Determination of irrigation regime for watermelon at Koga and Rib irrigation schemes in Amhara Region, Ethiopia

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Abstract

Determining the optimum crop water requirements is considered one of the most important factors affecting plant productions. Excessive application of water can damage watermelon and face fruit quality problems, leading to a reduction of the melon fruit yield, lower fruit quality characteristics, and plant disease. Therefore, the main objective of this study was to determine the crop water requirement of watermelon in a field experiment using the CROPWAT model at Koga and Rib irrigation schemes. The experiment was conducted from 2016 to 2018 irrigation seasons for two years in the Amhara region, Ethiopia. The experiment was (RCBD) in a factorial arrangement having 12 treatments; three irrigation intervals (14, 21, and 28 days) and the model generated depth of 50 %, 75 %, 100 %, and 125 %. The results indicated that 75 % depth of water applied within 14 days intervals at the Koga irrigation scheme gave a total of 40.2 t ha^{-1} yield with water productivity of 0.29 kg m^{-3}. In the case of Rib, 75 % of irrigation depth showed that better yield production within 21 days irrigation interval and produced 67.9 t ha^{-1} fruit yield with water productivity 0.94 kg m^{-3}. In both locations, the fruit diameter and fruit length were not statistically significant among treatments. Generally, this research showed that an appropriate regime of irrigation had significantly increased crop water use and yield production.

Keywords: *Irrigation scheduling, Koga, Rib, Watermelon, Water productivity*

Introduction

To maintain self-sufficiency in the food supply, one viable option is to raise the production and productivity per unit of land through irrigation (Clark et al., 2011; Tchangani, Dambrine, & Richard, 1998). Irrigation scheduling is planning when and how much water to apply in order to maintain healthy plant growth during the growing season. Irrigation scheduling methods are based on two approaches, that is soil measurements and crop monitoring (Hoffman & Martin, 1993). Irrigation scheduling based on crop water status should be more advantageous for science crops to respond to both the soil and the aerial environment (Yazar, Howell, Dusek, & Copeland, 1999). Excessive application of water can damage watermelon and face fruit quality problems, leading to a reduction of the melon fruit yield, lower fruit quality characteristics and plant disease (Sensoy, Ertek, Gedik, & Kucukyumuk, 2007). The major watermelon producers in the world are; China, Turkey, Iran, Brazil, United States, Egypt, and the Russian Federation (Fao & Isric, 2010) while this fruit in Ethiopia is newly introduced. The importance of this fruit is for the production of juices, nectars, and fruit cocktails (Wani, Sreedevi, Reddy, Venkateswarlu, & Prasad, 2008). Timely management of plant pests, weeds, and proper water application is essential during the production period of watermelon. Generally, excess application of water causes leaching of nutrients, reduction of yield which results in a reduction of water use efficiency (Refai, Mostafa, Hefzy, & Zahran, 2019). The application of appropriate water for crops can improve nutrient availability, soil erosion, aeration, and water productivity (Gaafer & Refaie, 2006). Optimum supply of water and nutrient has a better water use efficiency, good moisture content of the fruit, survival rate, and better fruit test (Raviv & Blom, 2001).

CROPWAT software model is a computer program used for irrigation planning and management developed by FAO and the model is widely used to estimate reference evapotranspiration (ET0) and crop evapotranspiration (ETc) (Abdalla, Zhang, Ishag, & Gamareldawla, 2010). It allows us for the development of recommendations, improved irrigation practices, the planning of irrigation schedules, and the assessment of production under rainfed conditions or deficit irrigation (Clarke, Smith, & El-Askari, 2001). Proper amount and timing of water applications is a crucial decision for a farm manager to meet the water needs of the crop, to prevent yield loss, and maximize the irrigation water use efficiency resulting in beneficial use and conserve water resources (Allen, Pereira, Raes, & Smith, 1998). However, crop water requirements and irrigation schedules of watermelon were not done in the study site (Koga and Rib) irrigation scheme. Therefore, the objectives of this study were to determine the crop water requirement and irrigation schedule of watermelon using the CROPWAT model.

