Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. V, 2016
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

THE EFFECTS OF DIFFERENT IRRIGATION WATER AND NITROGEN LEVELS ON THE WATER-NITROGEN-YIELD FUNCTIONS OF WATERMELON

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Abstract

Different irrigation methods (S: Sprinkler; D: Drip), nitrogen forms (L: Liquid; G: Granule), water and nitrogen levels (based on applied line source sprinkler) and watermelon varieties (P: Paladin; M: Madera) were studied in the experiment. The research was conducted in Research and Production Farm of Cukurova University. Experimental design was strip for the first year and split-strip for the second year. Irrigation water was calculated using cumulative evaporation (Ep) from Class A-pan. Significant linear relationships were obtained between the yield and irrigation water, and between the yield and evapotranspiration at 1% confidence level. Yield response factor (Ky) values were determined as 1.07 for total yield and 1.49 for marketable yield. Since Ky>1, watermelon was sensitive to water deficiency. In addition, total water use efficiencies (TWUE) and irrigation water use efficiencies (IWUE) ranged from 1.80 to 11.33 kg da^{-1} mm^{-1} and from 7.29 to 16.47 kg da^{-1} mm^{-1} respectively. This finding indicated that WUE and IWUE values increased with the decreasing evapotranspiration and irrigation water.

***Key words**: watermelon, evapotranspiration, water use efficiency, yield response factor.*

INTRODUCTION

An important portion of the natural water resources are used in agriculture. Decreasing available water resources brings a serious water shortage problem. In order to deal with this problem, the studies for the efficient use of irrigation water by providing water saving gain importance (Li et al., 2001; Fabeiro et al., 2001). However, more studies are still needed for deficit irrigation of vegetables (Chartzoulakis and Drosos, 1995; Mannini and Gallina, 1996). Deficit irrigation aims to increase the efficiency of irrigation water, to generate water stress at a level without excessive yield loss in the production period of the plant and, consequently, to obtain the highest yield corresponding to each unit of water (Stanley and Maynard, 1990; Kirda, 2002). While designing deficit irrigation programs, it should be designed according to the relationship between water and yield. Researches indicated that there is a linear correlation between relative evapotranspiration deficit and relative yield decrease, and this correlation is defined as yield response factor (Ky) (Stewart et al., 1977; Doorenbos and Kassam, 1986). Vegetables are grown widely with commercial purposes and they are very profitable plants. But, there are many differences in the yield quality and quantity among the regions.

These differences appear from some factors such as climate, soil productivity, labour, nutrient and water amount. The factors change more depending on the irrigation and fertilization practices (Doorenbos and Kassam, 1986; Gunay, 1993).

Irrigation is a vital importance for successful vegetable production. Because vegetables need irrigation water during the all growing period and get adequate benefit from irrigation, amount of the irrigation water applied and the irrigation duration must be calculated scrupulously (Cevik et al., 1996; Ertek et al., 2002). The determination of irrigation water amount based on pan evaporation method is very common due to its simple and easy usage (Elliades, 1988).

Nitrogen is also an important nutrient to stimulate growth and water use for watermelon which have very large leaf area, grown on light soil texture and are able to grow very fast (Yesılsoy, 1985; Pier and Doerge, 1995; Kırda et al., 1996). Selection of irrigation methods takes an importance role due to the water and yield economy.

Generally, pressured irrigation systems are preferred due to watermelon grown as crawl on the ground surface.

Watermelon producers widely use drip and sprinkler systems together with liquid fertilizer (Fertigation). Although the techniques look quite hopeful to use for plants such as watermelon which have a lot of problem with irrigation and fertilization, some problems may occur when these systems are not properly designed and managed.

This research aimed to determine the effects of different water and nitrogen levels under different irrigation methods on the evapotranspiration and water-nitrogen-yield functions of watermelon.

MATERIALS AND METHODS

Site Description

The research area was in the north of Lower Seyhan Plain in Turkey and located at latitute 36°59′ N, longitute 35°18′ E, altitude 20 m.

Soil Characteristics

The soil profile was deep and consists of clay in high rate. Some physical and chemical properties of soil used in the experiment were given in Table 1.

