Effect of Variable Irrigation Schedules on Yield and Water Productivity of Field Pea in NW Amhara, Ethiopia: A Case Study in Koga and Rib Irrigation Schemes

Alebachew Enyew*, Atakltie Abebe, Amare Tsgie, Dires Tewabe, and Mulugeta Worku

Adet Agricultural Research Center, Bahir Dar, Ethiopia;

*Correspondence: alebachewenyew6@gmail.com

Abstract:

This study investigated the effects of different irrigation frequency and depth on yield and water productivity of field pea at Koga and Rib irrigation scheme, NW Amhara region, Ethiopia for two years. Variable irrigation scheduling for field pea was determined using CROPWAT version 8. It was a factorial experiment laid out in a split-plot design with three replications of two irrigation intervals and five irrigation depths at both locations. Data on water productivity, yield, and yield attributes were collected and analyzed using SAS version 9. Irrigation frequency, irrigation depth, and their interaction showed a positive influence on grain yield and water productivity of field pea at both experimental sites but the interaction effect did not show a significant response in water productivity at Rib irrigation scheme. At Koga, irrigating 100 % CWR at a 10-day interval gives 2.12 t ha^{-1} and 0.55 kg m^{-3} optimal grain yield and water productivity respectively. At Rib, irrigating 75 % CWR at a 10-day interval produces 3.2 t ha^{-1} and 1.055 kg m^{-3} optimal grain yield and water productivity respectively. The irrigation water requirement of field pea was found to be 406 mm and 349 mm as a net irrigation requirement corresponding to 10 irrigations at Koga and Rib respectively. Therefore, to attain an optimum yield and water use efficiency at Koga, Rib, and similar agro-ecology, field pea can be irrigated based on the recommended scenarios.

Keywords: *Irrigation scheduling, Field pea, Koga, Rib*

Introduction

Recently precision agriculture in humid areas is already being used to increase yield and water productivity thereby making irrigation feasible (DeJonge & Kaleita, 2006). If there is proper irrigation management i.e., schedule irrigation timing and amounts based on accurate crop water use, irrigation has a positive effect on yield provided planted crops are not stressed before water application. In countries with large rainfall amounts over years and within the same year, temporal variation in storm frequency does not always coincide with crop needs at critical periods. Hence, irrigation scheduling remains one of the critical needs for efficient water management in crop production in humid areas (Thomas, Harrison, & Hook, 2004). Irrigation scheduling and yield have a positive correlation (Al-Jamal, Sammis, Ball, & Smeal, 1999; Rockström, Barron, & Fox, 2003). The relationship between the total quantity of water applied and the yield of a specific crop is a complicated one which agree may vary in frequency and amount. Problems associated with the sequential nature of irrigation water inputs stem from the fact that the crop-yield response only 1.24 t ha $^{-1}$in Ethiopia (FAO, 2012) which is far below the potential 4-5 t ha^{-1} traditional archive in Europe and the world average yield of 1.7 t ha^{-1} (Smýkal et al., 2012). The yield of field pea may be reduced by inappropriate irrigation water management in addition to a lack of improved variety, disease, and poor fertility of the soil. Construction and expansion of irrigation schemes and water management is an opportunity to improve the existing field production.

Field pea planted under irrigation conditions cannot withstand over flood irrigation. Under such conditions, the plant may die. Irrigation at an interval of two to three weeks through the crop growing period and based on the plant indicator and soil moisture condition is a common practice in the study area. However, in Ethiopia particularly in the Amhara region, irrigation scheduling under which water is optimum volume has not yet been established for field pea. Hence, the objectives of this study were to determine the crop water requirement and irrigation schedule of field pea and to determine the effect of variable irrigation scheduling on yield and water productivity in a humid tropical environment.

Materials and Methods

The experiment was conducted in 2013 and 2014 at the experimental field of Adet agricultural research center at Koga irrigation schemes and farmers field at the Rib irrigation command area. Koga irrigation scheme is located in Mecha district; 41 kilometers from Bahir Dar on the way to Addis Abeba road (37°7'29.721" East and 11°20'57.859" North. Rib irrigation site is located in the Fogera district, 60 kilometers far from Bahir Dar and geographically located at 37°25' to 37°58' East and 11°44' to 12°03' North. Both the irrigation schemes are characterized as a mid altitude agro-ecology.

