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ORIGINAL PAPER

Effects of Irrigation Management on Yield and Water Productivity of Barley *Hordeum vulgare* in the Upper Blue Nile Basin: Case Study in Northern Gondar

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Abstract
Deficit irrigation practices could be a sustainable crop production strategy in water-scarce regions. This paper presents the relationship between barley yield and various irrigation treatments based on a field-level experiment. The aim of this study is to determine irrigation depth and its effect on the yield and water productivity of barley, *Hordeum vulgare*. The field experiment was arranged in a randomized complete block design (RCBD) with four replications and five irrigation treatments (fully irrigated treatment (FIT), 90% FIT, 85% FIT, 80% FIT, and 75% FIT). The study showed yields of barley were significantly ($p < 0.05$) affected by the irrigation amount. At 80% FIT, the largest yield was recorded at 1700 kg/ha. The decrease in yield with increasing irrigation levels could be attributed to the variety of the barley in the region that performs well under water stress. Therefore, the highest yield is obtained at lower irrigation volume than the full irrigation level. The provision of a certain level of water stress (80% FIT) throughout the growing season translates to a better yield relative to full irrigation. The FIT (2.01 kg/m^3) and 80% FIT (2.95 kg/m^3) treatments had the lowest and highest water productivity, respectively. The finding indicates that barley production using deficit irrigation offers great potential in improving water use. Therefore, a deficit irrigation strategy that increases barley production and uses water efficiently in water-scarce areas is recommended.

Keywords Barley yield · Water depth · Water productivity · Deficit irrigation · Ethiopia

Introduction

In the face of climate change and the ensuing water scarcity problems in sub-Saharan Africa, increasing crop production is facing considerable challenges [1]. Many areas of the world are facing severe water scarcity [2]. Globally, around 4 billion people live under severe water scarcity [3]. Freshwater scarcity is a major problem for crop production in arid and semi-arid regions [4]. Without enhancing irrigation methods and technology in these regions, the goal of producing more crops tends to become a moving target [5]. The better water productivity can increase in the irrigated area [6]. Countries have been successful in using new irrigation technology to increase agricultural production [7]. Different field management strategies, such as mulching and deficit irrigation could be used to minimize unproductive evaporation loss from the soil. Furthermore, careful scheduling and proper planting are among the various ways to improve water usage [8]. In order to make sound decisions, crop water requirement estimation is an important tool to ensure sustainable crop production [9].

The pressure to produce more food to meet the requirements of the ever-increasing global population is expected to further strain the already limited water resources [10]. Given the fact that agriculture is the highest water user [11], freshwater stress may constrain global food production. In particular, crop production in water-scarce regions could be challenging due to

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climate disparity, longer dry environments, and associated problems [12]. Agricultural production is very difficult unless irrigation is well-managed in response to the challenges of water shortages and water scarcity [13]. Such water-related problems could be minimized by implementing the best water management techniques available [14]. For irrigated crops, understanding the optimum crop water requirement in areas where water is a limiting factor is important in increasing water productivity [15]. In places where rainfall is low, increasing irrigation will help to raise crop yield [9]. Nevertheless, maximum yield does not always mean highest water productivity and a reduced amount of applied irrigation water [16]. Therefore, there is a need for proper irrigation management in order to increase crop production, improve water productivity, and manage water resources properly [12, 15].