Materials and methods

Description of the study area

The Koga watershed is located in the headwaters of the Blue Nile basin, Ethiopia has a total area of 266 km^2 (Gebrehiwot, Taye, & Bishop, 2010). The soil type of the experimental site is Nitisols with the dominant texture of clay and the soil has strongly acidic characteristics. The Rib watershed is located in the South of

latitude with an altitude of 1774 m above sea level. The soil type of the Rib irrigation site is Fluvisols with the texture of clay and has neutral reaction soil properties. This woreda is located at a higher elevation of the region than the Mecha woreda. Both Koga and Rib irrigation schemes were located in west Amhara and belong to the modern large-scale irrigation schemes in Ethiopia as well as in the Amhara region (Figure 1). The climatic characteristics and the physical soil properties of the study area is displayed in Table 1 and 2.

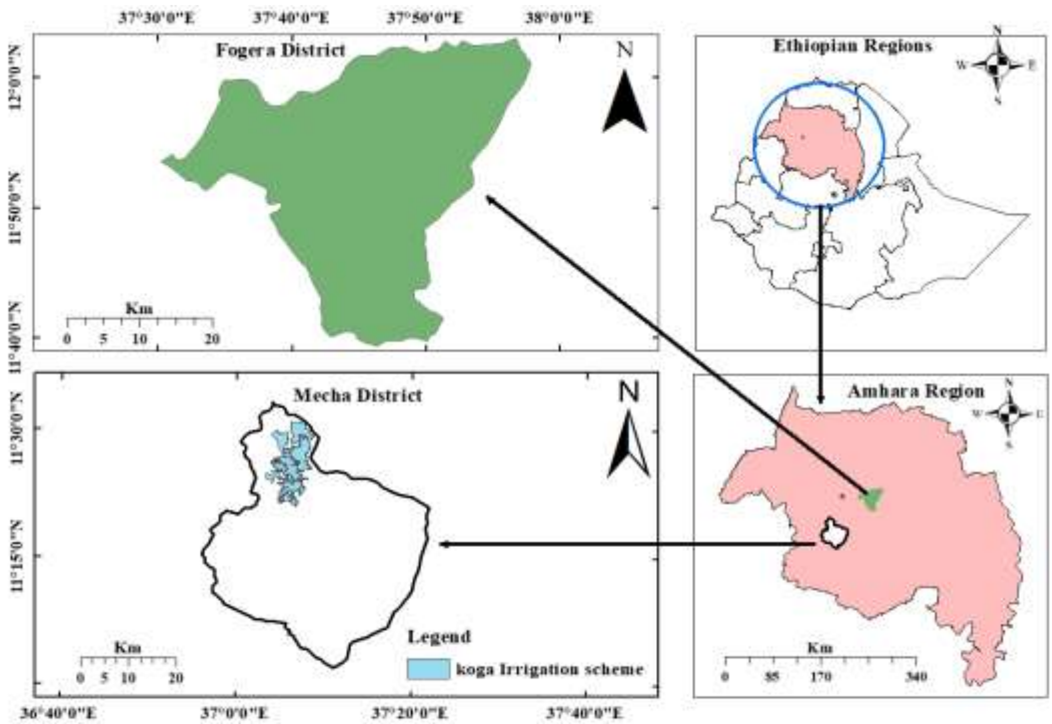


Figure 1. Map of the study areas

Table 1. Climatic characteristics of experimental sites

Parameters	Koga	Rib
Minimum temperature (ºc)	9.7	11.5
Maximum temperature (ºc)	26.8	30
Mean annual rainfall (mm)	1118	1400
Relative humidity (%)	68	70
Wind speed (m/sec)	2.0	1.5
Sunshine hour (hr)	10.4	7.9

Experimental Design

The design of this experiment was a factorial randomized complete block design (RCBD) having 12 treatments and consists of three irrigation intervals and four levels of irrigation depth. The irrigation intervals were 14, 21, 28 days and the levels of irrigation were 50 %, 75 %, 100 %, and 125 % of evapotranspiration (ETC) or crop water requirement for both locations. The treatments were replicated three times for each site and uniformly managed during the time of conducting the trial. The spacing between rows and plants was 1.8 m and 0.9 m respectively.

