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Determination of Optimal Nitrogen Fertilizer Rate and Soil Moisture Level for Onion in Jawe District, North West Ethiopian

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Abstract

Irrigation water shortage is one of the limiting factors to onion productivity in Ethiopian. The experiment was conducted at Jawe district, North West Ethiopian during 2021/22 and 2022/23 cropping season to determine the optimum rate of nitrogen rate and irrigation level and to identify the interactive effect of nitrogen and moisture levels on yield of onion and water productivity. The experiment was conducted in RCBD split plot design. The irrigation levels (100% ETc, 75% ETc and 50% ETc) have been be in the main plot while nitrogen fertilizer rate treatments (0 kg/ha,23 kg/ha, 46 kg/ha, 69 kg/ha, and 92 kg/ha) have been assigned to the sub plots. 100% ETc with 0 level of nitrogen rate was the control treatments for this experiment. Irrigation scheduling was estimating using CropWat with 60% efficiency. Convectional furrow irrigation was used and partial flume and stop watch were used to measure the required amount of water. Data analysis was conducted using R-software. Different irrigation levels with the nitrogen levels had a significant ($p<0.05$) influence on bulb yield of onion. The highest bulb yield of 141.06q/ha was obtained at the full application of irrigation and the lowest bulb yield of 120.76q/ha was obtained at 50%ETC irrigation level. The highest bulb yield of 157.1q/ha was obtained at 69kg/ha nitrogen rate and the lowest average bulb yield of 101.19q/ha was recorded from no application of nitrogen rate. The highest bulb yield of 178.89q/ha was recorded from 75%ETC irrigation level that combined with 69kg/ha nitrogen rate and the lowest bulb yield of 84.96q/ha was obtained at 50% ETC combined with no application of nitrogen rate. Different irrigation levels with the nitrogen levels also had a significant ($p<0.05$) influence on water productivity. The highest water productivity of 5.1 kg/m^3 and 4.77kg/m^3 was obtained at 50%ETC and 69kg/ha nitrogen rate respectively. The lowest water productivity of 3.00 kg/m^3 was obtained at 100%ETC and 3.024 kg/m^3 at no application of nitrogen rate. The highest water productivity of 6.12kg/m^3 obtained at 50% ETC combined with 92kg/ha nitrogen rate. The lowest water productivity of 2.46 kg/m^3 was obtained at 100% ETC combined with no application of nitrogen rate. Therefore, irrigating 75%ETc combined with application of 69kg/ha nitrogen rate and 50% ETC combined with 92kg/ha nitrogen rate were recommended to the study area to improve bulb yield of onion and to improve water productivity respectively.

Keywords: Irrigation Level, Nitrogen Rate, Onion, Jawe

1. Introduction

1.2. Background and Justification

Maximizing water productivity may be more advantageous to the farmer in places with limited water supplies and long summer droughts than increasing crop production. According to, adoption of techniques for conserving irrigation water and maintaining respectable yields could help to preserve this increasingly scarce resource [1]. It has become quite important to consider how to use water sustainably in agriculture. Soil moisture is one of the most important factors that influences onion yield. An onion has a shallow and limited root system and requires frequent irrigation as the crop extract very little water [2]. This crop should be irrigated frequently throughout out the growing season and new roots will not grow in to dry soil [3].

Poorly drained soils are not recommended for onion production, especially because of frequent problems with bulb diseases at harvest time that lead to more problems in marketing [4]. Onion requires varying temperature and day length for the purpose bulb production [5]. A relatively high temperature and long photoperiod are required for bulb formation, and for seed production, temperature is of immense importance than day length [6].

For optimum yield, onions require 350-550 mm of water, but may use more than that in tropical areas where evapotranspiration is appreciably higher [7]. However, onions are best grown when allowable depletion is maintained above 70% of the total available water, after which a yield reduction will occur [4,7]. Onion is most sensitive to water deficit during the yield formation period, particularly during the period of rapid bulb growth and transplantation. Water deficit of 50-75% during the total growing season at the yield formation period caused a large decrease in bulb yield [8]. In Ethiopia, the recommended fertilizer rate for the onion is, 200 kg/ha (DAP) and 100 kg/ha for urea and Infrequent and late application of irrigation water results low storable bulbs. [3]. Water should apply more frequently, every 4-5 days for the first 3 to 4 weeks after planting and extended to every 7-9 days then after. As the onion begins to mature and the tops begin to fall that is 15-25 days before harvest, irrigation should be terminated.