Studies on barley crop water needs have taken place in Ethiopia and other regions. The response to irrigation levels for the production of barley and investigation into the yield under various water depths and schedules was studied [17]. The effects of agronomy and soil on barley yield were examined [18]. The effects of fertilizer were analyzed [19]. Strategies for improving the productivity of water, enhancing management and advancing irrigation technologies at the farm or field level were studied [8]. Field level study in irrigated agriculture revealed that, for many crops, yield increases occurred without increasing the amount of water used [15, 18]. Effective, efficient, and appropriate water management is vital to maximize the production of crop products [14]. Information on proper irrigation is essential to maximize yield per unit area and for sustaining crop production. Even though research on different barley crops has been extensively conducted, the relationship between yield and crop water use has never been established in the study region. This work is new because it demonstrates the effects of various inputs at different treatment levels of water application to create improved water management for barley production. In this study, the barley *Hordeum vulgare* has been selected as a target plant for multiple reasons. Firstly, barley is the fourth most important annual cereal crop grown globally; secondly, the crop grows under a different agro-ecological zone; thirdly, it is the major food source in many African countries [19]. For better crop water productivity, knowledge of the crop water requirement helps to raise production and results in enhancing the water saving [20]. Consequently, in areas that experience water shortages, deficit irrigation could be an alternative strategy to maintain crop production [21]. Deficit irrigation could allow growers to save water and irrigate more areas [22]. For better crop water productivity, knowledge of the crop water requirement helps to raise production and results in enhanced water savings [23].

More advanced irrigation technologies lead to local water savings with less water applied. Studies [5, 6, 26] suggest that water is not lost, if the irrigation system is inefficient; instead, it remains in the hydrological system. Deficit irrigation could allow the reduction of the amount of applied water and irrigate more area [21]. One way of alleviating water insufficiency could be by increasing water use efficiency [2]. For better crop water productivity, knowledge of the crop water requirement helps to raise production and results in reducing the amount of applied water [23]. Sustainable water use can be achieved by setting the water volume that can be consumed [26]. Effective management of water can save water by increasing the water availability for reallocation to the other use, such as the industries. For example, studies in biorefinery processes use large volumes of water and chemicals which could impact the sustainability of the industry [24]. Use of groundwater, reclaimed water, and other impaired water sources is also an important strategy for fresh surface water conservation [25].

The Ethiopian national barley yield average is low [17]. Yield of barley has a strong relationship with the different levels of water depth. Therefore, proper irrigation scheduling or water management is needed. Yield of barley was reported to reduce when the water level was high in the study region. The increase in yield and water productivity was not significantly different compared with the water stress conditions [17]. Since soil moisture conditions affect nutrient availability to the crops, optimum irrigation could maximize water productivity and higher yield [27]. Barley is highly sensitive to waterlogging, and the regional variety responds well to water stress [17]. The crop water productivity values depend on crop yield (which fluctuates with factors such as variety, diseases, soil fertility, drought, and overall management practices), and evapotranspiration (ET) (which depends on factors such as climate, soil moisture, cropping calendars, mulching, rainfall, and irrigation [28]. Crop water requirements tend to be highly location-specific with different management strategies; therefore, studies conducted in some other areas cannot be directly adopted in this region. Deficit irrigation provides the means to optimize plant water use and to increase crop production. Therefore, the objective of this study was to determine the irrigation depth and its effect on the yield and water productivity of barley.

Materials and Methods

Study Area Descriptions

The field experiment was conducted at the Gondar University Agricultural Research Station, located in the upper Blue Nile sub-catchment 37° 26.105′ E longitude and 12° 35.96′ N latitude (Fig. 1).

The experimental site is at about 2111 MASL altitude. The area receives an annual average precipitation of 920 mm with maximum rainfall occurring from June to September. The average daily mean temperature value is about 21 °C. The laboratory analysis result revealed that the soil texture of the experimental area is clay loam. The area is generally

