Research Article
Volume 10:2, 2021

Irrigation and Drainage Systems Engineering

ISSN: 2168-9768

Open Access

Effect of furrow dimensions on yield and water productivity of maize in Sibu Sire district, Eastern Wollega, Ethiopia

Habtamu Bedane*, AdisuTadese, Gudeta Genemo, Eshetu Mekonnen

Oromia Agricultural Research Institute, Bako Agricultural Engineering Research Center, Ethiopia

Abstract

A field experiment was conducted during the dry season of 2017/2018 at the Sibu Sire district East Wollega zone of Oromia Regional State to evaluate the impact of furrow dimensions on yield and water productivity of maize. Climatic, plant and soil factors were used for the calculation of monthly crop water and irrigation requirements and results compared with actual performance of the irrigation system. The experiment was laid out in a randomized complete block design with three treatments replicated four times. The experimental treatments including Farmer practice or Furrow with top width of 21 cm, bottom width of oi; 13 cm and depth of 10 cm without determined flow rate (T1), Furrow with top width of 25 cm, bottom width of 14 cm and depth of 15 cm with determined flow rate (T2) and Furrow with top width of 18 cm, bottom width of 8cm and depth of 12 cm with determined flow rate (T3) having a plot size of 6m x 8m with spacing of 0.5m and 1m between plots and replications respectively.

The application efficiency in the treatment T2 was distinctly much higher (78.791%) in comparison to other treatments. The lowest (58.149%) application efficiency was found in T1 i.e. farmer practice. Distribution efficiency and water productivity were also highest (89.5% and 1.50 kg/m^3) in treatment T2 and lowest (81.75% and 1.23 kg/m^3) in treatment T1 respectively. The best treatment towards the yield of maize was T2 which produced mean yield of 7964.4 kg/ha while treatment T1 produced the least yield of 5629.8 kg/ha. Some maize growth related parameters were also investigated. There were significant differences in maize cob diameter, cob length, number of cob per plants between some treatments while no significant differences occurred in plant height among all treatments at significance level of 5%. Treatment T1 and T2 were significantly different whereas T2 and T3 were not significantly different. It is recommended that further research covering all soil types should be conducted.

Keywords: Furrow irrigation • Furrow dimension • Grain yield • Irrigation efficiency • Maize • Water productivity

Introduction

Irrigation plays an important role in food production, self-sufficiency and security but potential increase in irrigation water and land resource are limited. Despite the higher risks in rain fed agriculture, it is widely accepted that the bulk of the world's food will continue to come from rain fed systems [1]. Therefore accelerated and sustainable development in agriculture sector needs transformation of rain fed agriculture to be irrigated agriculture. Furrow irrigation is one of the extensively used means of irrigating crops in many developing countries. It is especially recommended for growing row crops on medium to heavy textured soils and is preferred over other surface irrigation methods due to its simplicity and low capital cost [2]. This method of irrigation as compared with sprinkler or trickle methods is inexpensive. Therefore, more attention is being paid to improve the efficiency of this method of irrigation. Irrigation water managements like how much to be irrigate, how often to irrigate and when to irrigate has vital impact on the sustainability of water resources, soil and crop production. If not appropriately managed, it will be resulted in complete or partial loss to their production, soil loss and irrigation water loss. Over irrigating will result not only in water loss but also production loss, and under irrigation result in yield loss.

In the study area, the existing furrow dimensions have been made on the trial and error basis. The incoming flow rate in to the field has been used for irrigation without measurement and furrow dimension design. The use of high flow rate overflows the furrow section and takes off the soil resources as surface runoff which in turn reduces the nutrient of the soil. This phenomenon is occurred if the furrow dimensions do not coincide with 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 [3]. 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 capable 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 maize due to the proper furrow dimensions.

Maize crop is widely produced in the study area under furrow irrigation system. However the farmers have no idea about the design of furrow which can affect the application efficiency, distribution uniformity and yield of the crop. The yield of crop is decreasing from year to year as a result of poor preparation of furrow dimensions. In addition to this, large amount of irrigation water has been lost in form of surface runoff and deep percolation which in turn deceases the productivity of irrigation water. Therefore, it is mandatory work to specify appropriate furrow dimensions which is suitable based on predetermined soil type. Hence, the main objective of this study was to investigate the effect of different furrow dimensions on yield and water productivity of maize.

