EFFECT OF DRIP IRRIGATION AND PLASTIC MULCH ON YIELD AND EARLY HARVEST OF MUSKMELON UNDER SEMI-ARID CLIMATE CONDITIONS

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ABSTRACT

The experiments were conducted on the clay loam soil of Esfahan in central of Iran during middle of March-July for 2 years to evaluate the yield of muskmelon (Cucumis Melo Var Reticulatus) under mulched, irrigation level and irrigation system treatments. Rainfall is erratic and meager during the crop season in the Esfahan region; therefore, muskmelon crop only can be grown with irrigation. Actual evapotranspiration for muskmelon crop was estimated by using a standard class A pan located close the experimental site and net daily irrigation requirement was estimated after subtracting effective rainfall. The trials involved three treatments: two kind of irrigation systems (surface and drip irrigation), two level of irrigation amount (75 and 100 percent of irrigation water requirement) and three level of mulches (black and transparent plastic mulches and without mulch as a control). The experiment was arranged in a split-Split-plot design and consisted irrigation systems in the main plots, irrigation level as subplots and mulches level as sub-subplots. In 2000, average yield from surface and drip irrigation systems are 66 and 62.5tha^{-1}, respectively. While in 2001, fruit yields for the same systems was 46.1 and 46.3tha^{-1}. The results shows that water use efficiency for surface and drip irrigation were 4.8 and 11.2 kg m^{-3}, respectively. Statistical analysis of the yield data indicated no significant ($P > 0.05$) difference between years and irrigation systems. But, water use efficiency in drip irrigation system was 2.5 times higher than that of for surface irrigation. The highest muskmelon yields from surface and drip irrigation systems were obtained at full irrigation treatments (received 100% of irrigation water requirement). Bigger fruits were obtained with optimum irrigation amounts for both of the irrigation systems. Therefore, the best irrigation system was drip irrigation system due to yield precocity, decreasing the water consumption and increasing the water productivity. Higher yield and better crop growth was observed in the mulched plots, which might be due to conservation of soil moisture. Application of black and transparent plastic mulched significantly ($p < 0.05$) increased the muskmelon fruit yield precocity, available soil moisture and decreased irrigation times particularly in early growth season and greatly controlled the weeds. Significantly, ($p < 0.05$) higher water use efficiency was recorded in the mulched plots compared to the non-mulched plots under the same irrigation treatment.

This result shows that, applying the drip irrigation system, irrigation management and plastic mulches can optimize the water consumption. Therefore, drip irrigation system

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and mulching were recommended for growing muskmelon in the region under limited water availability.
Keywords: Muskmelon, Plastic mulch, Drip irrigation, Esfahan, Iran

INTRODUCTION

The pressure on agriculture is increasing due to population growth thereby creating a need to improve agricultural production. Water has been identified as one of the most scarce inputs, which can severely restrict agricultural growth unless it is carefully conserved and managed. The Baraun Plain (52^{o} lon., 32.5^{o} lat) is one of the main plain of agricultural land in the Zayandeh Rud basin, Esfahan, Iran. The main river for this area is the Zayandeh Rud, runs for 350 km roughly in west-east from the Zagros Mountains to the Gavkhuni Swamp. The majority of the basin is a typical arid and semi-arid desert. The gross command area of the Baraun plain is about 80,000 ha. Cropped area is between 70 and 80%. Main crops are wheat, barley, rice, alfalfa, corn, sugar beet, vegetables and orchards. Muskmelon is one of the major vegetable crops in this region. Rainfall in this area, which is situated at an elevation of 1500 m, is very limited, around 120 mm annually, most occurring in the winter months from December to April. Most of the plain is irrigated using surface irrigation, mostly furrows and borders. However, due to present methods for utilization of water resources, the utilizable water for irrigation is limited. There exists a large gap between the irrigation potential created and utilized due to losses through conveyance system and application while adopting surface irrigation system. Therefore, adoption of modern irrigation techniques is needed to be emphasized to increase water use efficiency and covering more area under cultivation. (Akbari et al., 2009). Drip irrigation is the most effective way to supply water and nutrients to the plant and not only saves water but also increases yield of fruits and vegetable crops. Previous research shows that the yields and quality of the vegetable crops are improved through application of water by drip irrigation alone or along with different types of plastics and organic mulches (Tiwari et al., 1998; Tiwari et al., 2003). Sivanappan el al.,(1987) compared drip and furrow irrigation systems and found that about one-third to one-fifth of the normal quantity of water was sufficient for drip irrigated vegetable crops compared to those under surface irrigation. Sivanappan et al. (1987) also recommended drip irrigation in place of furrow irrigation due to the reduction in water use with as little as 15.3% water used without any loss of yield. Therefore, farmers in this region need more efficient irrigation systems such as drip irrigation systems for their high-income crops. Since there is a shortage of freshwater, crops are deficit irrigated. Deficit irrigation practices were well studied on agronomic crops such as soybean, and wheat (Dogan et al. 2006).