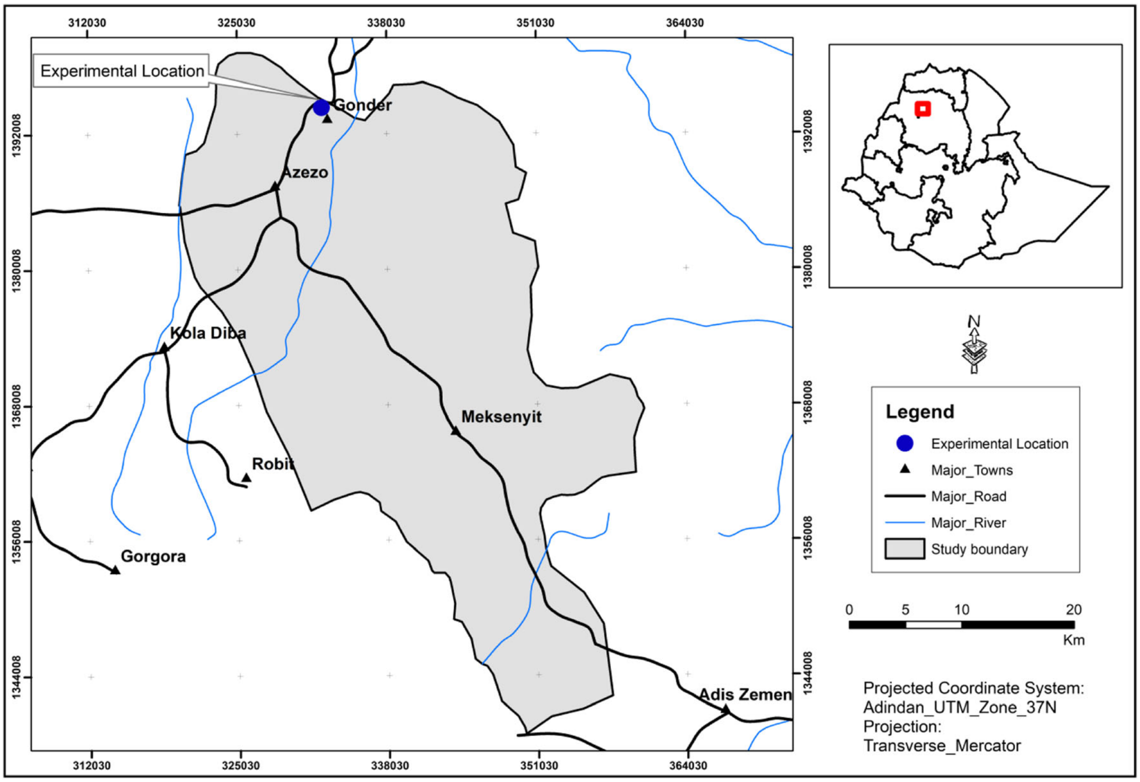

Fig. 1 Location map of the study area

characterized by poor drainage, with slow infiltration and permeability associated with heavy clay texture, flat topography, and a shallow groundwater table [29].

Experimental Design and Procedures

Ethiopia is one of the largest barley producers in Africa. It is a relatively dry heat-resistant grain and the fourth-ranked quantity produced in the world after maize, rice, and wheat as well as one of the main food sources in many African countries [19]. Moreover, barley is also found to be one of the major products around the study area [18]. Barley is one of the first food crops in the region in terms of area coverage and production. Recognition of the study district as one of the centers of diversity is another factor that made barley a suitable crop for investigating irrigation depth and its effect on the yield and water usage in the study area [30].

The field experiment was conducted during the dry season from 15 December 2016 to 15 May 2017. The experiment was arranged in a factorial randomized complete block design (RCBD) with four replications. An RCBD design study was chosen for the field experiment because it has been applied with comparable experimental units of different treatments which are grouped into blocks. Within each block, four irrigation regimes (Fig.2) were randomly distributed. Each treatment had a plot size of 3 m × 3 m with spacing between plots at 1 m, and between blocks at 1.5 m. A 1-m border was left to separate plots as it is useful, in avoiding border effect and facilitating management operations. Barley *Hordeum vulgare* seeds were planted on prepared plots in rows with 30-cm spacing between them. Each plot consisted of 10 furrows which were diked to contain the irrigation water and eliminate runoff. The layout of the experiment is represented in Fig. 2.

All standard plant management practices including fertilizer application, weed, and pest management were carried out. Fertilizer was applied based on the agronomic recommendation in the study area (69 kg/ha urea and 57 kg/ha of diammonium phosphate, DAP). Sixty-nine kilograms per hectare quantity of nitrogen fertilizer was used with half applied at sowing and the remaining half at the mid-season stage, while full P fertilizers were also applied at sowing. Crop water and yield data were taken from the central areas of each plot.

