Global Research in Environment and Sustainability
January 2024, Vol. 2, No. 1, pp. 01-14.

Determination of Irrigation Scheduling and Optimal Phosphorus Fertilizer Rate for Onion in Tiyo District, Arsi Zone, South Eastern Ethiopia

Kebede Nanesa, Bakasho Eticha, Samuel Lindi, & Mehiret Hone

1. Ethiopian Institute of Agricultural Research/Kulumsa Agricultural Research Center, Ethiopia

Abstract:
The three-years consecutive study was carried out at the Kulumsa Agricultural Research Center (KARC), Tiyo, Arsi Zone, Southeastern Ethiopia. The objectives of the study were to determine optimal irrigation levels and phosphorus rates, as well as the interacting effect of nutrient and moisture levels on onion yield and yield quality. The experiment was arranged in a split plot Randomized Complete Block Design (RCBD) with three replications. The main plots received three irrigation levels, whereas sub-plots received five phosphorus fertilizer rates. Key growth parameters such as plant height, number of leaves per plant, bulb diameter, sugar content, average bulb weight, and marketable yield were subjected to evaluation. The results demonstrated that irrigation and phosphorus levels had a significant impact on onion growth and yield components. The study result of onion bulb yield revealed significant differences at ($p<0.05$). The highest marketable bulb yield of onion 28.08 tons ha-1 was obtained at 100% crop evapotranspiration (ETc) and 30 kg ha-1 of phosphorus application. The highest water productivity 10.38 kg/m3 result was recorded from the treatment receiving 50% ETc and 20 kg ha-1 of phosphorus. The economic analysis found that treatment 100% ETc with 30 kg ha-1 of phosphorus was more profitable, with better net benefits and significant marginal rates of return when compared to other treatments. As a result, a phosphorus rate of 30 kg/ha combined with irrigation levels of 100% and 75% ETc also gave over 100% MRR as a promising option for maximizing onion output in the study area.

Keywords: Optimum irrigation, phosphorus fertilizer rate, onion bulb yield, water productivity

INTRODUCTION

Onion (Allium cepa L.) is an important bulb crop and it is widely produced by farmers and commercial growers throughout the year for local use and export market in Ethiopia (Teshome & Bogale, 2022). Onion is valued for its distinct pungency and forms essential ingredients for flavoring varieties of dishes, sauces, soups, sandwiches and snacks as onion rings etc(Teshome & Bogale, 2022). It is popular over the local shallot because of its yield potential per unit area, availability of desirable cultivars for various uses, ease of propagation by seed, high domestic (bulb and seed) and export (bulb, cut flowers) markets in fresh and processed forms. Ethiopia has high potential to benefit from onion production. The demand for onion increases from time to time for its high potential to benefit from onion production. The demand for onion increases from time to time because of its high bulb yield, seed and flower production potential (Lemma and Shimelis, 2003).

In most irrigable lands, horticultural crops in general and vegetables in particular, play an important role in contributing to household food security and income (Agumas et al., 2014). Vegetables being cash crops, with high nutritional value, generate income for the poor households. Higher profits can be achieved by increasing the production of a particular vegetable throughout the year when an efficient irrigation system is used (Yitagesu Kuma & Tigist Alemu, 2015). Onions have a shallow, sparsely branched root system with most roots in the top 30 cm of soil. Rooting density decreases with soil depth. Thus, it is important to maintain nutrient and soil moisture within the shallow rooting area (Teshome & Bogale, 2022).

Phosphorus fertilizer is one the most complex in production in many tropical soils, due to low native content and high phosphorus immobilization within the soil. Phosphorus is essential for root development when availability is limited, plant growth is usually reduced. In onions, phosphorus deficiencies reduce root and leaf growth, bulb size, and yield and also delay maturation(Ali & Gebeyehu, 2019). In soils that are moderately low in phosphorus, onion growth and yield can be enhanced by applying phosphorus. Onions are more susceptible to nutrient deficiencies than most crop plants because of their shallow and unbranched root system, hence they require and often respond well to the addition of fertilizer (Brewester,1994). Onion is grown in most parts of Ethiopia but, a lot of constraints have contributed to the low yield. Phosphorus deficiency is one of the constraints to onion production in many tropical soils. The use of sub-optimal phosphorus fertilizer is one of the prominent to mention. Still, well recommended rate of phosphorus fertilizer is not well identified(Teshome & Bogale, 2022). The low productivity of onions in Ethiopia could be ascribed to a host of agronomic, environmental, and management factors, with irrigation and fertilization being the important ones (Fekadu and Dandena,2006; Muluneh et al.,2019). Presently, both water and nutrients are not properly managed, resulting in crop yields far below their potential. Onions have a large water requirement and the shallow root system is, generally, more susceptible to water stress as compared to other crops. Also, onions producing large biomass would have high nutrient requirements, especially nitrogen and Phosphorus (Drechsel et al., 2015). Therefore, proper water and nutrient management is considered one of the strategies for enhancing the productivity of onions. There is still little or no information on the irrigation scheduling and optimum fertilizer P rate for onion production in the study area. Furthermore, the optimum nutrient rate, preferably, needs to be based on the interactive effect of irrigation and nutrients, as both inputs are linked, and failure to manage one affects the other, or improvement in one could enhance the efficiency of the other. Therefore, the objectives of this study were to determine appropriate irrigation levels and phosphorus rates and identify the interactive effect of nutrient and moisture levels on yield and yield quality of onion under the agroecological conditions of Tiyo, Arsi Zone, southern Eastern Ethiopia.

