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ECONOMIC EVALUATION OF AMARANTH PLANT GROWN BY DIFFERENT DRIP IRRIGATION METHODS AND STRATEGIES

Engin GONEN[1], Cagatay TANRIVERDI[2]

[1]Alata Horticultural Research Institute, Alparslan Turkes Bul., Mersin, Turkey, Email: engingonen@hotmail.com
[2]Kahramanmaras Sutcu Imam University, Agriculture Faculty, Biosystem Engineering, Email: ctanriverdi@ksu.edu.tr

Corresponding author: ctanriverdi@ksu.edu.tr

Abstract

This study was carried out to determine the effect of different irrigation treatments and economic analysis on surface and subsurface methods in amaranth under the Mediterranean climate conditions at the experimental fields of the Alata Horticulture Research Institution during 2018 and 2019 growing seasons in Turkey. In the study, surface drip and subsurface drip methods and six irrigation strategies (Full irrigation, FI; conventional deficit irrigation, DI-50 and DI-75; DI-25; Partial Root-Zone Drying, PRD-50 of full irrigation treatments and Rainfed) also a rain-fed treatment (RF) were considered. There was significant differences (P<0.01) for yields both irrigation system and irrigation method. Maximum yield was obtained from the FI treatment as 3,790 and 3,950 kg ha^{-1}; and the lowest yield was obtained from the rainfed treatment (RF) as 1,840 and 1,960 kg ha^{-1}, in the experimental years, respectively. The experimental design was split plots with four replications. Net profit ranged between 9,143 to 18,047 \$ ha^{-1} in 2018 and 9,742 to 19,454 \$ ha^{-1} in 2019 according to the irrigation treatments. Full irrigation treatment (FI) under subsurface drip irrigation method generated the highest net profit.

Key words: *Amarant, surface drip, subsurface drip, net return*

INTRODUCTION

Continuous and rapid increase in the country's population; increased that feeding, dressing, and other needs for life. The needs of people are increasing numerically by population growth, while also multiplying by the addition of the standard of living, which is raised by technological development. To meet the food requirement of the growing population and to agricultural sustainability, (a) effective management of existing water sources and increasing water usage efficiency, (b) development of additional water resources for irrigation, (c) the development of new products that are tolerant of stress conditions and can deliver more efficiency with less water is among the measures to be taken [9]. For this purpose, the production of more nutrients (vitamins, minerals, proteins, etc.) than the unit area, with plant types and varieties that can be easily grown in a variety of ecological conditions. It’s starting to matter. The kinoa and amarant plants, which can grow in different geographical conditions, are the focus of interest, because they have a broad adaptability to climate and soil conditions today [5, 16].

Amarant (*Amaranthus* spp.) C4 is a drought-tolerant plant [8] via photosynthesis and medium-strength plant to salinity [12, 3, 13]. Amarant seeds, high protein and fat content are very important because they provide the appropriate amino acid structure for human nutrition [11]. The content of the lyse is much higher than the other grain seeds [4]. Amarant is considered a promising plant, with high nutritional values, wide adaptability to different environments, being able to grow in marginal soil areas [1, 7].

One of the most important objectives of irrigation water is to protect the product that was raised during dry periods. While products raised in winter in our region do not usually show a sign of thirst, early yield or drought period can result in a significant drop in yield from the water insufficient. In these cases, the use of the new generation of irrigation technologies, as well as the use of irrigation programming, which includes the time of irrigation and the determination of the amount of irrigation water to be delivered, allows optimal use of limited water sources [11].

Amarant can be easily cultivated under current precipitation conditions in the half-drought climate zone [8], [6] and low severe drought do not cause reductions of amaranth yield [4].

The results of research on agricultural product costs are a tool that governments can apply to in determining price policies. Agricultural product costs are widely used in businesses, especially in determining the usage levels of physical production inputs, labour planning, financing programs and preparing product budgets [2].

In this study, the additional income for the amarant plant, which will generate the financial values of the yield differences caused by different irrigation methods and different irrigation treatments in the Çukurova region, has been concrete for the amarant plant.

MATERIALS AND METHODS

The research was carried out at the Alata Horticultural Research Institute Tarsus Soil and Water Resources Location in 2018 and 2019 cultivation periods. The average altitude of the experimental research area from the sea is 10 m and located at latitude is 36.894885°; longitude is 34.960193°. According to the climate station data of Alata BKAE Directorate Soil and Water Resources, the long annual rainfall average of the region (1950-2019) is 616 mm. The long annual temperature average in the region is 17.8^{o}C. The annual evaporation for long years measurements is 1,487 mm.