Amount of Water Under Different Treatments

As shown in Fig. 3, a long, dry season occurred from October to May while maximum rainfall between June and August which reflects that the dry months in the study area were longer than the rainy season. For the dry season irrigation experiment, no effective rainfall was recorded. The irrigation amount for different treatments are shown in Table 1 which refers to different treatments (crop stands) under various combinations of the four growth stages (I to IV) and irrigation applications starting from full irrigation treatment FIT to

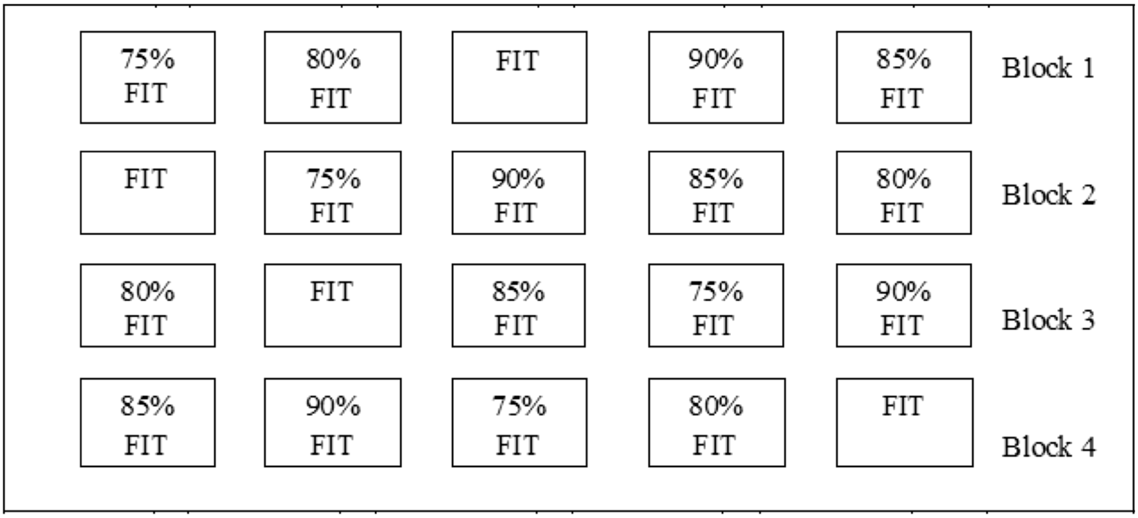

Fig. 2 Schematic representation of the experimental plot layout

90% FIT, 85% FIT, 80% FIT, and 75% FIT. In the experimental season, irrigation was applied at 5-day intervals. Water was applied using garden watering cans with a fixed interval for all treatments.

Crop Water Requirement and Irrigation Application

As previously noted, barley was selected because it is one of the dominant crops cultivated in the area and has considerable adaptability to the agro-ecological zone of the region. The growing season of the crop was mainly divided into four major growth periods: initial, development, mid-season, and late-season stages. Crop water requirements of barley over the growing period were determined by multiplying the reference evapotranspiration and crop coefficient for each of the four growth stages. Lengths of the four growth stages and the respective crop coefficients were taken from FAO. A selected combination of irrigation depth, water application, and the barley's growth stage were used in the experimental design to determine the optimum water application depth at specific growth stages with the objective of determining optimum crop water depth. Five different levels of irrigation water supply were scheduled. These were full crop water requirements with full irrigation at 90% FIT, 85% FIT, 80% FIT, and 75% FIT level application. Since there is no site-specific estimated crop coefficient in the region, the respective crop coefficients for initial, middle, and late growth stages were taken from Allen et al. [31].