The CROPWAT computer model version 8.0 was used to calculate ETC. Then, ETC was calculated as the product of reference evapotranspiration (ETo) and crop coefficient (Kc). The amount of fertilizer applied based on the blanket recommendation was 100 kg ha^{-1} NPS which means fertilizer formed from a combination of nitrogen, phosphorus, sulfur and used instead of diammonium phosphate (DAP) and 100 kg ha^{-1} Urea fertilizer. Split application of Urea was practiced, which is half at planting and half at 45 days after planting. The variety of the test crop was Crimson and all agronomic practices were carried out uniformly for each treatment and years at both locations. The soil moisture status and soil properties were monitored in order to use schedule both the timing of irrigations and the volume of water applied. Irrigation was practiced in order to study the behavior of the crop and the amount of water required at each phase of the growth stage and over the growth period.

Table 2. Physicochemical properties of soil for the experimental sites

Parameters	Koga	Rib
Filed capacity (%)	32.0	59.25
Permanent wilting point (%)	18.0	21.0
Total nitrogen (%)	0.21	0.003
Available phosphorus (ppm)	19.67	36.71
Cations exchange capacity (%)	20.06	33.0
Organic matter (%)	0.37	N.A
Power of hydrogen ((PH H_2O (1:2.5))	4.75	6.70
Electric conductivity ($mmhoscm^{-1}$)	1.01	N.A

Note: N.A = data not available

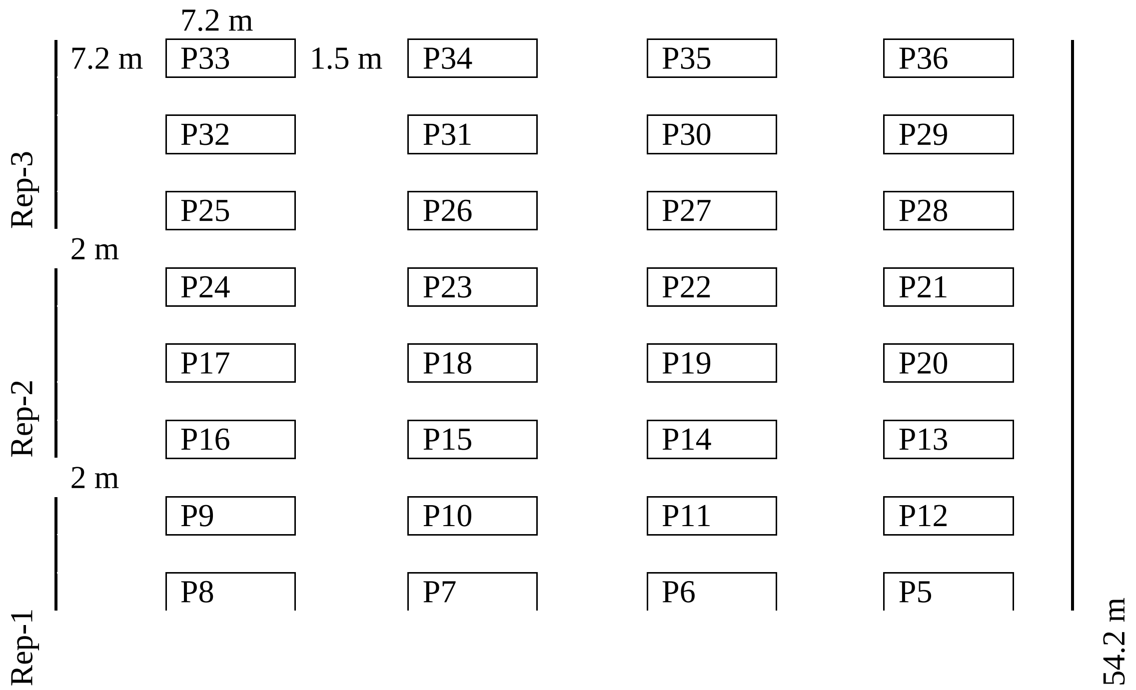
Table 3. Treatment combination of the experiment