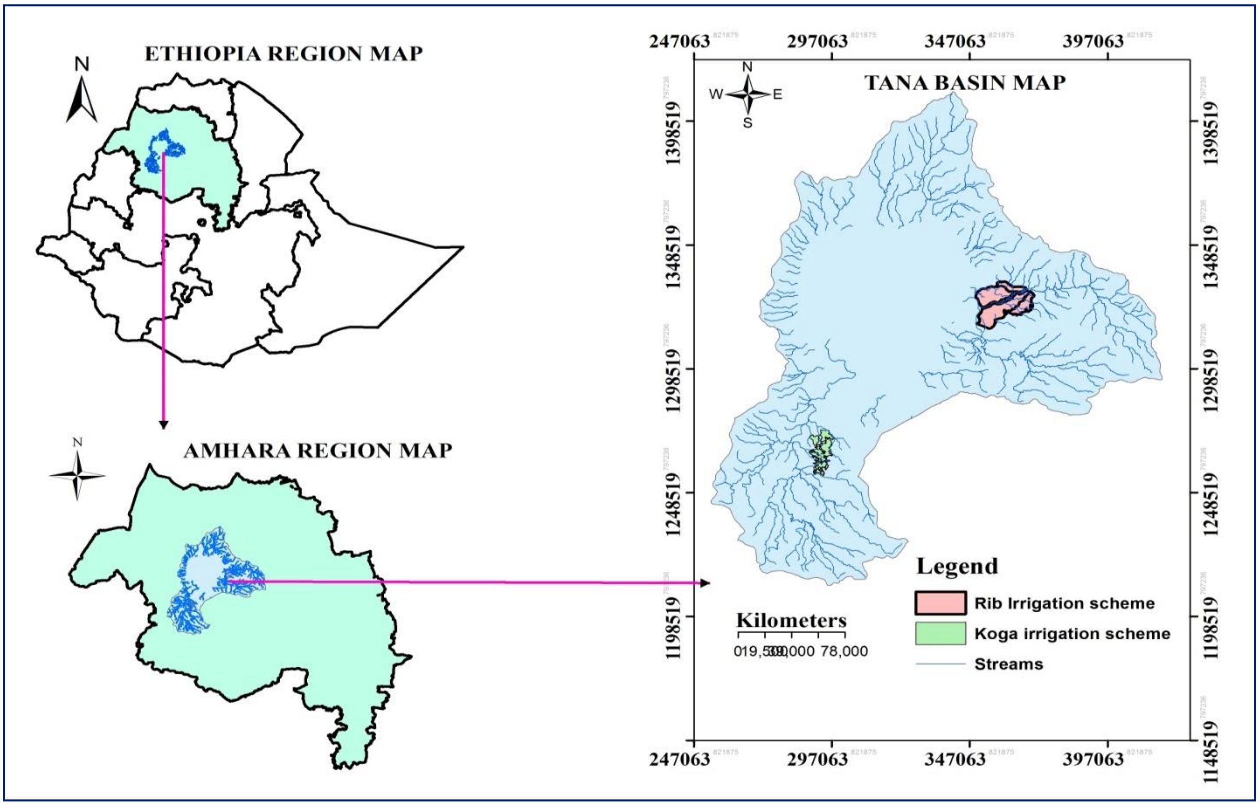

Figure 1. The map description of the study area

Table 1. Physicochemical properties of soil at Koga and Rib irrigation schemes

Parameters	Irrigation schemes	
	Koga	Rib
FC (%)	32	59.25
PWP (%)	18	21.0
Total nitrogen (%)	0.21	0.003
PH (1:2.5 H_2O)	4.75	6.7
CEC (cmol kg^{-1})	2.88	33
Available Phosphorus (ppm)	8.7	36
Soil texture	Clay	Clay

