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Effect of irrigation frequency and depth on yield and water productivity of Field Pea at Koga and Rib irrigation Scheme, Ethiopia

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Abstract*— Efficient irrigation scheduling is crucial for optimising crop yield and water productivity, particularly in water-scarce regions. This study evaluated the effects of different irrigation frequencies and depths on the yield and water productivity of field pea (Pisum sativum L.) at the Koga and Rib irrigation schemes in Ethiopia over two growing seasons. A factorial experiment with two irrigation intervals (10 and 14 days) and five irrigation depths (50 %, 75 %, 100 %, 125 %, and 150 % of crop water requirement) was conducted using a split-plot design with three replications. The results revealed that irrigation scheduling significantly influenced both grain yield and water productivity at both sites. At Koga, the highest grain yield (2.12 t ha^{-1}) and optimal water productivity (0.55 kg m^{-3}) were achieved by irrigating at 100 % crop water requirement (CWR) every 10 days. Conversely, at Rib, the highest yield (3.21 t ha^{-1}) and water productivity (1.05 kg m^{-3}) were obtained with 75 % CWR applied every 10 days. Increasing irrigation depth beyond these optimal levels did not further enhance yield and led to a decline in water productivity. These findings suggest that site-specific irrigation scheduling is essential for maximising field pea production while improving water use efficiency. The study recommends irrigating field pea at 100% CWR every 10 days in Koga and 75 % CWR every 10 days in Rib to achieve the best balance between yield and water conservation.

Keywords*— *Crop Water Requirement, Field pea, Irrigation Depth, Irrigation Frequency, Water Productivity

I. INTRODUCTION

Recently, precision agriculture in humid areas has already been used to increase yield and water productivity, thereby making irrigation feasible [1]. 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 the 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[2]. Irrigation scheduling and yield have a positive correlation [3, 4]. The relationship between the total quantity of water applied and the yield of a specific crop is a complicated one, which [5] 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 depends on the timing and adequacy of individual water applications. Applying the optimum amount at the right time as well as at critical growth stages has a crucial impact [5, 6]. Thus, to attain stable crop yields with unpredictable storm frequency variability, irrigation scheduling is often necessary.

In Ethiopia, the population is growing rapidly and is expected to continue growing, which inevitably leads to increased food demand. To maintain self-sufficiency in the 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 maximise the irrigation water use efficiency, resulting in beneficial use and conservation of the local water resources [7]. Field pea (Pisum sanctum L.) has important ecological and economic advantages in the highlands of Ethiopia, as it plays a crucial role in soil fertility restoration. It is also the source of income for the farmers and foreign currency for the country [8]. Having these multiple benefits for the livelihood, however, the average yield of the crop is only 1.24 t ha-1 in Ethiopia [9], which is far below the potential 40-50 t ha-1 traditional archive in Europe and the world average yield of 1.7 t ha-1 [10].

Efficient water management is crucial for sustainable agricultural production, particularly in regions where water resources are scarce or unevenly distributed. Irrigation scheduling plays a key role in ensuring optimal crop growth by supplying the right amount of water at the right time, thereby improving both yield and water productivity. Field pea (Pisum sativum L.) is an important legume crop widely cultivated in Ethiopia, providing nutritional, economic, and soil fertility benefits. However, its productivity remains significantly lower than the global average due to suboptimal irrigation practices, poor soil fertility, and limited research on site-specific irrigation requirements. In Ethiopia, irrigation development is expanding to address food security challenges and increase agricultural productivity. Despite this, a standardised irrigation schedule for field pea has not been established, particularly in the Amhara region, where most irrigation is traditionally managed based on farmers' experience rather than scientific guidelines. The lack of precise irrigation scheduling leads to either over-irrigation, which wastes water and reduces efficiency, or under-irrigation, which limits crop growth and yield potential. To optimise water use efficiency and enhance field pea production, it is essential to determine the crop's specific water requirements and ideal irrigation intervals. This study was conducted to evaluate the effects of different irrigation frequencies and depths on the yield and water productivity of field pea in two major irrigation schemes at Koga and Rib, representing different agro-ecological conditions. By using a combination of field experiments and the CROPWAT model, the study aimed to determine the optimal irrigation schedule that balances maximum yield with efficient water use.

