arranged as the main plots, irrigation level treatments were distributed into sub-plots and the two muskmelon cultivars were allocated in the sub-sub-plots. Each experimental plot comprised one row, 10 m long and 1 m wide with an area of 10 m^2 including 20 plants. The plant distance was 50 cm along one side of each row. The SAS mixed procedure 8.1 version (SAS Inst., 2008) was selected to analyze the experimental data, and the least significant difference (LSD) test was used to determine significant differences among means of the different treatments. The probability level for determination of significance is 5% based on Steel *et al.* (1997) procedure.

RESULTS

Vegetative growth traits: Both plastic mulch and irrigation level treatments significantly affected plant vegetative growth traits (plant height and leaf area) of the two muskmelon cultivars. The tallest plant and the highest leaf area were detected in 'Velta' F_1 cultivar in comparison with 'Parana' F_1 cultivar (Table 1). Plants grown on white-on-black plastic mulch produced taller plants and higher leaf area as compared to bare soil plants. Plant height and leaf area were greater by 23.4-24.8% and 20.8-21.2%, respectively in plants that received full irrigation level (100% ETc) than plants under water stress treatment (40% ETc).

Crop yield traits: Crop yield traits were significantly different between the two hybrids. 'Velta' F_1 cultivar had higher fruit number, early and total yields as compared to 'Parana' F_1 cultivar (Table 1). Mulch treatment had significant impact on crop yield traits (fruit number, early and total crop yield). Plastic mulch resulted in higher fruit number, early and total yields. Plants under higher irrigation water levels had higher fruit number, early and total yields.

Crop water productivity: 'Velta' F_1 cultivar had 16.34-16.71% and 16.37-17.10% higher values of WUE and IWUE, respectively as compared to 'Parana' F_1 cultivar (Table 2). Plastic mulch increased WUE and IWUE compared to non-mulch treatment. Higher water level treatment (100% ETc) had a minimum WUE value (35.75-36.92 kg m^{-3}) while, a maximum WUE value (44.32-47.35 kg m^{-3}) was obtained under water stress treatment (40% ETc). Similarly, IWUE value ranged from a minimum of 28.58-28.59 kg m^{-3} under 100% ETc to a maximum value of 35.45-36.93 kg m^{-3} under water stress treatment (Table 2). Therefore, crop water productivity increased with decreasing irrigation levels.

Interaction influence: Plant growth indicated that plant height and leaf area traits increased considerably under plastic mulch with high and medium irrigation levels (100 and 80% ETc) treatments. However, water stress with non-mulch treatment reduced plant height and leaf area. These irrigation levels (100% and 80% ETc) with 'Velta' F_1 cultivar resulted in the tallest plants with higher leaf area in comparison with 'Parana' F_1 cultivar under any irrigation level. The highest values of plant height and leaf area were obtained in 'Velta' F_1 cultivar with plastic mulch treatment.

Applying full irrigation level (100% ETc) with plastic mulch treatment produced the highest fruit number plant^{-1} and total crop yield followed by 80% ETc (Figures 1 A& B and 2 A & B). Similarly, both irrigation levels (80 and 100% ETc) with 'Velta' F_1 cultivar led to increased fruit number plant^{-1} and total crop yield as compared with 'Parana' F_1 (Figures 1 C & D and 2 C & D). However, medium irrigation level (80% ETc) showed superior earlier yield than the full irrigation level (100% ETc), particularly with mulch treatment or with 'Velta' F_1 cultivar. In contrast, water stress treatment (40% ETc) generated the lowest fruit number plant^{-1} (Figures 1 C & D) and total crop yield, particularly with 'Parana' F_1 (Figures 2 C & D). On the other hand, the highest fruit number and the heaviest crop yield were recorded with 'Velta' F_1 plants with plastic mulch treatment (Figures 1 E & F and 2 E & F). Medium irrigation level (80% ETc) accelerated fruit formation and produced earlier fruit yield, chiefly with 'Velta' F_1 plants (Table 3). 'Velta' F_1 plants also produced the highest fruit number and total crop yield under higher irrigation levels (100 and 80% ETc) with plastic mulch treatment in comparison with 'Parana' F_1 plants under the same treatments (Table 3).