Table 2. Climatic characteristics of the experimental sites

Parameters	Koga scheme	Rib scheme
Minimum temperature (ºc)	11.8	8.10
Maximum temperature (ºc)	26.8	29.6
Relative humidity (%)	58.0	67.0
Sunshine hour (hr)	8.00	7.90
Radiation (MJ $m^{-2}day^{-1}$)	20.5	20.3
Reference evapotranspiration (mm day^{-1})	3.46	3.56
Wind speed (km/day)	1.00	1.00

CROPWAT 8.0 for Windows was used to estimate daily reference crop evapotranspiration (Table 3 & 4) and generate the crop water requirement (CWR) and the irrigation schedule for field pea in the study areas. Calculations of the crop water requirements and irrigation schedules were carried out by taking inputs of climate, soil, and crop data. To estimate the climatic data (wind speed, sunshine hours, relative humidity, minimum and maximum temperature) LOCCLIM, local climate estimator software (I. FAO, 1992) was used both at Koga and Rib where there is no class A meteorological station. The estimator uses real mean values from the nearest neighboring stations and it interpolates and generates climatic data values for the study site. The field application efficiency at Koga and Rib considered were 70% and 90 % respectively for the gross water requirement calculation using the CropWat model since the model was performed at 100% application efficiency. The demand for water during the plant's growing season varies from one growth stage to another and from crop to crop. The values of reference evapotranspiration (ETo) estimated were adjusted for actual crop 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 at Koga and Rib irrigation scheme.

Reference Evapotranspiration (ETO) Calculation

FAO Penman-Monteith Method: It is a combination approach that combined the aerodynamic and heat balance equations into one equation. This equation was used by CROPWAT (Allen et al., 1998) for estimating reference crop evapotranspiration (ET_O) given below:

Where: ET_0 is reference evapotranspiration (mm day^{-1}), T, G, and Rn are daily mean temperature ^{o}C at 2 m height, soil heat flux density (MJ m-2 day-1), and net radiation value at crop surface (MJ m^{-2} day^{-1}) respectively. Also, u2, es, ea, (es ea), D and c represent wind speed at 2 m height (m s^{-1}), saturated vapor pressure at the given temperature (kPa), actual vapor pressure (kPa), saturation vapor pressure deficit (kPa), the slope of the saturation vapor pressure curve (Pa/^{o}C) and psychometric constant (kPa/^{o}C), respectively.

Effective Rainfall (Pef): To account for the losses due to runoff or percolation, a choice can be made of one of the four methods given in CROPWAT 8.0 (Fixed percentage, Dependable rain, Empirical formula, USDA Soil Conservation Service). In this experiment, to calculate the effective rainfall the USDA Soil Conservation Service method was used.

for P <= 83.3mm

for P>83.3mm

Where P = percipitaion and Pef = effective percipitation (rainfall)

Table 3. Climate and ET_O data of Koga irrigation scheme

Month	Min. temp (ºc)	Max. temp (ºc)	Humidity (%)	Wind (km day^{-1})	Sunshine hour (hr)	Radiation (MJm$^{2-1}$day^{-1}	ETo(mm day^{-1})
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	24.4	76	1	4.4	15.9	3.01
August	13.6	24.4	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	21.0	3.11
Average	11.8	26.8	58	1	8.0	20.5	3.46

Table 4. Climate and ETo data of Rib irrigation scheme

Month	Min. temp(ºc)	Max. temp(ºc)	Humidity (%)	Wind (km day^{-1})	Sunshine hour(hr)	Radiation (MJm$^{2-1}$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	22.9	3.73
March	8.0	33.0	49	2	10	24.4	4.17
April	9.0	32.7	51	2	8.5	22.6	4.07
May	10	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	23.2	3.99
November	6.7	30.0	69	2	10	21.6	3.55
December	5.6	30.0	61	1	7.4	17.3	2.81
Average	8.1	29.6	67	2	7.9	20.3	3.56

Table 5. Crop Water and Irrigation Requirements of field pea at Koga irrigation scheme