Based on the climate of the study area, crop water requirements of the barley were determined using the AquaCrop model. Thirty-four years (1980–2014) of meteorological data (Table 2) obtained from the Ethiopian National Meteorological Services Agency and the crop coefficient from the Food and Agriculture Organization (FAO) were used. The crop parameters used for the estimation of crop evapotranspiration, water balance calculations, and yield reductions due to stress were the crop coefficient (K_c) and length of the growing season. The FAO Penman–Monteith method was used to calculate evapotranspiration [31].

The following equation shows the crop water requirement for barley crops

$$\mathrm{CWR} = \mathrm{ET_O} X K_C \quad (1)$$

where:

CWR Crop water requirement (mm/day)
ET_o Initial evapotranspiration (mm/day)
K_c Crop coefficient (constant)

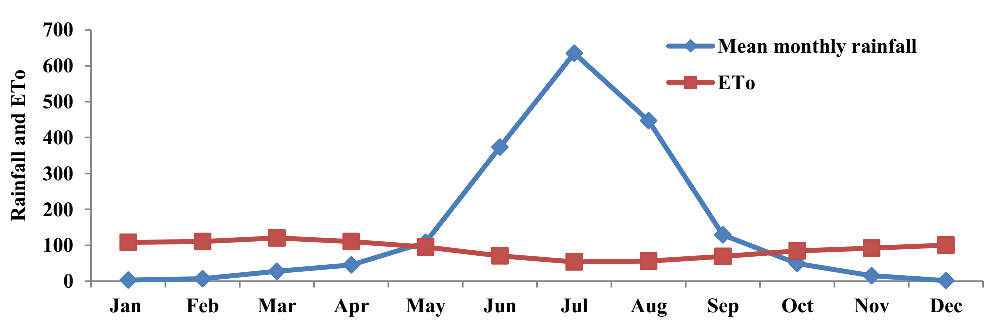

Fig. 3 Mean monthly rainfall and reference evapotranspiration (1980–2014)

Table 1 Summary of irrigation amount (m^3/ha) for each treatment in total growing season

Date	Treatments				
	FIT	90% FIT	85% FIT	80% FIT	75% FIT
15 December	7.1	6.7	6.3	5.9	7.9
20 December	7.1	6.7	6.3	5.9	7.9
25 December	7.1	6.7	6.3	5.9	7.9
30 December	16.2	15.3	14.4	13.5	18.0
04 January	16.2	15.3	14.4	13.5	18.0
09 January	16.2	15.3	14.4	13.5	18.0
14 January	16.2	15.3	14.4	13.5	18.0
19 January	16.2	15.3	14.4	13.5	18.0
24 January	16.2	15.3	14.4	13.5	18.0
29 January	29.3	27.7	26.0	24.4	32.5
03 February	29.3	27.7	26.0	24.4	32.5
08 February	29.3	27.7	26.0	24.4	32.5
13 February	29.3	27.7	26.0	24.4	32.5
18 February	29.3	27.7	26.0	24.4	32.5
23 February	29.3	27.7	26.0	24.4	32.5
28 February	33.9	32.1	30.2	28.3	37.7
05 March	33.9	32.1	30.2	28.3	37.7
10 March	33.9	32.1	30.2	28.3	37.7
15 March	33.9	32.1	30.2	28.3	37.7
20 March	33.9	32.1	30.2	28.3	37.7
25 March	33.9	32.1	30.2	28.3	37.7
30 March	36.3	34.3	32.3	30.3	40.4
04 March	14.2	13.4	12.6	11.8	15.8
09 April	14.2	13.4	12.6	11.8	15.8
14 April	14.2	13.4	12.6	11.8	15.8
19 April	14.2	13.4	12.6	11.8	15.8
24 April	14.2	13.4	12.6	11.8	15.8
29 April	14.5	13.7	12.9	12.0	16.1
04 May	14.5	13.7	12.9	12.0	16.1
09 May	14.5	13.7	12.9	12.0	16.1
Total	648.7	612.6	576.6	540.6	720.8

