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Journal of Horticulture and Forestry

Full Length Research Paper

Effects of furrow dimensions on water productivity and yield of onion at small scale Irrigation Ilu Gelan district West Shoa Ethiopia

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This study was conducted at the Ilu Gelan district Western Shewa zone of Oromia Regional State to evaluate the impacts of furrow dimensions on yield and water productivity of onion. The experiment was laid out in a randomized complete block design with three treatments replicated four times. The experimental treatments including farmer practice or T1 (farmer practice with top width of 23 cm, bottom width of 13 cm and depth of 11 cm without determined flow rate), T2 (Furrow with top width of 45 cm, bottom width of 20 cm and depth of 12 cm with determined flow rate) and T3 (Furrow with top width of 35 cm, bottom width of 14 cm and depth of 10 cm with determined flow rate) having a plot size of 8 m × 5 m with spacing of 0.5 m × 1 m between plots and replications respectively. The highest application efficiency of (75.87%) was recorded under treatment T2 and the lowest application efficiency of (56.17%) was recorded from T1 that is, farmer practice when compared with other treatments. The highest distribution uniformity of (89%) was recorded from treatment T2 and lowest (81%) was from treatment T1. In terms of water productivity and yield of onion the highest values of 5.2 kg/m3 and 1952 kg/ha were recorded from T2 respectively. Similarly, lowest values 3.11 kg/m3 and 15088 kg/ha were obtained from T1 respectively. There were significance differences in plant height among all treatments at significance level of 5%. The highest (41.525 cm) was recorded from T2 and the lowest (39.275 cm) was obtained from T1. Further research covering all soil types is recommended to be more inclusive.

Key words: Furrow irrigation, furrow dimension, grain yield, irrigation efficiency, onion, water productivity.

INTRODUCTION

The sources of water for crop production are rainfall and irrigation water. The two types of agriculture seen from the perspective of water management are rain fed and irrigation agriculture which both helps to present sufficient water in the root zone for germination, evapotranspiration and nutrient observation (Dupriez and De Leener, 2002). In Ethiopia irrigation is used as complementary with rain fed during dry season. One of the irrigation methods in agriculture is furrow irrigation. This technique has been used for a variety of crops. Improving small scale farmers need to consider efficient utilization of irrigation water (Shuhuai et al., 2012). Agronomic practices have a profound effect on farm water management practices. A number of factors such as nature of cultivar, plant density, sowing time, and nutrient and water management are involved in affecting profitable yield Masoud and
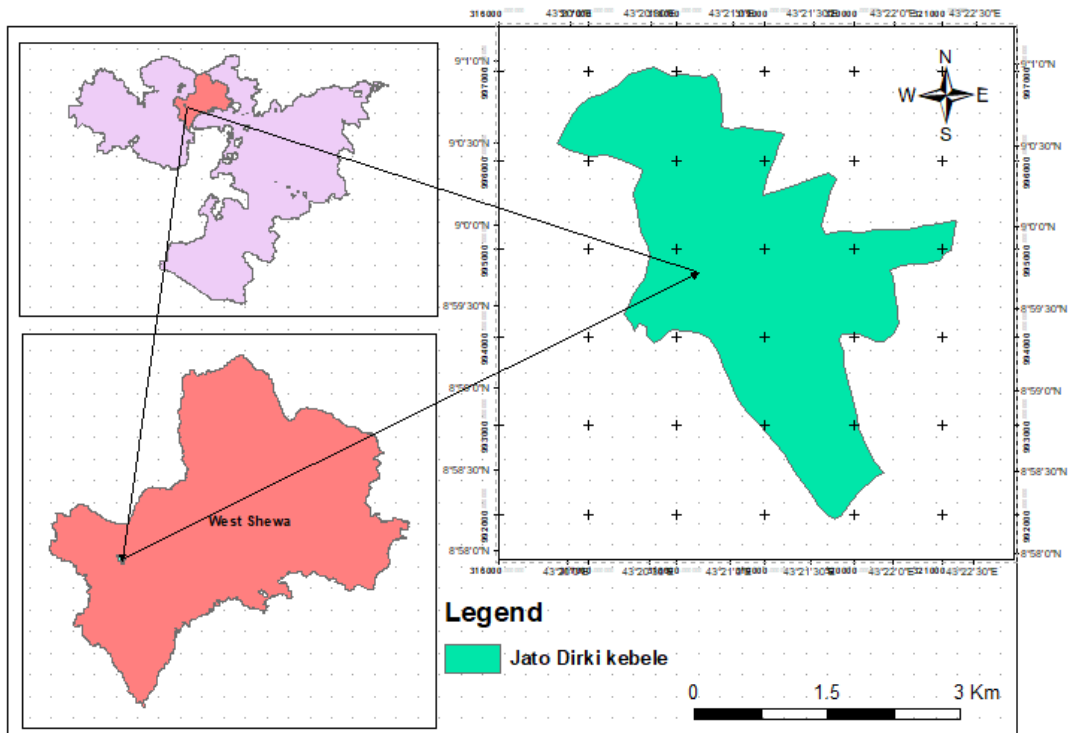
Figure 1. Location Map of the experimental site.