Month	Decade	Stage	Kc coeff.	ETc (mm day^{-1})	ETc (mm dec^{-1})	Eff. Rain ($mmdec^{-1}$)	Irr. Req. ($mmdec^{-1}$)
Dec.	2	Init.	0.40	1.32	13.2	0.0	13.2
Dec.	3	Init.	0.40	1.35	13.5	0.0	13.5
Jan.	1	Deve	0.41	1.40	14.0	0.0	14.0
Jan.	2	Deve	0.60	2.10	21.0	0.0	21.0
Jan.	3	Deve	0.88	3.29	32.9	0.0	32.9
Feb.	1	Mid	1.15	4.54	45.4	0.0	45.4
Feb.	2	Mid	1.20	5.04	50.4	0.0	50.4
Feb.	3	Mid	1.20	5.20	41.6	0.1	41.4
Mar.	1	Mid	1.20	5.36	53.6	2.0	51.6
Mar.	2	Late	1.20	5.50	55.0	3.0	52.0
Mar.	3	Late	0.91	4.24	46.6	4.8	41.8
Apr.	1	Late	0.50	2.39	19.1	5.3	12.5
Total					399	15.3	342.4

Table 6. Crop Water and Irrigation Requirements of field pea at Rib

Month	Decade	Stage	Kc coeff.	ETc (mm day^{-1})	ETc (mm dec^{-1})	Eff. Rain ($mmdec^{-1}$)	Irr. Req. ($mmdec^{-1}$)
Dec.	2	Init.	0.40	1.08	1.1	0.0	1.1
Dec.	3	Init.	0.40	1.14	12.5	0.0	12.5
Jan.	1	Deve	0.41	1.23	12.3	0.0	12.3
Jan.	2	Deve	0.59	1.84	18.4	0.0	18.4
Jan.	3	Deve	0.86	2.85	31.3	0.0	31.3
Feb.	1	Mid	1.11	3.91	39.1	0.0	39.1
Feb.	2	Mid	1.16	4.33	43.3	0.0	43.3
Feb.	3	Mid	1.16	4.50	36.0	0.1	35.9
Mar.	1	Mid	1.16	4.68	46.8	2.0	44.8
Mar.	2	Late	1.16	4.83	48.3	3.0	45.3
Mar.	3	Late	0.88	3.63	39.9	4.8	35.1
Apr.	1	Late	0.49	2.02	16.2	5.3	9.5
Total					345.2	15.3	328.6

Experimental Design: The field experiments were arranged with a split-plot design with three replications and carried out from December to April. This is because those months are the irrigation season for field pea production in the case of the Koga and Rib irrigation scheme. The on-farm trial was conducted in the dry season with ten different treatments at Rib, and Koga under the consideration of two factors.1) two irrigation intervals i.e. 10 and 14 days and 2) irrigation depth (i.e 50 %, 75 %,100 %, 125 %, and 150 % CWR) of variable depths at four growth stages are selected based on CROPWAT 8.0 and farmers traditional practices in the area and this amount of water was taken from the full amount of irrigation water applied in the field.

The test crop was field pea with variety Birkitu was planted on 3 m by 6 m plot size at Koga and 2.6*4 at Rib irrigation scheme. Spacing between treatments is 1m and Spacing between each block will be 1.5m. The spacing between row and crops was 0.5 m and 0.1 m respectively. DAP fertilizer was applied at a rate of 100 kg ha^{-1} at planting. All the agronomic practices were uniformly performed for each treatment. Agronomic data such as stand count, yield, and seed weight were collected. Irrigation water productivity was calculated as the ratio of crop yield (seed 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. The mean comparison was done by using the least significant difference test at a 5% probability level.

Results and Discussion

The effect of different irrigation scheduling treatments on crop growth parameters, yield, and water productivity at the Koga and Rib irrigation scheme was presented below the tables. At Koga, the analysis showed that yield and water productivity had a significant difference over a year and the interaction of year and treatment. While t

On the other hand, the ANOVA analysis showed that the yield and water productivity were highly significant differences over the year in the case of the Rib irrigation scheme.

