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Research Article

Response of Malt Barley (*Hordeum distichum L.*) to Different Phosphorus Fertilizer Rates and Irrigation Levels Under Furrow Irrigation Methods in South Eastern Ethiopia

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Abstract

Nutrient availability to crops is a function of soil type, moisture condition, environment, crop type, and management and their interaction affects nutrient use efficiencies and crop growth conditions. The objective of this study was to determine the optimum P rate and deficit irrigation level, as well as to identify the interactive effect of nutrient and moisture levels on yield and yield quality malt barley under irrigation in Ormiya region Tiyo district. The experiment was conducted at small plot level for three consecutive years from 2020/21 to 2022/23 G.C. This experiment was conducted at Kulumsa Agricultural Research Center On-Station arranged by split-plot layout with RCBD design by three replications. Irrigation amounts (100%, 75% and 50%) were assigned the main plot and phosphorus fertilizer rates (0, 10, 20, 30 and 40 kg) corresponded to the subplot. The combined effect of irrigation levels and phosphorus fertilizer rate had a significant effect ($p < 0.05$) on malt barely grain yield, above-ground biomass, thousand kernel weight and water productivity but not on plant height, seeds per spike and protein content. The highest grain yield and above-ground biomass were 3.16 t/ha and 6.77 t/ha obtained from the application of 100% ETc with 30 kg of phosphorus fertilizer. The maximum water productivity (0.97 kg/m^3) was observeat the application of 75% ETc with 30 kg of Phosphorus fertilizer while more profitable practice was found at 100% ETc with 30 kg of phosphorus application. The highest protein content (15.57%) was observed at the application of 50% deficit irrigation and the lowest (14.66%) was observed at 100% ETc irrigation application. Applying the optimum amount of irrigation with 30 Kg phosphorus fertilizer gives high grain and above biomass yield and is economically profitable in Tiyo district and agroecologies similar to Tiyo.

Keywords

Malt Barely, Irrigation Level, Phosphorus Fertilizer, Grain Yield and Water Productivity

1. Introduction

The performance of the Ethiopian economy as a whole is highly correlated with the agricultural sector [1]. Ethiopia's food supply and economy in general are largely dependent on rain-fed agriculture [2]. Hence, irrigation development is vital to minimize the risk of crop failure and sustain agricultural production [2, 3]. Irrigation development has been identified as an important tool to stimulate economic growth and rural development and is considered a cornerstone of

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food security and poverty reduction in Ethiopia [4]. However, the demand for fresh water is constantly increasing among all water users. Irrigation in Ethiopia consumes a large amount of water extracted from various sources [5]. Hence, efficient water use and management are currently the major concerns in the country [5]. Cereals (maize, sorghum, wheat, and barley) dominate by volume and value, followed by vegetables, cotton, and roots and tubers. The next group includes sugarcane, pulses, other annual crops, and citrus [6]. Barley is widely grown by smallholders as a staple food and as a source of cash income. It is concentrated in the Oromia and Amhara regions, which contribute 53% and 30% of national production respectively. Production is 95% rain-fed with 5% on irrigated land, so production is dependent on weather conditions [7]. According to the Business Innovation Facility [7], smallholder barley farmers have not embraced newer inputs that can boost yields, such as improved seed varieties and fertilizer.

More smallholders have utilized fertilizer on barley in recent years (up to 42% in 2014), and the rate is significantly below that of other cereals, except sorghum [7]. Malting barley is primarily used in commercial beer brewing, but it is also a desirable food source, particularly as injera (fermented thin bread), porridge, or roasted. It is also used to make local alcoholic beverages, and there is a growing demand for malting barley bread, particularly in Addis Abeba [7]. Demand for malting barley has been growing as a result of increased urbanisation and rising incomes contributing to growth in beer consumption. Therefore Barley (Hordeum vulgare L.) is the major malting grain used internationally where yield is critical to meeting market needs. However, when optimizing malting barley productivity targets, malt factories' strict quality criteria for protein, plump kernels, and test weight of barley grain must be taken into account [8]. Despite this, the optimal fertilizer rate and irrigation volume that produces the highest yield without compromising grain quality has not been studied in the Tiyo district. There for this activity was carried out to determine the optimum P rate and deficit irrigation level, as well as to identify the interactive effect of nutrient and moisture levels on yield and yield quality malt barley.