Ghodratolah (2010)

In the study area, farmers furrow dimensions by using animal power and local material prepared for plow. However, this material is made of different dimensions for using it at different points of the furrow length. The irrigation water diversion to the field is being done without considering design of furrow dimension. The release of high flow rate overtops the furrow section and takes off the soil resources as surface runoff which in turn reduces the nutrient of the soil. This phenomenon occurs if the furrow dimensions do not suite the incoming flow rate depending on the soil type of the area. The problem leads to erosion and frequent need of furrow construction. In other hand, application of very low flow rate results in deep percolation at furrow head while, other part of the furrow become under irrigated. Consequently, these practices are known to produce greater chance of water logging, tail water losses, salinity hazards, high yield loss and lower economical profit (Walker, 2003). Problems of irrigation water management leads to shortage of water and competitions among different agricultural and non- agricultural demands. The need of suitable water resource management is, therefore, serious concern for enhanced water use among different sectors. Proper use of furrow widths, depth, and length is one of the practices in irrigated agriculture to maximize irrigation efficiencies and enhanced crop yield as well as the water use efficiency. In addition, it can enable the users to conserve soil and water resources.

This study will provide indicative information on the response of irrigation performance indicators, yield and water use efficiency of onion due to the proper furrow dimensions.

In west Shoa zone of Oromia Regional state, onion is often produced by furrow irrigating under the limited water available for irrigation and onion crop is the most common irrigated horticultural crop in the district. Farmers growing onion crop in this area have not been practicing furrow management practices. Hence furrow management practice that can improve irrigation water productivity of small scale onion producing farmers is important in the area. This study investigated the effect of different furrow dimensions on irrigation water productivity and yield and yield components.

MATERIALS AND METHODS

Experimental site description

A field experiment was carried out in 2017/2018, at Jato Derke which is administratively located in Ilu Gelan district of West Shoa Zone in the Oromia Regional State (Figure 1). This site is considered a representative site for the midland irrigation schemes of West Shoa Zone of Oromia Regional State. It is located at 08°59'51''N latitude and 37°19'49''E with an altitude of 1812 m above sea level. The minimum and maximum monthly average temperatures are 13.8 and 28.1°C respectively. The average rainfall is around 1351 mm and this site has limited irrigation water that cover a large hectares of farmland in which onion is the

Table 1. Experimental treatment setup.

S/N	Treatment setting		Treatment statement	Code
	Furrow Dimension	Flow Rate		
1	23 cm TW,13 cm BW and 11 cm d	With Measured	Farmer practice (top width of 23 cm, bottom width of 13 cm and depth of 11 cm)	T1
2	45 cm TW, 20 cm BW and 12 d	With measured	Furrow with top width of 45 cm, bottom width of 20 cm and depth of 12 cm	T2
3	35 cm TW, 14 cm BW and 10 cm d	With measured	Furrow with top width of 35cm, bottom width of 14 cm and depth of 10 cm	T3

dominant crop grown in the command area followed by different horticultural crops.

Experimental design and management

The experiment was laid out in Randomized Complete Block Design (RCBD) with four replications. There were three levels of furrow dimensions with incoming flow rate measurement and this has a total of three treatments. The plot size was 8 m × 5 m and the distance between replication and plots were 2 and 1 m respectively. The plots in each replication were represented randomly for each treatment. The experimental field was fertilized UREA (46 Kg N ha^{-1}) and DAP (92 kg P_2O_5 ha^{-1}), (Melkasa Agricultural Research Center, 2000). The DAP was applied at basal but UREA was applied both during planting and three weeks after plating (1/3rd at basal and 2/3rd three weeks after planting). The experimental plot was ploughed three times before planting and managed carefully from weeds to minimize water and nutrient competition with crop. The variety of experimental crop was Bombay red onion variety and transplanted with spacing of 40 cm and 20 cm spacing between rows and plants, respectively (Table 1).