It is unanimously accepted that production and its components are highly influenced by the total irrigation volume (Fabiero et al., 2002) and that irrigation requirements are related to the cropping technique like the planting time, to the relatively deep preparatory tillage in autumn, to organic matter supply, to the possible use of mulches and to the cultivation environment (Rivelli et al., 2003). Hartz (1997) claimed that the use of drip irrigation system to irrigate melon production was increasing in semi-arid regions of the USA. In general, it was reported that drip irrigation system increases melon yield compared to furrow irrigations (Shmueli and Goldberg 1971; Bogle and Hartz 1986). Lester et al. (1994) also indicated that a 4-day irrigation interval produced the highest melon yield. Fabeiro (2002) claimed that similar to other agronomic and horticultural crops, the effect of irrigation water on melon production was found to be positive (Pier and Doerge 1995; Meiri et al. 1995).

Plastic mulches in the world are widely applied to vegetable crops and to muskmelon in particular. Plastic mulches have numerous advantages, one of them being a reduction in losses by evaporation from bare soil. Associated with the reduction in evaporation losses, transpiration increases because both sensible and radiative heat are transferred from the surface of the plastic cover to adjacent vegetation. Even though the transpiration rates in a muskmelon cantaloupe crop under plastic mulch may increase by 35% is reported in the literature because of reduced soil evaporation estimated to be about 80% (Battikhi and Hill, 1986).

Tiwari et al. (1998) evaluated the economic feasibility of drip irrigation in combination with different types of mulches for an okra crop. The study indicated that 100% irrigation requirement met through drip irrigation along with black plastic mulch resulted 72% increase in yield as compared to furrow irrigation. Tiwari et al. (1998) studied the economic viability of drip irrigation either alone or in combination with organic and black plastic mulches over conventional furrow irrigation system for tomato production. The study revealed that drip coupled with black plastic mulch displayed yields 65% more than obtained under conventional furrow irrigation. The beneficial effect of mulches on plants includes earlier production (Call and Courter,1989; Decoteau et al.,1989), greater total yield and reduced insect and disease problems(Jensen,1990). Use of different types of mulches such as black plastic film, paddy straw and crop residues have been found to conserve the moisture, control weeds, moderate soil temperature and increase in yield of different vegetables.

Lester et al. (1994), reported that drip irrigation increased yield but reduced soluble solid content. So, They indicated that over irrigation resulted in reduced yield and fruit-soluble solids content of melon. Srinivas et al. (1989) studied the effect of surface drip irrigations and deficit irrigation practices on watermelon yield and drip irrigation system produced more watermelon yield than surface irrigation systems. Additionally, fully irrigated plots had more yield compared to deficit irrigated ones. Orta et al. (2003) and Wang et al. (2004) applied water stress on watermelon plants and found that fully irrigated treatments produced the highest yield. It is reported that irrigation increased yield of melon and quality compared to deficit -irrigated crops (Meiri et al. 1995; Detar et al. 1983; Bhella 1985). In general, studies conducted in the Harran Plain indicated that 125% of class A pan evaporation values applied to watermelon produced the highest yield with about 80 t ha–1 (Simsek et al. 2004; Gu¨ndu¨z and Kara 1995). Irrigation studies with horticultural crops such as melon are limited. In addition, use of surface and surface drip irrigation systems with horticultural crops are relatively new and the effects of those highly efficient irrigation systems on crop yield and yield components are not well documented. However, very little work seems to have been undertaken on the muskmelon crop under surface and drip irrigation with mulch and non-mulch conditions for semi-arid climate of Esfahan in center of Iran. The present experiment is undertaken to study the influence of surface and drip irrigation system, irrigation levels, under mulch and non-mulch conditions on yield and to evaluate the water productivity of the cultivated muskmelon crop under semi-arid climatic conditions.