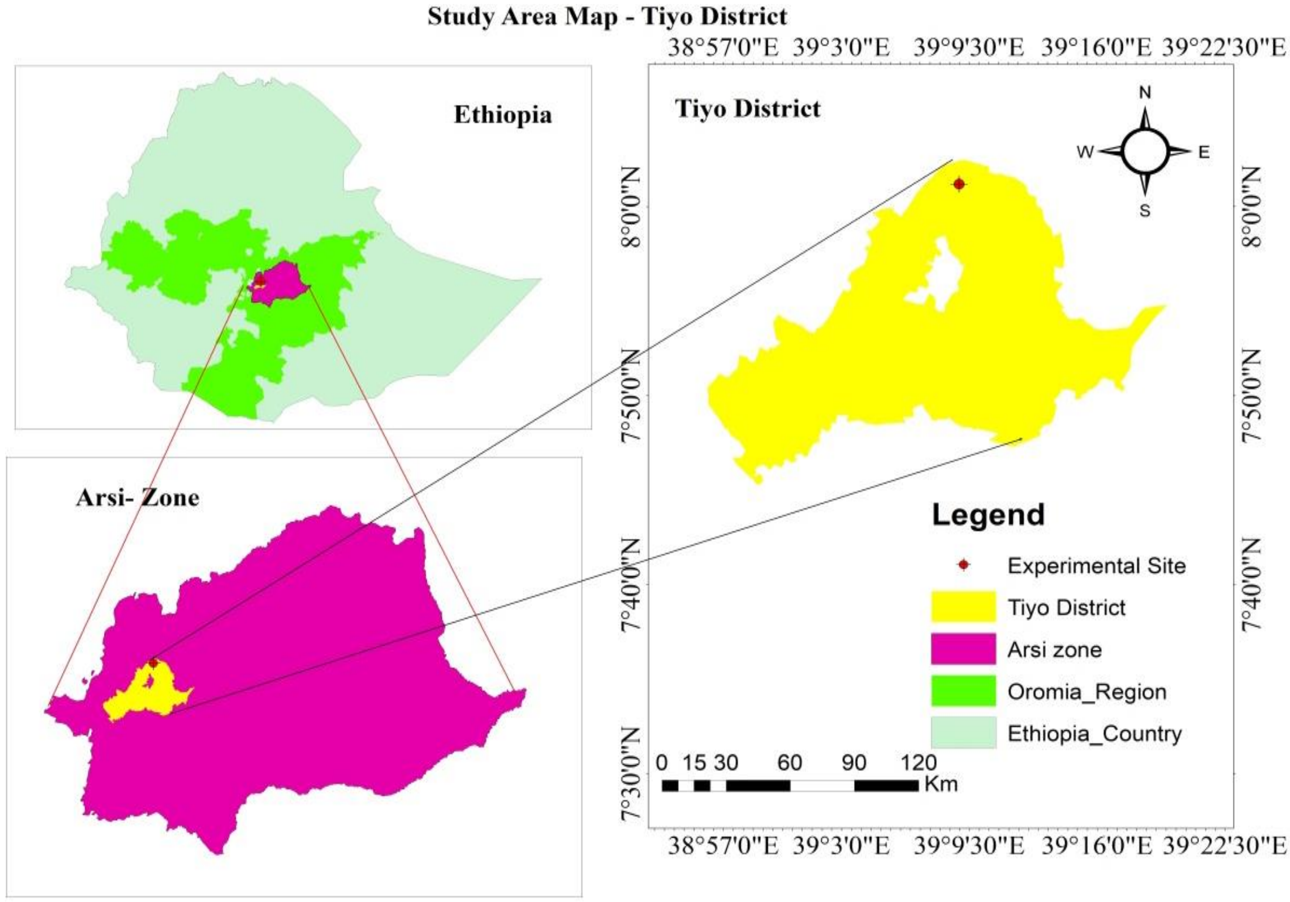

Figure 1. *Map of the experimental site.*

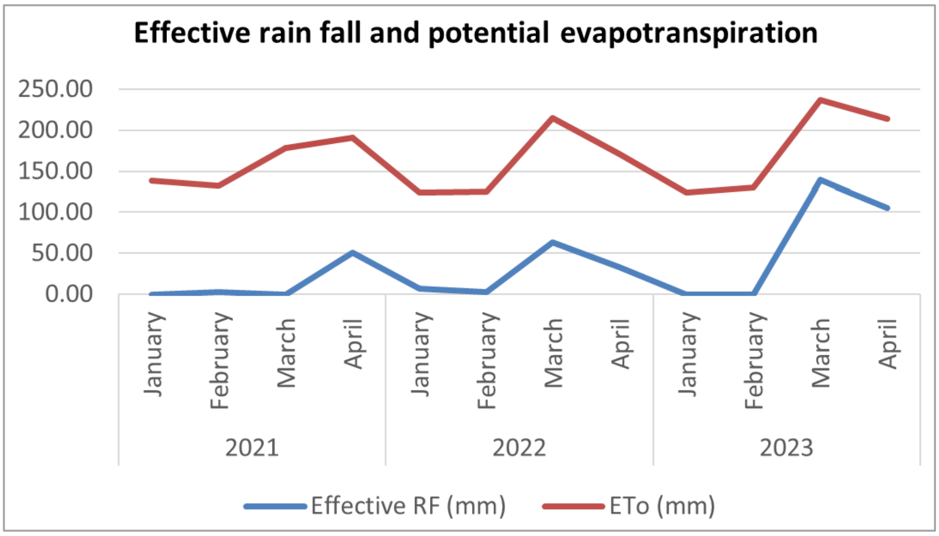

Figure 2. *Effective rain fall and potential evapotranspiration of the cropping season.*

2. Materials and Methods

2.1. Description of the Study Area

This study was conducted at Kulumsa agricultural research field on-station in the district of Tiyo, Arsi Zone (8.02°N and 39.15°E) (Figure 1), which is located in the semiarid climatic region of southwest Ethiopia. (i.e. the experiment was undertaken during the dry season (December–April) between 2021 to 2023. the elevation at the site was 2198 m above sea level. The climate condition of the study area is characterized by a sub-humid dry zone with a mean annual rainfall of 820 mm, among which most of the rain occurs in the main cropping season of spring and summer months [9]. The study area receives peak season rainfall from July to August. The average annual minimum and maximum temperatures are 9.9 and 23.1°C, respectively. Effective rainfall and potential evapotranspiration of the cropping season at the study area is shown in figure 2.

The most dominant soil texture of the study area is sandy clay loam, with a bulk density of 1.25 g/cm^3. The mean moisture content at field capacity and the permanent wilting point is 33.6 and 21.8%, respectively; with total available water of 118 mm per meter depth of the soil [9]. The chemical analysis conducted for the surface soil samples (0–20 cm) of the study area were pH, total nitrogen (TN), available phosphorous (avail P), and organic matter content (OM) indicated in Table 1.

Table 1. *Soil Physicochemical properties at the Experimental site.*

Physical properties							
BD (g/cm^3)	**Texture**			**Soil type**	**FC (%)**	**PWP (%)**	**TAW**
	Sand	**Silt**	**Clay**				
1.25	52	27	21	Sandy clay loam	33.60	21,8	11.8

Chemical properties				
pH	**TN (%)**	**OC (%)**	**OM (%)**	**Av. P (mg/Kg)**
6.11	0.12	2.16	3.72	11.12

2.2. Experimental Setup

The experiment was conducted in split-plot arrangement with RCBD. The treatments were randomized both at the main and sub-plot levels and replicated three times. The treatments had three crop ETc levels (100%ETc, 75% ETc and 50% ETc) and five fertilizer levels of phosphorus (0, 10, 20, 30 and 40 P kg/ha) and the experiment had a total of fifteen treatment combinations (Table 2). The deficit irrigation level was in the main plot while P fertilizer rate treatment was assigned to the subplots. 100%ETc and 0 Phosphorus was as a control treatment for this experiment.

