Optimizing Irrigation Frequency and Amount on Yield and Water Productivity of Snap Bean (*Phaseolus vulgaris* L.) NW, Ethiopia: A Case Study in Koga and Rib Irrigation Scheme

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Abstract

This study was investigated the effects of different irrigation frequency and depth on yield and water productivity of snap bean at koga and Rib irrigation scheme, NW Amhara, Ethiopia *from* 2010 to 2012. Variable irrigation scheduling for snap bean was determined using CROPWAT version 8. It was a factorial experiment laid out in split plot design with three replications of two irrigation interval and five variable irrigation depth at Koga and Rib irrigation scheme. Data on yield and water productivity were collected and analyzed using SAS 9. While irrigation depth showed significant effect on marketable yield, total yield and water productivity than irrigation frequency and their interaction showed not significant effect on marketable yield, total yield and water productivity of snap bean. Water productivity showed decreasing trend where irrigation depth increase from 50 to 150% CWR at 7 and10 day irrigation interval both at koga and Rib irrigation scheme. At Koga, application of 50%CWR gave marketable yield, total yield and water productivity of 10.98 t ha^{-1}, 11.04 t ha^{-1} and 3.14 kg m^{-3} respectively. At Rib, independent results show that application of 125% CWR at 7days interval gave marketable yield, total yield and water productivity of 13.16 t ha^{-1}, 13.6 t ha^{-1} and 2.63 kg m^{-3} respectively. At optimum yield and water productivity, Irrigation water requirements of snap bean were found to be 345.7 mm and 326.6 mm net irrigation requirement corresponding to 13 and 9 irrigation applications at Koga and Rib irrigation scheme respectively. Therefore, in order to attain an optimum yield and water productivity, at koga, Rib and similar agro ecology snap bean can be irrigated with 50%CWR at 7 days interval and 75%CWR at 10 days interval respectively. It can be applicable especially in areas where irrigation water resource scarce or limited.

Keywords*:* Irrigation scheduling, snap bean, Koga, Rib

Introduction

In Ethiopia, the population is growing rapidly and is expected to continue growing, which inevitably lead to increased food demand. To maintain self-sufficiency in food supply, one viable option is to raise the production and productivity per unit of land through irrigation. Proper amount and timing of irrigation 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 conservation of the local water resources (Richard et.al 1998).

Recently precision agriculture in humid areru114784 532.9 lr9(e)5(e)4(d1913(y)20( )-111(be)5(i resulting in beneficial use and conservation of the local water resources; and 3) minimize the leaching potential of nitrates and certain pesticides that may impact the quality of the groundwater.

Effective irrigation is possible only with regular monitoring of soil water and crop development conditions in the field, and with the forecasting of future crop water needs. Delaying irrigation until crop stress is evident, or applying too little water, can result in substantial yield loss. Applying too much water will result in extra pumping costs, wasted water, and increased risk for leaching valuable agrichemicals below the rooting zone and possibly into the groundwater.

Irrigation criteria, in terms of frequency of irrigation and amount of application per irrigation, seasonal net irrigation requirement and gross irrigation requirement for most of the lowland crops that are grown in the middle awash region of Ethiopia have been quantified by Melka Werer Research Center. However there was little effort undertaken in the highlands of Ethiopia especially in Amhara region. Crop water use studies which was conducted in some other area are not adopted because it highly location specific.

As a cash crop, snap bean is produced worldwide for export and canning industry.in Ethiopia, different plant types of diverse pod character of the crop are produce for export purposes. Snap bean production steadily increasing; due to the involvement of state horticulture enterprises. Local and foreign private investors and farmers (Dessalegn, 2003) and thus occupies the highest share (94%) of export potential among all vegetables (Dessalegn et al., 2006; Desalegn, 2011). In the last five years, there have been 12 fold increases of export potentials. Beside its export value, the crop is becoming important in local markets, big hotels, and festivals and in making various dishes (Dessalegn et al., 2006).However; such promising endeavours are not fully supported by the research system. The net irrigation requirements and irrigation schedule of snap bean is not yet known. Using climatic data is one of the quickest and fairly reliable means of crop water requirements. In the study area as such there is no an attempt to determine crop water requirements of irrigated crops. Therefore, this study was conducted to determine irrigation schedule of snap bean and to statistically determine effect of variable irrigation scheduling on yield and water productivity in humid tropical environment using CROPWAT computer model and verify the result with field trial in Koga and Rib irrigation project area.