Table 1. Some physical and chemical characteristics of the soil of experimental area

Soil layer (cm)	Clay (%)	Sand (%)	Silt (%)	Texture	Field Capacity ($g\ g^{-1}$)	Wilting Point ($g\ g^{-1}$)	Salt (%)	pH	Lime (%)
0-30	32.62	37.72	29.66	CL	30.40	16.93	15.8	7.80	9.29
30-60	31.59	35.68	32.72	CL	29.50	15.07	11.7	7.90	23.42
60-90	29.48	37.87	32.65	CL	23.20	11.56	8.8	7.90	27.51

Climatic Characteristics

Mediterranean climate is prevailing in experimental area with hot and dry summer and rainy and warm winter. According to long-term observation, the annual rainfall is 646.8 mm, average relative humidity, wind speed and temperature are 66%, 2.0 m/s, and 18.9 °C, respectively.

Fertilizers Used in Experiment

Triple super phosphate source of phosphorus (46% P_2O_5), potassium sulfate (50% K_2O) and ammonium sulfate (21% N) were used as granule fertilizer sources. In addition to, as liquid nitrogen source, UAN (Nitrogen of Urea and Ammonium Nitrate) fertilizer was employed during experiment period.

Irrigation Water Supply

Irrigation water was provided from Lower Seyhan Irrigation Project system.

Irrigation water was taken from a closed system with equipped a motor-pump was used to convey to the head of the field. Irrigation water is classified as C_2S_1 quality for irrigation (USSLS, 1954). Some chemical properties of irrigation water were given in Table 2.

Experimental Design and Treatments

The experiment was conducted at the Research and Application Farm of Faculty of Agriculture, University of Cukurova in 1996 and 1997 years. The strip plot design in the first year, and split-strip plot design in the second year with three replications were used. In the experiment, different irrigation methods (S: Sprinkler; D: Drip), nitrogen forms (G: Granule nitrogen; L: Liquid nitrogen), nitrogen and water levels and watermelon varieties (V_1:Paladin; V_2:Madera) were considered. Experimental design and treatments used in the study was shown in Figure 1.

Table 2. Analysis Results of Irrigation Water Used in Experiment

Class	EC (dS/m)	pH	Cations (me/l)			Anions (me/l)				Na (%)	SAR
			Na	K	Ca+Mg	CO_3	HCO_3	Cl	SO_4		
C_2S_1	0.358	7.1	0.45	0.07	3.08	-	1.60	0.94	1.06	12.5	0.36

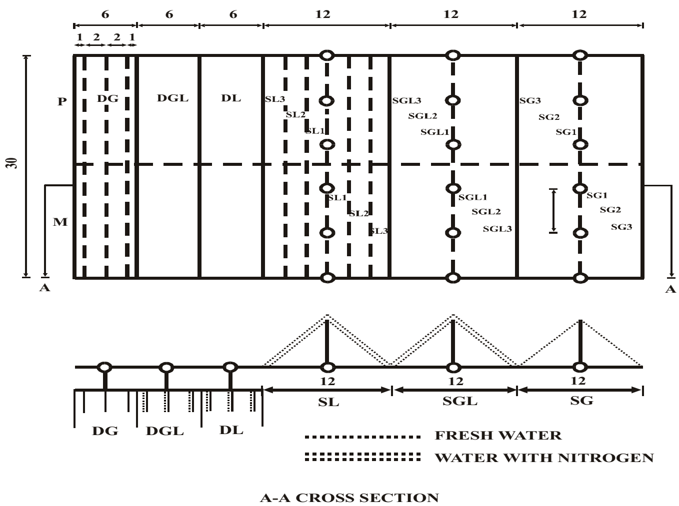

Figure 1. Scheme of experimental area for irrigation and nitrogen treatments

In the experiment, line source sprinkler irrigation technique was utilised because of that both different irrigation and nitrogen levels were proved. Planning and management of the system was made by the methods and principles given by Hanks et al. (1976) and Kanber et al. (1994). Full or half-turning sprinkler heads were placed with 6 m distance along the lateral line. Lateral distances were 12 m. Collecting cups were placed with 2 m distance between two laterals beginning 2 m from first line. In this way, three irrigation levels were created which varied from near the line in which plants received much water to far from line in which plants had less water. In the same condition, different nitrogen levels were obtained. Drip irrigation method was also used in the second year of the experiment. In- line drippers were placed with 50 cm distance along the laterals (q: 4 Lh^{-1}). Drip irrigation plots contain 3 watermelon rows and one lateral employs each row.