2.3. Crop Management

This experiment was conducted for three consecutive years from 2020/201 -2022/2023. The experimental site was plough three times before planting. The Sowing date was from December to January for those three consecutive years, Urea fertilizer (78kg/h) was applied split application method half at planting and half at 25-30 days after planting. Phosphorus fertilizer was applied at planting time based on the treatments. Hand weeding was takes place during the emergency of weeds and pesticides also applied during the emergency of aphides based on the recommendation rate. The amount of water was measured Parshall flume and applied on furrow irrigation system. Finally after all the necessary data were collected the net plot was harvested and threshed manually.

2.4. Data Collection

The data collected during the experimentation period were chemical properties of irrigation water (EC and PH), and date of irrigation (Irrigation Amount applied at every event was recorded. Daily weather variables (Rainfall, Maximum and Minimum air temperature, Wind speed, Relative humidity and sunshine hours) were collected from Kulumsa Agricultural Research Center weather station. Plant height, spike length, and number of seeds per spike were measured from a random sample of five plants in each treatment plot. Grain yield and aboveground total biomass were also assessed using the net plot area of 2.5m* 2.5m. The grain samples' moisture contents were measured with a moisture tester instrument and corrected to a standard value of 12.5%. Grain samples were taken from each plot and their kernel and hectoliter weights were determined in the crop physiology laboratory of KARC using seed counter and hectoliter weighing instruments, respectively. The crop water productivity was calculated by dividing grain yield by the total amount of water applied during the growing season [10, 11] (equation 1).

$$WP = (Y/ET) \quad (1)$$

Where WP is water productivity (kg/m^3), Y crop yield (kg/ha) and ET is the seasonal crop water consumption by evapotranspiration (m^3/ha).