During the research years (2018 and 2019), 103.4 and 97.1 mm of precipitation occurred during the plant growing season. In general, temperatures and humidity values in the 2018 and 2019 amaranth growing period were similar to the long annual average values.

Along the 60 cm profile layer of the trial area soil; having clayey structure, the pH of the soil according to the layers, 7.8-8.1; salt content 0.5-0.6 dS m^{-1}; volume weight 1.30-1.44 gcm^{-3}. Field capacity water content on the basis of volume varies between 30.07-31.44% and the wilting point between 18.05-18.98%. The total amount of usable water in the depth of 60 cm of the soil profile is 96 mm.

The research was carried out in four replications according to randomized blocks divided plots trial design. In the research, two different irrigation methods (Surface drip (SD) and subsurface drip (SSD)) and six different irrigation treatments were considered.

Irrigation systems (surface drip and subsurface drip are assigned to the main plots, irrigation treatments are assigned to the sub plots). Full irrigation (FI) in which soil water defcit was replenished to feld capacity when 50% of available water at 60 cm was depleted. Defcit irrigation treatments (DI75, DI50 and DI25) which received 75, 50 and 25% of full irrigation, respectively. Regulated defcit irrigation (RDI) received 50% of FI until fowering growth stage, then received 100% of water requirement. Rainfed (RF), in which no irrigation was applied except during emergence and crop establishment period.

Photo 1. A2 amarant variety
Source: Original.

The plant material used in the research was selected as the A2 *Amaranthus cruentus* L. variety with the highest yield as a result of the preliminary study conducted a year ago with 5 different amarants proposed as a result of the researches carried out at Çukurova University within the scope of the EU 7th Framework Project (SWUP-MED Project). A2 amaranth variety is a variety that is grown both as a grain and a vegetable (Photo 1).

The soil of the experimental area was corrected a few days before the planting of the goble-disc and made ready for seedling planting. Amarant seedlings were hand-planted on trial plots on March 25, 2018 and March 10, 2019. In each plot, 6 rows of plants with a length of 6 m were placed with 70 cm between rows and 20 cm above rows. With the planting, 75 kg ha^{-1} N and 75 kg ha^{-1} P^2O^5 pure substance basis 20-20-0 compound fertilizer were applied to the trial plots. After planting, irrigation water was applied equally to all trial subjects. The second fertilization was carried out at the beginning of flowering and 46% urea was applied on the basis of 75 kg ha^{-1} N pure substance. After reaching physiological maturity, the Amaranth plants were hand harvested on August 15, 2018 and August 10, 2019, by leaving a row from each side and one meter gap from the heads (4 m long middle rows) in each plot.

In both drip systems, the main pipe consisting of PE pipes, manifold and lateral pipes were used in the transmission system and these pipes were placed on the soil surface. Laterals are 16 mm in diameter and included in-line drippers with 40 cm intervals (Netafim). The dripper flow rate is 2.0 l h^{-1} at 100 kPa operating pressure. The dripper range and flow rate were determined, taking into account the infiltration properties of the soil.

Soil water content were monitored in traditional (gravimetric) in 0–60 cm and innovative manners (TDR) in 0–40 cm. Soil water content sensors (SM-150, Delta T) were placed between the two plants in the crop row at 20 and 40 cm depth at one replication for each irrigation treatment with data loggers.

Information regarding production costs and sale prices were obtained from the Chamber of Farmers' Association and the Agricultural Provincial Directorate in Mersin. Production costs include land rental, fertilizer, seed, soil cultivation, plant protection and labour cost for irrigation, harvesting and transportation costs. For the calculation of the total cost of eggplant production for one year, the sum of crop production costs, the yearly cost of the irrigation system, irrigation labour and water cost are taken into account.

Analysis of variance was performed to evaluate the statistical effect of irrigation treatments on eggplant yields and components, WP and ET using the JMP Statistical software developed by SAS (SAS Institute, Inc., Cary, NC, USA). Treatment means were compared using LSD test [15].

RESULTS AND DISCUSSIONS

Irrigation water amounts and grain yield values related to different irrigation methods and subjects during the research years are given in Table 1.