Materials and Methods

The trial was conducted from 2010 to 2012 at the experiment field of Adet agricultural research center in Koga irrigation schemes and farmers field at Rib irrigation command area. Koga irrigation scheme is located in Mecha district; 41 kilometres from Bahir Dar in the way to Addis abeba road (37°7'29.721"Easting and 11°20'57.859"Northing and at an altitude of 1953m a.s.l). The average annual rainfall of the area is about 1118 mm. The mean maximum and minimum temperatures are 26.8 ^{0}C and 9.7 ^{0}C respectively. The soil type is generally light clay nitisoil in its nature. The field capacity (FC) and permanent wilting point of the study area is 32(%w/w) and 18(%w/w) respectively. The soil chemical properties of koga was 4.6, 0.92-2.88, 0.62-2.35, 1.54-5.23, 0.18-0.24, 3.54-8.69, 1.01 and 2.34-4.44 Exchangable Al^{3+}, H^{+}, acidity (cmol/kg), total N(%), available P(ppm), ECe (mmhos/cm) and organic matter(%) respectively.

Rib irrigation site is located in fogera district, 60 kilometres from Bahir Dar in the way to Gondar road (37°25' to 37°58' Easting and 11°44' to 12°03' Northing) at an altitude of 1774 m a.s.l). It recieves 1400mm mean anual rainfall. The mean daily maximum and minimum tempreture of the study area was 30°c and 11.5°c. The area is characterized as mild altitude agro-ecology. The soil at the experimental site is fluvisol(an alluvial deposit). The soil has high available phosporous(36.71ppm) and low nitrogen content(0.003). The exchangeable cation capacity(CEC) is high(33.0). The field capacity(FC) and permanent wilting point(PWP) of the study area is 59.25(%w/w) and 21.(%w/w) respectivily.

CROPWAT 8.0 for Windows was used to estimate daily reference crop evapotranspiration (table 1 &2) and generate the crop water requirement and irrigation schedule for onion in the study areas. 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) was used 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 interpolates and generates climatic data values for the study site. Assuming 90 and 70 % application efficiency at Rib and Koga respectively, the gross water requirement was calculated. The demand for water during the plants growing season varies from one growth stage to another and from crop to crop. Values of potential evapotranspiration (ET0) 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. The on-farm trial was conducted in the dry season with ten different treatments in both locations 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 were selected based on CROPWAT 8.0 and farmers' traditional practices in the area.

The field experiments were arranged with split plot design with three replications and carried out from December to April. The test crop snap bean a variety of LP was used to sow on 3 m by 6 m plot size at Koga and 3*3 at Rib. The spacing between treatments was 1m and Spacing between each block will be 1.5m. The test crop was snap bean and the spacing between rows and plants were 0.5m and 0.1m respectively. DAP fertilizer was applied at a rate of 100 kg ha^{-1} at planting and 100 kg Urea ha^{-1} was applied half at planting and the remaining half at 45 days after planting. All the agronomic practices were equally done for each treatment. Agronomic data such as stand count, pod length, marketable and total yield were collected. Irrigation water productivity was calculated as the ratio of crop yield (marketable yield) and applied irrigation water.

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

Effect of different irrigation scheduling treatments on crop growth parameters, yield and water productivity at koga irrigation scheme was presented in (Table 1). ANOVA table showed that marketable yield, total yield and water productivity which are collectively termed farm productivity parameters were not significant difference over year and year by frequency and depth. Pod length and water productivity had an interaction effect of irrigation frequency and depth while marketable and total yield respond only for irrigation depth. At Rib, most biological parameters are not significant for irrigation frequency at ($p<0.05$) while do for irrigation depth. The production of snap bean was low at koga than Rib; this might be due to soil climate. Suitable PH for snap bean is in a range of 6-6.5 while 4.63 at koga. Snap bean is very sensitive to soil acidity, especially for Al^{3+} toxicity. The critical level of exchangeable Al^{3+} for onion is 0.4-0.8 extracted by $CaCl_2$ (Hazelton and Murph, 2007) while exchangeable Al^{3+} at Koga is 0.92-2.88 which is above the critical level. In addition, the soil at Koga has very low organic matter content and available phosphorus content according to the category by Clements and McGowen (1994). The total pod yield of snap bean at Fogera plain was much larger than Koga irrigation scheme, this might be the soils at Fogera are fluvisols which are deposited from upper catchments and have good nutrient content. This also in line with findings of Baye et al. (2010) and Birhanu et al. (2014), where the effect of phosphorus and its interaction with nitrogen was found statistically non-significant for most of vegetable yield parameters.