Table 2. *Treatment combinations.*

Treatment	P rate (kg/ha)				
Irrigation Intervals	**0**	**10**	**20**	**30**	**40**
100% ETc	T1	T2	T3	T4	T5
75% ETc	T6	T7	T8	T9	T10
50% ETc	T11	T12	T13	T14	T15

Remark: the source material for P was TSP, P= Phosphorus

2.5. Crop and Irrigation Water Requirement

The irrigation amount was computed with the help of the CROPWAT 8.0 model [12]. The crop reference evapotranspiration was computed by using Penman–Monteith equation [13] implemented on the CROPWAT8.0 model. It was computed from maximum and minimum air temperature, relative humidity, wind speed, sunshine hours and solar radiation. The crop evapotranspiration (ETc) was computed from the product of reference evapotranspiration (ETo) and crop coefficient (Kc), at each growth stage over the growing season (Equation 1). Kc of malt baraley at the experimental site was not known specifically, the value listed by FAO [12] for each development stage were adopted to for this experiment.

$$ETc = ETo * Kc \quad (2)$$

Where, ETc = crop evapotranspiration (mm/day), ETo = reference crop evapotranspiration (mm/day) and Kc = crop coefficient.

Irrigation Requirement (IR) was calculated by the following (equation 3).

$$IR = CWR - \text{Effective rainfall} \quad (3)$$

Where, IR in mm, CWR in mm, and effective rainfall is part of the rainfall that entered into the soil and made available for crop production in mm.

The barely crop growth stage was divided in to four growth stage which are initial, development, midseason and late season stage. It ranges from planting to 10% of ground cover, from 10%ground cover to effective full cover, from effective full cover to start of maturity and from maturity to harvesting respectively [11]. Regardless of treatment, the same volume of irrigation water was consistently provided to each plot twice until germination was established [11]. The amount of water (100%ETc) needed though out the growing period for malt barely was 252.55mm and the furrow system application efficiency was considered as 65% leads to 387.8mm gross water need. So the amount of Irrigation for each treatment of 100, 75 and 50 ETC leads to 387.8, 308 and 229 mm respectively. Irrigation scheduling was estimated by considering soil and weather condition at the experimental sites.

2.6. Partial Budget Analysis

The cost and benefit of each treatment was analyzed using partial budget analysis method [14] to evaluate the comparative advantage of each combine effect of fertilizer and amount of irrigation water applied. The main total costs were the operational cost and variable cost. The operational cost includes land preparation, implementation and seed cost whereas the variable costs are fertilizer, labor cost per time during irrigation events and unite price of water applied. The gross yield benefit from malt barely was obtained from the product of total grain yield in quintal and selling price per quintal. The net benefit was estimated from deduction of variable cost from the gross benefits. Marginal rate of return (MRR) estimated from change in net benefit divided by change in variable costs.

2.7. Data Analysis

The collected data was subjected to analysis of variance using the R- software. Mean separation was employed using the least significant difference (LSD) at a 5% probability level to compare the differences among the treatment means [15].

3. Result and Discussion

3.1. Plant Height, Spike Length, Hectoliter Weight and Seed Per Spike

Irrigation levels and phosphorus fertilizer rate interaction had no significant effect on plant height, spike length seed per spike and hectoliter weight. But irrigation level significantly affected ($p<0.05$) malt barely plant height, spike length, seed per spike and hectoliter weight. Phosphorus fertilizer application on malt barely under irrigation conditions has a significant effects ($p < 0.05$) spike length and hectoliter weight of malt barely but not plant height and seed per spike. The application of 100% ETC results the highest plant height (63.63cm) and the smallest (58.08cm) was obtained from the application of 50%ETc. This result agree with [16] which showed that giving plants the right amount of water at the root zone boosts their vegetative growth, while giving plants a less amount of water reduces cell elongation specialty plant height.