Furrow dimensions were made based on farmers dimensions. Most of the farmers in Ethiopia are make furrows using traditional ways of furrow making. In traditional furrow making furrows were made by local material pulled by oxen power. Furrow size made by this method is considered as farmers furrow dimension (top width of 23 cm, bottom width of 13 cm and depth of 11 cm). Other treatments were made based on the farmers furrow dimension that is, by taking above and below farmer's dimension. Furrows of T2 and T3 were closed end and the applied water was slowly infiltrated into the root zone. But un-designed or farmer practice was an open ended and the water was lost as surface runoff at the end of furrow length.

Crop water requirement and irrigation requirement

Crop water requirements (CWR) encompass the total amount of water used in evapotranspiration. Irrigation requirements (IR) refer to the water that must be supplied through the irrigation system to ensure that the crop receives its full crop water requirements. CROPWAT Version 8.0 is a computer program that can calculate CWR and IR based on climatic and crop data.

Irrigation performance Indicators

Water application efficiency

Water application efficiency is a measurement of how effective the irrigation system is in storing water in the crop root zone. It is expressed as the percentage of the total volume of water delivered to the field that is stored in the root zone to meet crop evapotranspiration (ET) needs.

$$Ea = Ws/Wf \times 100 \tag{1}$$

Where, Ea = water application efficiency, %
W_s = water stored in crop root zone, cm
W_f = water delivered at the head end of the furrows, cm.

Water distribution efficiency

Water distribution efficiency is defined as the percentage of difference from unity of the ratio between the average numerical deviations from the average depth stored during the irrigation. It was determined using the following formula:

$$Ed = (1- \overline{y}/\overline{d}) \times 100 \tag{2}$$

Where, Ed=Water distribution efficiency, %
d=Average depth of water stored in root zone along the furrow after irrigation, cm
y=Average numerical deviation from d, cm

Crop water productivity (CWP)

CWP is defined as the relationship between the amounts of crop produced or the economic value of the produce and the volume of water associated with crop production (Playa´n and Mateos, 2006). There are three dimensions of water productivity: physical productivity, expressed in kg per unit of water consumed; combined physical and economic productivity expressed in terms of net income returns from unit of water consumed, and economic productivity expressed in terms of net income returns from a given amount of water consumed against the opportunity cost of using the same amount of water (Kumar et al., 2005). The CWP considered in this study is physical productivity defined as: Mass of produce (kg) per volume of water supplied (m^3) expressed as in Equation 3 (Playa´n and Mateos, 2006):

$$CWP = \frac{Y}{WR} \tag{3}$$

Where, CWP = Crop water productivity, (kg/ m^3),
Y= Yield of the crop, (kg/ha)
WR= Water requirement of the crop, (m^3/ha).

Yield and yield components

Stand count

Plants that successfully established in the central rows were

Table 2. Chemical properties of soil at Ilu Gelan district.

Chemical properties	Value
1. Available phosphorus (ppm)	6.546
2. pH in H_2O	6.21
3. Total nitrogen (%)	0.240
4. Electrical conductivity (ms/cm)	0.035
5. Organic matter (%)	4.803
6. Exchangeable cations (meq/100 g soil)	
a. Ca	2.553
b. Mg	1.200
c. K	0.656
d. Na	0.261
e. CEC	35.283

counted at harvest and expressed as percentage.

Plant height (cm)

This was measured from the ground to the tip of the leaves from 10 randomly selected plants at maturity.

Marketable bulb yield (t ha^{-1})

This referred to the weight of healthy and marketable bulbs that range from 20 to 160 g in weight. Bulbs below 20 g in weight were considered too small to be marketed whereas those above 160 g were considered oversized according to Lemma and Aklilu (2003). This parameter was determined from the net plot at final harvest and expressed as t ha^{-1}.

Characterization of the soil of the study site

About 0-60 cm depth of disturbed (composite) and undisturbed soil samples were collected from different points by using soil auger and core sampler respectively for the analysis of physical and chemical properties. The composite sample (after being well mixed in a bucket) of about 2 kg of the mixed sub samples (composite sample) was properly bagged, labeled and transported to the laboratory for analysis of soil chemical properties. The soil pH was measured potentiometrically with a digital pH meter in the supernatant suspension of 1:2.5 soils to water ratio. The soil electrical conductivity measurement was done using a conductivity meter at 25°C using its standard procedures. Field capacity (FC) and permanent wilting Point (PWP) of sampled soil were determined using pressure plate apparatus at 1/3 and 15 bar, respectively. The soil texture was measured from samples collected at different depths using hydrometer method. The textural class of the soil profile was determined using USDA textural triangle.