II. Materials And Methods

A. Description of the Study Area

The study was conducted at two major irrigation schemes in the Amhara region of Ethiopia, at Koga and Rib irrigation schemes (Figure 1) [11]. These sites were selected due to their significance in agricultural production and their potential for improved irrigation water management. Both locations have distinct agroecological conditions that influence crop performance, making them ideal for evaluating the effects of irrigation scheduling on field pea (Pisum sativum L.) yield and water productivity. The Koga irrigation scheme is located in the Mecha district, approximately 41 km from Bahir Dar along the road to Addis Ababa. It lies at coordinates 37° 7' 29.72" East and 11° 20' 57.85" North, with an altitude of 1,948 meters above sea level (m a.s.l.). The climate of the area is classified as sub-humid tropical, characterised by a mean annual rainfall of 1,328 mm, with the rainy season occurring mainly from June to September. The mean maximum temperature is 26.8 °C, while the minimum temperature is 9.7 °C. The soil in Koga is predominantly light clay, with a field capacity (FC) of 32 % (w/w) and a permanent wilting point (PWP) of 18 % (w/w). The soil pH is 4.63. Additionally, the soil is characterised by low organic matter content and low available phosphorus levels. The Rib irrigation scheme is located in the Fogera district, approximately 60 km from Bahir Dar along the road to Gondar. It is situated between 37° 25' to 37° 58' East and 11° 44' to 12° 03' North, with an altitude of 1,774 m a.s.l.. The area receives a mean annual rainfall of 1,432 mm with a similar rainy season concentrated in the summer months. The mean maximum temperature is 30 °C, while the minimum temperature is 11.5 °C, making it relatively warmer than Koga. Both Koga and Rib irrigation schemes provide important opportunities for irrigated agriculture; they exhibit differences in temperature, soil properties, and water availability, which affect crop yield and water productivity. Koga has lower soil fertility and a more acidic pH, requiring careful irrigation and nutrient management. In contrast, Rib has a more fertile soil profile but experiences higher temperatures, which can negatively impact field pea growth during sensitive developmental stages.

B. Methods

The on-farm trial was conducted in the dry season with ten different treatments in both locations at the Rib and Koga irrigation scheme. Two irrigation intervals of 10 and 14 days and five irrigation levels (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 (Table I). The field experiments were arranged with a split-plot design with three replications. The test crop field pea, a variety of Birkitu, was planted on a 3 x 6 m plot size at Koga and 2.6 x 4 m at Rib. Spacing between treatments is 1 m, and spacing between each block was 1.5 m. The spacing between rows and plants was 0.5 m and 0.1 m, respectively. DAP fertiliser was applied at a rate of 100 kg ha^{-1} at planting. All the agronomic practices were applied equally for all treatments as per the agronomic recommendation [12]. Agronomic data such as stand count, yield, and seed weight were collected. Irrigation water productivity was calculated as the ratio of crop yield (grain yield) and applied irrigation water.

TABLE I. Treatment Setup Of The Experiment

Treatment	Depth and interval	Treatment	Depth and interval
T1	50% CWR at 10 days	T6	50% CWR at 14 days
T2	75% CWR at 10 days	T7	75% CWR at 14 days
T3	100% CWR at 10 days	T8	100% CWR at 14 days
T4	125% CWR at 10 days	T9	125% CWR at 14 days
T5	150% CWR at 10 days	T10	150% CWR at 14 days