At the beginning of the 2016 growing season, all treatments received 49 mm of irrigation water in two applications in order for establishing a good plant stand. In SD irrigation method, the total amount of irrigation water applied to FI issue was 453 mm, while 356 mm water was applied to DI-75, 257 and 158 mm to DI-50 and DI-25. In the RDI application, 50% of the irrigation water was reduced until the flowering period, and after this date, all of the missing water in the root area was covered. Thus, the total amount of irrigation water for RDI was 401 mm. In SSD application, 356 mm irrigation water was applied for FI, 282 mm for DI-75, 208 and 134 mm for DI-50 and DI-25. 304 mm irrigation water was given to the subject of TD irrigation method RDI.

In the second year of the study, a total of 50 mm of water was applied to all trial subjects in order to ensure uniform plant growth in the trial plots. While the total amount of irrigation water applied to FI subject in SD irrigation method was 488 mm, 378 mm was applied to DI-75 and 269 and 159 mm to DI-50 and DI-25, respectively. 413 mm irrigation water was given to the RDI issue.

Table 1. Irrigation water amounts and grain yield values of different irrigation methods and treatments during the research year

Years	Irr. System	Irrigation Treatments	Seasonal Irrigation (mm)	Yield (kg ha^{-1})
2018	SD	FI	453	3,790
		RDI	401	3,590
		DI-75	355	3,300
		DI-50	257	2,750
		DI-25	158	2,210
		RF	60	1,840
	SSD	FI	356	3,910
		RDI	304	3,680
		DI-75	282	3,450
		DI-50	208	2,920
		DI-25	134	2,320
		RF	60	1,840
2019	SD	FI	488	395
		RDI	413	376
		DI-75	378	345
		DI-50	269	270
		DI-25	159	225
		RF	45	196
	SSD	FI	404	406
		RDI	347	390
		DI-75	315	360
		DI-50	227	282
		DI-25	138	237
		RF	45	196

Source: Authors' results.

Table 2. LSD grouping on yield in amarant plant during research years

IM (SY)	Irrigation Treatments						IM Ave.
	FI	RDI	DI75	DI50	DI25	RF	
SSD	3,910a	3,680c	3,450e	2,920 g	2,320 ı	1,840 k	**3,020 a**
SD	3,790b	3,590d	3,300f	2,750 h	2,210 j	1,840 k	**2,910 b**
IT Ort.	**3,850a**	**3,630 c**	**3,370 b**	**2,840 d**	**2,270 e**	**1,840 f**	
	SY: LSD (0.05)=3.17; P=0.0018** SK: LSD(0.05)=2.88; P=0.0001** SY*SK: LSD(0.05)=4.08; P=0.0001**						

Source: Authors' results.

In SSD application, irrigation water was 404 mm in FI, 347 mm in DI-75, 227 and 138 mm in DI-50 and DI-25, respectively. 347 mm irrigation water was applied to RDI irrigation. The total amount of irrigation water applied to the subjects in the second year of the study was higher than in the first year. This is because the precipitation recorded in the second year during the growth period is less than the precipitation in the first year.

The amount of irrigation water applied in the study is similar to the previous studies. Patel et al. (2005) [10] , in their study on amaranth plant in India, the amount of irrigation water they applied was between 120-420 mm, Rule (2007) [14] investigated the effects on the yield of amaranth in dry and wet conditions in Manhattan, and the grain yield varied between 203-356 mm.

Pulvento et al. (2015) [12], in their study to determine the water requirements of amaranth in Italy, varied between 46-234 mm. The reason for using much less irrigation water than our study is thought to be due to the fact that the amount of rainfall is much higher.

Grain yields obtained from amaranth irrigated by using different irrigation methods and irrigation treatments were 3,910 kg/ha with 184 kg/ha in the first year; In the second year, it changed between 1,960 kg/ha and 4,060 kg/ha. The highest grain yields of 3,910 and 4,060 kg/ha were obtained in the 2018 and 2019 trial years of the SSD irrigation method, respectively.

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It may be possible for producers to adopt the proposed new cultivation technique only if they gain more economic returns. Economic analysis of different drip irrigation methods and irrigation issues are given in Table 3-6 in detail.

In the first year of the trial, according to the economic analysis results covering investment, operating and production costs, net income in different irrigation issues varied between 4,451-11,995 $/ha in surface drip irrigation. The highest net income for FI at different irrigation levels was 11,995 $/ha, followed by RDI (11,056 $/ha).