The highest WUE and IWUE values (48.6-51.6 kg m^{-3} and 39.8-40.3 kg m^{-3}, respectively) were recorded under water stress (40% ETc) with plastic mulch treatment. On the other hand, the lowest WUE and IWUE values (30.9-31.4 kg m^{-3} and 22.5-24.5 kg m^{-3}), respectively were obtained under the highest irrigation level with non-mulch treatment (Figures 3 A& B). 'Velta' F_1 cultivar with lower water level (40% ETc) gave the maximum WUE and IWUE values (48.5-52.3 kg m^{-3} and 38.7-40.8 kg m^{-3}, respectively). However, the minimum WUE and IWUE values (33.3-34.3 kg m^{-3} and 26.6-26.7 kg m^{-3}) were found in 'Parana' F_1 cultivar with higher water level (Figures 3 C & D). 'Velta' F_1 plants showed superiority in WUE and IWUE values with plastic mulch treatment while 'Parana' plants under non-mulch treatment had the lowest values of WUE and IWUE (Figures 3 E & F). Crop water productivity (WUE and IWUE) of muskmelon plants was more efficient in 'Velta' F_1 plants followed by 'Parana' F_1 plants grown under water stress (40% ETc) with mulch treatment (Table 3).

Crop yield enhancement and irrigation water saving: According to the interaction results, there were obvious crop yield enhancement from the combination treatment among irrigation levels, mulch treatments and muskmelon cultivars (Table 4). 'Velta' F_1 cultivar under 100% ETc with white-on-black plastic mulch treatment produced 37.06-40.11% higher crop yield than control treatment (100% ETc with non-mulch) followed by 80% ETc with white-on-black plastic mulch (36.02-36.36%). On the contrary, 'Parana' F_1 cultivar under 40% ETc with non-mulch treatment had the highest yield reduction (-27.99 to -31.60%). Full irrigation level (100% ETc) with plastic mulch treatment resulted in a slight increment in the total crop yield as compared with 80% ETc with plastic mulch treatment (Table 4). At 80% ETc, it is possible to conserve about 20% in water consumption and maintain an adequate muskmelon yield.

Table 1. Effect of plastic mulch, irrigation levels and cultivars on important agronomic traits of muskmelon plants during 2011/2012 and 2012/2013 growing seasons

Growing seasons	First season 2011/2012					Second season 2012/2013				
Traits / Treatments	Plant height (cm)	Leaf area (cm^2)	Fruit number $plant^{-1}$	Early fruit yield ($t\ ha^{-1}$)	Total crop yield ($t\ ha^{-1}$)	Plant height (cm)	Leaf area (cm^2)	Fruit number $plant^{-1}$	Early fruit yield ($t\ ha^{-1}$)	Total crop yield ($t\ ha^{-1}$)
(a) Plastic mulch										
Mulch	190.9^a	5116.3^a	5.19^a	19.991^a	79.047^a	194.0^a	5229.7^a	5.28^a	18.648^a	82.461^a
Non-mulch	183.3^b	4566.0^b	4.85^b	16.101^b	62.977^b	187.3^b	4678.0^b	4.90^b	15.234^b	65.344^b
(b) Irrigation levels										
100% ETc	200.9^a	5217.6^a	5.44^a	18.256^a	85.790^a	206.3^a	5347.8^a	5.48^a	19.513^a	88.610^a
80% ETc	198.4^b	5211.7^a	5.36^a	17.408^b	84.497^b	202.7^b	5341.8^b	5.43^b	18.662^b	87.437^b
60% ETc	186.4^c	4616.3^b	4.72^b	15.798^c	60.579^c	188.3^c	4713.8^c	4.78^c	17.685^c	62.737^c
40% ETc	162.8^d	4318.9^c	4.58^c	14.723^d	53.182^d	165.3^d	4412.1^d	4.67^d	16.478^d	56.828^d
(c) Cultivars										
Velta F_1	190.6^a	4963.0^a	5.15^a	19.002^a	76.234^a	193.8^a	5073.9^a	5.23^a	18.215^a	79.419^a
Parana F_1	183.5^b	4719.3^b	4.88^b	16.090^b	65.794^b	187.5^b	4833.8^b	4.95^b	16.654^b	68.387^b

Means, in each treatment group, followed by the same letters are not significantly different at LSD 0.05 level.

Table 2. Effect of mulch and irrigation levels treatments on crop water productivity (WUE and IWUE) of two muskmelon cultivars during 2011/2012 and 2012/2013 growing seasons

Crop water productivity	WUE		IWUE	
Treatments	**2011/2012**	**2012/2013**	**2011/2012**	**2012/2013**
(a) Plastic mulch				
Mulch	44.31^a	46.36^a	35.45^a	36.15^a
Non-mulch	35.77^b	37.25^b	28.62^b	29.05^b
(b) Irrigation levels				
100% ETc	35.75^d	36.92^d	28.59^d	28.58^d
80% ETc	37.86^c	39.21^c	30.29^c	30.58^c
60% ETc	42.25^b	43.72^b	33.80^b	34.10^b
40% ETc	44.32^a	47.35^a	35.45^a	36.93^a
(c) Cultivars				
Velta F_1	43.07^a	45.04^a	34.46^a	35.13^a
Parana F_1	37.02^b	38.59^b	29.61^b	30.00^b

Means, in each treatment group, followed by the same letters are not significantly different at LSD 0.05 level.