Treatment	Irrigation depth	Irrigation interval	Treatment Combinations
T1	50% ETC	14 Day intervals	50% ETC and 14 Day intervals
T2	75% ETC	14 Day intervals	75% ETC and 14 Day intervals
T3	100% ETC	14 Day intervals	100% ETC and 14 Day intervals
T4	125% ETC	14 Day intervals	125% ETC and 14 Day intervals
T5	50% ETC	21 Day intervals	50% ETC and 21 Day intervals
T6	75% ETC	21 Day intervals	75% ETC and 21 Day intervals
T7	100% ETC	21 Day intervals	100% ETC and 21 Day intervals
T8	125% ETC	21 Day intervals	125% ETC and 21 Day intervals
T9	50% ETC	28 Day intervals	50% ETC and 28 Day intervals
T10	75% ETC	28 Day intervals	75% ETC and 28 Day intervals
T11	100% ETC	28 Day intervals	100% ETC and 28 Day intervals
T12	125% ETC	28 Day intervals	125% ETC and 28 Day intervals

Note: ETC=Evapotranspiration of the crop, T=treatments

The water application method was a surface irrigation technique that applies through furrow and a siphon hose was used for measuring the amount of water applied using a constant head. The flow rate of the irrigated water was measured and calculated using the volumetric method of discharge determination. This can be done by collecting water in a container of known volume. Q = V/t where, V = volume of container (m^3), t = time taken (hr) and Q = discharge of irrigation water ($m^3\ hr^{-1}$) for both experimental sites (Gore & Banning, 2017).

Watermelon fruits were harvested at marketable maturity and were then counted, individually weighed and harvest plot yields calculated. The harvestable plot area was 25.92 m^2 at Koga and 19.4 m^2 at Rib. The area of the harvestable plot varies due to the land limitation in the case of Rib irrigation scheme. The watermelon should be harvested before vines become withered, and by understanding the maturity indicator of the fruit (Paltrinieri & Staff, 2014). The overall maturity of the melon sometimes happens which is characterized by flesh mealy in texture and reddish-orange in color. The circumference and the length of the watermelon were measured by the plastic meter and weighted by sensitive balance. In this finding, the furrow irrigation method was used by keeping specific irrigation time.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is because of the variation of soil properties between the two experimental sites and the two sites have climatic and agroecological differences. Since the water holding capacity of the soil at Rib (Table 2

soil. Since watermelon is deep-rooted it could tolerate water stress except for peak production due to the requirement of irrigation application timely. Regardless of irrigation technique care must be taken at the field to minimize wetting of the bed tops and reduced fruit contact with moist soil to develop unsightly ground spots and fruit rots. The quality yield of watermelon was produced with adequate irrigation depth. The soil properties were the inputs for calculating ETC using the CROPWAT model and had a great influence on the amount of water required.

Table 4. Mean yield and irrigation depth of watermelon for each treatment

Treatments	Experimental sites			
	Koga		Rib	
	Irrigation depth (mm)	Mean yield(t/ha)	Irrigation depth (mm)	Mean yield(t/ha)
14D50%	302.2	27.787	119.3	43.152
14D75%	453.3	40.164	179.0	50.751
14D100%	604.4	33.578	238.6	49.028
14D125%	755.5	37.58	298.3	44.132
21D50%	280.1	31.712	78.45	63.304
21D75%	420.1	23.237	117.7	67.889
21D100%	560.1	17.301	156.9	51.112
21D125%	700.1	17.891	196.1	57.131
28D50%	298.7	22.479	65.25	60.461
28D75%	448.0	23.407	97.88	46.068
28D100%	597.3	29.434	130.5	52.538
28D125%	746.6	25.696	163.1	53.391

Note: Treatments=14 days irrigation interval with 50 %, 75 %, and 125 % of 100 % ET_C, 21 days irrigation interval with 50 %, 75 %, and 125 % of 100 % ETC and 28 days irrigation interval with 50 %, 75 %, and 125 % of 100 % ET_C, ET_C=Evapotranspiration of the crop determined from the CROPWAT model.

As shown in Table 4, the seasonal water requirement of watermelon varies from 302.2 mm to 755.5 mm in the case of the Koga irrigation scheme and 65.25 mm to 298.3 mm for the Rib irrigation site. This variation depends on the climate and the total length of the growing period, as well as the soil characteristics of the test sites. The range of the amount of water required for watermelon in this research was lower than the other findings by Erdem & Yuksel, (2003); ;

(2009); Bastos, Silva, Rodrigues, Andrade Jr, and Ibiapina (2012), which varied from 460 mm to 600 mm under different climate and soil scenarios.