Irrespective of onion cultivars and that works only for furrow irrigation system, the recommended spacing for improved onion production in Ethiopia is 10 cm x 20 cm x 40 cm spacing where 10 cm is the spacing between plants, 20 cm spacing between rows and 40 cm is the width of plant bed including irrigation water path used for irrigating the plant [9]. A lack of fertilizer, improper spacing, and difficulty of obtaining high-quality planting materials coordinated with other cultural techniques can all limit onion production [10]. According to, numerous recent studies have been conducted on the water and nitrogen fertilizer needs of onion crops, as well as the impacts of irrigation levels on yield and yield components [11]. Nitrogen fertilizer level of less than 100 kg ha-1 was shown to be enough for the production of onions [12,13]. Even if finding of Russo's states that the output of onions was not significantly affected by nitrogen fertilizer finding of indicates that controlling soil moisture and nitrogen levels are essential to onion production [14,15].

Performance of agricultural inputs fertilizer and water use efficiency should be analyzed together, reflecting the overall effectiveness of the farming system, including crop yield and soil nutrient levels. Plant nutrients and water are complementary inputs, the incremental return to fertilizer inputs is larger when water is not limiting and vise verse. Information on the simultaneous application of water and nitrogen fertilization is not available in the study area. Irrigation is applied without considering the optimum irrigation water level, and the application of nitrogen is also based on the national recommendation which does consider soil fertility and moisture levels. Therefore, this study is conducted to determine the optimum rate of nitrogen and irrigation level, and to identify the interactive effect of nitrogen and irrigation water levels on yield of onion.

2. Materials and Methods

2.1. Description of Study Site

Jawi district is found at 602 km to North West direction far away from Addis Ababa with a geographical location of 36o 29’17.58’’ longitude and latitude of 11o 33’22.68’’. Jawi district is located in the lowland part of Awi zone which receives a mean annual rainfall of 1250 mm and its altitude ranges from 700 to 1500 m.a.s.l with mean annual temperature of 16oC to 32oC which ranges 12*oc* to 40*oc*. The Jawi meteorological station is located at 11.56° N and 36.52°E and at an elevation of 1227 m a s l. Jawi district is bounded in East by Dangla district, in South by Dangur and Pawe district, in West by Quora district and in North by Alefa Taqusa district. It is characterized as a warm humid low land area with high rain fall and the climate is hot and humid, with a unimodal rainfall pattern with high and heavy rainfall from May to October [16].

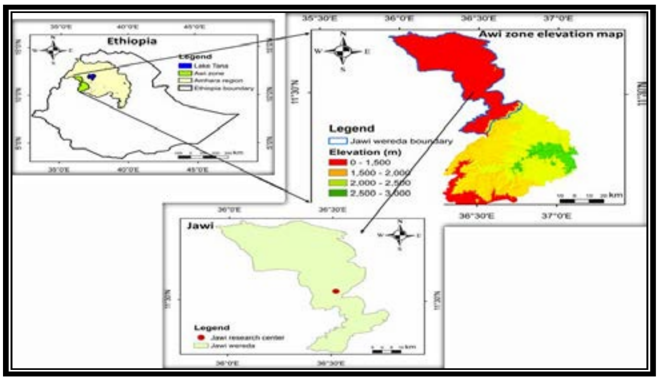

Figure 1: Location of the Study Area and Jawi District Meteorological Station

2.2. Experimental Design and Methodology

The seedlings of onions (Bombay Red v) were prepared and seedlings were hardened before transplanting to the main field to enable them to withstand the field conditions. After 45 days seedling have been transplanted. After transplanting full irrigations were applied uniformly to all plots with four days intervals, to ensure good plant establishment. The experiment was conducted in RCBD split plot design. The treatments have been randomized both at the main and sub-plot levels and replicated three times. The deficit irrigation levels have been was in the main plot while nitrogen fertilizer rate treatments have been assigned to the sub plots.

Treatment	Nitrogen rate (kg/ha)				
Irrigation water levels	0	23	46	69	92
100% ETc	T1	T2	T3	T4	T5
75% ETc	T6	T7	T8	T9	T10
50% ETc	T11	T12	T13	T14	T15

Table 1: Treatment Combinations

The experimental plots inter and intra row spacing was done based on the recommended agronomic value for onion. Onion is known by two row crops so onion seedlings from the nursery transplanted on plant row spacing across furrow was 30 cm, across the ridge was 30 cm and along the ridge 10 cm between plants.