Table 3. Interaction influence among irrigation levels, plastic mulch treatment and muskmelon cultivars on fruit number plant^{-1}, early yield, total crop yield, WUE and IWUE of muskmelon plants during 2011/2012 and2012/2013 growing seasons

Experimental treatments			First season 2011/2012					Second season 2012/2013				
Irrigation levels	**Plastic mulch system**	**Cultivars**	**Fruit number plant^{-1}**	**Early yield (t ha^{-1})**	**Total crop yield (t ha^{-1})**	**WUE**	**IWUE**	**Fruit number plant^{-1}**	**Early yield (t ha^{-1})**	**Total crop yield (t ha^{-1})**	**WUE**	**IWUE**
100% ETc	**Mulch**	**VeltaF_1**	5.8	19.860	105.989	44.2	33.3	5.9	21.513	110.881	46.2	34.0
		Parana F_1	5.4	17.387	89.033	37.1	29.7	5.5	18.682	92.740	38.6	30.1
	Non-mulch	**VeltaF_1**	5.3	16.113	77.333	32.2	25.8	5.4	17.356	79.140	32.9	25.7
		Parana F_1	5.1	15.273	70.806	29.5	23.6	5.2	15.247	71.680	29.9	23.3
80% ETc	**Mulch**	**VeltaF_1**	5.7	20.893	105.191	48.6	35.1	5.8	22.154	107.915	46.0	35.1
		Parana F_1	5.4	18.553	87.585	43.8	32.0	5.4	19.637	90.811	42.4	33.4
	Non-mulch	**VeltaF_1**	5.3	17.153	75.698	37.9	28.3	5.3	16.258	78.469	35.2	30.6
		Parana F_1	5.1	16.423	69.513	34.8	26.8	5.1	15.885	72.553	33.3	28.3
60% ETc	**Mulch**	**VeltaF_1**	4.9	16.380	71.219	52.5	35.6	5.0	18.234	73.871	54.2	36.0
		Parana F_1	4.7	15.853	67.989	45.4	33.0	4.7	16.254	69.609	37.3	33.1
	Non-mulch	**VeltaF_1**	4.7	15.567	68.125	41.8	30.1	4.8	14.755	69.519	39.2	32.0
		Parana F_1	4.6	14.390	64.983	36.3	29.5	4.6	12.452	57.947	36.2	30.3
40% ETc	**Mulch**	**VeltaF_1**	5.1	14.360	64.834	56.0	47.2	5.2	16.248	71.133	59.3	46.2
		Parana F_1	4.5	12.643	56.532	49.1	38.7	4.6	14.660	52.729	48.9	39.3
	Non-mulch	**VeltaF_1**	4.4	12.686	57.453	44.9	37.3	4.5	12.982	54.422	45.4	37.4
		Parana F_1	4.3	10.200	50.989	39.3	34.6	4.3	10.526	49.027	41.0	33.9
LSD at 0.05			0.193	0.752	1.320	1.48	1.17	0.146	0.927	1.673	1.89	1.11

Table 4. Yield losses (%) and water saving (%) due to the interaction effects among irrigation levels, plastic mulch treatment and muskmelon cultivars during 2011/2012 and 2012/2013 growing seasons

Experimental treatments			First season 2011/2012				Second season 2012/2013			
Irrigation levels	Plastic mulch system	Cultivars	Total crop yield (t ha^{-1})	Yield ratio to control treatment (%)	Yield losses (%)	Water saving (%)	Total crop yield (t ha^{-1})	Yield ratio to control treatment(%)	Yield losses (%)	Water saving (%)
100% ETc	**Mulch**	**VeltaF_1**	105.989	137.06	37.06	0	110.881	140.11	40.11	0
		Parana F_1	89.033	125.74	25.74	0	92.740	129.38	29.38	0
	Non-mulch	**VeltaF_1**	77.333	100.00	0	0	79.140	100.00	0	0
		Parana F_1	70.806	100.00	0	0	71.680	100.00	0	0
80% ETc	**Mulch**	**VeltaF_1**	105.191	136.02	36.02	20	107.915	136.36	36.36	20
		Parana F_1	87.585	123.70	23.70	20	90.811	126.69	26.69	20
	Non-mulch	**VeltaF_1**	75.698	97.88	-2.12	20	78.469	99.15	-0.85	20
		Parana F_1	69.513	98.17	-1.83	20	72.553	101.22	1.22	20
60% ETc	**Mulch**	**VeltaF_1**	71.219	92.09	-7.91	40	73.871	93.34	-6.66	40
		Parana F_1	67.989	96.02	-3.98	40	69.609	97.11	-2.89	40
	Non-mulch	**VeltaF_1**	68.125	88.09	-11.91	40	69.519	87.84	-12.16	40
		Parana F_1	64.983	91.78	-8.22	40	57.947	80.84	-19.16	40
40% ETc	**Mulch**	**VeltaF_1**	64.834	83.84	-16.16	60	71.133	89.88	-10.12	60
		Parana F_1	56.532	79.84	-20.16	60	52.729	73.56	-26.44	60
	Non-mulch	**VeltaF_1**	57.453	74.29	-25.71	60	54.422	68.77	-31.23	60
		Parana F_1	50.989	72.01	-27.99	60	49.027	68.40	-31.60	60