Table 3. *Main effects of Irrigation and Phosphorus fertilizer levels on Plant Height, Spike length, hectoliter weight and number of seed per spike on malt Barely.*

Irrigation Levels	Plant Height (cm)	Spike length (cm)	Seed per spike	HLW (gm)	Protein (%)
100% ETc	62.63^{a}	6.83^{a}	20.72^{a}	60.59^{a}	14.66^{b}
75% ETc	62.03^{a}	6.69^{a}	20.54^{a}	60.78^{a}	14.9^{ab}
50% ETc	58.08^{b}	6.24^{b}	19.23^{b}	56.96^{b}	15.57^{a}
LSD (0.05)	2.62	0.23	0.34	1.04	0.80
CV (%)	7.3	6	3.1	3	7.4
P (kg/ha)					
40	61.52	6.68^{ab}	20.16	59.65^{a}	14.66
30	61.44	6.72^{a}	20.12	59.89^{a}	14.94
20	61.48	6.54^{bc}	20.41	60.05^{a}	15.05
10	61.30	6.5^{bc}	20.13	59.47^{a}	15.19
0	60.32	6.4^{c}	20.011	58.16^{b}	15.37
LSD (0.05)	NS	0.16	NS	0.97	NS
CV (%)	5.4	4.4	4.7%	2.9	6.9

LSD 0.05 = least significant difference at 5%, CV (%) = Coefficient of variation, HLW = Hectoliter Weight. Means in the same column followed by the same letter(s) are not significantly different.

The highest spike length and seed per spike was observed on full irrigation (100% ETc) with values of 6.83cm and 20.72

respectively (table 3). But spike length (6.69cm) and seed per spike (20.64) obtained from 75% ETc was statistically equivalent with the result obtained from 100%ETc. the lowest splike length (6.24 cm) and seed per spike (19.23) was resulted from the application of half ETc of malt barely (Table 3). This result showed that spike length and seed per spike decrease when deficit irrigation level increases. There was no statistically significant difference in the spike length (6.68cm) obtained from applying 40 kg and 30 kg of phosphorus fertilizer, but the higher spike length (6.72 cm) was obtained from applying 30 kg of phosphorus fertilizer. The lowest spike length (6.4cm) was obtained from non-application of phosphorus fertilizer.

The highest hectoliter weight (60.78gm) obtained from the application of 75% ETc which was statistically equivalent to the hectoliter weight (60.59gm) obtained from the application of 100% ETc (table 3). The smallest hectoliter weight (56.96gm.) was obtained from the application of 50% ETC (table 3). The highest hectoliter weight (60.05gm) was obtained the application of 20 kg of phosphorus whereas the lowest (58.16) was obtained from the non-application phosphorus fertilizer (table 3). However with the exception of not applying phosphorus fertilizer, the hectoliter weight obtained from all fertilizers was statistically equivalent. This research finding showed that plant height, spike length, seed per spike and hectoliter weight increases as irrigation amount increases and direct re relationship with irrigation level. This finding was similar with the finding of [17] who reported that plants that received the optimal amount of irrigation water have higher plant height seed per spike and Plant height increased with increasing amount of irrigation.

3.2. Grain Yield, Above Ground Biomass and Harvesting Index of Malt Barely

Irrigation water amount and phosphorus fertilizer interaction brought significant effect ($P<0.05$) on grain yield, harvesting index and biomass of malt barely (Table 4). The highest grain yield (3.16t/ha) and biomass yield (6.77t/ha) were obtained on the application of 100% ETc and 30 kg phosphorus fertilizer application, which were statistically equivalent to grain yield (3.06 t/ha) and biomass yield (6.62t/h) obtained from the application of 100%ETc and 40kg of phosphorus fertilizer application (Table 4). This result supported by the report of [18] the highest barely grain yield was found at 30 kg of Phosphorus per hectare. The lowest grain yield (0.99 t/ha) and biomass yield (2.43 t/ha) observed on the application of 50% ETc with non-application of phosphorus fertilizer (Table 4). This result has an agreement with the finding of [19] which states that due to a decrease in the amount of available soil moisture, low plant height, a spike in grain weight, and a spike in grain number all result in low grain yield. This experiment showed that malt barely grain yield was increased when fertilizer rate and amount of water increased (Figure 3). However amount of yield increased up to 30 kg of phosphorus fertilizer, and adding more phosphorus fertilizer rate above 30 kg/ha did not brought significant effect, even, some yield decline observed at 40 kg/ha phosphorus fertilizer application (figure 3). However amount of yield increased up to 30 kg of phosphorus fertilizer, and adding more phosphorus fertilizer rate above 30 kg/ha did not bring significant effect. However some yield decline observed at 40 kg/ha phosphorus fertilizer application (figure 3). This trend was agreed with the finding of [20] who stated that There were sequential increases in yield with the phosphorus (P) rates being raised from 0 to 20 kg/ha. However, a considerable yield drop resulted from a subsequent rise in phosphorus rate.