Crop Water Productivity

Crop water productivity (CWP) is defined as the measure of the economic or biophysical gain from the use of a unit of water consumed in crop production [28]. Generally, it can be defined as the output, yield (kg/ha) over the water consumed (m^3/ha). In this study, CWP is defined as crop output over the volume of water depleted or diverted. CWP is computed as the ratio of yield to actual crop water use:

$$CWP = {}^{Y}/_{ET_a} \tag{2}$$

where:

CWP Expressed in kg/m^3 on a unit water volume basis

Y Grain yield (kg/ha)

ET_a Actual crop evapotranspiration (m^3/ha)

Data Collection and Analysis

Soil samples were collected from a depth of 0–40 cm to analyze its physical characteristics such as soil texture, initial soil moisture content, and its chemical characteristics including electrical conductivity (EC), pH, and organic matter. Soil samples were collected from the field based on the root depth of the experimental barley crop during irrigation season. The soil parameters were analyzed in the Bahir Dar soil testing laboratory.

Weather data including daily rainfall, maximum and minimum temperature, relative humidity, sunshine hours, and wind speed were obtained from the meteorological station 5 km away from the experimental field. The study area is characterized by a semi-arid climate in which the majority of rainfall occurs from June to September. The rainfall intensity showed marked spatial and temporal variations, and no rainfall was recorded at the experimental station during the growing season.

The mean monthly rainfall, reference evapotranspiration distribution for the study area of 34 years is shown in Fig. 3. Comparison of those graphs explicitly shows that there was no source of moisture other than irrigation for the study period. There was massive rainfall during the extended summer, which occurs between June and September. The dry season followed summer from October to April.

The soil pH was determined based on the H_2O (1:2.5) potentiometer method; texture (%) was based on the hydrometer method, organic matter (%) following Walkley black, and for the total nitrogen, Kejeldahl methods were used.

Crop water requirements of each treatment were calculated by multiplying the reference evapotranspiration values with the barley crop coefficients for the whole growing season [31]. Irrigation water was applied at 5-day intervals on a total of 6 days per month. All treatments were devised according to the initially planned framework, and each received the required irrigation depth. Mean monthly rainfall and reference evapotranspiration of the study area is shown in Fig. 3.

The statistical difference of barley yield receiving different treatments was studied for analysis of variance (ANOVA).

Result and Discussion

Soil Analysis

In the laboratory, soil samples were analyzed for pH, OC%, TN%, and texture%. The soil pH of the experimental field also varied with depth. From Table 3, the pH of the experimental site ranged from 6.5 to 6.6 in the 0–40-cm depth. The average

Table 2 Mean monthly meteorological data of the study area (1980–2014)

Months	T_{min} (°C)	T_{max} (°C)	Humidity (%)	Wind speed (m/s)	Sunshine hour (h)
January	10.7	29.1	33	2	22.4
February	12.4	30.8	28	2	23.7
March	14.2	31.7	30	2	23.3
April	15.5	31.7	32	2	23.0
May	15.4	29.8	45	1	22.1
June	13.6	25.4	70	1	20.1
July	12.8	20.2	90	1	16.1
August	12.3	20.1	92	1	17.1
September	11.3	23.8	81	1	23.9
October	11.8	26.4	59	1	22.7
November	11.3	28.6	43	1	21.7
December	10.6	28.7	35	1	21.7
Average	12.7	27.2	53	1	21.5

pH of the soil is 6.6, which indicates that the soil at the site is within the recommended range, making it suitable for barley crop production.

According to the laboratory result, soil properties of the experimental site are within the recommended ranges. The threshold of organic carbon necessary for sustaining soil quality is widely suggested to be about 2%. Soil productivity may be affected by organic matter (OM) in various ways. Soil organic matter is the portion consisting of plant or animal tissue in various stages of decomposition. Cations are positively charged ions such as calcium (Ca^{2+}), magnesium (Mg^{2+}), and potassium (K^+), and sodium (Na^+). The capacity of the soil to hold on to these cations is called cation exchange capacity (CEC). Cations are held by the negatively charged clay and OM particles in the soil through electrostatic forces. The CEC cations in the soil particles are easily exchangeable with other cations and, as a result, are plant-available. Soil characteristics are shown in Table 3.