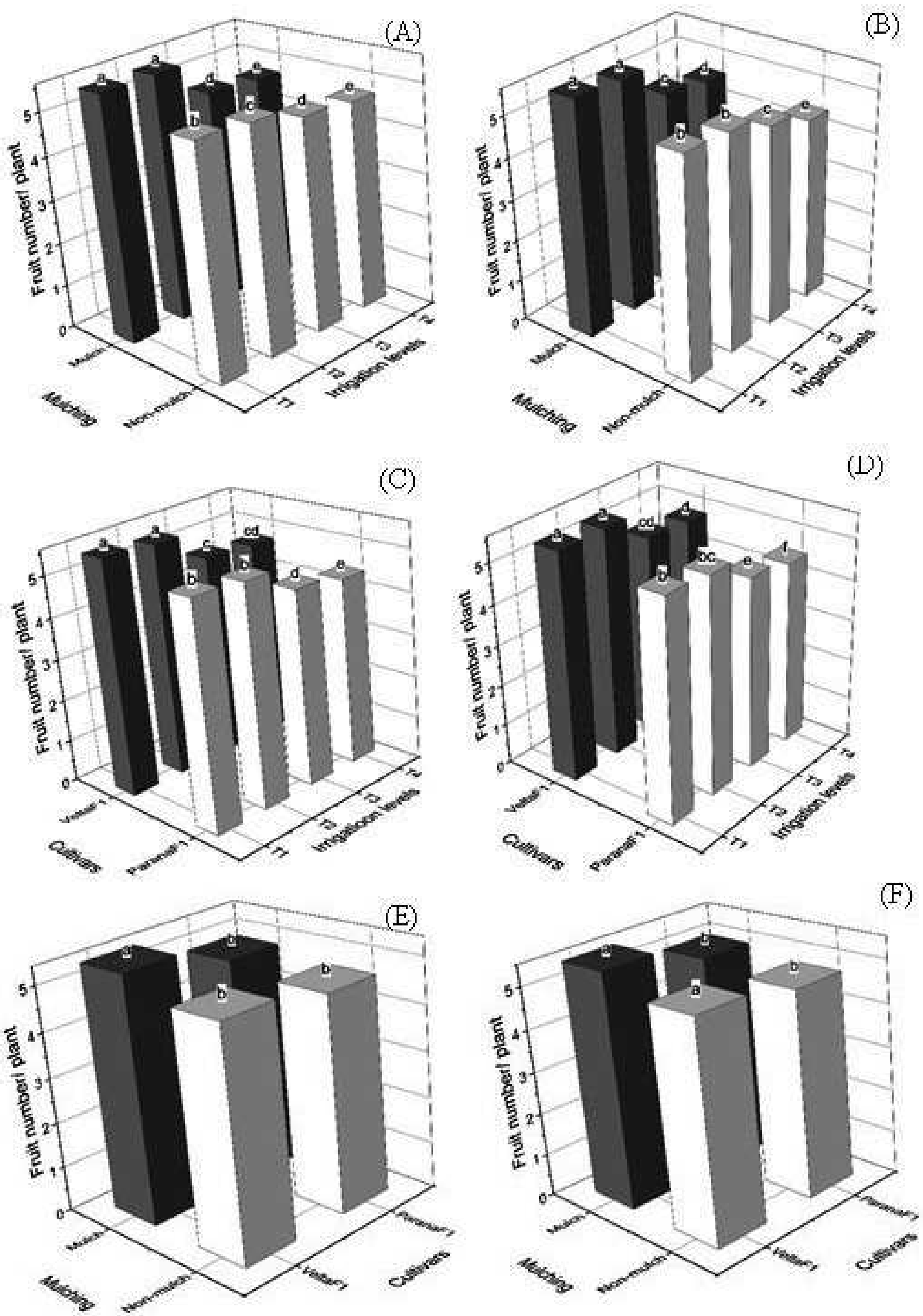

Figure 1. Interaction effect of plastic mulch X irrigation levels (A, B), muskmelon cultivars X irrigation levels (C, D) and muskmelon cultivars X plastic mulch (E, F) on fruit number plant^{-1} during 2011/2012 and 2012/2013 growing seasons, respectively. Means followed by the same letters are not significantly at LSD 0.05 level.