MATERIALS AND METHODS

Description of the Study Area

A field experiment was implemented at Kulumsa Agricultural Research Center (KARC) for three consecutive years (2020/21 to 2022/23). KARC is located in Tiyo district of Arsi Zone, Oromia regional state, Southeastern Ethiopia. The soil type is predominantly Luvisol/eutricnitosols with a good drainage system (Tafesse, 2003). The mean annual maximum temperature is 230C and monthly values range between 21 and 25 oC. The mean annual minimum temperature is 10 oC and monthly values range between 8 and 12 oC. The experimental site is located at a latitude of 08º00'8.55'' and a longitude of 039º09'23.7'' and situated at an altitude of 2192m asl.

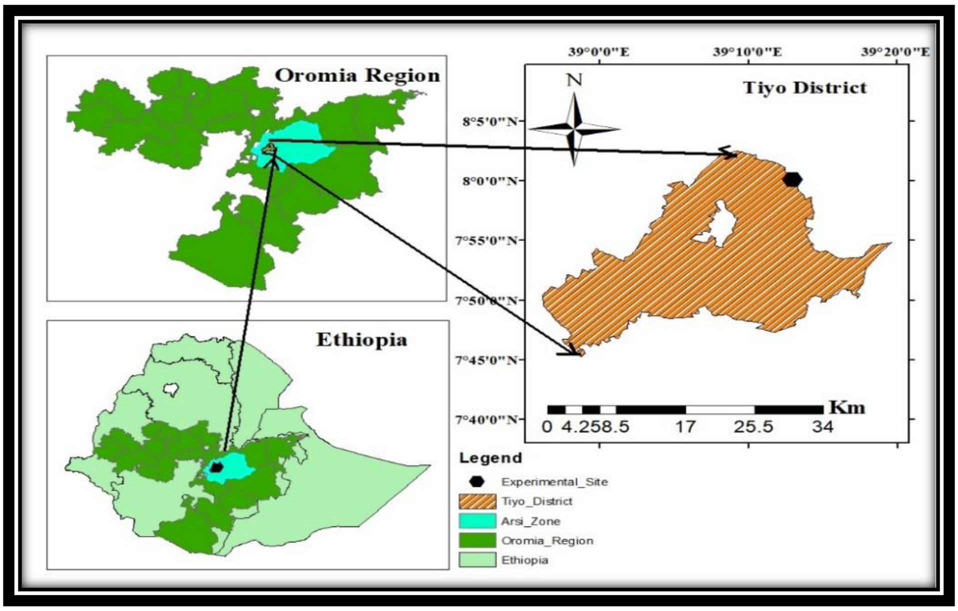

Figure 1: Map of the study area

The area receives an average annual rainfall of 821mm and is characterized by unimodal rainfall pattern. 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).

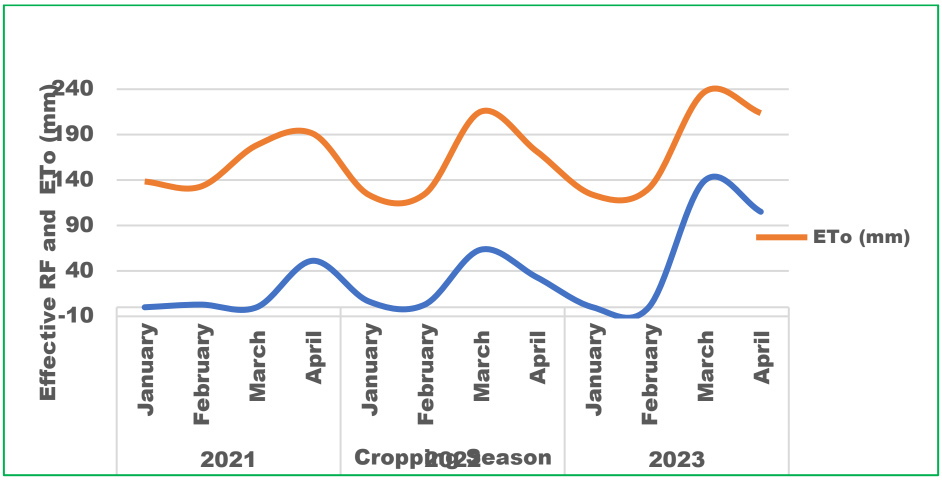

Figure 2: Effective rain fall and potential evapotranspiration of the cropping season

Experimental Design and Procedures

The experiment was laid out in RCBD with a split-plot arrangement. The treatments were randomized both at the main and sub-plot levels with three replications. The irrigation levels were in the main plot while phosphorus fertilizer rate treatments were assigned to the subplots.

Table 1: Description of treatment combinations

Levels	Phosphorus rate (kg/ha)				
	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

Agronomic Data Collection and Interpretations

Onion seedlings (*Bombay Red variety)* were raised following proper management practices as suggested by EARO (2004). Seedlings were hardened before being transplanted to the experimental field to enable them to withstand the field conditions. The 45 days healthy and vigorous seedlings were transplanted. After transplanting, three full irrigations were applied uniformly to all plots with three days intervals, to ensure good plant establishment. Immediately after crop establishment, irrigation was applied to each plot according to the treatment requirement using a Parshall flume. Urea was used as a source of N; half of the N dose was applied at the time of transplanting and the remaining half was side-dressed after 45 days of transplanting. The P fertilizer was applied as per treatment to all plots at the time of transplanting using triple superphosphate (TSP). The uniform field management was carried out on all plots as per the recommendations of EARO (2004).

