Effect of variable irrigation regime on yield and water productivity of pepper (capsicum annum) in western Amhara, Ethiopia

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Abstract

Field experiments were conducted at Koga and Rib irrigation schemes during 2010 to 2012 to determine the optimal irrigation regime for pepper. The treatments were arranged in a factorial combination of two irrigation intervals (7 and 10 days) and five irrigation depths (50, 75, 100, 125 and 150%) laid out in a randomized complete block design with three replications. Agronomic data, such as pod length, marketable and total yield were collected and analyzed using SAS 9 software and significant treatment means were separated using least significant difference at 5%. Irrigation frequency showed significant effect on pod yield than irrigation depth and their interaction also showed significant effect on total yield and water productivity. At Koga, application of 75% irrigation water amount (irrigation depth) at 7 days interval gave 8.2 t ha^{-1} marketable yield, 8.35 t ha^{-1} total yield, and 1.77 kg m^{-3} water productivity. While at Rib, application of 50% crop water requirement at 7 days irrigation interval gave 20.68 t ha^{-1} marketable yield and 5.69 kg m^{-3} water productivity. Net irrigation water requirement of pepper was 421.3 mm at Koga and 310 mm at Rib corresponding to 17 irrigations. Therefore, for optimum yield and water productivity, pepper can be irrigated with 75% CWR every seven days at Koga and with 50%CWR every seven days interval at Rib.

Key words: Irrigation regime, Koga, pepper, Rib, scheme

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Ketema, 2007). However, most of these studies assessed the effect of reduced water stress; irrespective of appropriate irrigation regime.

Capsicum planted under irrigation condition cannot withstand long dry period. Under such conditions, the plant may shade flowers and drop fruits. Irrigation at an interval of every other day for the first three weeks and 5-7 days then after depending on soil growing conditions can provide good yield. Irrigating late in the afternoon and over irrigating is not advisable in order to control root-rot disease (Asfaw et al., 2015).However in Ethiopia particularly in Amhara region irrigation regime under which crop water requirement is optimum has not yet been established for green pod peppers. Hence, the objectives of this study were to determine the crop water requirement and irrigation schedule of pepper.

Materials and methods

Site description

The trial was conducted during 2010 and 2012 at Koga and Rib irrigation schemes, west Amhara, Ethiopia. Koga irrigation scheme is located in Mecha District; 41 kilometres from Bahir Dar on the way to Addis Abeba via Debremarkos (37°7'29.721''Easting and 11°20'57.859''Northing and at an altitude of 1953 m a.s.l). The average annual rainfall of the area is about 1118 mm. The mean maximum and minimum temperatures are 26.8^{o}C and 9.7^{o}C respectively. The soil type is generally Nitisols and clay in its nature. The soil has low available phosphorous (6.12 ppm), medium nitrogen 0.21% strongly acidic soil reaction (pH =) 4.6. The field capacity (FC) and permanent wilting point of the study area were 32 (%w/w) and 18 (%w/w); respectively

Rib irrigation site is located in Fogera District, 60 kilometers from Bahir Dar in the way to Gondar road (37°25' to 37°58' Easting and 11°44' to 12°03' Northing and at an altitude of 1774 m a.s.l). It receives an average of 1400 mm rainfall annually. The mean daily maximum and minimum temperatures of the study area were 30°c and 11.5°c. The area is characterized as mild altitude agro-ecology. The soil at the experimental site is Fluvisols (an alluvial deposit). The soil has high available phosphorous (36.71ppm), very low nitrogen content (0.003%), high cation exchange capacity (CEC = 33.0 cmolc kg^{-1} soil) and neutral soil reaction (pH = 6.7). The field capacity (FC) and permanent wilting point (PWP) of the study area were 59.25 (%w/w) and 21 (%w/w) respectively.

Methods

CROPWAT 8.0 for windows was used to estimate daily reference crop evapotranspiration and generate the crop water requirement and the irrigation schedule for pepper in the study areas (Table 1 and 2). Calculations of the crop water requirements and irrigation schedule were carried out taking inputs of climate, soil and crop data. In order to estimate the climatic data (wind speed, sunshine hours, relative humidity, minimum and maximum temperature) LOCCLIM, local climate estimator software (FAO, 1992) were used for both at Koga and Rib where there is no class A meteorological stations. The estimator uses real mean values from the nearest neighbouring stations and it interpolated and generated climatic data values for the study site. Based on the technology we use, we assume 70 % application efficiency both at Rib and Koga, and then the gross water requirement was calculated. The demand for water during the plants growing season varies from one growth stage to another. Values of potential evapotranspiration (ET_0) estimated were adjusted for actual crop ET. Table 3 and 4 shows CROPWAT 8 Windows tables for ET.