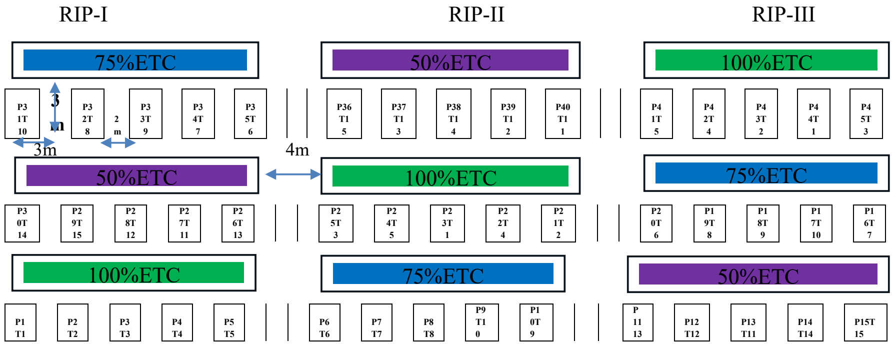

Figure 2: Experimental Layout

2.3. Soil Sampling, Preparation and Analysis

Undisturbed and disturbed Composite soil samples had been collected considering the root depth of onion at different soil depths (0-15 cm, 15-30 cm, 30-60 cm, 60 -90 cm) for bulk density and texture analysis respectively. Particle size distribution was measured by the standard Bouzoukis (1962) hydrometer method (Andres et al.). Field capacity (FC), permanent wilting point (PWP) and total available water (TAW) were determined by soil-plant air-water (SPAW). Maximum rain infiltration rate (mm/day) which was determined by double ring infiltrometer, initial soil moisture depletion (%), and initially available soil moisture (mmm) total available soil moisture (mm/m), maximum rooting depth (m), used as an input. Before transplanting composite soil, samples have been taken to analysis available nitrogen and after harvesting soil samples were taken on plot based from furrow, middle of furrow and ridge and on ridge to analysis available residual nitrogen level.

2.4. Water Requirements and Irrigation Scheduling

The amount of irrigation water applied have been calculated and applied water to the field measured by parshall flume and Irrigation scheduling was worked out using CropWat 8.0 windows by irrigating at 100% critical depletion time criteria and apply at refill to field capacity depth criteria. The Selected climate parameters used were rainfall, maximum temperature, minimum temperature, relative humidity, wind speed and sunshine hours. Characteristics of onion (growing stages, maximum rooting depth, crop coefficient, critical depletion in fraction, yield response factor, crop height) were collected and used as an input for CropWat. Soil Characteristics (field capacity, permanent wilting point, total available water, maximum rain infiltration rate initial soil moisture depletion and initially available soil moisture and maximum rooting depth of soil) used as an input. Irrigation water application interval was estimated using Cowpat model considering equation (1) and gross amount of water to be applied to the field was determined using 60 % irrigation efficiency separately (Yi, et., al).

$$\text{Interval (days)} = \frac{NIR}{ETC} \quad (1)$$

$$\text{GIR} = \frac{NIR}{Ea} \quad (2)$$

Where; NIR = Net Irrigation Requirement or ASMDL (mm), ETc = Crop Evapo-transpiration (mm/day), GIR = gross amount of water (mm) and Ea = irrigation application efficiency (60%).

2.5. Bulb Yield and Yield Components

During the implementation period yield and yield related parameters were collected following the data sheet including, stand count at harvesting, average plant Hight, bulb diameter, biomass yield and bulb yield explained as follows:

- Stand count at harvest: Total number of plants in harvestable row during harvesting at maturity. Average plant height (cm): Plant height was computed for five randomly selected plants using measuring tape from the ground level up to the tip of the leaf in the experimental plot at physiological maturity.
- Bulb diameter (cm): Bulb diameter was measured by using automatic caliper at the widest circumstance of the bulb of five sample plants in each experimental plot.
- Total biomass yield (q/ha): Total weight of bulbs including leaves.
- Total bulb yield (q/ha): Total bulb yield was measured as the total weight of healthy bulbs produced by all plants at central three double or six single harvestable rows per plot.

2.6. Water Productivity

The water productivity (WP) was also calculated using the following equation (Zwart and Bastiaanssen).

$$\text{WP} = \frac{\text{BY}}{\text{CWR}} \quad (3)$$

Where: WP = Water productivity (kg/m^3) is the amount of bulb yield of onion per meter cubic of water consumed, BY =Bulb yield of onion (kg/ha) , CWR=Crop water requirements (m^3/ha).