The inter and intra-row spacing in the experimental plots was determined using the recommended agronomic value for onion. Onion crop was transplanted on both sides of the ridge with 40 cm, 20 cm and 5 cm spacing of row plant (plant row spacing across furrow was 40 cm, across the ridge was 20 cm and along the ridge 5 cm between plants). The experimental field was divided into 45 plots and each plot size was 3m*3.5m in dimension (10.5 m^2) area to accommodate six furrows with a spacing of 60 cm and 3.5 m in length. Each plot consisted of five ridges and six furrows. A field channel was constructed for each block to irrigate the field.

Yield and Yield Components:

Growth Parameters of Onion:

The height of five randomly selected plants was measured from the ground level to the tip of the longest matured leaf at physiological maturity. The average number of leaves was counted from five randomly selected plants at physiological maturity.

At physiological maturity, the diameter of the bulbs of five randomly selected plants in each treatment was measured. The randomly selected onion bulbs were pressed into juices, and the refractometer reading was recorded when the liquids were placed into the refractometer. The total soluble solid content was measured in Brix. A digital balance was used to record the average weight of randomly selected matured bulbs from each plot, and a mean was reported. The weights of medium- to large-sized (20–160 g) bulbs from the three central rows that were free of disease, mechanical damage, and insect pests were converted to tons/ha to determine the marketable bulb production.

Soil Analysis:

Representative soil samples were taken from the experimental site for chemical analysis (PH, EC, CEC, total available N, OC, and OM) and physical properties (BD, Texture, FC, and PWP). Soil moisture was measured before and after irrigation using the gravimetric method.

Crop Water Requirement, Water Productivity and Yield Response Factor

Crop water requirement (CWR):

Crop water requirement (ETc) was calculated from climatic data integrating the effect of crop characteristics into reference crop evapotranspiration. FAO Penman-Monteith method was used to determine reference crop evapotranspiration (ETo). The crop coefficients (Kc), were utilized to relate ETc to ETo using the following equation:

$$\text{ETc} = \text{ETo} * \text{Kc} \tag{1}$$

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

Irrigation Requirement (IR) was calculated using the following equation:

$$\text{IR} = \text{CWR} - \text{Effective rainfall} \tag{2}$$

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

Irrigation scheduling was worked out using Cropwat 8.0 software. One of the computing approaches in the model for optimal irrigation scheduling with no yield reduction is the irrigation applied at 100% readily available soil moisture depletion to refill the soil to its field capacity. The readily available water (RAW) was computed by the following formula:

$$\text{RAW} = \text{P} * \text{TAW} \tag{3}$$

where RAW in mm, P is in fraction for allowable soil moisture depletion for no stress, and TAW is total available water in mm.

The total Available Soil Water (TAW) was computed from the soil moisture content at field capacity (FC) and permanent wilting point (PWP) using the following expression:

$$\text{TAW} = \frac{\text{FC} - \text{PWP}}{100\rho} * (\text{Bd} * \text{Dz}) \tag{4}$$

Where FC and PWP are soil moisture content at field capacity in % on a weight basis, B_d is the bulk density of the soil in gm/cm^3, the ρ density of the water in gm/cm^3 and D_z is the maximum effective root zone depth in mm.

Soil bulk density was determined by taking undisturbed soil samples from an effective root zone at 20 cm intervals using a core sampler. Soil samples were oven-dried for 24 hours at a temperature of 105°C. Then, bulk density (ρb) was determined as equation (5):

$$\text{Bd} = \frac{\text{Ms}}{\text{Vs}} \tag{5}$$

where B_d = Soil bulk density (g/cm^3), Ms = the mass of soil after oven-dry (g) and Vs = bulk volume of soil (cm^3).

The gross irrigation requirement, IR_g, in a particular event, was computed from the expression:

$$\text{IRg} = \frac{\text{CWR}}{\text{Ea}} \tag{6}$$

Where IRg is the gross irrigation requirement in mm, CWR is crop water requirement (mm/day) and Ea is the irrigation water application efficiency in fraction.

The time required to deliver the desired depth of water into each plot was calculated using the following equation:

$$T = \frac{IRg*w*l}{60q} \quad (7)$$

where IRg is gross irrigation requirement in mm *t* is application time (min), *l* is plot furrow length (m), *w* is plot width (m), and *q* is flow rate (l/s) at a specific Parshall flume head.

Water Productivity (WP)

Water productivity was estimated as a ratio of bulb yield to the total ETc through the growing season and calculated using the following equation (8).

$$WP = (Y/ET) \quad (8)$$

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

Yield Response Factor (Ky)

The yield response factor (Ky) was estimated from the relationship equation (9).

$$\left[1 - \left(\frac{Ya}{Ym}\right)\right] = Ky\left[1 - \left(\frac{ETa}{ETm}\right)\right] \quad (9)$$

Where, Ya=Actual harvested yield, Ym=Maximum harvested yield, Ky=Yield response factor, ETa=Actual evapotranspiration and ETm=Maximum evapotranspiration

The Ky values are crop-specific and vary over the growing season according to growth stages with: Ky>1: crop response is very sensitive to water deficit with proportional larger yield reductions when water use is reduced because of stress. Ky<1 the crop is more tolerant to water deficit and recovers partially from stress exhibiting less than proportional reductions in yield with reduced water use. Ky=1: yield reduction is directly proportional to reduced water use.

Statistical Data Analysis

Yield and yield component and water productivity data were subjected to statistical analysis using the R-Software package. Means separation was carried out using the least significance difference (LSD) test at a 5% probability level.

