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EFFECT OF DIFFERENT PLANT DENSITIES ON THE FRUIT YIELD AND SOME RELATED PARAMETERS AND STORAGE LOSSES OF FODDER WATERMELON (*Citrillus lanatus var. citroides*) FRUITS

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ABSTRACT

This study was conducted in order to determine the effect of different plant densities (4762, 7143, 9524, 14286, 28571 plants ha^{-1}) on the fruit yield and some other yield components of fodder watermelon under typical Mediterranean climate conditions during summer period of 2012 and 2013. Results indicated that average number of fruit per plant increased by decreasing plant densities but not single fruit weight and soluble solid content. It was suggested that 9524 plants ha^{-1} (210x50cm) of fodder watermelon was the most successful crop density regarding the total fruit yield (189 t ha^{-1}). It was also concluded that fodder watermelon fruits can be easily stored 210 days with 24% weight loss without any rot.

Key words: fodder watermelon, plant density, fruit yield, brix, storage.

INTRODUCTION

Fodder watermelon (FWM) (*Citrillus lanatus* (Thunb.) Matsum. & Nakai var. *citroides* (Balley) Mansf.) is a new species for agricultural potential in Turkey or some European countries like Serbia, Bosnia & Herzegovina and resembling ecologies (Acar, 2009). The fodder watermelon is a cucurbitaceous originating from Africa, introduced in the Northeast by the slaves, that through hybridization with other species of the genus is being diffused until today (Silva, 2003).

FWM is possibly a promising crop for growing in Turkey and other countries because of the following: i) a good stogare quality of the fruit; its fruit can be stored for one year, due to a high content of pectins; ii) large fruit and high yields; the fruit reach a weight of 15 to 20 kg; iii) resistant to a number of diseases and lesser demands on cultivation conditions (Simić et al., 2013). However, together with these mentioned qualities, there are also certain shortcomings: fairly late ripening and a fruit pulp which is not sweet and is too compact (Simić et al., 2011). The fruits of FWM used as a flavourant especially for straw in winter-feeding of animals and their hulled kernels are also a high protein (18.1%) and oil (23.3%) source (Acar et al., 2012).

Some farmers in northeast Brazil feed their animals by FWM during the dry season as they have jumbo fruit (sometimes more than 15 kg) (Aquino et al., 2000). Depending on the amount and distribution of the rainfall in Brazil, one hectare of the brushwood area can produce between 25 and 30 tons of the fruits. Storage of the production in the actual field is cheap and practical, allowing for conservation of the fruits during the dry season. The fodder species, on the contrary of traditional watermelons, has a skin tough enough to resist impact and deterioration, white and generally consistent pulp with a low sugar content, which renders it tasteless (Simić et al., 2013). Silva et al. (2009) recommended the fodder watermelon meal with hay for lambs in the ratio 35 to 66% of ration.

Some experiments on FWM indicated that the fruit yield depend on sowing date and plant density (Geren et al., 2011; Simić et al., 2011). As is the other cultivated plant, optimum plant density is an important factor in maximizing yields of FWM. Thus, the optimum plant density or plant population for any given situation results in mature plants that are sufficiently crowded to efficiently use resources such as water, nutrients, and sunlight, yet not so crowded that some plants die or are unproductive (Lyon, 2009). At this population, production from the entire field is optimized, although any individual plant might produce less than would have occurred with unlimited space.

Many factors influence the optimum plant population for a crop: availability of water, nutrients and sunlight; length of growing season; potential plant size; and the plant's capacity to change its form in response to varying environmental conditions (Ramírez et al, 2009). Currently, a common commercial (edible) triploid watermelon spacing is 244 cm by 92 cm or approximately 2.3 m^{-2} per plant (Schultheis et al., 2009). Acar et al. (2014) reported that number of fruit per plant and total fruit yield of FWM at density of 8334 plant ha^{-1} (1.5 m x 0.8 m) were 1.41 and 66 t ha^{-1}, respectively.

Generally, higher plant populations are suggested for lighter, less productive soils than for heavier, more productive soils. Watermelons can compensate somewhat for differences in plant population through adjustments in fruit size. Akimtoye et al. (2009) reported that average fruit weight of commercial watermelon decreased with increased planting density.

Walters (2009) investigated different crop densities (6150, 7687, 10252, 15377, 20502, 30754 plant ha^{-1}) on mini watermelon cultivars and reported that although number of fruit per plant decreased with increased plant density, the total fruit yield increased by increasing of plant population. Optimisation of plant density is necessary in FWM production.

The objective of this research was to evaluate the influence of different planting densities on the fruit yield, some yield components and storage losses of FWM under irrigated conditions of Mediterranean climate.