Granule Nitrogen (G) was provided from a granule nitrogen source as 10 kg da^{-1} and applied three times (Before sowing, branching period and first fruits became 3-4 cm diameter). Although different nitrogen and water level were not formed in the first year, gradient water level was created with line source sprinkler irrigation technique in the second year. Liquid Nitrogen (L) was provided from liquid nitrogen source and applied by fertigation technique. Any nitrogen application was done before planting and total nitrogen amounts were divided to irrigation number. Granule and Liquid Nitrogen (GL) was provided from a granule and liquid nitrogen source. A part (3 kg da^{-1}) of required total pure N of 10 kg da^{-1} was met by granule nitrogen sources, another part of N was from liquid nitrogen sources. (Conversion rate for 1 kg da^{-1} is equal to 10 kg ha^{-1}). At the end of irrigation events, water samples were taken from collecting cups in sprinkler system and from dripper in drip system during irrigation were analysed for obtaining actual amount of nitrogen applied to the each plot.

Sowing/Planting and Harvesting

The seeds were sown in the torf blocks with 5x5x7 cm in dimension. Then, when seedlings reached to a sufficient size, they were transplanted the experimental area. Seedlings were planted with a row spacing of 2 m and plant spacing of 0.5 m. Watermelon was harvested when atriums dried and peel reached to maturity colour (Gunduz and Kara, 1996).

Plot Dimensions

Sprinkler and drip plots covered an area of 12x30=360m^2 and 6x30=180m^2, respectively. Totally, there were 360 watermelon plants (180 plants for each variety) in sprinkler plots and 180 watermelon plants (90 plants for each variety) in drip plots.

Estimation of Irrigation Water Amount and Determination of Irrigation Time

Irrigation water was calculated using cumulative evaporation values (Ep) from Class A-pan measured between consecutive irrigation (Equations 1 and 2).

$$I = kcp \times Ep \times P \quad (1)$$

$$V = I \times A \quad (2)$$

where I and V, irrigation water, mm, and L; kcp, plant-pan coefficient (Considered to be 1); A, plot area, m^2; P, wetted area percentage (The value was taken as 0.7 in drip plots).

Irrigations were ceased in sprinkler plots, when water amount in the collecting cups next to laterals was equal to either I or V, in drip plots, when the water-meter inside of control units showed that the necessary amount of water was applied.

Measuring of Moisture Variation in the Soil Profile

During the study, moisture content of soil profile in 90 cm depth was measured using the gravimetric method. That practice was started at transplanting, repeated before and after irrigations and ended at harvesting. Moisture samples were taken from mid-point in each plot and every 30 cm depth of the soil profile.

Evapotranspiration

Water budget method was used to determine water consumption (James, 1988). The water budget equation was given in equation 3.

$$ET = I + P - Dp + Cp \pm Rf \pm \Delta S \quad (3)$$

where, ET, I, Dp, Cp, Rf and ΔS are evapotranspiration (mm), irrigation water (mm), precipitation (mm), deep percolation loses (mm), capillaric rise (mm), runoff loses (mm), and moisture storage in soil profile (mm), respectively. Irrigation water amounts, precipitation and soil moisture were measured during the experiment. Rf and Cp were assumed to be zero, because plots were surrounded with a ridge and level of water table was quite depth (more than 6 m) in the experimental area. If the soil moisture content after applied water amount with irrigation was more than field capacity, the difference was assumed as deep percolation (Kanber et al., 1992).

Water-Nitrogen-Yield Functions

Water Use Efficiency

Water use efficiency (kg da^{-1} mm^{-1}) was calculated for various water and nitrogen levels in different irrigation methods. For this purpose, the equation 4 given by Howell et al. (1990) was used.

$$WUE = \frac{MY}{ET \ or \ I} \quad (4)$$

where MY is marketable yield (kg da^{-1}) and ET and IR are evapotranspiration and irrigation water (mm), respectively. ET was used for total water use efficiency (TWUE) and I was used for irrigation water use efficiency (IWUE).