Maize (Zea mays) is one of the most important cereals broadly adapted worldwide. In Ethiopia, maize grows from moisture stress areas to high rainfall areas and from lowlands to the highlands. In Ethiopia maize is produced for food, especially in major maize producing regions mainly for low-income groups. The total annual production and productivity of maize in Ethiopia exceeds all other cereals (23.24% of 13.7 Million tons), and second after tef (Eragrostis tef) in area coverage (16.12% of the 8.7 Million ha). It

***Address for Correspondence:** Habtamu Bedane, Oromia Agricultural Research Institute, Bako Agricultural Engineering Research Center, Ethiopia, E-mail: habtamubedane503@gmail.com*

Received 24 October 2020; **Accepted** 18 February 2021; **Published** 25 February 2021

is an important field crop in terms of area coverage, production and utilization for food and feed purposes.

Generally, the main objective of this study was to investigate the effect of different furrow dimensions on yield and water productivity of maize.

Materials and Methods

Experimental site description

The study was conducted in Sibu Sire district, East Wollega Zone of Oromia Regional State, Western Ethiopia, from 2017-2018. It is one of the districts in east Wollega Zone and is located 281Km in West from Addis Ababa and 50km East from Nekemte, the administration town of East Wollega Zone.

This district is bordered in the East by Gobu Seyo, in the West by Wayu Tuka, in South by Wama Hagalo and Billo Boshe and on the North by Gudeya Bila and Guto Gida. It lies between 8°56'- 9°23'N latitudes and 36°35'- 36°56' E longitudes. The altitude of the district ranges between 1360masl to 2500masl. There are three agro-ecological zones represented in this district. The majority (74.3%) of the district is classified as mid-land with lowland (18.27%) and only 7.53% is considered as highland.

The minimum, maximum and mean temperature of this area was 14.09^{o}c, 27.30^{o}c, and 22.55^{o}c respectively. The highest temperature occurs in February and March. The lowest temperature occurs in July and august. The annual average rainfall of the district is 1295mm (Figure 1).

Design of experiment and treatments

The experiment was laid out in Randomized Complete Block Design (RCBD) with four replications consisting of three treatments. The treatments were composed of:

T1 or Farmer practice (Furrow with top width of 21 cm, bottom width of 13 cm and depth of 10 cm without determined flow rate).

T2 (Furrow with top width of 25 cm, bottom width of 14 cm and depth of 15 cm with determined flow rate).

T3 (Furrow with top width of 18 cm, bottom width of 8 cm and depth of 12 cm with determined flow rate) having a plot size of 6mx8m (48m^2) with spacing of 0.5m and 1m between plots and replications respectively.

Both treatments of designed furrows (T2 and T3) were closed at the end and the applied water was slowly infiltrated into the root zone.

However the furrows of farmer practice (T1) was opened at the end of furrow length and the water was lost as surface runoff.

Maize crop of Limmu variety was planted with spacing of 75cm x 30cm between rows and plants respectively (Figure 2).

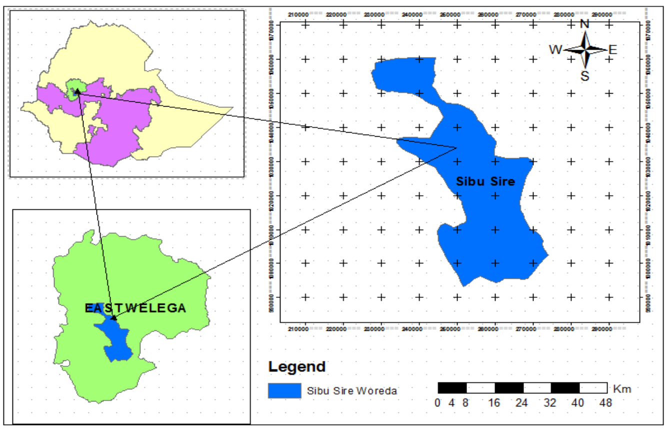

Figure 1. Map of study area.

Figure 2. Sibu Sire experimental site.

Determination of crop water requirements

Crop water requirements (CWR) refer to the amount of water required to compensate the evapotranspiration losses from a cropped field during a specified period of time. It is the product of crop factor and reference evapotranspiration. Reference evapotranspiration is calculated by cropwat 8.0 software from climate data.

ETc = ETo x Kc,

Where, ETc: crop evaporation or crop water need (mm/day), Kc: Crop factor, ETo: Reference evapotranspiration (mm/day).

Irrigation requirement

Irrigation water requirements can be defined as the quantity, or depth, of irrigation water in addition to precipitation required to produce the desired crop yield and quality and to maintain an acceptable salt balance in the root zone. It can be calculated by the following equation.