C. Climate Data Collection and Analysis

Understanding the climatic conditions of an agricultural region is essential for optimising irrigation scheduling and improving crop performance. This study was conducted at the Koga and Rib irrigation schemes, which show variations in temperature, rainfall, relative humidity, wind speed, and solar radiation. These climatic factors significantly influence crop water requirements and irrigation planning. The climate data for both locations were used as inputs for the CROPWAT 8.0 software, and LOCCLIM (Local Climate Estimator) was used for interpolating meteorological data based on the nearest weather stations [13]. These tools interpolate meteorological data from the nearest weather stations, specifically Koga and Bahir Dar meteorological stations for Koga, and Addis Zemen and Debre Tabor meteorological stations for the Rib irrigation scheme. During the crop water requirement determination, a 70 % application efficiency was applied at both locations. It is important to note that water demand during the crop's growing season varies across different growth stages and from crop to crop. To validate the CROPWAT model’s output, field experiments were conducted over two consecutive years at both irrigation schemes. Inputs for the model included local rainfall data, reference evapotranspiration (ETo), soil data, and crop data. The climate data used in this study covered the ten years from 2007 to 2016. The crop data (such as root depth, crop coefficient, critical depletion, yield response factor, and length of plant growth stages) were taken from FAO Irrigation and Drainage Paper 56 [7]. Planting in the study area began in mid-November and continued through December.

Soil properties such as field capacity (FC), permanent wilting point (PWP), infiltration rate, and initial soil moisture depletion were determined at the Adet Agricultural Research Center soil laboratory using the gravimetric method. Additionally, reference evapotranspiration (ETo), crop evapotranspiration (ETc), and irrigation water requirements (IWR) were estimated using the FAO Penman-Monteith method, as detailed in (Eq.1), (Eq.2), and (Eq.3). The effective rainfall (ER) was estimated using the USDA Soil Conservation Service method [14], which was then used to calculate crop water requirements (CWR). Crop water requirement (CWR) is the water lost from a cropped field through evapotranspiration (ET), expressed as the rate of ET in mm/day. CWR is derived from crop evapotranspiration (ETc) and is calculated using the following equation [15]. The crop coefficient (Kc) varies over the crop's development stages (initial development, mid-season, and late-season) [7, 15]. Proper irrigation scheduling determines when and how much water should be applied to specific field crops [15]. Irrigation requirement (IR) is a critical parameter for the planning, design, and operation of irrigation systems and water resource management [16]. Mismanagement of irrigation requirements can lead to inadequate reservoir storage capacities, low water use efficiency, reduced irrigated areas, and increased development costs [16]. Therefore, the accurate estimation of irrigation requirements is essential for efficient irrigation management.

$$ETo = \frac{0.408\Delta(Rn-G)+\gamma\frac{900}{T+273}U2(es-ea)}{\Delta+\gamma(1+0.34U2)} \quad \text{(Eq.1)}$$

$$ETc = ETo \ x \ Kc \quad \text{(Eq.2)}$$

$$IRn = ETc - (Pe + Ge + Ws) + LR \quad \text{(Eq.3)}$$

Where: ETo = reference evapotranspiration [mm day-1], Rn = net radiation at the crop surface [MJ m-2 day-1], G = soil heat flux density [MJ m-2 day-1], T = mean daily air temperature [°C], U2 = wind speed at 2 m height [m s-1], es = saturation vapour pressure [kPa], ea = actual vapour pressure [kPa], es-ea = saturation vapour pressure deficit [kPa], Δ = slope vapour pressure curve [kPa °C-1], γ = psychrometric constant [kPa °C-1], ETc = Crop Evapotranspiration (mm day-1), ETo = Reference Crop Evapotranspiration (mm day-1), Kc = Crop coefficient, IRn = Net irrigation requirement (mm), ETc = Crop evapotranspiration (mm), Pe = Effective dependable rainfall (mm), Ge = Groundwater contribution from water table (mm), Ws = Water stored in the soil at the beginning of each period (mm) and LR = Leaching requirement (mm)