MATERIALS AND METHODS

Site description

The experiment was conducted at the experimental farm in Kaboutarabad research station of Esfahan, Iran, (52^{o} lon., 32.5^{o} lat, 1500 m above sea level) during the months of March- July for two years (2000-2001). The texture of the soil was clay loam soil with gravimetric-based field capacity and wilting point values of 31 and 15%, respectively (Table 1). Average soil bulk density, pH, and electrical conductivity values of top 60 cm were 1.4 g cm^{-3}, 7.5, 5.5 dS m^{-1}, respectively. Climatic conditions in 2000 and 2001 years were typical of long-term weather conditions of the study area, which has a semi-arid climate. In 2000, seasonal average temperatures, relative humidity, solar radiation, and wind speed during melon-growing season were 23.0^{C}, 20.7%, 2717 cal cm^{-2}, and 2.3 ms^{-1}, while in 2001, those values were 23.1^{C}, 23.1%, 2674 cal cm^{-2}, and 2.3 ms^{-1}, respectively (Table 2).

Table 1. soil properties of experimental site in the study area.

Texture	Soil particle distribution (%)			OM	Bulk density	PWP	FC	Soil depth
	Sand	Silt	Clay	%		%	%	
Clay loam	10	49	41	1	1.31	14.5	32.5	0-30
Silty clay loam	20	43	37	0.5	1.44	15.8	30.4	30-60

FC field capacity, PWP permanent wilting point, AWC available water capacity, OM organic mater

Table 2. Climatic condition during the experiments

Months	Minimum air temperature (C)	Maximum air temperature (C)	Average relative humidity (%)	Average air temperature (C)	Wind speed (ms^{-1})	Total solar radiation (cal cm $^{-2}$)
2000						
March	4.1	19.6	25.6	12.4	2.6	2322.0
April	11.2	27.2	22.9	19.9	2.6	2439.4
May	15.3	32.6	18.2	24.9	2.7	2911.6
June	18.1	35.6	18.0	27.3	1.8	2877.0
July	20.9	37.7	20.5	29.9	1.7	3026.0
2001						
March	5.5	19.5	39.1	12.7	2.0	2358.1
April	10.8	27.1	21.0	19.6	2.5	2576.5
May	14.1	30.8	24.5	23.3	2.5	2697.0
June	18.5	35.7	16.5	27.9	1.9	2915.8
July	23.0	39.6	16.2	32.0	2.2	2761.6

Experimental design

The experiment was arranged in a split-Split-plot design and consisted of two kind of irrigation systems include, surface and drip irrigation systems in the main plots, 75 and 100 percent of irrigation water requirement as subplots and three levels of mulches (black and transparent plastic mulches and without mulch as control) as sub-subplots with three replications. In the spring of 2000, a drip irrigation system with 16-mm lateral diameter was installed for drip irrigation treatments. Emitters were 0.5 m apart (one for each plant) and had a constant discharge rate of 4lh^{-1}. Each row had ten plants were 0.5 m apart. Treatment plots had 30 plants in total. Each plot had a valve and Flow-meter at the entrance of the drip lateral in order to control irrigation water amounts. Each plot had three 6 m long and 4.5 m width and an area of 27m^{2} in 2000 and 2001. Additionally, there was a 2 m empty gap between plots in order to eliminate any water movement from adjacent plots.

Sowing technique

First, the soil surface was leveled, manure and chemical fertilizer were applied, and black and transparent plastic film was mulched by hand every year. Then holes were drilled by hand in 0.2m in diameter with rows of 0.5m apart and 5cm deep in the center of rows, right next to the emitters in drip irrigation. Holes were separated 0.5m apart within rows. Muskmelon was seeded 3-4 grains in each hole on the end of March in 2000 and 2001 in treatment plots. Then the holes filled with soil. All above operations were done by hand.