MATERIALS AND METHODS

Location of Experiment

Field experiment was conducted during the main cropping seasons in 2012 and 2013 on a private farm in Soke-Aydin, located about 35 m above sea level. The climate is typical Mediterranean, with temperate and rainy winter season, and hot and dry summer. Average temperature of experimental area was 26.5-23.8°C, total precipitation 13-44 mm and relative humidity 51-56% from beginning of June to end of October in 2012 and 2013, respectively. The soil had loamy texture (65% silt, 20% clay and 15% sand) with a pH of 7.1, 3.3% organic matter, 1.2% $CaCO_3$, 31.0 ppm available P and 218.0 ppm available K. There was not any limiting factor in terms of meteorological conditions and soil properties to grow FWM. The preceding crop at experimental site was *Vicia villosa*.

Field applications and experimental design

A local FWM population originated from Turkmenistan was used as plant material. The field experiment was set up in a randomised complete block design with three replications. Six plant densities (70x50, 70x100, 140x50, 140x100, 210x50, 210x100 cm or 28571, 14286, 14286, 7143, 9524, 4762 plants ha^{-1}, respectively) were evaluated. The experimental plots were sown in five rows (for 70 cm apart), three rows (for 140 cm apart) and two rows (for 210 cm apart) (width of plot was 3.5 m) 7 m long on 10 June 2012 and 2013 by hand. Four FWM seeds with high germination rate (98%) sown directly into soil at 2-3 cm depth. Seedlings with 3-5 leaf stage were singled out per hole. Crops were fertilised by 800 kg ha^{-1} NPK (15:15:15) and 200 kg ha^{-1} ammonium nitrate (33%). In both years, the plots in the field were irrigated by drip irrigation method in every 8 days until the end of harvest season. The weed was controlled twice by hand-hoed.

Measurements

Harvest was performed only once at the end of growing seasons on 29 October 2012 and 2013. All fruits were collected from the plots and the following measurements were recorded: number of fruits per plant, fruit yield (kg ha^{-1}), average fruit weight (kg $fruit^{-1}$) and total soluble solids concentration (brix). The soluble solid content of the juice obtained from the central endocarp was determined by a refractometer. The samples were randomly selected by taking 3 fruits of different sizes (marked with numbers) from each plant density treatment and stored during 7 months in an ordinary dark warehouse (uncontrolled) condition. They weighted monthly, and the mean of the loss percentage of each marked samples was calculated on the basis of the weight of the fresh samples in both years.

Statistical analysis

All data were statistically analyzed using analysis of variance (ANOVA) with the Statistical Analysis System (SAS, 1998). Probabilities equal to or less than 0.05 were considered significant. If ANOVA indicated differences between treatment means a LSD test was performed to separate them.

RESULTS AND DISCUSSION

The results indicated that the effects of different plant population densities of FWM were statistically significant but not year except on soluble solid content of the juice.

Number of fruit

There were statistically significant differences among plant densities regarding average number of fruit per plant (Table 1). Minimum plant density being 4762 crop ha^{-1} had the highest average number of fruit (5.32 fruit $plant^{-1}$), whereas maximum plant density being 28571 crop ha^{-1} was the lowest (1.80 fruit $plant^{-1}$). It was found that lower plant population of fodder watermelon increased average number of fruit per plant in the experimental area.

There are many reports and reviews on the theoretical aspects of the relationship between number of fruit and plant population density (NeSmith, 1993; Akimtoye et al. 2009; Walters, 2009). In general, increasing a plant population produces a greater yield per unit land area for most crops up to some upper limit or threshold density for the species, after which further increases in plant density either maintain the same yield or cause yield decline (Sanders et al., 1999). NeSmith (1993) reported that marketable fruit number increased 3.75 to 5.75 $plant^{-1}$ as plant population increased from 3030 plant ha^{-1} (1.5-2.2 m) to 7407 plant ha^{-1} (1.5-0.9 m) in commercial watermelon. Some researchers emphasized that average number of fruits of FWM were 5.7, 2.5 or 1.4 per plant under the ecological conditions of Belgrade (Simić et al., 2013), Izmir (Geren et al., 2011) and Konya (Acar et al., 2014), respectively.

Table 1. Effect of different plant populations on the fruit yield and other yield components of FWM grown under Soke ecological conditions in different years.