D. *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 5% probability level.

III. Results And Discussion

A. *Crop and Irrigation Water Requirement*

The results of this study revealed that crop water demand varied across months and locations, influenced primarily by temperature differences. The climatic conditions at Koga and Rib irrigation schemes differed slightly, affecting the crop evapotranspiration (ETc) and irrigation water requirements. At Koga, the mean maximum and minimum temperatures were 26.8 °C and 11.8 °C, respectively, with an average reference evapotranspiration (ETo) of 3.46 mm day-1 (Table II). At Rib, the mean maximum temperature was 29.6°C, while the minimum was 8.1°C, with a slightly higher average ETo of 3.56 mm day-1 (Table III). These climatic variations contributed to differences in irrigation water demand between the two locations. The total seasonal crop water requirement (CWR) at Koga was 399 mm, with a net irrigation requirement (NIR) of 342.4 mm, whereas at Rib, the total CWR was 345.2 mm, with an NIR of 328.6 mm (Tables IV and V). The slightly higher irrigation requirement at Koga could be attributed to lower effective rainfall and soil characteristics. The results indicated that efficient irrigation scheduling is crucial for optimising water use and maximising crop yield.

TABLE II. Climate Characteristics Of Koga Irrigation Scheme

Month	Temperature (°C)		Relative Humidity (%)	Wind speed (km day-1)	Sunshine hours	Radiation ($MJ/m^2/day$)	ETo (mm/day)
	Min	Max					
Jan	7.5	26.5	51	61	9.8	21.3	3.13
Feb	9.2	28.0	45	69	9.8	22.8	3.48
Mar	12.0	29.5	42	86	9.1	23.1	3.80
Apr	13.3	29.8	43	95	8.8	23.1	3.98
May	14.4	28.9	53	86	8.6	22.4	4.03
Jun	14.0	26.6	67	86	6.7	19.2	3.59
Jul	13.7	24.4	76	69	4.4	15.9	3.01
Aug	13.6	24.4	77	69	4.3	15.9	3.00
Sep	12.9	25.1	72	69	5.9	18.2	3.30
Oct	12.5	26.2	63	69	9.0	21.9	3.70
Nov	10.4	26.3	57	61	9.5	21.2	3.35
Dec	7.9	26.2	54	61	10.0	21.0	3.11
Mean	11.8	26.8	58	73	8	20.5	3.46

TABLE III. CLIMATE CHARACTERISTICS OF RIB IRRIGATION SCHEME

Month	Temperature (°C)		Relative Humidity (%)	Wind speed (km day-1)	Sunshine hours	Radiation ($MJ/m^2/day$)	ETo (mm/day)
	Min	Max					
Jan	4.6	30.5	54	156	9.2	20.3	3.12
Feb	6.3	33.0	51	156	10.0	22.9	3.73
Mar	8.0	33.0	49	147	10.0	24.4	4.17
Apr	9.0	32.7	51	130	8.5	22.6	4.07
May	10.0	31.6	65	156	6.7	19.6	3.76
Jun	10.4	28.5	80	156	5.4	17.4	3.41
Jul	9.8	25.0	85	104	1.6	11.8	2.39
Aug	10.1	25.5	86	86	6.7	19.6	3.57
Sep	9.8	27.0	82	104	9.0	22.9	4.08
Oct	7.4	29.0	76	138	10.0	23.2	3.99
Nov	6.7	30.0	69	138	10.0	21.6	3.55
Dec	5.6	30.0	61	112	7.4	17.3	2.81
Mean	8.1	29.6	67	132	7.9	20.3	3.56

TABLE IV. CROP WATER AND IRRIGATION REQUIREMENTS AT KOGA

Month	Decade	Stage	Kc	ETc	ETc	Eff. Rain	Irr. Req.
				($mm\ day^{-1}$)	($mm\ dec^{-1}$)	($mm\ dec^{-1}$)	($mm\ dec^{-1}$)
Dec	2	Init	0.4	1.32	13.2	0	1.3
Dec	3	Init	0.4	1.35	14.8	0	14.8
Jan	1	Dev	0.4	1.40	14.0	0	14.0
Jan	2	Dev	0.6	2.10	21.0	0	21.0
Jan	3	Dev	0.9	3.29	36.2	0	36.2
Feb	1	Mid	1.2	4.54	45.4	0	45.4
Feb	2	Mid	1.2	5.04	50.4	0	50.4
Feb	3	Mid	1.2	5.20	41.6	0.1	41.4
Mar	1	Mid	1.2	5.36	53.6	2	51.6
Mar	2	Late	1.2	5.50	55.0	3	52.0
Mar	3	Late	0.9	4.24	46.6	4.8	41.8
Apr	1	Late	0.5	2.39	19.1	5.3	12.5
Total					399	15.3	342.4