Estimation of water requirement and irrigation application

Climate data were obtained from Kaboutarabad meteorological station in the vicinity of the experimental site. A standard class A pan located close by the research area was used to determine evaporation from open water surface and then irrigation amounts depending on treatment rates were determined. Irrigation was started in equal amounts of water were applied to all plots until muskmelon plants reached 20% field coverage. The irrigation treatments were applied to experimental plots using a 3-day irrigation interval in drip irrigation and 7-day in surface irrigation system. Irrigation water amounts were determined using the following equation (Allen et al., 1998)

$$I=E_{pan}AK_{cp}P$$

where I irrigation water amounts (mm), E_{pan} evaporation from a standard class A pan (mm), A plot area (m^2), K_{cp} crop pan coefficient (0.75), and P crop coverage (%).

Agronomy management and crop measurements

At the usual time, some of the cultivation practices such as hand-hoeing, pesticide and herbicide applications and fertilizations were completed. In both of the years, all plots received nitrogen at 100 kg ha^{-1} rate as ammonium nitrate in three equal amounts injected through surface and drip irrigation systems.

The time of melon fruit harvest was determined based on visual observations, and all mature muskmelon fruits were hand harvested. Results from middle row of each plot were used in this study and the other two rows were border rows. There were a total of three harvest events in both 2000 and 2001. During harvest, fruit weight with a balance, fruit number, fruit flesh thickness with a digital compass, and soluble solid content of muskmelon with a digital pocket reflectometer (china) were measured. Additionally, as an indicator of fruit size, mean fruit weight for all treatments and replications were determined by dividing total weight to total number of fruits from treatment plots. Any fruit bigger than 0.5 kg was assumed to be of an acceptable size and any fruit smaller and/or had any blemishes was assumed not to be marketable and therefore was not considered in this study. Differences in measured values among main plot (irrigation systems), sub-main effects (irrigation levels) and sub-subplot effects (black and transparent plastic mulches and without mulch as control) were analyzed using ANOVA test procedure.

RESULTS

Effect of irrigation levels on muskmelon yield.

During 2000-2001, the yield was recorded in each treatment for both irrigation systems Fig. 1. In 2000, average muskmelon fruit yield from surface and drip irrigation systems are 66 and 65.5tha^{-1}, respectively. While in 2001, fruit yields for the same systems was 46.1 and 46.3tha^{-1}. Observed yield data in this study were similar to previous study results conducted by Farhadi et al., (2002). Fruit yield analysis of 2000 data using ANOVA test procedure indicated that no significant ($P < 0.05$) difference between irrigation systems, but the highest muskmelon yields was obtained from drip irrigation systems at full irrigation treatments (received 100% of irrigation water requirement). The results show that water applied for full irrigation in surface and drip irrigation were 12556 and 5092 m^{3}ha^{-1}, respectively. However, water applied in surface irrigation was 2.5 times of drip irrigation system, but statistical analysis of the yield data indicated no significant ($P > 0.05$) difference between irrigation systems. Hence, it show that even by 60% reduced water application through drip resulted higher yield than that of conventional surface irrigation as was found by Sivanappan et al. (1987).