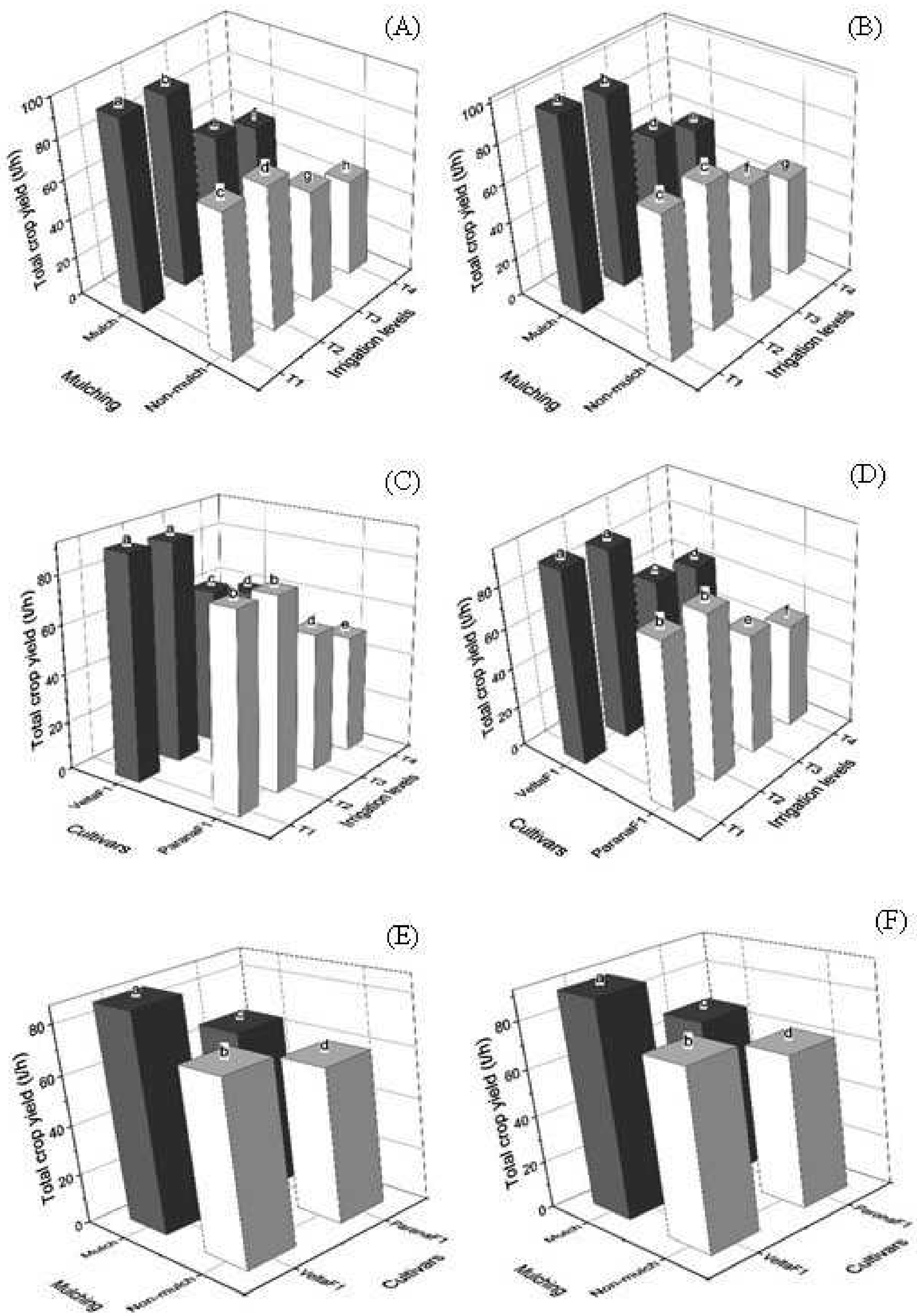

Figure 2. Interaction effect of plastic mulch X irrigation levels (A, B), muskmelon cultivars X irrigation levels (C, D) and muskmelon cultivars X plastic mulch (E, F) on total crop yield during 2011/2012 and 2012/2013 growing seasons, respectively. Means followed by the same letters are not significantly at LSD 0.05 level.