2.7. Data Analysis

Yield and yield components data 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.

3. Result and Discussion

3.1. Bulb Yield and Yield Components

Over year recorded bulb yield and yield parameters data were analyzed using R-Software and the treatments were compared based on bulb yield and yield parameters, as shown in the following.

Irrigation level	BY(q/ha)	Bd(cm)	BIMY(q/ha)	APH(cm)	SC/ha
100%ETc	141.07[a]	3.88[a]	235.45	40.6[a]	189251.0
75%ETc	140.34[a]	3.94[a]	235.74	39.88[ab]	188769.5
50%ETc	120.76[b]	3.49[b]	214.9	37.64[b]	182288.0
LSD (@=0.5)	9.6	0.24	NS	2.41	NS
CV (%)	33.3	14.03	41.76	12.87	10.09
N-rate(kg/ha)	BY(q/ha)	Bd (cm)	BIMY(q/ha)	APH(cm)	SC/ha
0	101.19[d]	3.44[b]	158.4[b]	39.1	182784.7
23	115.29[c]	3.53[b]	200.58[b]	38.5	184883.4
46	142.45[b]	3.92[a]	281.51[a]	39.58	193017.7
69	157.1[a]	3.99[a]	257.52[a]	40.07	187242.7
92	154.26[ab]	3.96[a]	245.53[a]	39.68	185918.9
LSD (@=0.5)	12.39	0.31	43.44	3.11	12273.06
CV (%)	30.18	13.79	NS	13.22	NS
**BY=bulb yield, Bd=bulb diameter, BIMY=biomass yield, APH= average plant Hight, SC=stand count at harvest.					

Table 2: Effect of Nitrogen Rate and Irrigation Level on Onion Bulb Yield and Yield Components

As shown in table 2, different irrigation level had significant ($p<0.05$) influence bulb yield, bulb diameter and ravage plant height of onion. Different irrigation level had significant ($p<0.05$) influence on biomass yield and stand count of onion. There was 14% bulb yield penalty by the application of 50%ETC irrigation level over full (100%ETC) application of irrigation level. Even if there were no significant ($p<0.05$) different between application of 100%ETC and 75%ETC, there were 1.34quntal per hectare bulb yield advantage due to the application of 100%ETC irrigation level than application of 75%ETC irrigation level. The increasing nitrogen rate increased the bulb yields up to 92 kg/ha nitrogen rate, but the response was significant only up to 69kg/ha nitrogen rate. Different nitrogen rate affects bulb yield, bulb diameter, and biomass yield significantly ($p<0.5$) but there was not significant effect on average plant height, and stand count of onion. There was no significant difference between application of 69kg/ha nitrogen rate and application of 92kg/ha nitrogen rate on production of bulb yield but they were significant difference with the others (46kg/ha, 23kg/ha) and no application of nitrogen fertilizer. Application of 69kg/ha nitrogen rate increase bulb yield significantly by 9.33%, 26.61% and 35.59% over the 46kg/ha, 23kg/ha zero fertilizer rate respectively and 1.81% bulb yield advantage was also recorded over application of 92kg/ha nitrogen fertilizer rate.

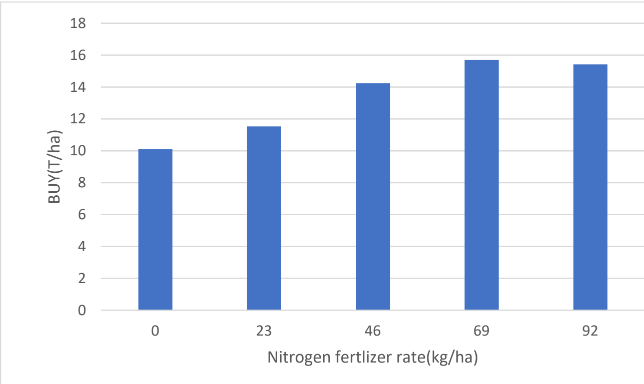

Figure 3: Effect of Nitrogen Fertilizer Rate on Onion Bulb Yields

Generally, the highest bulb yield of 141.06q/ha was obtained at the full application of irrigation and the lowest bulb yield of 120.76q/ha was obtained at 50%ETC irrigation level. The highest bulb yield of 157.1q/ha was obtained at 69 Kg/ha N rate and the lowest average bulb yield of 101.19q/ha was recorded from no application of nitrogen rate. Application of 69 kg/ha nitrogen fertilizer rate enhanced the growth of onion plant and resulted in optimum fresh total and marketable bulb yield on the vertosol of Shewa Robit, North east Ethiopia [17].