Subsurface drip irrigation issues varied between 4,497-12,053 $/ha. The highest net income for FI at different irrigation levels was at 12,053 $/ha, followed by RDI 1,114 $/ ha. Net income decreased with decreasing irrigation water in the research year. A net income of (3,133 $/ha) was obtained for non-irrigation RF.

Table 3. The summary of the combined economic analysis of the different irrigation treatments in surface in 2018

Treatments	**Irrigation Water (mm) (1)**	**Irrigation Water (m^3ha^{-1}) (2)**	**Irrigation duration for the irrigation season (h) (3)**	**Labor cost for irrigation ($ h^{-1}) (4)**	**Total cost for irrigation labor ($) (3x4) (5)**	**Water price ($ m^{-3}) (6)**	**Water price ($ ha^{-1}) (2x6) (7)**	**Crop production costs (8)**
YDTS	453	4,530	25	3	76	0.1	453	6,010
YDRDI	401	4.005	22	3	67	0.1	401	6,010
YDKS75	355	3.548	20	3	59	0.1	355	6,010
YDKS50	257	2.565	14	3	43	0.1	257	6,010
YDKS25	158	1.583	9	3	26	0.1	158	6,010
RF	60	600	3	3	10	0.1	60	6,010
Treatments	Irrigation systems for 1 ha ($ ha^{-1}) (9)	Annual cost for the irrigation system ($ ha^{-1}) (9/6 year) (10)	Total cost for 1 year ($ ha^{-1} $yıl^{-1}$) (5+7+8+10) (11)	Yield (kg ha^{-1}) (12)	Amarant sales price ($/kg) (13)	Gross income per ha ($/ha/year) (12x13) (14)	Net income ($/ha/year) (14-11) (15)	
YDTS	2,500	416.6667	6,955	3,790	5	18,950	11,995	
YDRDI	2,500	416.6667	6,894	3,590	5	17,950	11,056	
YDKS75	2,500	416.6667	6,841	3,298	5	16,488	9,647	
YDKS50	2,500	416.6667	6,726	2,748	5	13,738	7,012	
YDKS25	2,500	416.6667	6,611	2,213	5	11,063	4,451	
RF	0	0	6,080	1,843	5	9,213	3,133	

Source: Authors' results.

Table 4. The summary of the combined economic analysis of the different irrigation treatments in sub-surface in 2018

Treatments	**Irrigation Water (mm) (1)**	**Irrigation Water (m^3ha^{-1}) (2)**	**Irrigation duration for the irrigation season (h) (3)**	**Labor cost for irrigation ($ h^{-1}) (4)**	**Total cost for irrigation labor ($) (3x4) (5)**	**Water price ($ m^{-3}) (6)**	**Water price ($ ha^{-1}) (2x6) (7)**	**Crop production costs (8)**
TDTS	356	3,560	20	3	59	0.1	453	6,010
TDRDI	304	3,040	17	3	51	0.1	401	6,010
TDKS75	282	2,820	16	3	47	0.1	355	6,010
TDKS50	208	2,080	12	3	35	0.1	257	6,010
TDKS25	134	1,340	7	3	22	0.1	158	6,010
RF	60	600	3	3	10	0.1	60	6,010
Treatments	Irrigation systems for 1 ha ($ ha^{-1}) (9)	Annual cost for the irrigation system ($ ha^{-1}) (9/6 year) (10)	Total cost for 1 year ($ ha^{-1} $yıl^{-1}$) (5+7+8+10) (11)	Yield (kg ha^{-1}) (12)	Amarant sales price ($/kg) (13)	Gross income per ha ($/ha/year) (12x13) (14)	Net income ($/ha/year) (14-11) (15)	
TDTS	3,000	375	6,897	3,790	5	18,950	12,053	
TDRDI	3,000	375	6,836	3,590	5	17,950	11,114	
TDKS75	3,000	375	6,787	3,297.5	5	16,487.5	9,701	
TDKS50	3,000	375	6,676	2,747.5	5	13,737.5	7,061	
TDKS25	3,000	375	6,566	2,212.5	5	11,062.5	4,497	
RF	0	0	6,080	1,842.5	5	9,212.5	3,133	

Source: Authors' results.

In the second year of the trial, according to the results of the economic analysis covering investment, operation and production costs, net income in different irrigation treatments varied between 4,637-12,754 $/ha in surface drip irrigation. The highest net income for FI at different irrigation treatments was 12,754 $/ha, followed by RDI 11,891 $/ha.