TABLE V. CROP WATER AND IRRIGATION REQUIREMENTS AT RIB

Month	Decade	Stage	Kc	ETc	ETc	Eff. Rain	Irr. Req.
				($mm\ day^{-1}$)	($mm\ dec^{-1}$)	($mm\ dec^{-1}$)	($mm\ dec^{-1}$)
Dec	2	Init	0.4	1.08	1.1	0	1.1
Dec	3	Init	0.4	1.14	12.5	0	12.5
Jan	1	Dev	0.4	1.23	12.3	0	12.3
Jan	2	Dev	0.6	1.84	18.4	0	18.4
Jan	3	Dev	0.9	2.85	31.3	0	31.3
Feb	1	Mid	1.1	3.91	39.1	0	39.1
Feb	2	Mid	1.2	4.33	43.3	0	43.3
Feb	3	Mid	1.2	4.5	36	0.1	35.9
Mar	1	Mid	1.2	4.68	46.8	2	44.8
Mar	2	Late	1.2	4.83	48.3	3	45.3
Mar	3	Late	0.9	3.63	39.9	4.8	35.1
Apr	1	Late	0.5	2.02	16.2	5.3	9.5
Total					345.2	15.3	328.6

B. Analysis of Variance (ANOVA)

The analysis of variance (ANOVA) results presented in Tables 6 and 7 highlight the effects of irrigation scheduling, both irrigation frequency and depth on grain yield and water productivity at the Koga and Rib irrigation schemes. The results indicate that irrigation depth and frequency significantly influenced both yield and water productivity at both locations, though with site-specific differences.

Grain Yield: At Koga (Table 6), grain yield was significantly affected by irrigation depth ($P < 0.01$) and the interaction between irrigation depth and frequency ($P < 0.01$), confirming that the optimal yield response depended on the combination of both factors. Additionally, the year-by-treatment interaction was highly significant ($P < 0.01$), suggesting that environmental variations between the study years played a role in determining the crop's response to irrigation. At Rib (Table 7), grain yield was significantly influenced by irrigation depth ($P < 0.05$), while the effect of irrigation frequency alone was not significant ($P > 0.05$). However, the interaction of irrigation depth and frequency was significant ($P < 0.05$), indicating that the combination of irrigation depth and frequency played a critical role in determining yield.

Water productivity: At Koga (Table VI), irrigation depth had a highly significant effect on water productivity ($P < 0.01$), while irrigation frequency alone did not have a significant impact ($P > 0.05$). The interaction between depth and frequency was also significant ($P < 0.01$), indicating that both factors influenced water use efficiency. At Rib (Table VII), irrigation depth had a highly significant effect on water productivity ($P < 0.01$), whereas irrigation frequency and the depth-frequency interaction were not significant ($P > 0.05$). The lack of significance for irrigation frequency suggests that reducing irrigation frequency at Rib did not drastically affect water productivity, possibly due to better soil moisture retention compared to Koga.

TABLE VI. ANOVA MEAN SQUARE FOR YIELD AND WATER PRODUCTIVITY AT KOGA

Source of Variation	DF	Yield	Water productivity
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 x Treatment	4	0.15^{**}	0.1^{**}
Replication x Interval	2	0.003^{ns}	0.0003^{ns}
Depth x Interval	4	0.34^{**}	0.06^{**}
Error	28	0.01	0.001
CV		6.79	6.700

Where: DF = Degree of freedom, ns = not significant, * = significant, and** = highly significant at 5 % level of confidence intervals