The Effects of Water Depth on Yield and Water Productivity

The effect of water depth on grain yield for the same seeding rates and management practice is shown in Table 4. The analysis of variance (ANOVA) showed that the effects of irrigation amount on yield had a substantial effect on levels at $p < 0.05$ (Table 4). For yield analysis, grain was considered because it was the best predictor of treatment response. A one-way ANOVA test showed that there is a statistically significant difference between the groups in at least two of the treatments applied ($F = 22.88$). Using the least significant difference (LSD) test, the F test was significant at level 0.05. The effect of different levels of irrigation on barley grain yield showed a notable variation ($p < 0.01$) between the treatments.

The LCD test also showed that a substantial difference in the means of yield exists at 0.05 significant levels. The result displayed in Table 4 indicated that yield of barley depends on the amount of water depth with different levels of deficit irrigation. The results revealed that the higher barley yield was obtained under 80% FIT (1700 kg/ha) treatment with an irrigation depth of 577 m^3/ha that was subjected to 80% FIT application (Table 4) water stress, whereas, after 80% FIT application, the yield declined. Accordingly, the minimum yield was obtained under FIT application (1450 kg/ha). A similar result was reported when a lesser amount of irrigation water was required to improve barley yield [29]. By contrast, high yield was found under full irrigation [17].

Since barley is a shallow-rooted crop, it demands less water during the growing seasons, up to a certain water limit. In other words, if the amount of water applied decreased to a certain level (80% FIT), the yield will increase under the best crop management conditions. The yield drops with any further increase in the applied irrigation amount, which could be due to a waterlogging problem [17]. There was no notable difference between the yield of 85% FIT (1680 kg/ha) and 80% FIT (1700 kg/ha) despite the fact that it was applied with 90% FIT and 80% FIT level differences throughout the growing season. This clearly shows that application of water to the crop down to 80% FIT is important in improving the yield while simultaneously enhancing water productivity. This might be due to the fact that the barley crop water requirement is far less than wheat and oats. However, reducing the irrigation application beyond 80% FIT adversely affects the yield of barley; any reduction in 80% FIT irrigation significantly affects the yield. Any increase in irrigation, say to 90% FIT, reduces the yield slightly. Yield drops after 80% FIT due to waterlogging and a crop variety that requires less water.

Table 3 Results of laboratory analysis for samples from the experimental site

Depth (cm)	pH H_2O (1:2.5)	Texture (%)			Classes	OC%	TN%	FC (%)	PWP (%)	TAW (%)
		Sand	Silt	Clay						
0–20	6.51	23	38	39	Clay loam	2.35	0.21	35.0	17.2	17.8
20–40	6.62	23	44	33	Clay loam	1.92	0.17	34.5	16.6	17.9

Table 4 Yield, irrigation depth (mm/total growing period), and WP (from the field experiment)

Treatments	Irrigation depth (m^3/ha)	Yield (kg/ha)	WP (kg/m^3)	Yield rank	WP rank
FIT	721	1450 ± 21[a]	2.01	5	5
90% FIT	649	1510 ± 24[b]	2.33	3	4
85% FIT	612	1680 ± 32[c]	2.75	2	2
80% FIT	577	1700 ± 16[c]	2.95	1	1
75% FIT	541	1480 ± 24[a]	2.74	4	3
CV (%)	3.13				

Superscript lowercase letters show the significant difference between the treatments. [a] Full irrigation treatment (FIT) and 75% FIT; [b] 90% FIT; [c] 85% FIT and 80% FIT

The difference in yield when compared with the harvest obtained in [17] could be due to the crop water requirement which itself depends on factors such as climate, soil, cropping calendars, soil treatment, mulching, rainfall patterns, irrigation scheduling, and irrigation systems. Moreover, the crop water productivity was influenced by yield, which changes with variety, diseases, soil fertility, and overall management practices. Grain yield of barley reportedly fell when the crop was waterlogged at the early growth stage and at the mid or late period [32, 33]. Tied ridging markedly improved the barley yield since low yield is attributed to waterlogging problems [17].