Partial Budget Analysis

The dominance analysis method, employed to identify potentially profitable treatments, involves listing treatments in ascending order of varying costs. A treatment is deemed dominated if its net benefits are less than or equal to treatments with lower varying costs. The treatments selected through this approach are termed dominant treatments. In evaluating pairs of ranked undominated treatments, a percentage marginal rate of return (% MRR) is computed. The % MRR between any pair of dominated treatments signifies the return per unit of investment in crop management practices, expressed as a percentage. The calculation of MRR (%) follows the CIMMYT 1988 methodology. To be considered a viable option for farmers, a treatment must have a marginal rate of return (MRR) of at least 100%.

Hence, a minimum acceptable rate of return was set at 100%. The economic analysis of phosphorus fertilizer involved utilizing partial budget analysis, taking into account the overall connection between phosphorus fertilizer rates and onion yield per hectare. Employing the CIMMYT procedure, the partial budget analysis involved examining total revenue, total variable cost, total fixed cost, total cost, net income, and benefit-cost ratio for each treatment. The economic analysis focused on fixed and variable costs.

The evaluation was conducted to determine the local market price of onions. According to the assessment, the price of 1 kg of onions was 50 ETB at the field level. For calculating the labor cost, the rate for human labor was set at 150 ETB in the field. The net income (NI) in ETB/ha derived from the onion crop was calculated by subtracting the total cost (TC) in ETB/ha from the total return (TR) in ETB/ha obtained from onion sales, following the approach outlined by Kuboja and Temu (2013).

$$\mathrm{NI} = \mathrm{TR} - \mathrm{TVC} \tag{9}$$

Total cost (TC) is the combination of fixed costs (FC) and variable costs (VC). Fixed costs (FC) encompass expenses that remain constant across different fertilizer treatments, including onion seeds, fertilizer, and land rent.

Conversely, variable costs were different between fertilizer treatments and included expenses like fertilizer and labor. The benefit-cost ratio (BCR) for each treatment was calculated as the ratio of the net income (NI) earned to the total cost (TC) incurred as follows:

$$\mathrm{BCR} = \mathrm{NI}/\mathrm{TC} \tag{10}$$

RESULT AND DISCUSSION

Soil Physical and Chemical Properties of the Experimental Site

Some selected soil physical and chemical properties of the experimental site l were presented in Table 2. Percent of particle size determination revealed that the soil texture of the study area is sandy clay loam. The mean bulk density of soil in the study area was 1.25g/cm^3. The pH was computed by Potentiometry (1:2.5 soil: water ratio), where total nitrogen was calculated by Kjeldahl method, OC and OM were analyzed by Walkley and Black while available phosphorus was analyzed by Bray-II method.

The mean pH, TN, OC, OM and Available P of the soil of the study area were 6.06, 0.11%, 1.45%, 2.51% and 11.12 mg/kg, respectively. The moisture content at field capacity, permanent wilting point, and total available water were 33.6, 21.8%, and 11.8% respectively.

Table 2: Physical and chemical properties of the experimental site

<table>
<tr><td colspan="8">Physical properties</td></tr>
<tr><td>BD (g/cm³)</td><td colspan="3">Texture</td><td>Soil type</td><td>FC (%)</td><td>PWP (%)</td><td>TAW</td></tr>
<tr><td rowspan="2">1.25</td><td>Sand</td><td>Silt</td><td>Clay</td><td rowspan="2">Sandy clay loam</td><td rowspan="2">33.60</td><td rowspan="2">21,8</td><td rowspan="2">11.8</td></tr>
<tr><td>52</td><td>27</td><td>21</td></tr>
<tr><td colspan="8">Chemical properties</td></tr>
<tr><td>pH</td><td>TN (%)</td><td colspan="2">OC (%)</td><td colspan="2">OM (%)</td><td colspan="2">Av. P (mg/Kg)</td></tr>
<tr><td>6.06</td><td>0.11</td><td colspan="2">1.45</td><td colspan="2">2.51</td><td colspan="2">11.12</td></tr>
</table>

Yield and Yield Component of Onion

Plant Height, Leaves Number and Bulb Diameter of Onion:

The statistical analysis showed that the plant height of onion was significantly ($P < 0.05$) influenced by the variation of irrigation levels and phosphorus rate application. The result of the study revealed that the longest plant height 52.15cm was recorded from the application of 100% ETc and 30 kg of P per ha. The shortest plant height (40.56 cm) was recorded from an experimental plot treated with 50% ETc and 0kg of P per ha. The increase in plant height with increased irrigation water could be mainly due to better availability of soil moisture that has enhanced the vegetative growth of plants by increasing cell division and elongation. The study findings were consistent with those of Ramada and Ramanathan (2017) on onions. The increasing plant height with adequate depth of irrigation application also indicates the favorable effect of water in maintaining the cell's turgor pressure, which is the major prerequisite for growth. On the contrary, the shortening of plant height under soil moisture stress may be due to stomatal closure and reduced CO_2 and nutrient uptake by the plants and, hence, photosynthesis and other bio-chemical processes hampered, affecting plant growth (El-Noemani et al., 2009).