Principally, CropWat outputs generated by default were used to identify irrigation timing of when 100% of readily available moisture occurs and application depth where 100% of readily available moisture status is attained. To verify the CropWat output, field experiments were carried out for two consecutive years in both locations.

Table 1. Climate and ETo data of Koga

Month	Min Temp °C	Max Temp °C	Humidity %	Wind km/day	Sun hours	Rad MJ/m²/day	ETo mm/day
January	7.5	26.5	51	1	9.8	21.3	3.13
February	9.2	28.0	45	1	9.8	22.8	3.48
March	12.0	29.5	42	1	9.1	23.1	3.80
April	13.3	29.8	43	1	8.8	23.1	3.98
May	14.4	28.9	53	1	8.6	22.4	4.03
June	14.0	26.6	67	1	6.7	19.2	3.59
July	13.7	24.0	76	1	4.4	15.9	3.01
August	13.6	24.0	77	1	4.3	15.9	3.00
September	12.9	25.1	72	1	5.9	18.2	3.30
October	12.5	26.2	63	1	9.0	21.9	3.70
November	10.4	26.3	57	1	9.5	21.2	3.35
December	7.9	26.2	54	1	10.0	21	3.11
Average	11.8	26.8	58	1	8	20.5	3.46

Table 2. Climate and ETo data of Rib

Month	Min Temp °C	Max Temp °C	Humidity %	Wind Km day^{-1}	Sun hours	Rad MJ $m^{-2}day^{-1}$	ETo Mm day^{-1}
January	4.6	30.5	54	2	9.2	20.3	3.12
February	6.3	33.0	51	2	10.0	22.9	3.73
March	8.0	33.0	49	2	10.0	24.4	4.17
April	9.0	32.7	51	2	8.5	22.6	4.07
May	10.0	31.6	65	2	6.7	19.6	3.76
June	10.4	28.5	80	2	5.4	17.4	3.41
July	9.8	25.0	85	1	1.6	11.8	2.39
August	10.1	25.5	86	1	6.7	19.6	3.57
September	9.8	27.0	82	1	9.0	22.9	4.08
October	7.4	29.0	76	2	10.0	23.2	

Table 3. Crop water and irrigation requirements for pepper at Koga

Month	Decade	Stage	Kc coeff	ETc mm day^{-1}	ETc mm dec^{-1}	Eff rain mm dec^{-1}	Irr. Req. mm dec^{-1}
Dec	3	Initial	0.6	2.02	8.1	0	8.1
Jan	1	Initial	0.6	2.06	20.6	0	20.6
Jan	2	Initial	0.6	2.1	21	0	21
Jan	3	Development	0.62	2.31	25.4	0	25.4
Feb	1	Development	0.75	2.98	29.8	0	29.8
Feb	2	Development	0.9	3.77	37.7	0	37.7
Feb	3	Development	1.03	4.46	35.7	0	35.7
Mar	1	Mid	1.11	4.95	49.5	0	49.5
Mar	2	Mid	1.11	5.1	51	0	51.0
Mar	3	Mid	1.11	5.22	57.4	0.1	57.3
Apr	1	Mid	1.11	5.34	53.4	1.8	51.6
Apr	2	Late	1.08	5.29	52.9	2.6	50.2
Apr	3	Late	1.01	4.87	48.7	3.9	44.8
May	1	Late	0.96	4.68	4.7	0.2	4.7
					495.8	8.5	487.4

Where: Coef = coefficient, Irr.req.= irrigation requirement

Table 4. Crop water and irrigation requirements for pepper at Rib

Month	Decade	Stage	Kc coeff	ETc mm day^{-1}	ETc mm dec^{-1}	Eff rain mm dec^{-1}	Irr. Req. mm dec^{-1}
Dec	3	Initial	0.60	1.87	07.5	0	07.5
		Initial	0.60	1.87	18.7	0	18.7
Jan	2	Initial	0.60	1.88	18.8	0	18.8
Jan	3	Development	0.62	2.00	22.0	0	22.0
Feb	1	Development	0.73	2.45	24.5	0	24.5
Feb	2	Development	0.85	2.95	29.5	0	29.5
Feb	3	Development	0.96	3.44	27.5	0	27.5
Mar	1	Mid	1.02	3.78	37.8	0	37.8
Mar	2	Mid	1.03	3.89	38.9	0	38.9
Mar	3	Mid	1.03	3.95	43.5	0.1	43.4
Apr	1	Mid	1.03	4.02	40.2	1.8	38.4
Apr	2	Late	0.99	3.94	39.4	2.6	36.8
Apr	3	Late	0.91	3.65	36.5	3.9	32.6
May	1	Late	0.87	3.49	03.5	0.2	03.5
					388.3	8.5	379.9