Plant Density (plant ha^{-1})	2012	2013	Mean	2012	2013	Mean
	Average number of fruit per plant			**Average fruit weight (kg)**		
28571 (70 x 50 cm)	1.81	1.78	1.80 d	2.14	1.98	2.06 d
14286 (70 x 100 cm)	2.22	2.33	2.27 c	4.16	4.35	4.26 c
14286 (140 x 50 cm)	2.19	2.25	2.22 cd	4.31	4.32	4.32 c
7143 (140x100 cm)	4.12	4.29	4.21 b	4.83	4.64	4.74 b
9524 (210 x 50 cm)	4.59	4.62	4.61 b	4.86	4.96	4.91 b
4762 (210x100 cm)	5.31	5.32	5.32 a	5.18	5.25	5.22 a
Mean	3.37	3.43	3.40	4.25	4.24	4.25
LSD (0.05)	Y:ns P:0.45 YxP:ns CV(%):10.96			Y:ns P:0.28 YxP:ns CV(%):5.51		
	Total fruit yield (t ha^{-1})			**Soluble solid content (%)**		
28571 (70 x 50 cm)	88.67	90.91	89.79 e	1.88	1.89	1.88 d
14286 (70 x 100 cm)	109.93	112.11	111.02 d	1.97	2.07	2.02 c
14286 (140 x 50 cm)	110.10	111.62	110.86 d	2.01	2.08	2.05 c
7143 (140x100 cm)	120.14	118.54	119.34 c	1.98	2.18	2.08 c
9524 (210 x 50 cm)	190.45	188.19	189.32 a	2.42	2.46	2.44 b
4762 (210x100 cm)	133.65	137.42	135.53 b	3.37	3.55	3.46 a
Mean	125.49	126.46	125.98	2.27	2.37	2.32
LSD (0.05)	Y:ns P:5.61 YxP:ns CV(%):3.72			Y:0.08 P:0.13 YxP:ns CV(%):4.77		

Y: year, P: plant population, YxP: interaction, ns: not significant, CV: coefficient of variation
Means in the same columns followed by the same letters are not significantly different at the 0.05 level.

Fruit weight

The effect of plant population on average fruit weight of FWM was significant (Table 1). The highest average fruit weight was recorded at 210x100 cm (4762 plant ha^{-1}) (5.22 kg) as compared to 70x50 cm (28571 plant ha^{-1}) (2.06 kg). It is possible that the lower number of plants per unit area helps the growth of plants because of better accessibility of light, fertilizer nutrients and water, thereby increasing the accumulation of nutritive ingredients in the fruits. These results are in agreement with those recorded by Schultheis et al. (2009). Sanders et al. (1999) investigated different crop densities (4444 [1.5-0.45m], 5555 [1.5-0.60m], 7407 [1.5-0.90m], 11111 [1.5-1.2m], 14815 [1.5-1.5m] plant ha^{-1}) on commercial watermelon cultivars and reported that although number of fruit per plant decreased with increased plant density, fruit weight per plant (7.5 to 10 kg) slightly increased by increasing of plant population. They also stated that higher population caused higher cull fruits number. Generally, higher plant populations are suggested for lighter, less productive soils than for heavier, more productive soils. Watermelons can compensate somewhat for differences in plant population through adjustments in fruit size, and, appear to be able to exploit the below- and aboveground resources (water, nutrients, light) equally well whether or not they are uniformly spaced (Lyon, 2009).

Total fruit yield

Significant difference in total fruit yield was recorded among plant populations. The highest fruit yield (189.32 t ha^{-1}) was obtained at 210x50 cm (9524 plant ha^{-1}) while the least value (89.79 t ha^{-1}) was obtained with 70x50 cm (28571 plant ha^{-1}). Fruit yield of FWM gradually increased with the decreasing plant density until 9524 plant ha^{-1}, but following that density, yield was also decreased due to the lack of the number of plants per unit area. Though lower densities increased yield per hectare, it leads to an increase in the fruit mass (kg $fruit^{-1}$) which may be attributed to limited competition among plants for sunlight and nutrients. Sanders et al. (1999) and Walters (2009) reported that the total fruit yield increased by increasing of plant population.

Duthie et al. (1999) indicated that watermelon yield per plant tends to decrease with higher plant densities because interspesific competition intensifies and this directly suppresses plant growth, resulting in lower yields per plant. Although Duthie et al. (1999) suggested that high plant populations (18150 and 12100 plants ha^{-1}) provided the greatest marketable numbers of fruit, our results indicated that lower plant density (9524 plants ha) can be used to increase FWM number and weight. However, there is a paucity of information concerning the influence of plant population on FWM yield and yield components, particularly available information to growers. Some researchers reported that total fruit yield of FWM were 152, 88 or 66 t ha^{-1} at different plant densities under the ecological conditions of Belgrade (Simić et al., 2013), Izmir (Geren et al., 2011) and Konya (Acar et al., 2014), respectively.