The analysis variance showed that the number of leaves of onion was significantly affected by irrigation levels and phosphorus fertilizer rates (Table 3). The maximum number of leaves (15) was recorded from the experimental plot treated with 100% ETc and 40 kg Phosphorus per hectare followed by 100% ETc and 30 kg P ha^{-1}. At optimum irrigation levels, increasing the Phosphorus rate increases the number of leaves of onion. This might be because phosphorus is an essential component of nucleic acids, phospholipids and some amino acids and absorbed phosphorus helped a direct stimulation of cellular activity in roots and leaves, it is useful for the process of cell division and meristematic growth and the net assimilation rate of phosphorus fed plants were accelerated by their increased content and the absorbed phosphorus helped the formation of food reserves due to higher photosynthetic activity so, therefore, increases of the number of leaves. Similar results were found by Horneck (1999) and Singh et al., (2000). The lowest number of leaves (6.95) was recorded experimental plot treated with 50% of ETc and 0 kg ha^{-1}.

The higher leaf number per plant resulting from the application of 100% ETc irrigation level is due to the irrigation effect that facilitates nutrient availability and photosynthesis for the undisrupted growth of the plant. Similarly, the reduced number of leaves per plant at 50% ETc of irrigation level or depth is attributed to the effects of water stress on cell expansion (Abbey and Joyce, 2004). This indicated that when plants respond to water stress by closing their stomata to slow down water loss by transpiration, gas exchange within the leaf is limited; consequently, photosynthesis and growth would slow down. The result is also in agreement with the findings of Ramada and Ramanathan (2017) who found that leaf numbers had a linear correlation with the availability of soil moisture.

Bulb diameter was significantly ($P < 0.05$) affected by the amount of irrigation and phosphorus levels (Table 3). Maximum bulb diameter of 6.28 cm was recorded from the plot received 100% ETc with 30 kg/ha of phosphorus, followed by 100% ETc with 40 kg/ha phosphorus, 75% ETc with 30 kg/ha phosphorus, 50% ETc with 30 kg/ha Phosphorus which were statistical the same to the superior treatment. The lowest Bulb of 3.41 cm diameter was recorded by the application of 50% ETc with 0 kg/ha P. However, statistically not different with the treatment receiving 75% ETc and 0 kg/ha P. The results indicated that bulb diameter varied proportionally with the irrigation water applied and phosphorus level. The relation between diameter and irrigation water applied indicates that an increase in bulb diameter in different treatments was attributed to an increase in the application of water, hence water applied influences onion bulb size.

Singh et al., (2000) found similar results. The higher phosphorus rise in bulb diameter could be attributed to the phosphorus-improving carbohydrate content of the plants and extending root growth, which in turn raised bulb diameter. These findings are consistent with the findings of Kumar et al. (2007b), who found that irrigation at 1.20 Ep resulted in the largest bulb size. Similarly, David et al. (2016) observed that a greater level of irrigation 1.0 IW no water stress throughout the growing stage resulted in maximum bulb diameter, which is similar to the current conclusion.

Table 3: Effects of irrigation and phosphorus levels on plant height, leaves number and bulb diameters

Treatments	Plant Height (cm)	Leaves Number	Bulb diameters (cm)
100% ETC*0 P	44.70^{def}	9.61^{efg}	4.31^{fg}
100% ETC*10 P	46.90^{bcde}	12.05^{bcd}	5.17^{de}
100% ETC*20 P	50.18^{ab}	13.13^{ab}	5.61^{bcd}
100% ETC*30 P	52.15^{a}	14.55^{a}	6.28^{a}
100% ETC* 40 P	51.50^{a}	14.90^{a}	5.92^{ab}
75% ETC*0 P	43.36^{efg}	8.54^{fgh}	3.80^{gh}
75% ETC*10 P	45.77^{cdef}	9.87^{defg}	4.73^{ef}
75% ETC*20 P	48.60^{abc}	10.80^{bcdef}	5.52^{bcd}
75% ETC*30 P	52.03^{a}	12.07^{bcd}	6.00^{ab}
75% ETC* 40 P	49.83^{ab}	12.80^{abc}	5.78^{abc}
50% ETC*0 P	40.56^{g}	6.95^{h}	3.41^{h}
50% ETC*10 P	42.89^{fg}	8.37^{gh}	4.31^{fg}
50% ETC* 20 P	47.89^{bcd}	9.69^{defg}	5.29^{cde}
50% ETC* 30 P	49.85^{ab}	11.00^{bcde}	6.04^{ab}
50% ETC* 40 P	49.10^{abc}	10.47^{cdefg}	5.72^{abcd}
LSD (0.05)	**3.61**	**2.41**	**0.56**
CV (%)	**5.80**	**9.70**	**8.30**

Mean values in columns and rows followed by the same letter are statistically not different at $P < 0.05$, LSD = least significant difference; CV= coefficient of variation in percent.

Total Soluble Sugar:

The interaction of irrigation levels and phosphorus rates did not affect the total soluble sugar content (TSS) of onion. However, phosphorus rates had a substantial effect on onion TSS. The maximum TSS value of 15.47 °Brix was observed in the application of 40 kg ha^{-1} of p, while the lowest TSS value of 11.88 °Brix was obtained in the control treatments (Table 4).

Table 4: Effects of irrigation and phosphorus levels on TSS

Irrigation Levels	TSS (°Brix)
100% of ETc	14.17^{a}
75% of ETc	13.87^{a}
50% of ETc	13.91^{a}
LSD (0.05)	**NS**
CV (a) in %	**20.69**
Phosphorus rates (kg/ha)	
0	11.87^{d}

10	13.19[c]
20	14.17[b]
30	15.22[a]
40	15.47[a]
LSD (0.05)	0.96
CV (b) in %	7.05

Mean values in columns and rows followed by the same letter are statistically not different at P< 0.05, LSD = least significant difference; CV= coefficient of variation in percent.