Water-Nitrogen-Yield Relationships and Yield Response Factor

Yield functions were used to determine the relationships between various water amounts and watermelon yields and between nitrogen levels and watermelon yields. Utilising those relationships, relationships between the relative ET deficit and the relative decrease in yield was estimated. The methods and approaches given by Stewart et al. (1977) and Doorenbos and Kassam (1986) were used for referred processes. The formula given in equation 5 was utilised for obtaining yield response factor (Ky).

$$(1 - \frac{Y}{Ym}) = Ky \ (1 - \frac{ET}{ETm}) \quad (5)$$

where, Y, Ym, ET and ETm are actual and maximum yields (kg da^{-1}) and evapotranpirations (mm), respectively.

RESULTS AND DISCUSSIONS

Irrigation and Nitrogen Amounts, Evapotranspiration and Yield

Three water and nitrogen levels were established by allowing water and nitrogen to decrease gradually in only SL applications during the irrigation season of first year. The water amount in SL1 treatment, nearest to lateral, was 164.9 mm. The SL2 and SL3 treatments were taken 77% and 72.3% of the water amount applied to the SL1 treatment, respectively. Second year of the study, various water levels were created in the all sprinkler irrigation treatments except drip irrigation method (Table 3). Irrigation water was reduced in SG treatment by 18% (SG2) and 26% (SG3), in SGL treatment by 14% (SGL2) and 22% (SGL3), and in SL treatment by 20% (SL2) and 29% (SL3). Differences were occurred between treatments caused by spoiled water distribution uniformity due to effect of wind during irrigation.

Nitrogen amounts varied depending on applied irrigation water amount and irrigation method except granule nitrogen applications. Nitrogen amounts decreased by about 50% were applied to some treatments (Table 3). During irrigation, total nitrogen saving was a result of gradually decreased water amount. For example, nitrogen amount was reduced by 24-31% in SGL, by 54-74% in SL application as compared to SG. The saving under drip irrigation was by 13-43%.

There was no significant difference between ET values of watermelon varieties and irrigation methods (Table 3). This could be resulted from similar irrigation programs. Same ET values were obtained from varying nitrogen levels in this study. Here, it can be concluded that the liquid fertilizer applied in less amount than granule fertilizer had same effect on the growth and water consumption of the watermelon. The results agreed with findings of Gunduz and Kara (1996), Ghawi et al. (1989), Sezgin et al. (1997). Eylen and Tok (1988) found that ET was 226 mm. But, this value is very low for the region of Tarsus that is in Cukurova region. In presented study, ET was 361 mm in the highest yield treatment and this value may more suitable for Cukurova conditions.

Similar differences were observed in total yield as seen in ET. In the second year, the yield increased by 70% according to first year (Table 3). This could be resulted from the changes in climate, plant growth and cultural practices between the years. Marketable yield was similar to total yield amounts and marketable yield varied linearly with changing total yield. It was recorded that the higher yield given the higher marketable yield.

Water-Nitrogen-Yield Functions

Water Use Efficiency

Water use efficiencies of the treatments were calculated from marketable yield. Total water use efficiencies (TWUE) and irrigation water use efficiencies (IWUE) ranged from 1.80 to 11.33 kg da^{-1} mm^{-1} and from 7.29 to 16.47 kg da^{-1} mm^{-1}, respectively (Table 3). TWUE and IWUE values generally decreased with the increasing irrigation water and evapotranspiration. The results obtained in this study were parallel with the studies of Ertek et al. (2006) in the eggplant, Xuesen et al. (2003) in cucumber, Costa and Gianquinto (2002) in pepper, and Erdem et al. (2001) in watermelon.

Water-Yield Relationships and Yield Response Factor

Yields of both varieties were used together in the relationships. There were significant linear relationships between yields (total and marketable) and irrigation water amounts, and ET at 1% confidence level (Figure 2). From this reason, it can be concluded that watermelon yields increased with irrigation water and ET increased.

Relationship between in relative ET deficit and relative decrease in yield were shown in Figure 3. Yield response factor shows yield reduction with respect to reduction in the water amount. The yield response factor (Ky) for total yield was 1.07 and for marketable yield was 1.49 (Since Ky>1, watermelon was sensitive to water deficiency. Yield decreased by 1.49 units in marketable yield and by 1.07 units in total yield with a unit decrease in water.