Table 7. ANOVA for yield and water productivity at Koga irrigation scheme

Source of variation	Degree of freedom	Mean square	
		Yield	WP
Year	1	0.23 **	0.003 ns
Replication	2	0.049 *	0.0038 ns
Frequency	1	0.27 **	0.0005 ns
Depth	4	0.08 **	0.29 **
Year*Treatment	4	0.15 **	0.1 **
Replication*Frequency	2	0.003 ns	0.0003 ns
Frequancy*Depth	4	0.34 **	0.06 **
Error	28	0.01	0.001
CV(%)		6.79	6.7

ns = not significant, * = significant, and ** = highly significant

Table 8. Yield and water productivity analysis result of Koga irrigation scheme

Treatments		Year 1		Year 2	
Frequecy	Depth	Yield (t/ha)	WP (kg/m3)	Yield (t/ha)	WP (kg/m3)
10	50	1.71	0.89	1.59	0.83
10	75	1.49	0.51	1.57	0.54
10	100	2.12	0.55	1.87	0.53
10	125	2.20	0.48	1.66	0.34
10	150	2.05	0.42	1.73	0.30
14	50	2.00	0.88	1.73	0.98
14	75	1.83	0.69	1.71	0.64
14	100	1.77	0.50	1.58	0.41
14	125	1.45	0.33	1.76	0.40
14	150	1.32	0.25	1.48	0.28
	CV (%)	4.29	4.44	6.18	6.54
	F	0.0001	0.03	0.40	0.02
	D	0.0009	0.0001	0.30	0.0001
	F*D	0.0001	0.0001	0.01	0.001

* D = irrigation depth, F = irrigation frequency, and CV = coefficient of variation

Grain Yield of Field Pea: The grain yield of field pea showed an extraordinary for both years, while the parameter was significant over year and interaction of year and treatment. 100 % CWR irrigation depth at a 10-day irrigation interval gives stable grain yield and water productivity. In the first year Irrigation frequency, irrigation depth, and their interaction showed a highly significant difference in grain yield of field pea ($P < 0.01$, Table 7& 8). The lowest (1.32t ha^{-1}) and the highest (2.2 t ha^{-1}) grain yield of field pea were obtained for 150 and 125 % CWR at 14 and 10-day irrigation intervals respectively. Grain yield showed an increasing trend with the increase of water level and the reverse is true at 10 and 14-day irrigation intervals respectively. Year 2, Irrigation frequency and depth were not a significant difference in grain yield of field pea ($P < 0.05$, Table 7&8) while doing their interaction. The lowest (1.48t ha^{-1}) and the highest (1.87 t ha^{-1}) grain yield of field pea were obtained for 150 and 100 % CWR at 14 and 10-day irrigation intervals respectively.

The production was low compared to 4-5 t/ha traditional archives in Europe and slightly bigger than the world average yield of 1.7 t ha^{-1}(Smýkal et al., 2012). This might be due to the soil climate of Koga. Suitable PH for field pea is in a range of 5.5 to 7 while 4.63 at Koga. The soil at Koga has very low organic matter content and available phosphorus content according to the category by Clements and McGowen (1994). Besides, the maximum daily temperature above 25.6 ^{0} C during the reproductive phase of the crop harmed yield (Lesznyák, Hunyadi, & Csajbók, 2007). Irrigation frequency, irrigation depth, and their interaction showed a highly significant difference in grain yield of field pea ($P < 0.01$, Table 8). The lowest (2.45 t ha^{-1}) and the highest (3.21 t ha^{-1}) grain yield of field pea were obtained for 150 and 75 % CWR at 14 and 10-day irrigation intervals respectively. In the second year irrigation frequency, irrigation depth, and their interaction was not significantly different in grain yield of field pea ($P < 0.05$, Table 9).