TABLE VII. ANOVA FOR YIELD AND WATER PRODUCTIVITY AT RIB

Source of Variation	DF	Yield	Water productivity
Year	1	9335968.8**	1.12^{**}
Replication	2	20231.0^{ns}	0.0018^{ns}
Frequency	1	47137.5^{ns}	0.0017^{ns}
Depth	4	100528.09*	1.07^{**}
Year x Treatment	4	70483^{ns}	0.0068^{ns}
Replication x Interval	2	3682^{ns}	0.001^{ns}
Depth x Interval	4	84725^{*}	0.02^{ns}
Error	28	26938.7	0.003
CV		6.99	8.4

C. *Grain Yield*

The results from Table VIII for Koga and Table IX for Rib show that grain yield was strongly influenced by both irrigation depth and frequency. The effects of different irrigation scheduling (combining irrigation depth and frequency) on grain yield at Koga and Rib

irrigation schemes over two growing seasons indicate significant variations in yield across different treatments. At Koga, the highest grain yield (2.12 t ha^{-1}) was achieved with 100 % CWR applied every 10 days in the first year, while in the second year, the highest yield (1.87 t ha^{-1}) was recorded under the same treatment. This consistency suggests that 100 % CWR every 10 days is the most effective irrigation strategy for maximising yield at Koga. The lowest yield (1.32 t ha^{-1}) was observed at 150 % CWR applied every 14 days, demonstrating that over-irrigation reduced productivity, likely due to waterlogging, nutrient leaching, and reduced soil aeration. The results also show that applying less water (50 % CWR every 10 or 14 days) resulted in relatively stable yields (1.71 - 2.00 t ha^{-1}), though not as high as the 100 % CWR treatment. These findings confirm that moderate to full irrigation (100 % CWR every 10 days) is ideal for maximising yield at Koga, while excessive irrigation (150 % CWR) has negative effects. At Rib, the highest grain yield (3.21 t ha^{-1}) was recorded at 75 % CWR applied every 10 days, while the lowest yield (2.45 t ha^{-1}) occurred at 150 % CWR every 14 days. Unlike Koga, 75 % CWR was sufficient to maximise yield at Rib, indicating that field pea in this location required less irrigation to achieve optimal growth. The yield pattern at Rib suggests that over-irrigation did not lead to additional benefits and, in some cases, reduced yield. This could be due to the better soil fertility and moisture retention capacity at Rib compared to Koga, allowing crops to achieve higher yields with less irrigation. The higher overall yields at Rib compared to Koga are likely due to better soil nutrient availability, favourable temperatures, and improved water retention. This further reinforces the importance of site-specific irrigation scheduling rather than a one-size-fits-all approach. The production was low compared to traditional archives in Europe and slightly bigger than the world average yield (40 - 50 t ha-1) [10]. This might be due to the soil condition of Koga. Suitable PH for field pea is in a range of 5.5 - 7, while at the Koga irrigation scheme, the value was 4.63. The soil at Koga has very low organic matter content and available phosphorus content according to the category by Besides, the maximum daily temperature above 25.6 0 C during the reproductive phase of the crop harmed yield [17]. Studies indicated that applying the optimum amount of water at an exact time can improve the yield up to 1 t ha-1, as compared to the finding of [18], who reported 2.2 - 2.4 t ha-1 was achieved using Birkitu and Tegenche variety under irrigation in Koga and Rib. The total grain yield at Rib (Fogera plain) was much larger than the Koga irrigation scheme, because the soils are deposited from the upper catchments and have good nutrient content. However, the production was low compared to Europe and the world average yield [10] due to the optimum temperature and safe environment for field pea production. The suitable maximum temperature for field pea is less than 25.6 while at the Rib irrigation scheme it was 29.6 0 C. The finding is in line with [17], who reported that the maximum daily temperature, above 25.6 0 C during the reproductive phase of the crop, harmed yield.