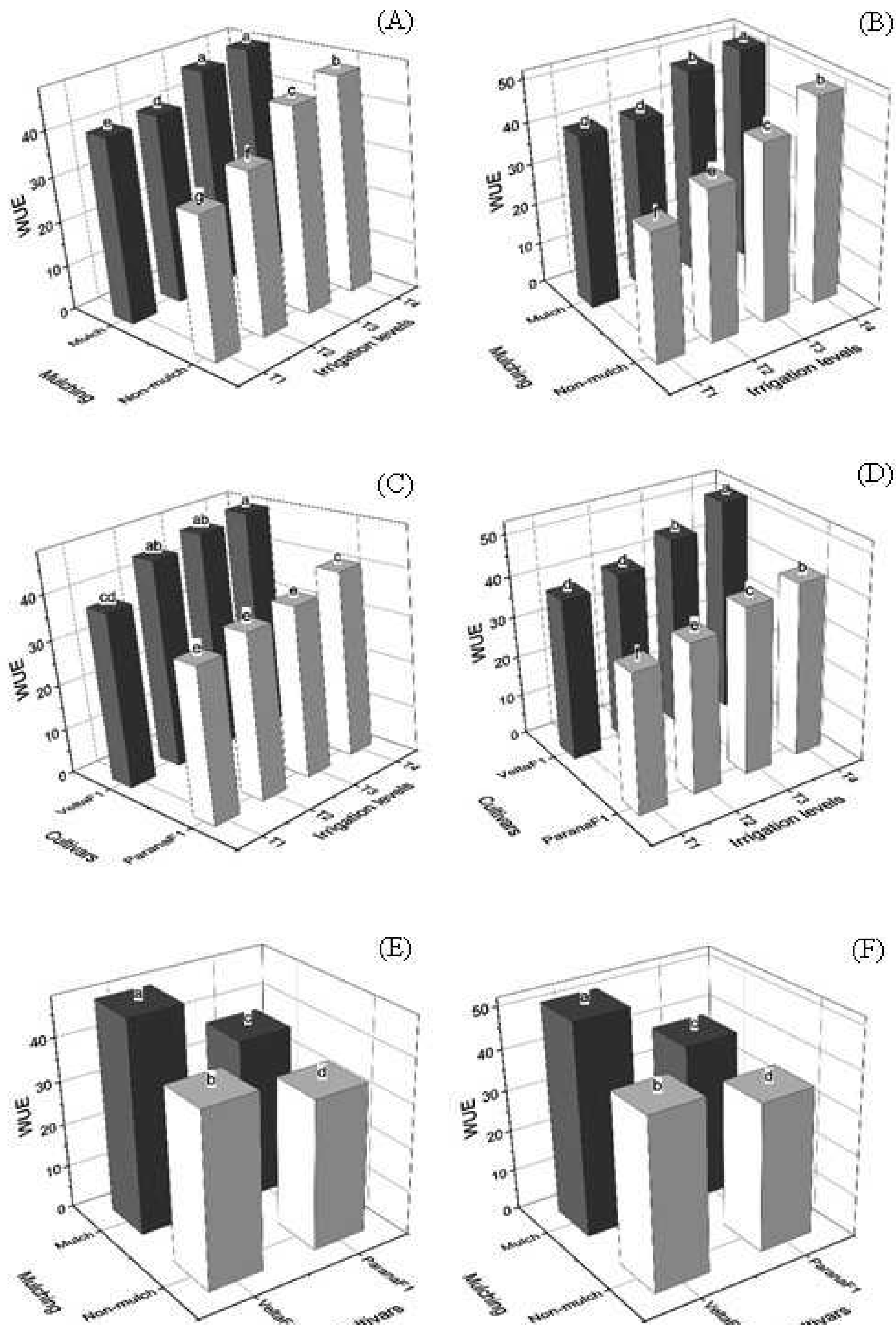

Figure 3. Interaction effect of plastic mulch X irrigation levels (A, B), muskmelon cultivars X irrigation levels (C, D) and muskmelon cultivars X plastic mulch (E, F) on WUE during 2011/2012 and 2012/2013 growing seasons, respectively. Means followed by the same letters are not significantly at LSD 0.05 level.