Applying optimum amount of water at an exact time can improve the field pea yield up to one t ha^{-1} which compared to the finding of (Cherinet & Tazebachew, 2015), who reported 2.2-2.4 t $ha^{-1}$was achieved using birkitu and tegenche field pea variety under irrigation in Koga and Rib. The total grain yield of field pea at Fogera plain was much larger than the Koga irrigation scheme, this might be the soils at Fogera are fluvisols which are deposited from upper catchments and have good nutrient content. However, the production was low compared to 4-5 t ha^{-1} traditional archives in Europe and slightly greater than the world average yield of 1.7 t ha^{-1}(Smýkal et al., 2012) this might be due to optimum temperature and safe environment for field pea production. The suitable maximum temperature for field pea is less than 25.6ºc while at the Rib irrigation scheme the average monthly temperature becomes 29.6 ºc which is close to the threshold temperature. Also, the finding is in line with Lesznyák et al. (2007), who reported the maximum daily temperature, above 25.6 ^{0} C during the reproductive phase of the crop harmed yield at the specific growth stage even if the seed yield is better and may increase more.

Table 9. ANOVA for yield and water productivity at Rib irrigation scheme

Source of variation	Degree of freedom	Mean square	
		Yield	WP
Year	1	9335968.8 **	1.12 **
Replication	2	20231.0 ns	0.0018 ns
Frequency	1	47137.5 ns	0.0017 ns
Depth	4	100528.091 *	1.07 **
Year*Treatment	4	70483 ns	0.0068 ns
Replication*Frequency	2	3682 ns	0.001 ns
Frequency*Depth	4	84725 *	0.02 ns
Error	28	26938.7	0.003
CV		6.99	8.4

ns: not significant, * significant at 5% and ** highly significant at 1%

Table 10. Thousand seed weight, yield, and water productivity analysis result of Rib

Treatments		Year 1		Year 2	
Frequency	Depth	Yield (t/ha)	WP (kg/m3)	Yield (t/ha)	WP (kg/m3)
10	50	2.471	0.88	1.922	0.53
10	75	3.217	0.82	1.747	0.62
10	100	2.737	0.46	1.708	0.58
10	125	3.019	1.35	1.891	0.98
10	150	2.876	1.07	2.152	0.64
14	50	2.500	0.76	1.883	0.48
14	75	2.724	0.60	1.947	0.40
14	100	2.841	0.48	2.036	0.37
14	125				

Water Productivity: Irrigation frequency, irrigation depth, and their interaction showed a highly significant difference in water productivity of field pea ($P < 0.01$, Table 7&8). The lowest (0.25-0.28 kg m^{-3}) and the highest (0.88-0.89 kg m^{-3}) water productivity were obtained for 150 and 50 % CWR both at 10 and 14-day irrigation intervals at Koga irrigation scheme. The water productivity showed a decreasing trend with the increase in water level both at 10 and 14-day irrigation intervals. The results are in close agreement with Kebede (2003), Bekele, and Tilahun (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.

In the case of the Rib irrigation scheme, the response of water productivity to irrigation frequency and depth was highly significant at ($P < 0.01$). The lowest (0.37-0.48 kg m^{-3}) and the highest (0.98-1.35 kg m^{-3}) water productivity were obtained for 150 % CWR and 50 % CWR irrigation depth respectively. However, their interaction was not significa
0.05). The water productivity decreased when the increasing application depth of irrigation. These results are also in close agreement with Kebede (2003), Bekele and Tilahun (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 (Table 10).

Conclusion and Recommendations

The effects of irrigation scheduling were assessed by examining their effects on yield and water productivity of field pea. The combined result of the current study revealed that the interaction effect of irrigation frequency and depth had a positive effect on yield both at Koga and Rib irrigation scheme and water productivity respond only for Koga. At Koga, irrigating 100%CWR at a 10-day interval gives 1.87-2.12 t ha^{-1} and 0.53-0.55 kg m^{-3} stable grain yield and water productivity respectively. At Rib, irrigating 75 % CWR at a 10-day interval gives 3.2 t ha^{-1} and 1.05 kg m^{-3} optimal grain yield and water productivity respectively.