Subsurface drip irrigation issues varied between 5,304-13,444 $/ha. The highest net income for FI was 13,444 $/ha at different irrigation levels, followed by RDI 12.710 $/ha. Net income decreased with decreasing irrigation water in the research year. A net income of 3,732 $/ha was obtained for non-irrigation RF.

Table 5. The summary of the combined economic analysis of the different irrigation treatments in surface in 2019

Treatments	**Irrigation Water (mm) (1)**	**Irrigation Water (m^3ha^{-1}) (2)**	**Irrigation duration for the irrigation season (h) (3)**	**Labor cost for irrigation ($ h^{-1}) (4)**	**Total cost for irrigation labor ($) (3x4) (5)**	**Water price ($ m^{-3}) (6)**	**Water price ($ ha^{-1}) (2x6) (7)**	**Crop production costs (8)**
TS	488	4,880	27	3	81	0.1	488	6,010
RDI	413	4,130	23	3	69	0.1	413	6,010
KS75	378	3,780	21	3	63	0.1	378	6,010
KS50	269	2,690	15	3	45	0.1	269	6,010
KS25	159	1,590	9	3	27	0.1	159	6,010
RF	50	500	3	3	8	0.1	50	6,010
Treatments	Irrigation systems for 1 ha ($ ha^{-1}) (9)	Annual cost for the irrigation system ($ ha^{-1}) (9/6 year) (10)	Total cost for 1 year ($ ha^{-1} $yıl^{-1}$) (5+7+8+10) (11)	Yield (kg ha^{-1}) (12)	Amarant sales price ($/kg) (13)	Gross income per ha ($/ha/year) (12x13) (14)	Net income ($/ha/year) (14-11) (15)	
TS	2,500	417	6,996	3,950	5	19,750	12,754	
RDI	2,500	417	6,909	3,760	5	18,800	11,891	
KS75	2,500	417	6,868	3,450	5	17,250	10,382	
KS50	2,500	417	6,741	2,700	5	13,500	6,759	
KS25	2,500	417	6,613	2,250	5	11,250	4,637	
RF	0	0	6,068	1,960	5	9,800	3,732	

Source: Authors' results.

Table 6. The summary of the combined economic analysis of the different irrigation treatments in sub-surface in 2019

Treatments	**Irrigation Water (mm) (1)**	**Irrigation Water (m^3ha^{-1}) (2)**	**Irrigation duration for the irrigation season (h) (3)**	**Labor cost for irrigation ($ h^{-1}) (4)**	**Total cost for irrigation labor ($) (3x4) (5)**	**Water price ($ m^{-3}) (6)**	**Water price ($ ha^{-1}) (2x6) (7)**	**Crop production costs (8)**
TS	404	4,040	22	3	67	0.1	404	6,010
RDI	347	3,470	19	3	58	0.1	347	6,010
KS75	315	3,150	18	3	53	0.1	315	6,010
KS50	227	2,270	13	3	38	0.1	227	6,010
KS25	138	1,380	8	3	23	0.1	138	6,010
RF	50	500	3	3	8	0.1	50	6,010
Treatments	Irrigation systems for 1 ha ($ ha^{-1}) (9)	Annual cost for the irrigation system ($ ha^{-1}) (9/6 year) (10)	Total cost for 1 year ($ ha^{-1} $yıl^{-1}$) (5+7+8+10) (11)	Yield (kg ha^{-1}) (12)	Amarant sales price ($/kg) (13)	Gross income per ha ($/ha/year) (12x13) (14)	Net income ($/ha/year) (14-11) (15)	
TS	3,000	375	6,856	4,060	5	20,300	13,444	
RDI	3,000	375	6,790	3,900	5	19,500	12,710	
KS75	3,000	375	6,753	3,600	5	18,000	11,248	
KS50	3,000	375	6,650	2,820	5	14,100	7,450	
KS25	3,000	375	6,546	2,370	5	11,850	5,304	
RF	0	0	6,068	1,960	5	9,800	3,732	

Source: Authors' results

CONCLUSIONS

As a result of the economic analysis, marginal revenues were taken from full irrigation irrigation for both irrigation methods. When compared with irrigation methods, higher net income was obtained in SSD irrigation methods compared to SD irrigation method.

High net incomes have been calculated on DI-75 and RDI issues after full irrigation. Marginal income values decreased due to decreasing amount of irrigation water. For these reasons, RDI and DI-75 issues are seen as a good alternative to FI topic for Çukurova conditions.

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