Average Bulb Weight and Marketable Bulb Yield:

Average Bulb Weight:

The result of the study showed that average bulb weight was significantly (P<0.05) affected by irrigation levels and phosphorus rates. A maximum average bulb weight of 94.53g was recorded from the application of 100% ETc with 30 kg P ha^{-1} followed by 93.23g of average bulb yield recorded from the application of 100% ETc with 40 kg ha^{-1}P, while the lowest average bulb weight of 63.61g was observed in plots received 50% of ETc with 0 kg ha^{-1}P (Table 3.5). This finding is in line with Tesfaye's (2009) result. It could be because the phosphorus boosted the carbohydrate content of the plants and extended root growth, which increased the number of blubs and blub size, increasing bulb weight.

Marketable Bulb Yield:

A statistically significant variation in onion yield was observed across the experiments, with a notable difference (P<0.05). The highest yield of the marketable yield of 28.08 tons/ha was recorded at 100% of ETc with 30 kg ha^{-1} P. This treatment was found statistically equivalent to treatment received 100% of ETc with 40 kg ha^{-1} P. Conversely, the lowest 17.72 tons/ha marketable yield of onion was observed in the 50% ETc without phosphorus application (Table 5). This outcome suggests that an increase in irrigation levels and phosphorus contributes to enhanced vegetative growth in the plants. This improvement results in a higher average assimilate available for storage and an increased average bulb weight, ultimately leading to a higher marketable onion yield According to Fairhust et al. (1999), phosphorus is necessary for root growth, which leads to the absorption of water and other nutrients and a rise in the weight of fresh bulbs. According to Aster (2009), applying phosphorus level has a favorable and significant impact on bulb length, bulb diameter, average bulb weight, dry matter content, marketable yield, and total bulb yield.

Table 5: Irrigation and phosphorus levels on average bulb weight and marketable bulb yield

Treatments	Average bulb weight (gm)	Marketable bulb yield (t/ha)
100% ETC*0 P	76.60[def]	19.11[i]
100% ETC*10 P	83.75[abcd]	21.70[fg]
100% ETC*20 P	91.94[ab]	24.68[c]
100% ETC*30 P	94.53[a]	28.08[a]
100% ETC*40 P	93.23[a]	26.75[ab]
75% ETC*0 P	69.13[fg]	18.74[ij]
75% ETC*10 P	76.55[def]	20.50[gh]
75% ETC*20 P	83.88[abcd]	23.20[de]
75% ETC*30 P	88.40[abc]	25.52[bc]
75% ETC* 40 P	80.97[bcde]	24.20[cd]
50% ETC*0 P	63.61[g]	17.72[j]
50% ETC*10 P	71.02[efg]	19.24[hi]

50% ETC* 20 P	78.57^{cdef}	21.91^{efg}
50% ETC* 30 P	86.77^{abcd}	22.92^{def}
50% ETC* 40 P	81.53^{bcde}	22.28^{ef}
LSD (0.05)	**11.57**	**1.36**
CV (%)	**8.87**	**3.60**

Means values in columns and rows followed by the same letter are statistically not significantly different at P< 0.05, LSD = least significant difference; CV= coefficient of variation in percent.

Crop Water Requirements, Water Productivity and Yield Response Factor

Crop Water Requirement (CWR):

Crop water required was calculated using Cropwat 8 and the computed irrigation amount was applied to meet crop water requirements under the dry conditions. During the growing season 441mm, 331 and 220mm for 100%, 75%, and 50%, crop evapotranspiration (ETc) was applied respectively. It is very important to notice that about 25% and 50% of ETc was saved when 75% and 50%Etc of water were applied in comparison with optimal irrigation treatment (100%ETc). This result is in agreement with the findings of Igbadun et al. (2012) who showed that the water needs of onion crops reduced by about 20% with an increase in irrigation deficit of 50% of reference evapotranspiration.

Water Productivity (WP):

The analysis of variance showed that the interaction of irrigation levels and phosphorus rates had a significant effect on the water productivity (WP) of Onion at P<0.05. The highest WP of 10.38kg/m^3 was obtained from the application of 50% of ETc with 20 kg P ha^{-1} and statistically different for all other treatments except treatment receiving 50% of ETc with 30 kg ha^{-1} P. The lowest WP of 4.33 kg/m^3 was obtained from the treatment receiving 100% of ETc with 0 kg P ha^{-1}. This treatment was significantly different from all other treatments except 100% of ETc with 10 kg P ha^{-1}. This indicated that irrigating with 50% of ETc level resulted in higher WP than irrigating with 100% of ETc. As shown in Table 6, the WP decreased as the irrigation amounts increased from 50% to 100% ETc. This could be due to an improvement in yield when the amount of irrigation water was increased while maintaining favorable soil moisture conditions throughout the cropping season. These results agree with that of Teferi (2015) who reported a higher mean value of irrigation water use efficiency was observed under the drip method with a mean value of 7.1 kg m^{-3} which is 33.8% higher than that obtained in the furrow method (4.7 kg m^{-3}).

Yield Response Factor (Ky):

The observed yield response factors (Ky) result of onion for irrigation and N fertilizer level ranged between 0.00 and 1.37. According to Kirda, et al. (2000) the Ky value for field crops goes from 0.2 to 1.15 which agrees with the reported result by Watkinson (2008). From the study result of Table 6 the highest Ky was 1.37 attained at the treatment 75% ETC*0 kg/ha P (irrigating 75%ETc without N fertilizer). The higher Ky values could be an indication of the severity of water deficit and P fertilizer rate at onion bulb yield. The lowest result of yield response factors of 0 and 0.40 was observed at the treatment receiving 50%ETc*30kg/ha P followed by 75% ETC*30kg/ha P, respectively. This demonstrated the optimal response of water and fertilizer amount on onion yield. According to the results of Table 5, a moisture deficit of more than 25% combined with a fertilizer rate of less than 10 kg/ha P results in a yield reduction of 28.47 to 34.61%. (Table 6).