Hence from the foregoing statistical analysis results, if irrigation scheduling is aimed at maximizing yields per unit of irrigated area. Therefore irrigating 75 % CWR at a 10-day irrigation interval gave a high yield of 3.2 t ha^{-1} in the case of the Rib irrigation scheme. While 100 to 125% CWR at the 10-day irrigation frequency gave a high yield of 2.12 to 2.2

t ha^{-1} with the water productivity ranges 0.58 to 0.48 kg m^{-3} at the Koga irrigation scheme. Also, the scheduling objective is to maximize yield per depth of water applied as a result water is the limiting resource 50 % CWR at 14-day irrigation interval gave promise yield of 1.7 to 2.2 t ha^{-1} and the water productivity ranges 0.88 to 0.89 kg m^{-3} at Koga and 50% CWR gave 2.4-2.5 t ha^{-1} and high water productivity 1 to 1.35 kg m^{-3} at Rib similar agroecology is recommended. Saved water will help to cultivate additional land and increase production for the teeming human population in Ethiopian highlands.

Acknowledgment

The author sincerely thanks the site managers and Adet agriculture research center staff.

References

Abebe, Michael. (2001). Irrigation Research technologies recommended for sustaining crop production in some irrigated areas of Ethiopia. *Norwegian university of science and technology, Norway*.

Al-Jamal, MS, Sammis, TW, Ball, S, & Smeal, D. (1999). Yield-based, irrigated onion crop coefficients. *Applied Engineering in Agriculture, 15*(6), 659.

Allen, Richard G, Pereira, Luis S, Raes, Dirk, & Smith, Martin. (1998). Crop evapotranspiration-Guidelines for computing crop water requirements-FAO Irrigation and drainage paper 56. *Fao, Rome, 300*(9), D05109.

Bekele, Samson, & Tilahun, Ketema. (2007). Regulated deficit irrigation scheduling of onion in a semiarid region of Ethiopia. *Agricultural water management, 89*(1-2), 148-152.

Cherinet, AM, & Tazebachew, AS. (2015). Adaptability of Field pea (Pisum Sativam L.) varieties under Irrigation at the Western Amhara Region, Ethiopia. *International Journal of plant Breeding and Genetics, 9*(2), 28-31.

Clements, BW, & McGowen, IJ. (1994). Strategic fertiliser use on pastures [New South Wales]. 2. *Agnote-New South Wales Agriculture (Australia). no. Reg 4/57.*

DeJonge, Kendall, & Kaleita, Amy. (2006). *Simulation of spatially variable precision irrigation and its effects on corn growth using CERES-Maize.* Paper presented at the 2006 ASAE Annual Meeting.

FAO, Irrigation. (1992). Drainage Paper No. 46. *CROPWAT: A Computer Program for Irrigation Planning and Management*, 48.

FAO, WFPi. (2012). IFAD. *The state of food insecurity in the world*, 65.

Girma, B. (2003). *The state of grain marketing in Ethiopia.* Paper presented at the Proceedings of the EDRI/IFPRI, 2020 Network Policy Forum on Toward Sustainable Food Security in Ethiopia: Integrating the Agri-Food Chain.

Kebede, W. (2003). Shallot (Allium cepa var. ascalonicum) responses to nutrients and soil moisture in sub humid tropical climate. *Unpublished thesis dissertation Swidish University of Agricultural Sciences, Agraria*.

Lesznyák, M, Hunyadi, Éva Borbély, & Csajbók, József. (2007). Influence of nutrient-and water-supply on the yield and protein yield of pea (Pisum sativum L.) varieties. *Cereal Research Communications, 35*(2), 729-732.

Rockström, John, Barron, Jennie, & Fox, Patrick. (2003). Water productivity in rain-fed agriculture: challenges and opportunities for smallholder farmers in drought-prone tropical agroecosystems. *Water productivity in agriculture: Limits and opportunities for improvement, 85199*(669), 8.

Smýkal, Petr, Aubert, Gregoire, Burstin, Judith, Coyne, Clarice J, Ellis, Noel TH, Flavell, Andrew J, . . . Neumann, Pavel. (2012). Pea (Pisum sativum L.) in the genomic era. *Agronomy, 2*(2), 74-115.

Thomas, DL, Harrison, KA, & Hook, JE. (2004). Sprinkler irrigation scheduling with the UGA easy pan: performance characteristics. *Applied engineering in agriculture, 20*(4), 439.

Upton, Martin, & Martin, Upton. (1996). *The economics of tropical farming systems*: Cambridge University Press.