D. *Water Productivity*

Water productivity, expressed as the ratio of grain yield per cubic meter of irrigation water applied. It was significantly influenced by irrigation scheduling at both sites. At Koga, the highest water productivity (0.89 kg m^{-3}) was achieved with 50 % CWR every 10 and 14 days, followed closely by 100 % CWR every 10 days (0.55 kg m^{-3}). This indicates that reducing irrigation depth improved water productivity by maximising the amount of yield per unit of water applied. Conversely, the lowest water productivity (0.25 kg m^{-3}) was recorded at 150 % CWR every 14 days, demonstrating that excessive irrigation led to inefficient water use. As the irrigation depth increased beyond the crop's actual requirement, water use efficiency decreased, confirming that water productivity is optimised at moderate irrigation depths (50–100% CWR). At Rib, the highest water productivity (1.35 kg m^{-3}) was recorded at 50 % CWR every 10 days, while the lowest (0.29 kg m^{-3}) occurred at 150 % CWR every 14 days. Similar to Koga, reducing irrigation depth improved water productivity, as lower water applications resulted in more efficient use of available moisture. These results suggest that water productivity can be maximised by applying less water at appropriate intervals. At

Rib, 50 % CWR every 10 days provided the best balance between yield and water use efficiency, while at Koga, 100 % CWR every 10 days was the most effective strategy. These results are also in close agreement with [19], [20], 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 VIII. YIELD AND WATER PRODUCTIVITY ANALYSIS AT KOGA

F	D	Year 1		Year 2	
		Yield (t ha^{-1})	WP (kg m^{-3})	Yield (t ha^{-1})	WP (kg m^{-3})
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	0.3
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	0.4
14	150	1.32	0.25	1.48	0.28
CV		4.29	4.44	6.18	6.54
F		0.0001	0.03	0.4	0.02
D		0.0009	0.0001	0.3	0.0001
F*D		0.0001	0.0001	0.01	0.001

Note: F = Frequency and D = Depth of applied water

TABLE IX. YIELD AND WATER PRODUCTIVITY ANALYSIS AT RIB

F	D	Year 1		Year 2	
		Yield (t ha^{-1})	WP (kg m^{-3})	Yield (t ha^{-1})	WP (kg m^{-3})
10	50	2.47	0.88	1.92	0.53
10	75	3.22	0.82	1.75	0.62
10	100	2.74	0.46	1.71	0.58
10	125	3.02	1.35	1.89	0.99
10	150	2.88	1.07	2.15	0.64
14	50	2.50	0.76	1.88	0.49
14	75	2.72	0.61	1.95	0.41
14	100	2.84	0.48	2.04	0.37
14	125	2.58	0.39	2.04	0.58
14	150	2.44	0.29	2.19	0.27
CV		5.1	7	9.1	9.55
F		0.001	0.02	0.07	0.003
D		0.003	0.0001	0.07	0.0001
F*D		0.01	0.0864	0.48	0.59

IV. CONCLUSION AND RECOMMENDATION

This study evaluated the effect of irrigation scheduling (frequency and depth) on the yield and water productivity of field pea (Pisum sativum L.) at the Koga and Rib irrigation schemes in Ethiopia. The results demonstrated that both grain yield and water productivity were significantly influenced by irrigation frequency and depth. At Koga, the highest grain yield (2.12 t ha-1) was obtained when 100 % of the crop water requirement (CWR) was applied every 10 days. However, water productivity was maximised at 50 % CWR applied every 14 days, suggesting that reducing irrigation depth improves water use efficiency. At Rib, the highest yield (3.21 t ha-1) was recorded at 75 % CWR applied every 10 days, while the highest water productivity (1.35 kg m^{-3}) was achieved at 50 % CWR applied every 10 days. The findings indicate that site-specific irrigation scheduling is essential for balancing yield optimisation and water conservation. Over-irrigation (applying more than 100 % CWR) did not increase yield and water productivity, emphasising the need for efficient irrigation management. Additionally, the differences between Koga and Rib highlight the importance of soil characteristics, climatic conditions, and crop water demand in determining optimal irrigation schedules. Therefore, at Koga, field pea should be irrigated at 100 % CWR every 10 days and at Rib, applying 75 % CWR every 10 days is recommended to achieve the highest yield, showing that a slightly lower irrigation depth is sufficient.

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