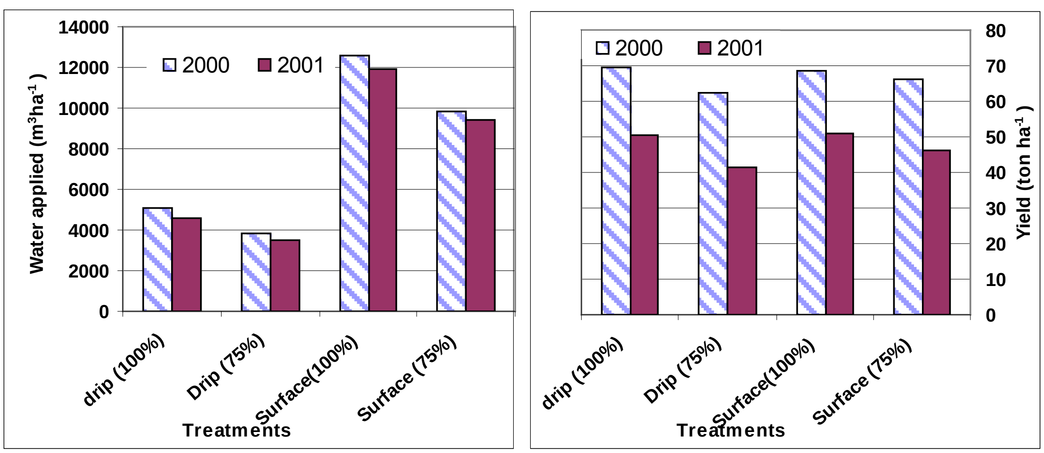


Figure 1. Yields and water applied for different treatment in surface and drip irrigation systems.

Comparison of water use efficiency in different treatment

Figure 2 present the water use efficiency for different treatment in surface and drip irrigation systems. There is a least variation in water use efficiency obtained in 2 years in case of different yields and water applied. The water use efficiency of muskmelon at all irrigation levels under drip irrigation was significantly greater (5% level) than that of surface irrigation for the 2 years. The results show that water use efficiency for surface and drip irrigation was 5.4 and 13.2 kg m^{-3}, respectively. Statistical analysis of the water use efficiency data indicated the significant ($P > 0.01$) difference between years and irrigation systems. Water use efficiency in drip irrigation system was 2.5 times higher than that of for surface irrigation. The highest muskmelon water use efficiency was obtained from drip irrigation system that received 75% of irrigation water requirement (Fig 2).

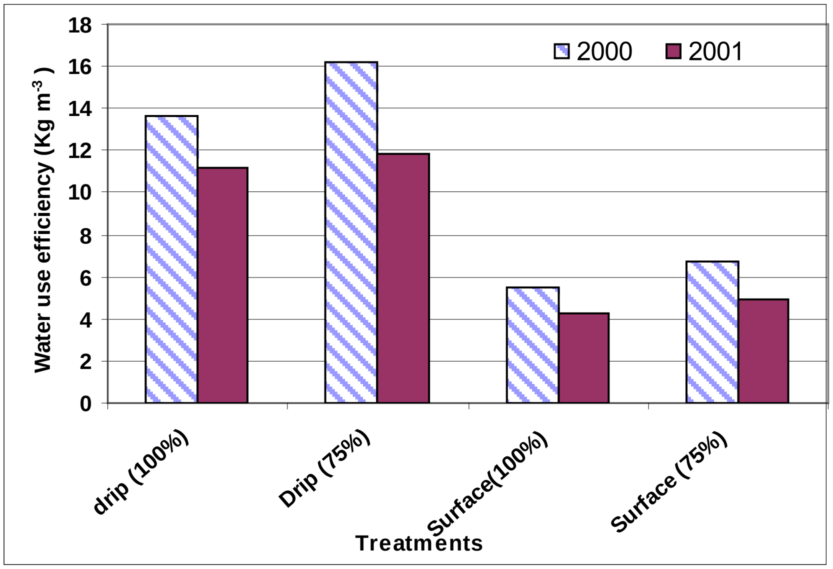
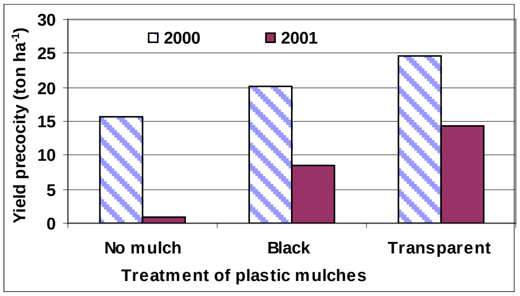


Figure 2. Water use efficiency for different treatment in surface and drip irrigation systems.