Soil sample collected from the study site was analyzed for some chemical properties such contents of Nitrogen, Phosphorus, Organic matter, and soil pH and as well as exchangeable cations.

Data analysis

The collected data were arranged and organized for the suitability of statistical analysis and finally analysis of variance (ANOVA) was performed using statistix.8 software. Least significant difference (LSD) at 5% level significance was used to make mean separation among treatments.

RESULTS AND DISCUSSION

Physical and chemical soil parameters

Laboratory analysis of particle size distribution indicated that the soil is clay in textural class throughout the soil depth with an average particle size distribution of 34% sand, 21% silt and 45% clay whereas the average gravimetric moisture content at field capacity and permanent wilting point were 33.02 and 24.8%, respectively. The value of bulk densities (1.303 gcm^{-3}) were obtained by considering the average of the 0-40 cm depth. This value is in the recommended range for crop production. The average total available water was found to be 106.8 mm/m. The pH in H_2O under this study area is ranged in optimum value as suggested by Jones (2003) (Table 2). An electric conductivity of 0.035 ms/cm was recorded which is at lower limit of saline soils, hence the soil samples are non-saline soils (Table 2). Plants growing in this area do not have the problem of absorbing water because of the lower osmotic effect of dissolved salt contents.

The total nitrogen of study area as suggested by Tekalign (1991) rated as high percent which is suitable for plant growth (Table 2). Since the plant obtains phosphorus (P) from the soil solution through its roots or root symbiosis, available P is composed of solution P plus P that enters the solution during the period used to define availability. As per the rating suggested by Jones (2003) the available P of soil of experimental field of the studied area was qualified as low (Table 2). As per the ratings recommended by Hazelton and Murphy (2007), the CEC value of the agricultural land of the present study area is in high value range.

Table 3. Irrigation efficiencies and distribution efficiency of treatments.

Treatments	Application efficiency (%)	Water distribution efficiency (%)
T1	56.17[c]	81.00[b]
T2	75.87[a]	90.50[a]
T3	69.48[b]	89.00[a]
LSD 0.05	5.6817	8.3
CV%	12.89	10.31

Means with the same letter in a column are not significantly different.

The high CEC value recorded may be attributed to the fact that soils which recorded high CEC accumulate high percent OC and has greater capacity to hold cations thereby resulted in greater potential fertility in the soil (Table 2). The value of available Ca and Mg were below the optimum range whereas that of K was within the recommended optimum range as suggested by Takuya et al. (2013) (Table 2). The organic matter was rated as medium which is suitable for crop growth (Table 2).

Irrigation efficiencies and distribution efficiency

Table 3 shows the irrigation efficiency and distribution efficiency.

Irrigation efficiencies

Results of analysis of variance revealed significant difference for some of the characters among treatments. Significant variation in water application efficiency was observed between treatment two (T2) and other treatments at 5% level of significance. The lowest application efficiency (56.17%) was gained from treatment one (T1) and the highest application efficiency (75.87%) was recorded treatment two (T2). Highest water distribution efficiency (90.5%) was also recorded from treatment two (T2) as well as the lowest water distribution efficiency (81%) was from treatment one (T1) as showed in Table 3. The results indicated that water application efficiency and distribution uniformity were highly affected by dimensions of furrow and as well as flow rate. As furrow dimension are managed based on flow rate, water application efficiency and distribution uniformity can be increased. As indicated in Table 3, water application efficiencies showed significant differences among all treatments from which treatment T2 was highest (75.87%) and followed by treatment T3 which amounted 69.44%. But treatment T1 revealed lowest (56.17%) water application efficiency among others due to mismanagement of irrigation water. Significant differences in irrigation water distribution efficiencies were also observed between treatment T1 and the rest treatments at $p \leq 0.05$ which ranged from 81% (T1) to 90.5% (T2).

However, no significant variation recorded between treatments T2 and T3. There were significant differences among all treatments in water productivity.

Yield and yield components

Analysis of variance showed that, there were significant differences among the means of plant height and grain yield (Table 3). There were significant differences between treatments T2 and other two treatments in plant height. However no significant variation was recorded between treatments T1 and T3. Plant height ranged from 39.28 to 41.53 cm under T1 and T2 respectively. Significant difference was obtained among all means of treatments under grain yield. The highest grain yield (19520 kg/ha) was gained from T2 when compared with the lowest (15088 kg/ha) observed in T1. This was due to blockage of designed furrow at the end of its length and the required crop water requirement was satisfied. In the end blocked furrow, the water only infiltrates to the crop root zone and runoff is reduced. This increases appropriate utilization of delivered irrigation water such as irrigation efficiencies, water productivity and crop yield. About 13000 to 16000 kg/ha has been produced under local farmers' experience. Similarly, previous research findings reported by Guesh (2015) found a closer result for the same crop. There were no significant differences in percentage of stand count of onion among all treatments as shown in Table 4.