Irrigation Level	Bulb Yield (q/ha)				
	Nitrogen Level (kg/ha)				
	0	23	46	69	92
100%Etc	114.63[f]	122.93[def]	150.90[bc]	154.84[bc]	162.03[ab]
75%Etc	103.99[fg]	121.42[ef]	139.60[cde]	178.89[a]	157.77[abc]
50%Etc	84.96[g]	101.5[fg]	136.86[cde]	137.50[cde]	142.97[bcd]
LSD (@=0.5)	21.46				
CV (%)	13.78				

Table 3: Interaction Effect of Irrigation Levels and Nitrogen Rate on Onion Bulb Yield

As shown in table, interaction of irrigation levels and nitrogen rate on had significant ($p<0.5$) influence on onion bulb yield. The highest bulb yield of 178.89q/ha was recorded from 75%ETC irrigation level that combined with 69kg/ha nitrogen levels and the lowest bulb yield of 84.96q/ha was obtained at 50%ETC combined with no application of nitrogen rate.

3.2. Water Productivity

Irrigation level	WP (kg/m^3)
100%ETc	3.024[c]
75%ETc	4.01[b]
50%ETc	5.1[a]
LSD (@=0.5)	0.32
CV (%)	36.06
N-rate(kg/ha)	WP (kg/m^3)
0	3.0[c]
23	3.48[b]
46	4.36[a]
69	4.77[a]
92	4.7[a]
LSD (@=0.5)	0.41
CV (%)	38.67

Table 4: Effect of Nitrogen Rate and Irrigation Level on Water Productivity

As shown in table 4, different irrigation levels had a significant ($p<0.05$) influence on water productivity. The highest water productivity of 5.1 kg/m^3 obtained at 50%ETC and the lowest crop water productivity of 3.024 kg/m^3 was obtained at 100%ETC irrigation level. Different nitrogen fertilizer rate had also a significant ($p<0.05$) influence on water productivity. The highest water productivity of 4.77kg/m^3 and the lowest crop water productivity of 3 kg/m^3 were obtained at 69kg/ha nitrogen rate and no application of nitrogen rate respectively.

Irrigation Level	Water Productivity (kg/M^3)				
	Nitrogen Level (Kg/ha)				
	0	23	46	69	92
100%Etc	2.46[h]	2.63[gh]	3.24f[g]	3.32[efg]	3.47[ef]
75%Etc	2.97[fgh]	3.47[ef]	3.98[cde]	5.11[b]	4.50[bc]
50%Etc	3.64[def]	4.34[cd]	5.86[a]	5.89[a]	6.12[a]
LSD (@=0.5)	0.71				
CV (%)	15.17				

Table 5: Interaction Effect of Irrigation Levels and Nitrogen Rate on Water Productivity

As shown in table 5, interaction of irrigation levels and nitrogen rate has significant effect on irrigation water productivity. The highest irrigation water productivity of 6.12kg/m3 obtained at 50%ETCcombined with 92kg/ha nitrogen rate. The lowest irrigation water productivity of 2.46 kg/m3 was obtained at 100%ETC combined with no application of nitrogen rate (control treatment). Therefore, irrigating 75% ETc combined with application of 69kg/ha nitrogen rate and 50%ETC combined with 92kg/ha nitrogen rate were recommended to the study area to improve bulb yield of onion and to improve water productivity.

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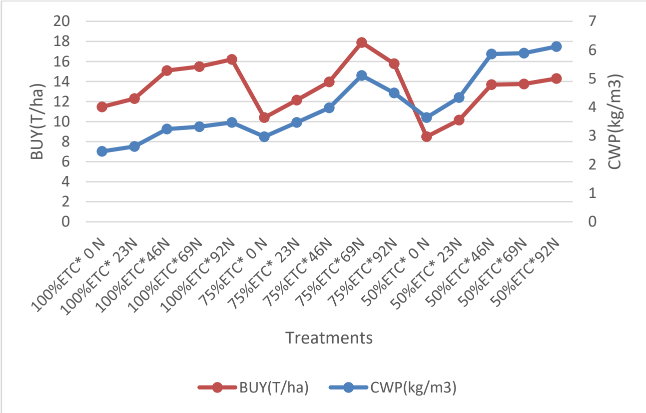