DISCUSSION

Vegetative growth traits: Application of plastic mulch leads to increased vegetative growth traits of muskmelon plants. Vigorous plant growth (taller plants and higher leaf area) resulted from white-on-black plastic mulch treatment as compared with non-mulched treatment (Table 1). Plastic mulch enhances moisture conservation and availability, which in turn results in improving plant growth (Mahadeen, 2014). Similar observations with respect to improvement in plant growth traits using black plastic mulch were also reported in watermelon (Parmar *et al*., 2013) and summer squash (Mahadeen, 2014).

Higher values of vegetative growth traits were found under higher water levels than under lower water levels. The reduction in plant height and leaf area under water stress treatment (40% ETc) is due to a decrease of the available water in active root zone, which cause a disturbance in the physiological processes essential for plant growth (Refaie *et al*., 2012; Mirbad *et al*., 2013).

'Velta' F_1 plants showed superior vegetative growth traits than 'Parana' F_1 plants. This response could be attributed to the genetic structure of the individual cultivar. Keshavarzpour and Rashidi (2011) reported that cantaloupe cultivars differ in their vegetative growth traits.

Crop yield traits: Crop yield traits **(**fruit number, early and total crop yield) were higher in mulched plants due to the conservation of soil moisture content and temperature maintenance as compared to bare soil plants (Kumar and Lal, 2012; Mahadeen, 2014). Plastic mulch has been recognized for its ability to produce early and high yield in muskmelon (Bonanno and Lamont, 1987; Ibarra *et al*., 2001) and watermelon (Romić*et al*., 2003; Ban *et al*., 2009). Higher soil moisture content and temperature under plastic mulch can improve plant microclimate conditions which hastened growth and decreased time to anthesis and harvest (Mahadeen, 2014). Mulches always increased yield traits when compared to non-mulch application (Ekinci and Dursun, 2009; Gordon *et al*., 2010).

Increasing irrigation levels resulted in high fruit number and thus high crop yield. This approves the suggestion of Hernandez *et al*. (1995) that more fruits of muskmelon were obtained under full irrigation rather than under limited irrigation levels. Faberiro *et al*. (2002) reported that muskmelon crop yield and its components were highly affected by the total volume of irrigation water. The increase in muskmelon fruit yield with full irrigation level (100% ETc) treatment can be attributed to the highest number of fruit plant^{-1} (Table 1). Mousavi *et al*. (2009) found a linear relationship in cantaloupe between the fruit number and crop yield.

'Velta' F_1 cultivar gave the highest fruit number plant^{-1}, early and total crop yield than 'Parana' F_1 cultivar. Fruit number recorded in this study (4.3-5.9) were relatively similar to that detected in Galia-type muskmelon 'Gal-152' cultivar (4.5-7.3) grown under greenhouse conditions (Rodriguez *et al*., 2007). Parallel results related to cultivar differences were recorded in different melon species (Kosterna *et al*., 2011; Sengul *et al*., 2014). Also, Ekinci and Dursun (2009) indicated that the earliest flowering formation and fruiting among five melon cultivars were recorded in 'Galia' F_1 and 'Falez' F_1, respectively.

Crop water productivity : Determination of the optimum crop water productivity represents a fundamental factor influencing crop production, particularly in areas with limited water resources (Mirbad *et al*., 2013). Muskmelon plants grown under plastic mulch had higher WUE and IWUE than non-mulched plants (Table 3). This result was in accordance with Palada *et al*. (2000) who reported that bell pepper plants grown under white-on-black plastic mulch treatment were more efficient in utilizing water as compared with bare soil plants. In general, mulching reduces evaporation at soil surface and plays essential role in decreasing crop evapotranspiration, chiefly in the primary stages of melon plant development. Mulching represents an important option for saving crop water use (Monteiro *et al*., 2008). Furthermore, mulching improves moisture distribution which leads to maximum and efficient water use (Monteiro *et al*., 2014).

WUE and IWUE values under 40% ETc were higher than 80 or 100% ETc irrigation levels (Table 2). Kirnak *et al*. (2005); Simsek and Comlekcioglu (2011) reported similar results. On the other hand, the lowest WUE and IWUE values were found in the 100% ETc level. However, the maximum crop yield (85.79-88.61 t ha^{-1}) was obtained from this treatment (Table 1). This finding confirms that muskmelon is very sensitive to irrigation deficiency as indicated by Fabeiro *et al*. (2002).

Differences in WUE and IWUE values in response to muskmelon cultivars were more evident in 'Velta' F_1 plants (Table 2). These differences in crop water productivity clearly indicate the genetic variability between the two cultivars.