Table 3. Irrigation water amounts, nitrogen amounts, evapotranspiration, total and marketable yields, total and irrigation water use efficiencies

V	T	1996							1997						
		I	N	ET	Y	MY	TWUE	IWUE	I	N	ET	Y	MY	TWUE	IWUE
P	SG1	174.9	10.0	274	1928	869	3.17	4.97	334.2	10.0	427	4352	3475	8.14	10.40
	SG2								273.5	10.0	369	4832	4056	10.99	14.83
	SG3								246.0	10.0	356	4566	3724	10.46	15.14
	SGL1	170.6	7.3	270	2233	1205	4.46	7.06	346.8	8.7	440	3280	2528	5.75	7.29
	SGL2								297.3	7.7	392	3485	2884	7.36	9.70
	SGL3								270.4	6.9	380	3108	2341	6.16	8.66
	SL1	164.9	4.3	264	2429	1401	5.31	8.50	350.5	5.9	444	3567	3040	6.85	8.67
	SL2	126.6	2.9	228	1630	551	2.42	4.35	280.5	4.6	376	4236	3505	9.32	12.50
	SL3	119.2	2.6	236	1325	425	1.80	3.57	248.3	3.6	358	3611	2546	7.11	10.25
	DG								251.7	10.0	340	3840	3018	8.87	11.99
	DGL								251.7	8.7	346	3421	2801	8.10	11.13
	DL								251.7	5.7	339	3343	2796	8.25	11.11
M	SG1	174.9	10.0	266	2003	1244	4.68	7.11	334.2	10.0	435	4981	4160	9.56	12.45
	SG2								273.5	10.0	376	4466	3953	10.51	14.45
	SG3								246.0	10.0	362	4386	3876	10.71	15.76
	SGL1	170.6	7.3	272	2682	1633	6.00	9.57	346.8	8.7	443	4214	3384	7.64	9.76
	SGL2								297.3	7.7	398	4549	3815	9.59	12.83
	SGL3								270.4	6.9	382	4199	3339	8.74	12.35
	SL1	164.9	4.3	260	2529	1622	6.24	9.84	350.5	5.9	438	3485	2754	6.29	7.86
	SL2	126.6	2.9	238	2530	1465	6.16	11.57	280.5	4.6	380	4832	3972	10.45	14.16
	SL3	119.2	2.6	236	1811	806	3.42	6.76	248.3	3.6	361	5013	4090	11.33	16.47
	DG								251.7	10.0	346	3737	2897	8.37	11.51
	DGL								251.7	8.7	350	3822	3174	9.10	12.61
	DL								251:7	5.7	341	3934	3253	9.54	12.92

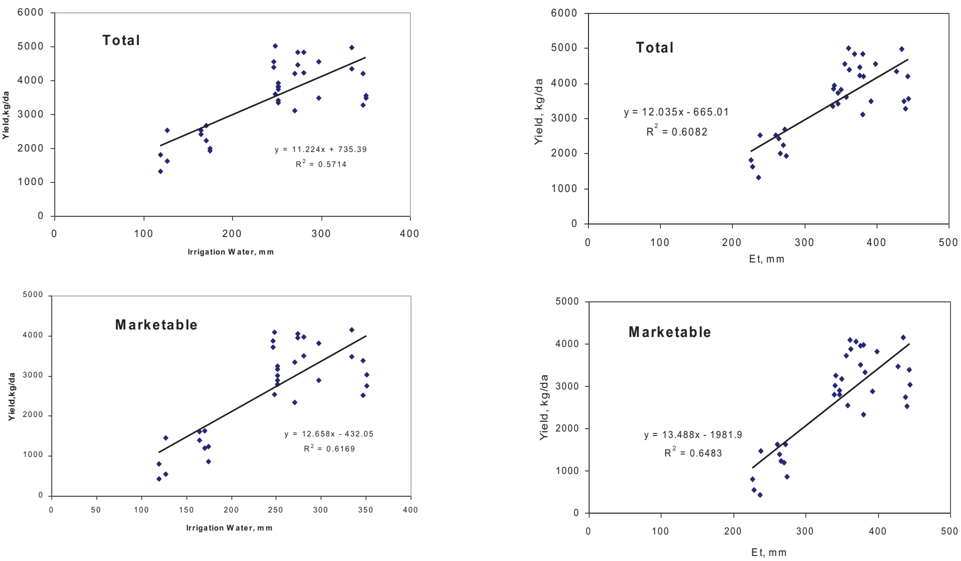

Figure 2. Relationships between yields (total and marketable) and irrigation water, and ET