Table 1: ANOVA for pod length, marketable, total yield and water productivity at Koga (2010/11 and 2011/12)

	Degree of Freedom	Pod length (cm)	Marketable yield	Total yield	Water productivity
year	1	0.87 ns	2 ns	2.1 ns	0.07 ns
rep	2	0.47 ns	20.4 *	21.4 *	0.68 *
frequency	1	57.4 **	4.2 ns	4.1 ns	0.1 ns
depth	4	0.4 ns	4.5 *	4.5 *	10.2 **
y*f*d	13	0.1 ns	0.1 ns	0.1 ns	0.01 ns
r*f	2	2.8 *	8.7 *	8.7 *	0.79 *
f*d	4	1.95 *	2.4 ns	2.4 ns	0.33 *
error	28	0.57	1.53	1.58	0.09
CV(%)		8.6	11.9	12.1	15.1

Table 2: pod length, marketable yield, Total yield and water productivity result at Koga

Irrigation frequency (day)	Irrigation depth (%CWR)	Pod length (cm)	Water productivity (kg/m3)		Marketable yield (t/ha)	Total yield (t/ha)
7	50	10.1	3.34	7	10.59	10.66
7	75	9.84	2.89	10	10.06	10.13
7	100	9.54	2.36			
7	125	8.88	1.14	50	10.98	11.04
7	150	10.2	0.84	75	10.46	10.54
10	50	7.7	2.94	100	9.57	9.63
10	75	7.3	2.6	125	9.8	9.89
10	100	7.9	2.2	150	10.8	10.87
10	125	8.2	1.45			
10	150	7.7	1.12			

Table 3: pod length, marketable yield, Total yield and water productivity result at Rib

Irrigation frequency (day)	Irrigation depth (%CWR)	Pod length (cm)	Marketable yield (t/ha)	Total yield (t/ha)	water productivity (kg/m3)
7	50	8.07	9.8	9.94	4.90
7	75	8.13	9.14	9.34	3.05
7	100	8.56	10.78	11.07	2.69
7	125	8.59	13.16	13.6	2.63
7	150	8.33	11.23	11.49	1.87
10	50	8.2	9.96	10.09	4.57
10	75	7.91	13.38	13.52	4.10
10	100	8.6	10.52	10.7	2.42
10	125	7.9	11.28	11.49	2.07
10	150	8.23	12.1	12.26	1.85
		5.6	17.1	16.8	
	F	ns	ns	ns	
	D	ns	1.57	1.57	
	F*D	ns	1.35	1.403	

Pod length

At Koga, Irrigation level was not significant for pod length of snap bean at (P < 0.05). The effect of irrigation frequency pod length and interaction of irrigation depth and frequency was significant at P < 0.05. The lowest (7.3 cm) and the highest (10.2 cm) marketable pod yield of snap bean were obtained at 75 and 150% CWR at 10 and 7 day irrigation interval, respectively.

At Rib, Irrigation frequency and depth showed not significant (P < 0.05) effect pod length of snap bean. The interaction of irrigation depth and frequency was also not significant at P < 0.05. The lowest (7.9 cm) and the highest (8.6 cm) pod length of snap bean were obtained at 125 and 100% CWR at 10 day irrigation interval, respectively.

The pod length is low in both locations as compared to central rift vally of Ethiopia which is in a range of, 10.6-12.8 cm (Hussien et al, (2015)). This might be due to variety LP which is out dated and lack of monitoring the soil water regime.