Table 6: Crop and irrigation water requirement, water productivity, and yield response factor of onion

Treatment	kg/ha	ETC (mm)	WP (kg/m^3)	Relative Water Saved (%)	Relative Yield Reduction (%)	Yield Response Factor (ky)
100% ETC*0 P	19,110	441.6	4.33	-	33.32	-
100% ETC*10 P	21,700	441.6	4.91	-	24.28	-
100% ETC*20 P	24,680	441.6	5.59	-	13.89	-
100% ETC*30 P	28,080	441.6	6.36	-	-	-
100% ETC*40 P	26,750	441.6	6.06	-	6.66	-
75% ETC*0 P	18,740	331.2	5.66	25.00	34.61	1.37
75% ETC*10 P	20,500	331.2	6.19	25.00	28.47	1.14
75% ETC*20 P	23,200	331.2	7.00	25.00	19.05	0.76
75% ETC*30 P	25,520	331.2	7.71	25.00	10.96	0.44
75% ETC* 40 P	24,200	331.2	7.31	25.00	15.56	0.62
50% ETC*0 P	17,720	220.8	8.03	50.00	38.17	0.76
50% ETC*10 P	19,240	220.8	8.71	50.00	32.87	0.66
50% ETC* 20 P	21,910	220.8	9.92	50.00	23.55	0.47
50% ETC* 30 P	22,920	220.8	10.38	50.00	20.03	0.40
50% ETC* 40 P	22,280	220.8	10.09	50.00	22.26	0.45

Partial Budget Analysis

An economic assessment was conducted utilizing partial budget analysis, dominance, and marginal rate of return. The onion bulb was valued based on the average market price over three consecutive production years. The average cost of urea, and TSP was 42 birr per kg. A daily wage rate of 150 birr per person was considered. The partial budget analysis employed concepts such as gross field benefit (GFB), total variable cost (TVC), total fixed cost (TFC), and net benefit (NB) (CIMMYT,1988).

The economic comparison of the data in Table (7) reveals that the direct impact of irrigation level and phosphorus fertilizer rate significantly increased net income (NI) per hectare per season compared to the absolute control. The treatment 100%ETc*40 kg/ha P incurred the highest total cost (16,522.00ETB), while the control (50%ETc*0 kg/ha P) had the lowest variable cost (6400ETB). The economic analysis highlighted (100%ETc*30 kg/ha P) as the most economically viable treatment, exhibiting a high optimal net benefit. The marginal rate of return above 100%, deemed acceptable to farmers (CIMMYT, 1988), was notably high for treatments receiving 30, 20 and 10 kg/ha P at all levels of irrigation amount. Consequently, 100%ETc*30 kg/ha P application produced the highest net benefits and marginal rate of return compared to other treatments. In conclusion, farmers in the study area benefited economically from applying 100%ETc*30 kg/ha P and 75%ETc*30 kg/ha P or 100%ETc*20 kg/ha P rather than choosing for the other treatments which are not economically viable for onion production under irrigated condition.

Table 7: Partial budget analysis based on mean values for onion production using different levels of N fertilizer and irrigation amount at Kulumsa

ETC*FR	Gross Return (ETB)	TVC (ETB/ha)	Net Return (ETB/ha)	MRR (%)
100ETc*0P	515970	6,400	509,570.00	-
100ETc*10P	585900	8,920.00	576,980.00	2675
100ETc*20P	666360	11,482.00	654,878.00	3041
100ETc*30P	758160	4,002.00	744,158.00	**3543**

100ETc*40P	722250	16,522.00	705,728.00	D
75ETc*0P	505980	4,800.00	501,180.00	-
75ETc*10P	553500	7,320.00	546,180.00	1786
75ETc*20P	626400	9,882.00	616,518.00	2745
75ETc*30P	689040	12,402.00	676,638.00	2386
75ETc*40P	653400	4,922.00	638,478.00	D
50ETc*0P	478440	3,200.00	475,240.00	-
50ETc*10P	519480	5,720.00	513,760.00	1529
50ETc*20P	591570	8,282.00	583,288.00	2714
50ETc*30P	618840	10,802.00	608,038.00	982
50ETc*40P	601560	13,322.00	588,238.00	D

CONCLUSION

The study was carried out at the Kulumsa Agricultural Research Centre (KARC) in Tiyo, Arsi Zone, Southeastern Ethiopia. The objectives of this research were to determine optimal irrigation levels and phosphorus rates, as well as the interacting effect of nutrient and moisture levels on onion yield and yield quality. The experiment was arranged in a Randomized Complete Block Design (RCBD) split plot with three replications. The experiment utilized three irrigation levels (100%, 75%, and 50% ETc) were paired with five phosphorus rates ranging from 0 to 40kg/ha. The study results revealed significant differences among treatments. Key growth parameters such as the plant height, number of leaves per plant, bulb diameter, sugar content, average bulb weight, and marketable yield were subjected to evaluation. The study result demonstrated that irrigation and phosphorus levels had a significant impact on onion growth and yield components. The highest marketable bulb yield of onion 28.08 tons/ha was obtained at 100% crop evapotranspiration (ETc) and 30 kg/ha of phosphorus application. The tallest plants (52.15 cm), maximum leaf numbers (14.55), and largest bulb diameter (6.28 cm). Moreover, this treatment yielded the highest average bulb weight (94.53) and marketable bulb yield (28.08 tons/ha). The study emphasized that adequate irrigation and phosphorus application positively impacted vegetative growth, bulb development, and overall onion yield. Water productivity analyses indicated the highest **water** productivity 10.38 kg/m^3 result was recorded from the treatment receiving 50% ETc and 20 kg/ha of phosphorus. Additionally, yield response factors indicated the sensitivity of onion yield to water deficit and phosphorus levels, emphasizing the importance of optimal irrigation and phosphorus management. Economic analysis results revealed the profitability of treatments involving 100% ETc with 30 kg/ha of phosphorus, demonstrating higher net benefits and substantial marginal rates of return (above 100%) compared to other treatments. Therefore, P rate of 30 kg ha^{-1} and irrigation level given at 100 and 75% ETc sounds good and can be recommended for onion production in the studied area.