Nitrogen-Yield Relationships

Parabolic and significant relationships were calculated between the nitrogen amounts and yields (total and marketable) at 5% confidence level (Figure 4).

Similar relationships were obtained between this study and other studies (Gunduz and Kara, 1996; Cetin and Nacar, 1997).

Data from all the treatments (varieties and irrigation methods) were used together to produce the relationships. These relationships indicated that to obtain maximum total yield, a nitrogen amount of 8.7 kg da^{-1} was required while nitrogen amount of 8.5 kg da^{-1} to obtain maximum marketable yield in watermelon. The result agreed with finding of Doorenbos and Kassam (1986); Eylen and TOK (1988). These nitrogen amounts should be provided from a liquid source and it is necessary to apply through irrigation water during the irrigation season.

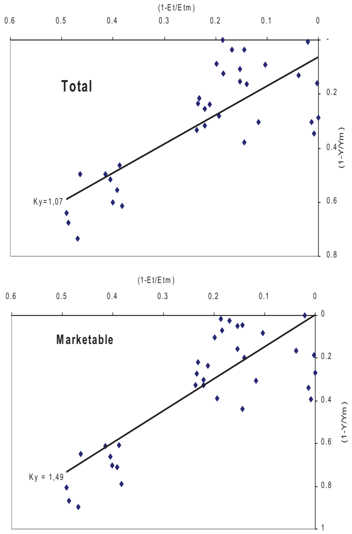

Figure 3. Relationships between relative ET deficit and relative decrease in yield

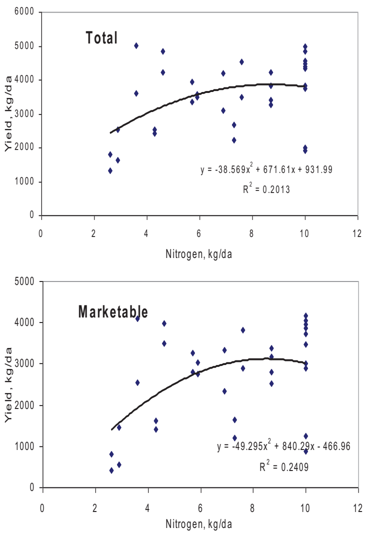

Figure 4. Relationships between nitrogen levels and yield (total and marketable)

CONCLUSIONS

In the study, the effects of different water and nitrogen levels under different irrigation methods on the water-nitrogen-yield functions of watermelon were determined. According to results of the study, TWUE and IWUE values increased with the decreasing evapotranspiration and irrigation water. Varieties, irrigation methods, and nitrogen levels and forms had different influences on water use efficiency. In this case, Madera variety, drip irrigation system, liquid fertilizer, all together, constituted best combination for plant to achieve a better water use efficiency. Significant linear relationships were obtained between the yield and irrigation water, and between the yield and evapotranspiration. Yield response factor (Ky) values were determined as 1.07 for total yield and 1.49 for marketable yield. From the results, marketable yield was more affected by water deficit. It can be concluded that to obtain high marketable yield, plant should not undergo water deficient. Parabolic and significant relationships between the nitrogen amounts and yields indicated that to obtain maximum total and maketable yields, a nitrogen amount of 8.7 kg da^{-1} and 8.5 kg da^{-1} was required.

ACKNOWLEDGEMENTS

This paper is prepared from the part of Master Thesis (The Effects of Different Irrigation Methods and Different Nitrogen Dosses and Forms on the Yield and Quality of Watermelon) accepted by CIHAEM-IAM/Bari, Italy. Authors would like to thanks the Research Fund of Cukurova University and Mediterranean Agricultural Institute (IAM) for their financial support.

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