Interaction influence: Improvement of plant growth traits (plant height and leaf area) for muskmelon plants grown under plastic mulch with higher and medium irrigation levels (100 and 80% ETc) was probably due to increasing amounts of irrigation water which initiated plant growth faster than lower irrigation levels. Similar results in muskmelon were reported by Zeng *et al*. (2009). Generally, black plastic mulch application in protected cultivation can help in maintaining optimum soil moisture and reduce the need for more irrigation water (Saleh and Ibrahim, 2007).

Plastic mulch combined with medium and higher irrigation levels (80 and 100% ETc) result in increased fruit number, early and total yield since such treatments provide more moisture conservation, better utilization of nutrients, higher rates of photosynthesis and excess of dry matter accumulation, which in finally lead to vigor plant growth and best crop yield (Rashidi and Keshavarzpour, 2011; Mirabad *et al*., 2013). Full irrigation treatment (100% ETc) with 'Velta' F_1 generated the highest values of fruit number and total crop yield compared to Parana F_1. Similar tendency was obtained with cantaloupe (Refaie *et al*., 2012). The highest irrigation level (120% ETc) produced the highest fruit number of 'Arafa' F_1 hybrid in comparison with 'Rafigal' and 'Primal' cultivars under 80 or 100% ETc (Refaie *et al*., 2012). Water stress treatment (40% ETc) generated the lowest values of muskmelon total yield, particularly with 'Parana' cultivar. Water shortage results in flowers drop and immature fruits which in turn leads to low yield. Application of plastic mulch, particularly with 'Velta' F_1 cultivar resulted in high yield which might be attributed to sufficient soil moisture near the root zone that ensures better plant growth traits as compared to 'Parana' F_1 plants grown in bare soil. Bonanno and Lamont (1987); Ekinci and Dursun (2009) reported that plastic mulches increased early and total crop yield of some melon and muskmelon cultivars compared to non-mulch applications.

The highest crop water productivity (WUE and IWUE) values were recorded under water stress treatment (40% ETc) with white-on-black plastic mulch, while the lowest WUE and IWUE values were recorded with the highest water level (100% ETc) with non-mulch treatment (Table 3). White-on-black plastic mulch positively improved crop water productivity of muskmelon. These results are in agreement with those of Kirnak and Demirtas (2006) who concluded that black plastic mulch caused an improvement in both WUE and IWUE under half irrigation for cucumber plants grown under field conditions. Higher WUE was recorded in mulched plants compared to non-mulched plants under the same lower irrigation treatment. This finding indicates that applying water through drip irrigation system and plastic mulch can enhance irrigation water consumption. Therefore, drip irrigation and mulching were recommended for growing muskmelon in areas with limited water sources. The maximum WUE and IWUE values were detected in 'Velta' F_1 cultivar under lower water level (40% ETc). However, the minimum WUE and IWUE were found with 'Parana' F_1 cultivar under full water level (100% ETc). It is interested to note that 'Velta' plants exhibited higher crop water productivity under the two mulch treatments on WUE and IWUE values in comparison with 'Parana' plants. In this case, 'Velta' cultivar was able to sustain water stress conditions better than 'Parana' cultivar. Ban *et al*. (2006) showed in their study on melon species that the influence of plant genotype was more pronounced than the effect of polyethylene mulches.

Crop yield enhancement and irrigation water saving: Increasing the muskmelon crop yield under 80% ETc with white-on-black plastic mulch treatment for 'Velta' F_1 cultivar can be achieved while saving 20% of applied water (Table 4). Yildirim *et al*. (2009) indicated that application of full irrigation water did not significantly increase crop yield of 'Kırkağac' melon cultivar (the common Turkey cultivar) compared with the application of 75% of full irrigation water. Hernandez *et al*. (1995); Alizadeh *et al*. (1999) reported that application of limited irrigation water might improve the crop yield though saving water in comparison with the use of full irrigation water. Therefore, using white-on-black plastic mulch under medium irrigation level (80% ETc) for 'Velta' F_1 cultivar might have a positive impact on muskmelon production under greenhouse conditions.

Conclusions: Muskmelon yield enhancement and irrigation water saving can be achieved by appropriate management practices such as mulching and irrigation regime treatments. Irrigation management in combination with plastic mulch treatment can improve WUE along with enhancement of muskmelon yield. The use of plastic mulch in muskmelon gave rise to more efficient use of irrigation water and higher crop yield for 'Velta' as compared to 'Parana' plants. Plastic mulch and the application of medium irrigation level (80% ETc) might be the most proper treatment for muskmelon productivity while saving water (about 20%) under greenhouse conditions.

Acknowledgments: We acknowledge the Deanship of Scientific Research, King Saud University and Agricultural Research Center, College of Food and Agriculture Sciences for the financial support to this research.

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