Ethiopia's barley yields have increased over the last ten years, averaging 1.43 mT/ha. However, this is still less than half of the yields in Kenya (3.26 mT/ha) and South Africa (2.93 mT/ha), the two best-performing African nations [7]. Thus the grain yield obtained from this study was higher than the best performed South African malt barely average gain yield and approached Kenya average yield. In contrast to the best-performing nations, including France, Germany, and the Netherlands, where average barley yields exceed 6 mT/ha, this experiment's greatest yield (3.16 t/ha) is extremely low [7].

The highest biomass yield (6.77 t/ha) was observed at the application of 100%ETc with 30 Kg of phosphorus while the lowest (2.43 t/ha) was observed at 50% ETc with non-fertilizer application (Table 4). Even though the biomass yield (6.62 t/ha) produced from 100% ETc with 40 kg of phosphorus was lower, there was no statistical difference with the highest biomass yields. The highest harvesting index (48.64%) obtained from 75% with 20 kg of phosphorus fertilizer (Table 4). However, statistically equivalent to the application of 100% ETc with 20, 30, and 40 kg of phosphorus, 75% ETc with 20 kg phosphorus and 50ETc with 40 kg of phosphorus fertilizer. The lowest harvesting index was 41.01% which obtained from the 50% ETc with non-application of phosphorus fertilizer (Table 4).

3.3. Thousand Kernel Weight and Protein Content of Malt Barely

Irrigation water amount and phosphorus fertilizer interaction brought significant effect on thousand cornel weight but no protein content of malt barely. The highest thousand kernel obtained from the application of 100% ETc with 40 kg of phosphorus fertilizer was 47.56 gm which was statistically the same to thousand kernel weight 46.61, 47.29, 47.37, observed from 100% ETc with 10, 20, 30, kg of phosphorus and 46.76, 47.52, 47.3 observed from 75% ETc with 20, 30, 40 kg phosphorus fertilizer respectively. The lowest thousand kernel weight was 40.49 gm which was obtained from 50% ETc with non-application of phosphorus fertilizer. This result indicates thousand kernel weight increases when the amount of water and phosphorus fertilizer increased while the increment was not significant above 10 kg/ha p with 100% ETc. When the amount of water applied decreases thousand kernel weight decreased while application of phosphorus more than 10 kg/ha was an important on thousand kernel weight. This study finding agreed with [21] who described as reducing the amount of water available at the soil profile's root zone led to lower 1000-grain weights; and maximal 1000-grain weights produced by complete irrigation.

Malt barely protein content not significantly affected on the interaction of water level and phosphorus fertilizer. The application of different water levels had significant effect ($p< 0.1$) on malt barely protein content but not affected on the variation phosphorus fertilizer rate (Tabel 3). The highest protein content (15.57%) was observed at the application of 50% deficit irrigation and the lowest (14.66%) was observed at 100% ETc irrigation application. However protein content at 100% was lowest, there was no statistical difference protein content (14.9%) obtained at the application of 75% ETc irrigation. Based on this result when the irrigation deficit level increases the protein content of malt barely become increased. This result was matched with [21] who demonstrated that the protein content rose with decreasing irrigation levels, with 50% irrigation level having the maximum protein content compared to 75% and 100% irrigation levels. Also, protein content found at this study were higher and not satisfied Malt Barely quality for malt beer standards which grain protein concentration (GPC) higher than 13% deteriorate malting products and final beer quality [22].

Table 1. *Effects of Irrigation and Phosphorus fertilizer levels on Grain yield, above ground Biomass and water productivity of malt barely.*