Effect of irrigation regimes on watermelon

Yield and water productivity

The results showed that treatments have a significant effect on the yield and water productivity of watermelon for both irrigation schemes (Table 5 and 6). The maximum yield was produced for treatment two (40.2 t ha^{-1}) in the case of Koga and 67.9 t ha^{-1} yields were produced in the case of the Rib irrigation scheme (T6). According to Ajao and Oladimeji (2017) report, the potential yield of this fruit ranges from 7.39 t ha^{-1} to 58.49 t ha^{-1}. The yield production of watermelon at the Koga irrigation scheme was too low due to strongly acidic problems in the scheme (Tewabe, Abebe, Enyew, & Tsige, 2020). The water productivity of watermelon was calculated as the ratio of total yield obtained and the amount of water applied for each treatment. The maximum water productivity of watermelon was obtained at treatment nine which gave 0.34 kg m^{-3} and 1.15 kg m^{-3} at Koga and Rib respectively. This finding was somehow agreed with (Rashidi & Gholami, 2008) they reported that the water productivity of watermelon was ranged from 2.7 kg m^{-3} to 14.33 kg m^{-3}. For both locations, the yield produced had a significant response to the amount of irrigation water applied at different application depths. Therefore, irrigating watermelon with 14 days irrigation interval at Koga and 21 days irrigation interval at Rib (75 % CWR) generated depth gave maximum yield and water productivity of watermelon.

Table 5. Combined ANOVA for the effect of irrigation regime on the yield and yield components of watermelon at Koga

Source of variation	DF	Mean squares							
		Yield (t ha^{-1})	Pr >F	WP (kg m^{-3})	Pr > F	Diameter (cm)	Pr > F	Fruit length (cm)	Pr > F
Rep	2	14.44		9.76		9.78		1.81	
Trt	11	316.6	<0.001	67.2	0.033	4.46	0.393	1.29	0.98
Year	1	5173	<0.001	794.8	<0.001	60151	<0.001	2941.3	<0.001
Trt XYr	11	253.9	<0.001	37.21	0.314	3.5	0.58	2.714	0.78
Residual	46	66.99		31.00		4.1		4.216	
Total	71								

Table 6. Combined ANOVA for the effect of irrigation regime on the yield and yield components of watermelon at Rib

Source of variation	DF	Mean squares							
		Yield (t ha^{-1})	Pr >F	WP (kg m^{-3})	Pr > F	Diameter (cm)	Pr > F	Fruit length (cm)	Pr > F
Rep	2	45.59		0.003		0.367		0.475	
Trt	11	353.61	<0.001	0.393	<0.001	1.73	0.54	4.890	0.727
Year	1	6460.3	<0.001	1.073	<0.001	30.34	<0.001	106.77	<0.001
Trt XYr	11	68.11	0.71	0.022	0.14	2.64	0.234	6.98	0.454
Residual	46	0.72		0.014		1.97		6.93	
Total	71								

Diameter and fruit length

The diameter and fruit length of watermelon were not statistically significant among treatments for both experimental sites. But the mean fruit length and diameter of watermelon were closely related between the irrigation schemes. Even though the analysis indicated that no significant difference among the treatments in the fruit diameter and the fruit length but relatively large fruit diameter and the length were observed for some treatments at both experimental sites (Table 7 and 8) below. In the report of (Ramos & Ramos, 2009) different water depths had no significant effect on the fruit length of the fruit. Application of agronomic practices with the collaboration of irrigation water management may significantly vary among treatments. The yield variations between the two locations were sought because of the features of soil, water and climatic condition, and source of water.

Yield and Irrigation depth

The fruit yield of watermelon has a significant variation among the arranged treatments for Koga and Rib irrigation schemes (Figures 3 and 4). As indicated below the figure the yield of the watermelon decreased along with the treatments when the amount of irrigation water depth declines. Relatively with the safe management of irrigation water (T2) gave the optimal yield at the Koga irrigation scheme and treatment (T9) generated sufficient yield in the case of the Rib irrigation scheme. The trend line showed that the yield of watermelon had positively correlated with the irrigation depth for both irrigation schemes. But the correlation coefficient (R^2) indicated below (Figures 3 and 4) describes weak positive relations between the amount of irrigation water applied and the yield produced at each irrigation scheme.