$IR_n = (\theta_{fc} - \theta_{pwp}) \times p \times D_b \times Z_r \times 1/10$

Where, θ_{fc} = field capacity (mm/m)

θ_{pwp} = permanent wilting point (mm/m)

p= depletion fraction (%)

Zr= root depth of crop (m)

D_b= bulk density (g/cm^3)

Irrigation performance parameters

Water application efficiency

Water application efficiency is a measurement of how effective the irrigation system is in storing water in the crop root zone.

Application efficiency can be defined as the ratio of the volume of water stored in the subject region to the volume of water diverted into the subject region.

$$Ea = Ws/Wf \times 100 \quad (1)$$

Where, Ea = water application efficiency, %

W_f = 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:

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

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)

Crop water productivity (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. 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 [4]. The CWP considered in this study is physical productivity defined as:

$$CWP = \frac{Y}{WR} \quad (3)$$

Where, CWP = Crop water productivity, (kg/ m^3),

Y= Yield of the crop, (kg/ha)

WR= Water requirement of the crop, (m^3/ha).

Laboratory analysis of soil samples

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^{o}c using its standard procedures.

Soil available P was extracted by the Bray-II method [5] and quantified using spectrophotometer (Wave length of 880ηm) colorimetrically using vanadomolybedate acid as an indicator. Exchangeable basic (Ca, Mg, K and Na) ions were extracted using 1 M ammonium acetate (NH_4OAc) solution at pH 7. The extracts of Ca and Mg ions were determined using atomic absorption spectrophotometry (AAS) while K and Na were determined by flame photometer. To determine the cation exchange capacity (CEC), the soil samples were first leached with 1 M NH_4OAc, washed with ethanol and the adsorbed ammonium was replaced by Na.

The CEC was then measured titrimetrically by distillation of ammonia that was displaced by Na following the micro-Kjeldahl procedure. 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 samples for field capacity and bulk density were taken from pits 0.6 m deep dug at the center of each experimental block. The samples were taken using core samplers of known volume (98.2 cm^3) from depths 0-20 cm, 20-40 cm and 40-60cm. The samples were then sealed in containers to avoid moisture loss before being sent to the laboratory for analysis. Field capacity was determined as the moisture content at pF 2.4 (0.3 bar) using pressure plate apparatus.

Soil samples for field capacity determination were also used to determine the permanent wilting point of the soil. Measurements of permanent wilting point were made from disturbed soil samples on a pressure plate apparatus in the laboratory. Wilting point was determined as the moisture content at pF 4.2 (15 bar).

The core soil samples were dried in oven dry apparatus at 105 °C for 24 hours and the bulk density was calculated using equation:

$$Pb = \frac{Ms}{Vc} \quad (8)$$

Where,

ρb = soil bulk density (g/cm^3),

Ms = weight of dried soil (g), and

Vc = volume of core sampler (cm^3)

Data management and analysis

All relevant data were recorded periodically and stored and managed in Microsoft excel .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. Lest significant difference (LSD) at 5% level significance was used to make mean separation.

Results and Discussion

Soil chemical properties

Many soil chemical and biological reactions are controlled by the pH of the soil solution in equilibrium with the soil particle surfaces. In the present study, results of standard measurement of soil pH using H_2O, $CaCl_2$ and KCl are presented in (Table 1). The pH in H_2O under this study area is ranged in optimum value which is slightly acidic as recommended by Jones. An electric conductivity of 0.035 ms/cm lies in the range which is <3 ms/cm, hence the soil samples are non- saline soils. 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 rated as high percent which is suitable for plant growth. Since the plant obtains phosphorus (P) from the soil solution through its roots or root symbionts, 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, the available P of soil of experimental field of the studied area was classified as low value. As per the ratings recommended by Hazelton and Murphy, the CEC value of the agricultural land of the present study area was within the range. Normally it is satisfactory for agriculture if realizers are used. The value of exchangeable Ca was low and Mg was medium whereas that of K was high as suggested by T. Matsumoto et al. (2013). The organic matter of this study area was found to be mediu which is suitable for crop growth (Table 1).

Soil physical properties

As depicted from laboratory analysis, particle size distribution indicated that the soil is sandy clay loam in textural class throughout the soil depth with an average particle size distribution of 29.3.6% sand, 23% silt and 47.7% clay whereas the average gravimetric moisture content at field capacity and permanent wilting point were 32.6 and 24.1%, respectively.