Treatment combinations	Grain yield (t/ha)		Biomass yield (t/ha)		Harvesting index (%)		Water productivity (kg/m^3)		TKW (gm.)	
100%: 0kg	2.48^{ef}		5.78^{cd}		42.9^{cd}		0.67^{f}		46.48^{bcd}	
100%: 10kg	2.49^{ef}		5.76^{cd}		43.57^{cd}		0.67^{f}		46.61^{abcd}	
100%: 20kg	2.91^{bc}		6.15^{bc}		47.28^{ab}		0.79^{de}		47.29^{abc}	
100%: 30kg	3.16^{a}		6.77^{a}		47.41^{ab}		0.86^{bcd}		47.37^{abc}	
100%: 40kg	3.06^{ab}		6.62^{ab}		46.24^{abc}		0.83^{cde}		47.56^{a}	
75%: 0kg	2.25^{g}		5.46^{de}		41.27^{d}		0.78^{e}		45.93^{d}	
75%: 10kg	2.34^{fg}		5.44^{de}		43.34^{cd}		0.83^{cde}		46.38^{cd}	
75%: 20kg	2.45^{efg}		5.09^{e}		48.64^{a}		0.85^{cd}		46.76^{abcd}	
75%: 30kg	2.73^{cd}		$5.78c^{d}$		47.49^{ab}		0.97^{a}		47.52^{ab}	
75%: 40kg	2.63^{de}		5.97^{cd}		44.3^{bcd}		0.93^{ab}		47.3^{abc}	
50%: 0 kg	0.99^{j}		2.43^{h}		41.03^{d}		0.47^{g}		40.49^{g}	
50%: 10kg	1.6^{i}		3.79^{g}		42.63^{d}		0.76^{e}		42.74^{e}	
50%: 20kg	1.72^{hi}		$3.9f^{g}$		44.45^{bcd}		0.83^{cde}		42.32^{e}	
50%: 30kg	1.75^{hi}		4.46^{f}		41.27^{d}		0.81^{cde}		41.19^{fg}	
50%: 40kg	1.82^{h}		3.94^{fg}		47.92^{a}		0.88^{bc}		42.22^{ef}	
LSD	0.2		0.59		3.45		0.07		1.08	
CV (%)	(a) 13.2	(b) 9.1	(a) 15.7	(b) 11.7	(a) 5.7	(b) 8.0	(a) 11.7	(b) 9.2	(a) 7.9	(b) 2.5

LSD 0.05 = least significant difference at 5%, CV (%) = Coefficient of variation. TKW= Thousand kernel weight, Means in the same column followed by the same letter(s) are not significantly different.

3.4. Water Productivity Malt Barely

The interaction between the amount of water and phosphorus fertilizer under irrigation conditions had significant effects ($p<0.05$) on the water productivity of malt barely (table 5). The highest water productivity (0.97 kg/m^3) was at the application of 75% ETC with 30 kg of phosphorus fertilizer, while the lowest (0.47 kg/m^3) was at the application of 50% ETC with no phosphorus fertilizer, despite the fact that the water productivity (0.93kg/m^3) obtained from 75% ETc with 40 kg of phosphorus was statistically equivalent to the highest water productivity. As can be seen from the result when irrigation amount increases the water productivity of malt barely decrease while when irrigation water decreases by 25% the water productivity become in increases. However, when we decrease the irrigation water by half from its full requirement the water productivity was become decreased. This result was support the finding of [23, 24] who stated that when irrigation water decreased, the WUE increased to a certain point, when the crop water requirement is dramatically decreased WUE decreased, mainly due to the significant decline in productivity.

3.5. Yield Response Factor (Ky)

The yield response factor (Ky) for this experiment the highest Ky was 1.4 and the lowest was 0.5 (Table 5). The highest yield response factor was observed at 75ETc with no Phosphorus fertilizer while the lowest was observed at 75% ETc with 30 kg of Phosphorus fertilizer application. The yield response factor (Ky) reported by [25] was Barely yield response factor ranged from 0.5 to 1.10. When the yield response factor increase from 0.5 to 1.14 the Relative yield reduction was increased from 14% to 69%. According to this, greater Ky values may indicate how much P fertilizer is being used and how little water is available for growing malt.

Table 2. *Crop water requirement, water productivity and yield response factor.*

Treatments	Grain Yield (kg/ha)	CWR (mm)	WP (Kg/m^3)	Relative water saved (%)	Relative yield reduction (%)	Ky
100%: 0kg	2480	388	0.67f	-	22	-
100%: 10kg	2490	388	0.67f	-	21	-
100%: 20kg	2910	388	0.79de	-	8	-
100%: 30kg	3160	388	0.86bcd	-	-	-
100%: 40kg	3060	388	0.83cde	-	3	-
75%: 0kg	2250	291	0.78e	25	29	1.2
75%: 10kg	2340	291	0.83cde	25	26	1
75%: 20kg	2450	291	0.85cd	25	22	0.9
75%: 30kg	2730	291	0.97a	25	14	0.5
75%: 40kg	2630	291	0.93ab	25	17	0.7
50%: 0 kg	990	194	0.47g	50	69	1.4
50%: 10kg	1600	194	0.76e	50	49	1
50%: 20kg	1720	194	0.83cde	50	46	0.9
50%: 30kg	1750	194	0.81cde	50	45	0.9
50%: 40kg	1820	194	0.88bc	50	42	0.8

CWR = Crop Water Requirement, WP = Water Productivity, Ky = Yield Response Factor