Marketable Yield

At Koga, Irrigation level showed positive respond for marketable pod yield of snap bean at (P < 0.05). The effect of irrigation frequency on marketable pod yield and interaction of irrigation depth and frequency was not significant at P < 0.05. The lowest (9.57 t ha-1) and the highest (10.98 t ha-1) marketable pod yield of snap bean were obtained at 100 and 50% CWR irrigation depth, respectively. The production is low as compared to central rift vally of Ethiopia which is in a range of, 12.27-21.23 (Hussien et al, (2015)). This might be due to soil climate of koga. Suitable PH for snap bean is in a range of 6-7.5 while 4.63-5.1 at koga. In addition, the soil at Koga has very low organic matter content and available phosphorus content according to the category by Clements and McGowen (1994).

At Rib, Irrigation frequency showed not significant (P < 0.05) effect on marketable pod yield of snap bean. The effect of irrigation levels on the marketable pod yield and interaction of irrigation depth and frequency was significant at P < 0.05. The lowest (9.14 t ha-1) and the highest (13.38 t ha-1) marketable pod yield of snap bean were obtained at 75% CWR and 7 and 10 day irrigation interval, respectively.

Total pod Yield

At Koga, Irrigation level showed positive respond for total pod yield of snap bean at (P < 0.05). The effect of irrigation frequency on total pod yield and interaction of irrigation depth and frequency was not significant at P < 0.05. The lowest (9.61 t ha-1) and the highest (11.04 t ha-1) total pod yield of snap bean were obtained at 100 and 50% CWR irrigation depth, respectively

At Rib, Irrigation frequency showed not significant (P < 0.05) effect on total pod yield of snap bean. The effect of irrigation levels on the total pod yield and interaction of irrigation depth and frequency was significant at P < 0.05. The lowest (9.34 t ha-1) and the highest (13.6 t ha-1) total pod yield of snap bean were obtained 75 and 125 %CWR at 7 day irrigation interval, respectively.

The total green pod yield of snap bean at Fogera plain was much larger than Koga irrigation scheme as well as in line with the central rift vally a production of green pod psnapbean, this might be the soils at Fogera are fluvisols which are deposited from upper catchments and have good nutrient content.This is in line with findings of Husein et al. (2015), where the yield of green pod snap bean was high in fluvi soil of Hawasa. This also in line with findings of Baye et al. (2010) and Birhanu et al. (2014), where the effect of phosphorus and its interaction with nitrogen was found statistically non-significant for all of the onion yield parameters

Water productivity

Interaction effect between irrigation frequency and depth had significantly influence on waWHU SURGXFWLYLW\ RI VQDS EHDQ 3 ” 7DEOH on water productivity. The water productivity, however, decreased with increasing depth of irrigations. When irrigation depth increase 50 to 150 % CWR; water productivity of snap bean increase 0.83-3.34 and 1.12-2.94 kg/m3 at7 and 10 days irrigation interval, respectively.These results are also in a close agreement with Kebede (2003) Samson and Ketema (2007) who reported that when irrigation water becomes a limiting factor, yield losses due to reduced soil moisture could be compensated for by water use efficiency.

At Rib ,QWHUDFWLRQ HIIHFW EHWZHHQ LUULJDWLRQ IUH 0.01) influence on water productivity of snap bean (Table 7). Both irrigation frequency and depth have positive effect on water productivity. The water productivity, however, decreased with increasing depth of irrigations, whereas increasing irrigation frequency significantly increased water productivity when it lowers from 7 days to 4 day interval. (Table 7). Thus at 4 day interval, decreasing irrigation depth from 150 to 50 % CWR increase water productivity of onion 2.29 to 6.22. These results are also in a close agreement with Kebede (2003) Samson and Ketema (2007) who reported that when irrigation water becomes a limiting factor, yield losses due to reduced soil moisture could be compensated for by water use efficiency.

Conclusion and Recommendations

The effects of irrigation scheduling were assessed by examining their effects on yield and water productivity of snap bean. The result of current study revealed that irrigation depth had a significant effect on marketable yield, total yield and water productivity than irrigation frequency both at koga and Rib irrigation scheme. Pod length had positive respond for irrigation frequency as well as their interaction at koga; while Rib. At Rib, Marketable and total yield had positive correlation with irrigation depth up to 125%CWR at 7 day irrigation interval. However, further increase in depth showed negative respons

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