Water productivity

As statistical analysis showed, there were significant differences in productivity among all treatments. As indicated in Table 4 the highest water productivity (5.20 kg/m^3) was resulted from treatment two (T2) and the lowest (3.11 kg/m^3) was obtained from treatment one (T1). Similar result was found by (Kang et al., 2000) on water productivity of furrow irrigation system.

CONCLUSION AND RECOMMENDATIONS

As the study showed, treatment two (T2) revealed

Table 4. Growth parameters, yield and water productivity of onion.

Treatments	Stand count (%)	Plant height (cm)	Grain yield (kg/ha)	Water productivity (kg/m³)
T1	97.713[a]	39.275[b]	15088[c]	3.11[c]
T2	97.278[a]	41.525[a]	19520[a]	5.20[a]
T3	97.282[a]	39.800[b]	18009[b]	4.36[b]
LSD 0.05	Ns	1.4898	1224.6	0.6126
CV%	1.35	7.14	14.04	8.38

Means with the same letter in a column are not significantly different.

superiority in water application efficiency over other treatments. The highest water distribution efficiencies also recorded in treatment two (T2) as compared to the rest treatments. Moreover treatment two (T2) indicated better advantage in water productivity over other treatments. Yield and growth related parameters of farmer practice were found to be the lowest as compared to treatment two (T2) and treatment three (T3). Generally treatment two (T2); Furrow with top width of 45 cm, bottom width of 20 cm and depth of 12 cm indicated better performance in both efficiencies and water productivity as well as yield and growth related parameters. Hence this dimension is recommended for furrow irrigation applied on clay soil texture like in that of the study area.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Dupriez H, De Leener (2002). Land Use and Life: Ways of Water, Run Off, Irrigation and Drainage; Tropical Handbook. CTA and TERRES ET VTE, Netherlands, ISBN: 2-87105-011-2.
Guesh T (2015). Growth and bulb yield of onion in response to plant density. Ethiopian Journal of Science and Technology 11(2).
Hazelton P, Murphy B (2007). Interpreting soil test results: What do all the numbers mean? 2nd Edition. CSIRO Publishing, P. 152.
Jones JB (2003). Agronomic Handbook: Management of crops, soils, and their fertility. CRC Press LLC, Boca Raton, Florida, USA. 482p.
Kang S, Liang Z, Pan Y, Shi P, Zhang J (2000). Alternate furrow irrigation for maize production in an arid area. Agricultural Water Management 45(3):267-274.
Kumar A, Reddy AVR, Nair AGC, Amar AG (2005). Availability of essential elements in Indian and US tea brands. Food Chemistry 89(3):441-448.
Lemma D, Aklilu S (2003). Research Experiences in Onion production. Research Report No. 55. Ethiopia Agricultural Research Organization, Addis Ababa, Ethiopia.
Masoud R, Ghodratolah S (2010). Water use efficiency of corn as affected by every other furrow irrigation and planting. World Applied Science Journal 11(7):826-829.
Melkasa Agricultural Research Center (2000). Progress Report for 1999, EARO, Ethiopia.
Playa´n E, Mateos L (2006). Modernization and optimization of irrigation systems to increase water productivity. Agricultural Water Management 80(1-3):100-116.
Shuhuai J, Xiaoli G, Jibao L, Pengke W, Jinfeng G, Yang Q, Baili F (2012). Effect of different furrow and mulched ridge on water moisture conversation and water saving of spring mung bean planted farmland. Journal of Agricultural Science 4(7):132.
Takuya M, Osman C, Tsugiyuki M (2013). Characterization of soil properties in relation to maize productivity in Andosols of the western highland of Guatemala. Soil Science and Plant Nutrition 59(2):195-207. DOI:10.1080/00380768.2012.760430.
Tekalign T (1991). Soil, plant, water, fertilizer, animal manure and compost analysis. Working Document No. 13. International Livestock Research Center for Africa, Addis Ababa.
Walker WR (2003). SIRMOD III Surface Irrigation Simulation, Evaluation and Design, Guide and Technical Documentation, Utah State University.