Effect of mulches on yield and yield precocity

Figure 3 presents the yield and yield precocity of muskmelon under different plastic mulches in surface and drip irrigation systems. Higher yield and better crop growth was observed in the mulched plots, which might be due to conservation of soil moisture. Application of black and transparent plastic mulched significantly ($p < 0.05$) increased the muskmelon fruit yield and precocity, available soil moisture and decreased irrigation times particularly in early growth season and greatly controlled the weeds. Significantly, ($p < 0.05$) higher water use efficiency was recorded in the mulched plots compared to the non-mulched plots under the same irrigation treatment. This result shows that, applying the drip irrigation system, irrigation management and plastic mulches can optimize the water consumption. Therefore, drip irrigation system and mulching were recommended for growing muskmelon in the region when limited water was available.
The initial economic analysis of plastic mulch in muskmelon field show that, the net seasonal income, benefit–cost ratio and net profit per mm of water used were found to be highest for the treatments with plastic mulched. So it was of more benefit in economic that plastic mulch be applied under lower water availability conditions in muskmelon field. However, plastic mulch increased muskmelon fruit yield and yield precocity, but soil was polluted by small-plastic debris left in field. Li et al. (1999) found that the use of transparent plastic film over a period longer than 40 days was detrimental to grain yields and might produce soil pollution. Therefore, plastic film should be removed from field carefully after muskmelon fruit harvest. Bigger fruits were obtained with full irrigation amounts for both of the irrigation systems. Hence, the best irrigation system was drip irrigation system due to yield precocity, decreasing the water consumption and increasing the water use efficiency.



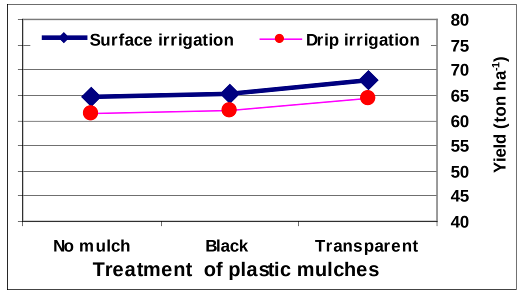


Figure 3. Yield and yield precocity of muskmelon under different plastic mulches in surface and drip irrigation systems.

CONCLUSINS AND RECOMMENDATION

In 2000 and 2001, until 30% field coverage, full irrigation water requirement was applied to all treatment plots in order to ensure a good plant stand. Fully irrigated treatment plots in 2000 and 2001 received a total of 509 and 455 mm irrigation water, respectively. Based on two years experimental results and analysis of surface and drip irrigation systems for cultivating muskmelon, the following conclusions can be drown:

Irrigation water amounts in this study from 2000 were a little higher than 2001 because of late germination and about a 15-day longer growing season along with more severe climatic conditions. On average, monthly relative humidity in 2000 was 2.5% lower, compared to 2001. Approximately 5000 m^3ha^{-1} irrigation water requirement would be need for muskmelon in Esfahan semi-arid climatic condition.

The use of drip irrigation either alone or in combination with mulched can not increased the total muskmelon yield significantly rather than surface irrigation. But, application of black and transparent plastic mulched significantly ($p < 0.05$) increased the muskmelon fruit yield precocity, available soil moisture and decreased irrigation times particularly in early growth season and greatly controlled the weeds. In addition, water use efficiency in drip irrigation system with mulched was 2.5 times higher than that of surface irrigation.

Fruit yield analysis of 2000 data using ANOVA test procedure indicated that there was significant ($P < 0.05$) difference among irrigation levels and the highest yield ($P < 0.05$) was from full irrigation treatments from surface and drip irrigation systems, even though the highest mean yield was from full irrigation treatment in both of the surface and drip irrigation systems.

Overall, muskmelon fruit yield results indicated no significant difference between surface and drip irrigation system. Fruits size from both of the irrigation systems was bigger at optimum irrigation water amounts. Overall, study results clearly shows that under semiarid climatic conditions any reduction in irrigation amount from optimum irrigation water requirement for surface and drip irrigation systems would result in reduced ($P < 0.05$) muskmelon yield along with fruit size. Hence, drip irrigation system used 60% less water and produced the same amount of muskmelon fruit yield. Therefore, under limited water sources it could be recommended that farmer might use drip irrigation system under semi-arid climatic conditions.

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