REFERENCE

Abbey, L., & Joyce, D. C. (2004). Water deficit stress and soil type effects on spring onion accumulation and partitioning in two potato cultivars. Journal of Plant Nutrition, 25, 1621–1630.

Agumas, B., Abewa, A., & Abebe, D. (2014). Response of Irrigated Onion (Allium cepa L.) to Nitrogen and Phosphorus Fertilizers at Ribb and Koga Irrigation Schemes in Amhara Region, North western Ethiopia. In *International Research Journal of Agricultural Science and Soil Science* (Vol. 4, Issue 4). http://www.interesjournals.org/IRJAS

Ali, S., & Gebeyehu, S. A. (2019). Response of Phosphorus fertilizer rate on Growth, Yield and Yield Components of Onion (Allium cepa L.) at East Gojjam Zone, North Western Ethiopia Article in Agricultural. *Science Research Journal*. https://doi.org/10.14662/ARJASR2018.044.

Aster Korea, 2009. Effect of nitrogen and phosphorous fertilizers on yield and yield Component of Onion (Allium cepa, L.) at Melkassa, central rift valley of Ethiopia, Pp: 109 Bsawas, T.D., and S.K. Mukherjee, 1993. Textbook of Soil Science (5th Ed). Tata Mac Grow-Hall, New Delhi. 170-197.

David, K., Emmanuel, C., & John, K. (2016). Effects of deficit irrigation on yield and quality of onion crop. Journal of Agricultural Science, 8(3), 1916–9752.

El-Noemani, A. A., Aboamera, A. A. A., & Dewedar, O. M. (2009). Growth, yield, quality and water use efficiency of pea plant as affected by evapotranspiration and sprinkler height. Journal of Agricultural Research, 34, 1445–1466.

Enchalew, B., Gebre, S. L., Rabo, M., Hindaye, B., Kedir, M., Musa, Y., & Shafi, A. (2016). Effect of deficit irrigation on water productivity of onion (Allium cepal.) under drip irrigation. Journal of Irrigation and Drainage Systems Engineering, 5(3), 168–9768

Fairhust T, Lefroy R, Mutert E, Batijes N (1999). The importance, distribution and causes of phosphorus deficiency as a constraint to crop production in the tropics. Agrofor. Forum, 9: 2-8.

Horneck DA (1999). Function of Phosphorus in plants. Better crop, (83):6-7.

Kirda C., 2000 - Deficit irrigation scheduling based on plant growth stages showing water stress tolerance. Deficit Irrigation Practices, FAO Water Reports, Rome, Italy, 22: 3-10.

Kumar, S., Imtiyaz, M., & Kumar, A. (2007b). Effect of differential soil moisture and nutrient regimes on post-harvest attributes of onion (Allium cepa L.). Journal of Science of Horticulture Research, 112, 121– 129.

Ramada, S., & Ramanathan, S. P. (2017). Evaluation of drip fertigation in aerobic rice-onion cropping system. International Journal of Current Microbiology and Applied Sciences, 6(4), 2623–2628.

Singh, Kumar, JVA & Singh C (2000). Influence of phosphorus on growth and yield of onion (Allium cepa L.). Indian JAgric 34(1): 51-54.

Tafesse, D. (2003). *The Federal Democratic Republic of Ethiopia Ethiopian Agricultural Research Organization National Soil Research Center (NSRC) Soil Survey and Land Evaluation Section Based on the works of Sahlemedhin Sertsu (PhD.) Abayneh Esayas (MSc)*.

Teferi G (2015). Effect of Drip and Surface Irrigation Methods on Yield and Water Use Efficiency of Onion (Allium Cepa L.) under Semi-Arid Condition of Northern Ethiopia. Journal of Biology, Agriculture and Healthcare, 5 (14), 88-94

Tesfaye B (2009). Effect of Phosphorus Nutrition on growth of Potato Genotypes with constricting Phosphorus efficiency. African Crop Science Journal 17(4): 199-212.

(20) (PDF) Effect of sowing dates and phosphorus levels on growth and bulb production of Onion.

Teshome, Y., & Bogale, N. (2022). Review on the effects of phosphorus on growth and yield of onion (Allium cepa L.). *International Journal of Agriculture and Nutrition*, 4(1), 6–11. https://doi.org/10.33545/26646064.2022.v4.i1a.46

Yitagesu Kuma, A. N., & Tigist Alemu, A. A. (2015). Onion Production for Income Generation in Small Scale Irrigation Users Agropastoral Households of Ethiopia. *Journal of Horticulture*, *02*(03). https://doi.org/10.4172/2376-0354.1000145