Treatment setup

The on-farm trial was conducted in the dry season with ten different treatments in both location at Rib and Koga. Two irrigation intervals i.e. 7 and 10 days and five irrigation interval (50, 75,100,125 and 150 % CWR) of variable depths at four growth stages are selected based on CROPWAT 8.0. Thus the following treatments were set and evaluated for verification of the Cropwat prediction with field experimentation:

1. 50%CWR at 7 day interval
2. 75%CWR at 7 day interval
3. 100%CWR at 7 day interval
4. 125%CWR at 7 day interval
5. 150%CWR at 7 day interval
6. 50%CWR at 10 day interval
7. 75%CWR at 10 day interval
8. 100%CWR at 10 day interval
9. 125%CWR at 10 day interval
10. 150%CWR at 10 day interval

The treatments were arranged in a randomized complete block design (RCBD) replicated three times. The experiment was carried out from December to April. The test crop was pepper with variety Marco Fana. The plot size was 2.8 m by 6 m plot at Koga and 2.8m by 3m at Rib. Spacing between treatments was 1m while between block was 1.5m. Spacing between rows and plants were 0.7cm and 0.3cm; respectively. Di-ammonium phosphate (DAP) fertilizer was applied at a rate of 200 kg ha^{-1} at planting while 100 kg urea ha^{-1} was applied half at planting and the remaining half at 45 days after planting. Stand count, total yield, marketable yield, pod length, pod weight, and unmarketable yield were collected. Water productivity was calculated as the ratio of marketable yield to amount of water consumed based on Arega (2003).

Data analysis

The means of the above parameters were subjected to analysis of variance (ANOVA) using SAS version 9 computer software. Mean comparison was done by using least significant difference test at 5% probability level.

Results and discussion

ANOVA (showed that agronomic data such as marketable yield, unmarketable yield, and total yield was not show significant difference over year, year by frequency and depth. At Koga, the response of most biological parameters to the interaction of irrigation frequency and depth was significant at ($p < 0.05$). At Rib, the response of most biological parameters to irrigation depth and irrigation frequency was non-significant at ($p < 0.05$).

Pod length

Pod length showed significant response for irrigation depth at Rib ($p<0.05$). The interaction of irrigation depth and frequency was not significant at Rib while did for Koga ($p<0.05$). The lowest (9.33cm) and the highest (10.35) pod length of pepper were obtained for 75% and 150% crop water requirements; respectively. The result was in harmony with Habtamu et al., (2014). In his report the average pod length ranged between 9.6-10.05 cent meters.

Pod weight

Average pod weight showed significant response for irrigation depth at Rib ($p<0.05$). The lowest (9.9gm) and the highest (11.5) average pod weight of pepper were obtained for 50% and 150% crop water requirements; respectively. The result was in harmony with Habtamu et al., (2014) who reported average pod weight in the range of 12-17.5 gram.

Marketable yield

At Koga, irrigation frequency and depth showed significant effect on marketable pod yield of pepper ($P < 0.05$, Table 5 and 6). The lowest (3.7 t ha^{-1}) and the highest (8.6 t ha^{-1}) marketable pod yield of pepper were obtained at 75%CWR with 10 days interval and at 125%CWR with 7 days irrigation interval; respectively. Marketable yield of pepper increased when frequent irrigation was given than longer durations. Even if marketable yield was not respond to irrigation depth; yield decrease with increase of water level at 10 days interval. However, at 7 days interval irrigation depth did not show any trend. This implies much higher and lower irrigation depth can adversely affect marketable yield through the development of physiological disorder such as aeration and create favorable environment for root rot and cut worm.

The yield obtained from this experiment was very low might be due to the occurrence of root rot, wilt and cut worm (Table 6). The production was low compared to other areas as well as world average yield of green pod which is 16.28 t ha^{-1} (FAOSTAT 2012); this might be due to poor soil fertility and acidification at Koga. Pepper is very sensitive to soil acidity and its suitable pH ranges between 6 to 7 while at Koga it is about 4.6 which is below the critical level.

The soil organic matter and available phosphorus are also very low at the study site based on Clements and McGowen (1994) category.