Soluble solid content (SSC)

There were significant differences among plant densities in terms of SSC. Minimum plant density (4762 plant ha^{-1}) had the highest SSC (3.46%), whereas maximum plant density (28571 plant ha^{-1}) was the lowest SSC (1.88%). Year effect was also significant and average SSC of first year (%2.27) was lower than the second year (%2.37). No interaction was detected between year and plant density. It was found that lower plant population increased the soluble solid content of FWM juice in experimental area. As expected, the soluble solid contents of FWM were lower compared to commercial (edible) triploid watermelon genotypes (Akimtoye et al., 2009; Walters, 2009). Walters (2009) and Schultheis et al. (2009) reported that watermelon fruit quality was not influenced by plant density, but was frequently affected by cultivar.

Storage losses

Effect of year, storage period, plant population and the interaction among them on storage losses (fresh weight) were significant. The highest weight loss was recorded in 70x50 cm spacing and storing period of 210 days in 2013 being %28.9 as compared to minimum loss in 210x100 cm and storing period of 30 days in 2013 being %2.4 (Table 2). In our study, generally, prolonged storage period and increasing plant populations increased weight loss in fruits of FWM. Lower plant population in FWM reduced weight loss due to higher SSC values and thickness of the rind. For example, the loss after 210 days in population of 9524 plant ha^{-1} ranged between 22.2 and 21.9% for warehouse storage in 2012 and 2013, respectively. These results are comparable to those reported by Simić et al. (2012) in which they reported that the weight loss was below 10% (in Belgrade) or below 20% (in Izmir) after 7 months at uncontrolled storage conditions. Also some researchers (Geren et al. 2011; Acar et al., 2012) reported that the weight loss in FWM varies according to the size and shape of the exposed surface. The big fruits relatively loose more weight than smaller ones.

Table 2. Effects of different storage period and plant population on the loss (%) of fresh weight of FWM grown under Soke ecological conditions in different years

Spacings (cm)	Storage periods (days): 30	60	90	120	150	180	210	Mean
				2012				
70x50	6.7	10.8	13.0	16.6	19.1	23.2	27.9	16.8
70x100	5.6	9.3	12.2	16.1	17.4	21.6	25.7	15.4
140x50	5.5	9.5	12.5	15.9	17.6	21.8	26.1	15.6
140x100	5.0	8.2	11.3	14.7	16.9	19.4	24.7	14.3
210x50	4.8	7.1	10.1	12.7	15.4	18.6	22.2	13.0
210x100	2.8	4.9	6.5	8.0	9.3	11.7	15.0	8.3
Mean	5.1	8.3	10.9	14.0	16.0	19.4	23.6	13.9
				2013				
70x50	6.1	10.1	14.2	15.4	18.7	24.0	28.9	16.8
70x100	5.2	9.4	11.7	12.8	16.6	21.9	24.9	14.6
140x50	5.1	9.1	11.8	13.0	16.8	22.0	25.0	14.7
140x100	4.6	8.8	9.6	10.7	14.9	19.3	23.0	13.0
210x50	4.0	6.5	9.4	10.5	13.8	17.9	21.9	12.0
210x100	2.4	4.7	5.7	6.9	10.9	11.6	14.1	8.1
Mean	4.6	8.1	10.4	11.6	15.3	19.5	23.0	13.2

LSD (.05) Y:0.18 SP:0.34 P:0.32 YxSP:0.48 YxP:0.45 SPxP:0.84 YxSPxP:1.18 CV: 5.42%

Y: Year, SP: Storage period, P: Population

Storage of the FWM production is cheap and practical, allowing for conservation of the fruits during the long period with low losses of fresh weight. Storage losses caused by respiration have been controlled through the utilization of forced-air ventilation (Acar, 2009). He also suggested that to cover the clump with 20 cm of straw or a suitable cover material for protecting FWM fruits from low temperatures and frost. Ventilation is required to reduce heat build up and rotting. It was also concluded that FWM fruits can be easily stored 210 days with 24% weight loss without any rot.

CONCLUSION

This study was performed to determine the effect of different planting densities on fruit yield and some yield components and storage losses of FWM under irrigated conditions of Mediterranean climate. Higher plant densities of FWM produced significantly lower yield per hectare compared to lower densities. These results can be attributed to lower competition among plants for the availability of nutrients, sunlight and space. Our results indicate that plant densities influenced the weight, number and mass (kg fruit^{-1}) of FWM fruits. It was suggested that 9524 plants ha^{-1} (210x50cm) of FWM was the most productive crop population regarding the total fruit yield (189.32 t ha^{-1}) compared to higher plant densities (14286 or 28571 plants ha^{-1}). The mature FWM fruits can be conserved for more than half a year without significant losing their nutritional qualities and without any rot. It is important that their conservations are viable without the need for sophisticated storage practices. Future experiments on FWM should be conducted at different locations with various agronomical treatments and additional plant densities to be sure that results are relatively consistent over time.

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