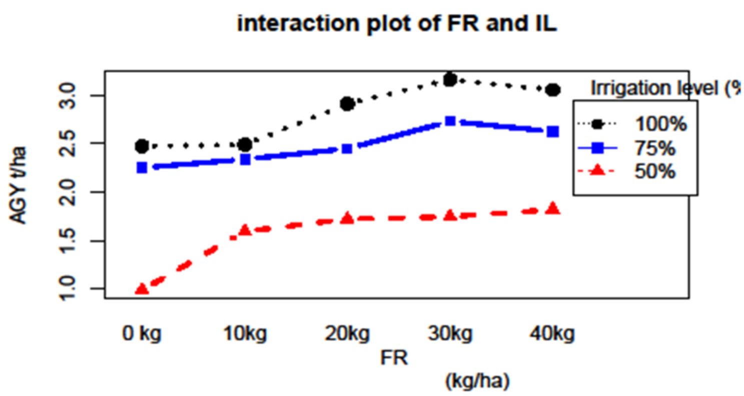

Figure 1. *Malt barely gain yield response to Phosphorus fertilizer and water level interaction.*

3.6. Partial Budget

Irrigation level and phosphorus fertilizer brought big difference on profitability of malt barely production (table 6). Applying 100% ETc with 30 kg of phosphorus was the first profitable compared to excess phosphorus fertilizer (40 kg) application (Table 6). The second profitable was the application of 100 100% ETc with 20 Kg phosphorus fertilizer application. This result was somehow equivalent to the result of [26] that showed, farmers Rift valley area need to use 100% ETc irrigation water level and 46kg P_2O_5 ha^{-1} application rate in order to maximize their profitability. Therefore to get more yield and profitable farmers can be apply 100% ETc with 30 kg of phosphorus for malt barely production at the study area.

Table 3. *Partial budget analysis.*

Treatment	Grain Yield (kg/ha)	TVC (ETB/ha)	Net Return (ETB/ha)	MRR (%)
50%ET& 0kg P	990.00	5,774.00	29,866.00	-
75%ETc&0kg P	2,251.11	7,374.00	73,666.00	2737.50
50%ETc&10kg P	1,594.44	7,762.68	49,637.30	D
100%ET&0kg P	2,475.56	8,974.00	80,146.02	2518.64
75%ETc&10kg P	2,338.89	9,362.68	74,837.32	D
50%ETc&20kg P	1,722.22	9,751.37	52,248.62	D
100%ETc&10kg P	2,490.00	10,962.68	78,677.32	2181.82
75%ETc&20 kg P	2,450.00	11,351.37	76,848.63	D
50%ETc&30kg P	1,745.56	11,740.05	51,099.96	D
100%ETc&20kg P	2,912.22	12,951.37	91,888.62	3367.30
75%ETc&30 kg P	2,731.11	13,340.05	84,979.94	D
50%ETc&40 kg P	1,822.22	13,728.74	51,871.26	D
100%ETc&30 kg P	3,116.00	14,940.05	93,379.95	3426.74
75%ETc&40 kg P	2,627.78	15,328.74	79,271.27	D
100%ETc&40 kg P	3,057.78	16,928.74	93,151.27	867.50

NB. TVC= total variable cost, MRR= marginal rate of return

4. Conclusion

Nutrient availability to crops is a function of soil type, moisture condition, environment, crop type, and management and their interaction affects nutrient use efficiencies and crop growth conditions. The interaction between irrigation water and phosphorus fertilizer significantly impacted grain yield, biomass yield, and water productivity of malt barely. This study showed that the application of 100% ETC with 30 kg of Phosphorus results the highest grain yield and above-ground biomass for malt barely production under irrigation conditions. However, the application of full irrigation requirements affected its water productivity. The better water productivity malt barely was obtained from the application of 75% ETc with 30 kg of phosphorus fertilizer application. Therefore in the area water resources are a limited factor practicing 75% ETc with 30 kg of phosphorus fertilizer should be advisable. Grain quality is hardly taken into consideration during the malt production process. According to this study, the grain protein level for every treatment was higher than the national average; hence, it was not employed as an input for malt factories. But right now, bread is very much in demand and consumed in large quantities over Ethiopia, especially in Addis Ababa and neighboring cities. With its high protein content, malt barley grown under irrigation is therefore essential for making barley bread.

Abbreviations

RCBD	Random Complete Block Design
ETc	Crop Evapotranspiration
FC	Field Capacity
PWP	Permanent Wilting Point
TAW	Total Available Water

TN	Total Nitrogen
OC	Organic Carbon
OM	Organic Matter
Av.P	Available Phosphorus
KARC	Kulumsa Agricultural Research Center
HLW	Hectoliter Weight

Conflicts of Interest

The authors declare no conflicts of interest.

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