At Rib, irrigation frequency showed significant effect on marketable pod yield of pepper ($p < 0.05$, Table 7). The lowest (17.31 t ha^{-1}) and the highest (20.68 t ha^{-1}) marketable pod yield of pepper were obtained for 10 and 7 days irrigation interval; respectively. The effect of irrigation levels on the marketable pod yield was not significant at ($p < 0.05$, Table7). The lowest marketable yields (17.83 t ha^{-1}) was recorded at 50% CWR, reaching maximum (19.91 t ha^{-1}) at 125% CWR. Marketable yield of pepper increased when frequent irrigation is given than longer duration. Even if marketable yield was not respond to irrigation depth; yield increase with increase of water level up to 125%CWR. However, further increase in irrigation level had negative effect on marketable yield of pepper.

The total green pod yield of pepper at Rib was much larger than Koga irrigation scheme as well as in line with the world average production of green pod pepper, this might be the soils at Rib are Fluvisols which are deposited from upper catchments and have good nutrient content. The finding was in line with findings of Baye et al. (2010) and Birhanu et al. (2014), where they found a non-significant effect of phosphorus for all agronomic parameters.

Table 5. ANOVA for pod length, marketable, unmarketable, total yield, disease incidence and water productivity at Koga (2010/11 and 2011/12)

Source	Df	Pod (cm)	Marketable yield (t ha^{-1})	Unmarketable yield (t ha^{-1})	Total yield (t ha^{-1})	Disease incidence (%)	Water Productivity (kg m^{-3})
Year(Y)	1	9.10 ns	0.63 ns	0.03 ns	0.37 ns	0.93 ns	0.01 ns
Rep (R)	2	2.10ns	1.58 ns	0.1 ns	2.4 ns	61.6 ns	0.01 ns
Freq.(F)	1	37.20 **	195**	7.01 **	128.3 **	4208 **	5.28 **
Depth (D)	4	6.97 ns	0.34 ns	0.48 **	1.14 ns	258 ns	0.87 **
Y*F*D	13	2.00 ns	2.4 ns	0.23 ns	2.87 ns	162 ns	0.07 ns
R*F	2	0.18 ns	0.2 ns	0.16 ns	0.55 ns	105 ns	0.004 ns
F*D	8	18.28 **	6.43 **	0.34 *	9.64 **	585.5 *	0.23 **
Error	28	3.87	1.34 **	0.1	1.64	144	0.05
CV(%)		20.98	19.08	73.1	19.7	51.7	19.7

*Where: Df = Degree of freedom, ns not significant * significant and ** highly significant*

Table 6. Marketable yield, total yield, disease incidence and water productivity analysis result of Koga

Frequency	Depth	Marketable yield (t ha^{-1})	Total (t ha^{-1})	Disease Incidence (%)	Water Productivity (kg m^{-3})
7	50	6.8	6.96	19.6	1.53
7	75	8.2	8.35	16.2	1.77
7	100	7.5	7.60	16.2	1.55
7	125	8.6	8.67	10	1.3
7	150	8.2	8.26	12.1	0.97
10	50	5.6	7.00	12.9	1.32
10	75	3.7	4.30	22	0.81
10	100	4.2	5.00	30.4	0.87
10	125	3.9	4.50	35.4	0.64
10	150	3.8	4.27	37	0.52

Table 7. Pod weight, pod length, marketable yield, total yield and water productivity analysis result of Rib

					Pod		Marketable yield (t/ha)
Frequency	Depth	Productivity (kg/ m3)			Weight (gm)	Length (cm)	
7	50	5.69		7	10.9	9.73	20.68
7	75	4.14	F	10	10.1	9.69	17.31
7	100	3.25					
7	125	2.58		50	9.9	9.64	17.83
7	150	2.21		75	10.1	9.33	18.72
10	50	5.12	D	100	10	9.4	19.17
10	75	3.43		125	11	9.83	19.91
10	100	2.56		150	11.5	10.35	19.36
10	125	2.25					
10	150	1.71					
		6.8			12.5	7.7	14.9
	D	1.03			1.083	0.622	ns
	F	0.87			0.685	ns	1.583
	D*F	1.7			ns	ns	ns

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and 1.77 kg/ m3 that is reasonable yield and water productivity; respectively. While at Rib, 50%CWR at 7 day interval, 20.68 t ha^{-1} and 5.69 kg/ m3 yield and water productivity were achieved respectively. Hence, if irrigation scheduling is aimed at maximizing yields per unit of irrigated area; 50%CWR with 7 day interval recommended for Rib and 125% CWR with 7 day interval recommended for Koga and similar agro ecology. However, if the scheduling objective is to maximize yield per unit depth of water applied, 75%CWR with 7 day interval is recommended for Koga and similar agro ecology. For Rib and similar agro-ecologies 50%CWR with 7 day interval recommended.

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