Table 7. Analysis of yield and water productivity of watermelon at Koga

Treatment	fruit length (cm)	Diameter (cm)	Yield (t ha^{-1})	WP (kg m^{-3})
14D50%	28.15^{a}	38.68^{a}	27.8^{ab}	0.23^{ab}
14D75%	27.62^{a}	38.86^{a}	40.2^{a}	0.29^{ab}
14D100%	27.10^{a}	38.08^{a}	33.6^{ab}	0.21^{ab}
14D125%	26.98^{a}	36.87^{a}	37.6^{a}	0.20^{ab}
21D50%	27.57^{a}	37.24^{a}	31.7^{ab}	0.32^{ab}
21D75%	26.79^{a}	38.52^{a}	23.2^{ab}	0.25^{ab}
21D100%	27.86^{a}	38.99^{a}	17.3^{b}	0.15^{b}
21D125%	26.80^{a}	37.71^{a}	17.9^{b}	0.15^{b}
28D50%	27.17^{a}	36.65^{a}	22.5^{ab}	0.34^{a}
28D75%	27.37^{a}	38.70^{a}	23.4^{ab}	0.31^{ab}
28D100%	28.02^{a}	39.31^{a}	29.4^{ab}	0.32^{ab}
28D125%	27.11^{a}	38.07^{a}	25.7^{ab}	0.25^{ab}
Mean	27.38	38.14	27.5	0.25
CV (%)	7.6	7.3	15.9	11.6
LSD (5%)	ns	ns	9.5	0.08

Note: Numbers followed by the different letters indicate statically significant between treatments at a level of 5 % and ns = non-significant

Table 8. Analysis of yield and water productivity of watermelon at Rib

Treatment	Length (cm)	Diameter (cm)	Yield (t ha^{-1})	WP (kg m^{-3})
14D50%	22.99^{a}	39.18^{a}	43.2^{c}	0.45^{ef}
14D75%	22.09^{a}	37.03^{a}	50.8^{abc}	0.46^{ef}
14D100%	22.07^{a}	37.34^{a}	49.0^{abc}	0.40^{f}
14D125%	22.83^{a}	38.87^{a}	44.1b^{c}	0.32^{f}
21D50%	23.07^{a}	39.27^{a}	63.3^{ab}	1.00^{ab}
21D75%	23.29^{a}	38.88^{a}	67.9^{a}	0.94^{abc}
21D100%	22.85^{a}	38.18^{a}	51.1^{abc}	0.63^{de}
21D125%	22.74^{a}	38.54^{a}	57.1^{abc}	0.64^{de}
28D50%	21.96^{a}	37.32^{a}	60.5^{abc}	1.15^{a}
28D75%	22.56^{a}	38.01^{a}	46.1b^{c}	0.77^{bcd}
28D100%	22.00^{a}	36.46^{a}	52.5^{abc}	0.78^{bcd}
28D125%	23.57^{a}	39.18^{a}	53.4^{abc}	0.72^{cd}
Mean	22.6	38.1	53.2	0.68
CV (%)	11.7	7.7	26.5	26.8
LSD (5%)	ns	ns	0.21	1.63

Note: Numbers followed by the different letters indicate statically significant between treatments at a level of 5% and ns = non-significant