The highest and least water productivity was observed in 80% FIT (2.95 kg/m^3) and FIT (2.01 kg/m^3), respectively. Similar results were reported [33] when applying 80% FIT water level which demonstrates better water productivity than applying the highest and the lowest irrigation depth with 75% FIT application and no deficit irrigation, respectively.

The rank of all treatments with regard to the highest yield and water productivity is presented in Table 4. Eighty percent FIT obtained the highest (1700 kg/ha) rank while FIT is placed in the lowest (1450 kg/ha) yield category. Applying 577 m^3/ha irrigation water at 5-day intervals offered a relatively higher yield than the application of 721 m^3/ha irrigation water at 5-day intervals (Table 5). Similar studies [29] also reported that, for barley crops, the highest yield is achieved during irrigation of less water from its ideal crop water requirement while minimum yield was also observed with highest water depth. As clearly shown in Table 5, applying 577 m^3/ha and 721 m^3/ha has delivered the highest (1700 kg/ha) and the lowest (1450 kg/ha) yield respectively.

Table 5 Barley yield, reduced amount of applied irrigation water, and relative water productivity

Treatments	Irrigation depth (m^3/ha)	Yield (kg/ha)	Reduced amount of applied water (%)	Relative WP
FIT	721	1450 ± 21[a]	0	1.00
90% FIT	649	1510 ± 24[b]	10	1.16
85% FIT	612	1680 ± 32[c]	15	1.37
80% FIT	577	1700 ± 16[c]	20	1.47
75% FIT	541	1480 ± 24[a]	25	1.36
CV (%)	3.13			

Superscript lowercase letters show the significant difference between the treatments. [a] Full irrigation treatment (FIT) and 75% FIT; [b] 90% FIT; [c] 85% FIT and 80% FIT

Barley Yield and Reduced Amount of Applied Irrigation Water

During the field experiment, using FIT as a control, (maximum crop water requirement base) for all treatments, the highest and lowest reduced amount of applied irrigation water were recorded at 75% FIT (25%) and under FIT (0%), respectively. The amount of reduced applied irrigation water in 75% FIT was 25%, which is higher than the other four treatments (FIT, 90% FIT, 85% FIT, and 80% FIT). However, relative water productivity was better in 80% FIT which ensures the highest yield. Results of relative WP are also presented in Table 5 which indicates that the highest and lowest values were obtained in 80% FIT (1.47) and FIT (1), respectively.

The average barley yield of the region between 2004 and 2014 varies from 1188 to 1513 kg/ha [34] which is similar to the current study. Comparable results were reported by other researchers [25, 31, 32, 35], showing that the progressive increase in barley yield with an optimum irrigation level of water depth will enhance water productivity. Barley production at Mezezo has been recorded up to 1926 kg/ha [29]. Studies by Carter and Stoker [36] and Hussain and Al-Jaloud [37] also reported the effect of irrigation depth on yield and yield components of barley, the results of which were in line with the current findings. Analysis of the results clearly shows that there is a high potential for enhancing water productivity of barley in the region through different levels of water application. In general, the application of an ideal amount of water was accompanied by increased barley yield and water productivity in water-scarce region.

Conclusions

Application of different systems of irrigation water use for barley production improves water productivity by saving water while maintaining a better yield. The study showed barley can withstand a maximum level of irrigation water up to 80% FIT application level. A maximum yield of 1700 kg/ha was obtained under irrigation when barley was subjected to the aforementioned level of application. The lowest yield was observed under 75% FIT and FIT of irrigation application. Nevertheless, application beyond 80% FIT was found to produce lower yields indicating that too much water stress could decrease the yield. Generally, the study provides an optimal irrigation treatment of 80% FIT which results in better yields of barley production. Barley

Hordeum vulgare is a good, drought-resistant crop that provides a better yield with less water. Hence, this method is recommended for application in the water shortage area.

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