Figure 4: Interaction Effect of Irrigation Water Level and N Fertilizer Rate on Bulb Yields and WP

National production of onion yield per hectare is 9.6 ton [10]. However, the productivity of onion in Ethiopia is lower than the world and Africa average. According to FAO report the average yield tones ha- for the world, Europe, Asia, American, Africa and Ethiopia are 17.05, 15.7, 20.64, 10.47, 12.14 and 10, respectively [7]. In Ethiopia, the total area under onion production was about 38,952.58 ha, of which 3,460,480.88 tons were produced in 2020/2021, with an average yield of about 8.8 t ha−1 [10]. This showed that the production of onion in Ethiopia (8.8 t ha−1) is significantly under the global average (18.8 t ha−1). According to, 31.1t/ha and 30.5t/ha bulb yield of onion produced with combined application of 100%ETC and 75%ETC with 69 (kg/ha) nitrogen respectively in rift valley and 33.1t/ha and 31.4t/ha obtained under combination of 100%ETC and 75%ETc with 92 kg/ha nitrogen rate [18].

Irrigation level	TN (%)
100%ETc	0.165
75%ETc	0.177
50%ETc	0.195
LSD (@=0.5)	0.032
CV (%)	36.51
N-rate(kg/ha)	TN (%)
0	0.144^{b}
23	0.181^{ab}
46	0.18^{ab}
69	0.185^{ab}
92	0.199^{a}
LSD (@=0.5)	0.041
CV (%)	36.00

Table 6: Residual Total Nitrogen Percentage After Harvesting

The influence of irrigation level and nitrogen fertilizer application rates on soil nitrogen content after harvest is shown in Table 6. Irrigation levels do not have a significant effect ($p<0.05$) on soil nitrogen content after harvest. The nitrogen application rate had significant effect ($p<0.05$) on soil nitrogen content after harvest. But only the control and 92kg/ha nitrogen application rate showed significant differences in soil nitrogen content. The lowest total nitrogen (0.144%) and the highest (0.199%) were observed in the control and 92kg/ha nitrogen application rate. Generally, the total nitrogen increased as the nitrogen rate increased with the exception of 69kg/ha nitrogen rate application treatments. But there is no significant difference on soil nitrogen content among nitrogen fertilizer treatments. Increased soil nitrogen caused by high-rate urea fertilizer could be due to the rapid vigorous growth of plants which resulted in addition of carbon through root biomass and residue decay or could also be due to increased microbial activities as a result of nitrogen application which led to enhanced production and mineralization of organic matter from the soil [19,20].

The soil residual nitrogen ranged from 0.18 to 0.36% across nitrogen application rates and increased at higher application rates with the highest in 150 and 200 kg/ha nitrogen from the field experiment that was conducted with five nitrogen application rates (control–0, 50, 100, 150, and 200 kg N ha−1) to determine optimum rate for best maize yield with limited effect on soil acidification on the Volcanic Soils of Buea Cameroon [21,22].

4. Conclusion and Recommendation

4.1. Conclusions

The aim of this experiment was to determining optimal nitrogen fertilizer rate and soil moisture level for onion yield and water productivity. The experiments have been laid out in a split-plot design with three water level as main plot and four nitrogen fertilizer rate and zero nitrogen fertilizer rate as sup plot treatments. The result shown that the irrigating 75% ETC combined with application of 69kg/ha nitrogen fertilizer rate had significant effect on bulb yield of onion. Thus, it indicated that the use of 75% ETC irrigation level combined with 69% ETC nitrogen fertilizer rate resulted in a yield increment of onion by 56.14%. Compared to control treatment (100%ETC with no application of nitrogen fertilizer). Irrigating 50%ETC combined with 92kg/ha nitrogen fertilizer rate improve water productivity. The lowest water productivity was recorded from the full irrigation that was no nitrogen fertilizer (control treatment).

Recommendations

Recommended Nitrogen fertilizer rate (69kg/ha) combined with phosphors fertilizer rates should be conducted to onion. Validation and demonstration trial should be conducted before adopting the recommendation to the farmers. Partial budget analysis should be estimated. The potential of the area for production of onion may not be this (178.89 q/ha) so, conducting these experiments in different kebeles of the district may exploit the potential.

Conflict of Interests

The authors have not declared any conflict of interests.

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