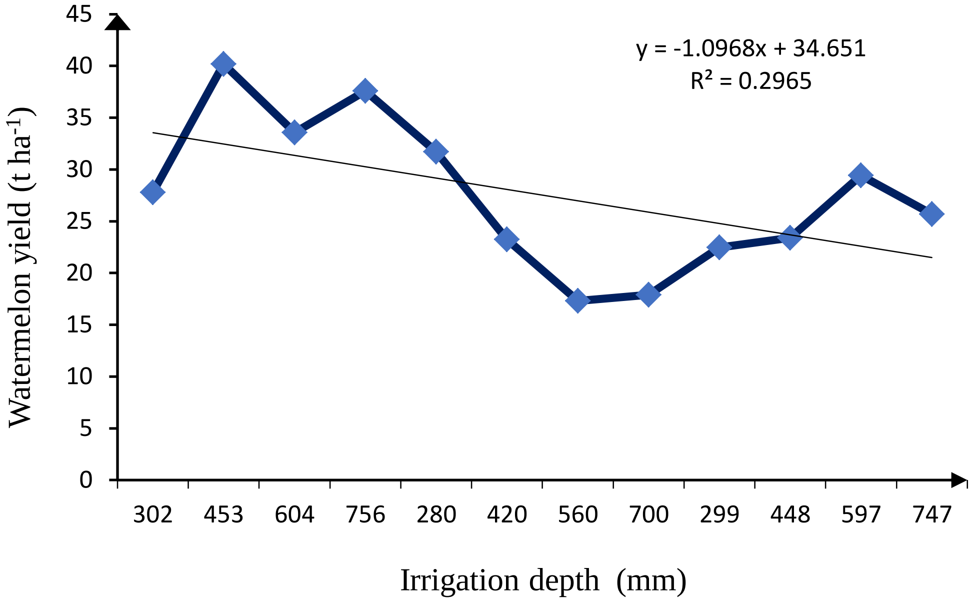

Figure 3. Trend of yield and irrigation depth interaction at Koga irrigation scheme

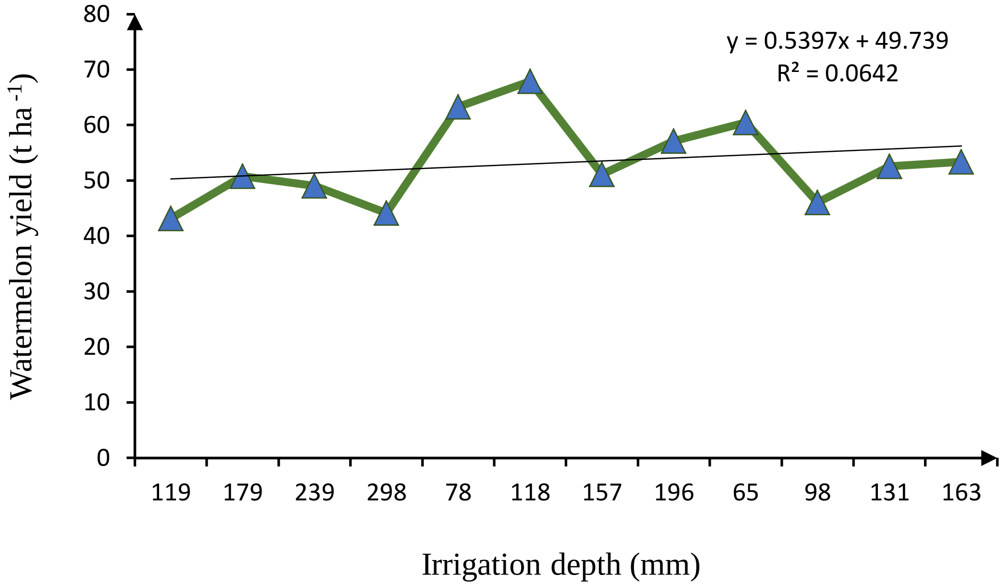

Figure 4. Trend of yield and irrigation depth interaction at Rib irrigation scheme

According to Amaral et al. (2016), the productivity and final quality of the watermelon crop were related to several factors, which acted during all phases of its growth and development. In this study similar acts of growth and development determinant factors related to irrigation, the amount was observed during the period of the experiment at both locations.

Conclusions and recommendations

The amount of irrigation depth and scheduling had a significant effect on the yield and water productivity of crops. Spatial and temporal variation had also its impact on the amount and depth of irrigation water applied. This research indicated that the interaction of irrigation scheduling and depth across locations had a significant effect on the yield and water productivity of watermelon at Koga and Rib irrigation schemes. The result showed that 40.2 t ha^{-1} yield within 14 days intervals and 67.9 t ha^{-1} yield within 21 days intervals at Koga and Rib irrigation scheme. The result also showed that 0.34 kg m^{-3} and 1.15 kg m^{-3} water productivity was achieved with appropriate depth and scheduling at Koga and Rib respectively. Generally, this study revealed that the total depth of water produced the maximum yield of watermelon was 453 mm and 117 mm over the growing period at Koga and Rib irrigation schemes respectively. Irrigation significantly increased crop water use and therefore watermelon yield. Therefore, the determination of appropriate depth and irrigation scheduling can improve the yield and water productivity of watermelon.

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