The value of bulk densities (1.3 gcm^{-3}) were obtained by considering the

Table 1. Chemical composition of the soil at Sibu Sire experimental field.

Chemical properties	Value
1. Available phosphorus (ppm)	10.666
2. pH in H_2O	6.17
3. Total nitrogen (%)	0.257
4. electrical conductivity (ms/cm)	0.066
5. Organic matter (%)	5.136
6. Exchangeable cations (meq/100 g soil)	
a. Ca	2.138
b. Mg	2.138
c. K	0.736
d. Na	0.325
e. CEC	30.290

Table 2.

Treatments	Application efficiency (%)	Distribution efficiency (%)	Water productivity (kg/m^3)
T1	58.15b	81.75b	1.23b
T2	78.79a	89.50a	1.50a
T3	73.27a	85.25ab	1.32b
LSD 0.05	5.10	3.01	0.10
CV%	8.87	12.84	9.68

average of the 0 - 60 cm depth. Since the value of bulk density has to be <1.6, this value has no problem with the crop growth. Moreover, the average available water under this depth was found to be 109.1mm.

Irrigation efficiencies and water productivity

Various irrigation efficiencies are the important and real indicators of the hydraulic performance of an irrigation system. Water application efficiencies, Water distribution efficiencies, and water productivity were calculated for each treatment.

Statistical analysis revealed that there were significant differences among some treatments as shown in Table 3 below.

Significant differences in water application efficiencies were observed between T1 and the rest two treatments at $p \le 0.05$. However, there were no significant variations between T2 and T3 statistically, but there was difference between them numerically. The highest (78.79%) application efficiency was resulted from T2 while the lowest (58.149) was recorded under treatment T1. In coincidence with this result, Manisha et al. (2016) reported that furrow irrigation application efficiencies range was found to be 65.26%-81.96%.

There were significant differences among some treatments in water distribution efficiency. Treatment T1 was significantly different from treatment T2 and not significantly different from T3. Significantly lowest (81.75%) water distribution efficiency was recorded from T1 while the highest (89.5%) was obtained under T2. Similarly Manisha et al. (2016) also reported the closest result in water distribution efficiency.

Significant differences were obtained between T2 and other treatments in water productivity. The highest (1.50 kg/m^3) in water productivity was resulted from T2 while the lowest (1.23 kg/m^3) was obtained under T1. These all variations between treatment T2 and the rest two treatments are due to the all furrows of treatment T2 and T3 were closed at the end of their length and no water was lost by run off. Even if treatment T1 had no significant statistical difference with T3, it revealed numerical variation with it. Hence treatment T2 showed better efficiencies and productivity advantage than the rests of treatments [6] (Table 2).

Yield and growth related parameters of maize

As statistical analysis depicted in Table 4, there were significant differences in maize cob diameter, cob length, number of cob per plants and maize grain yield between some treatments while no significant differences occurred in percentage of stand count and plant height among all treatments at significance level of 5%.There were significant differences in cob diameter between treatments T1 and T2. The highest (5.1 cm) cob diameter was recorded in treatment T2 and the lowest (4.875 cm) was obtained from T1. Similarly, Sharifai et al. (2012) reported cob diameter range of 5-6 cm. Significant differences were recorded between treatments T1 (farmer practice) and T2 (designed furrow), however there was no variation between treatments T2 and T3 in cob length. An average of 24.64cm and 21.42 cm cob length were resulted from treatments T2 and T1 respectively. Grain yield of T2 also revealed better advantage as compared to T1 statistically and T3 numerically. It also amounted 7964.4 kg/ha and 5629.8 kg/ha for T2 and T1 respectively. In line with results of this study, Legesu (2017) reported that yield of limmu variety maize was 8271 kg/ha which is closer to each other. Also from the local experience, the yield of limmu variety in this study area was 3000 kg/ha-6500 kg/ha, hence T2 revealed better yield advantage than the local practice. This was due to the designed furrow was blocked at the end and the delivered water was infiltrated directly to crop root zone (Table 3).

Conclusions and Recommendation

As the study showed, T2 (Furrow with top width of 25cm, bottom width of 14cm and depth of 15cm with determined flow rate) revealed superiority in water application efficiency, water distribution efficiency and water productivity over other treatments, whereas T1 (Furrow with top width of 21cm, bottom width of 13cm and depth of 10cm without determined flow rate) showed lowest results as compared to others. Moreover T2 indicated better advantage in water productivity over other treatments. Yield and growth related parameters of T1 (farmer practice) were found to be the lowest as compared to T2 and T3 (Furrow with top width of 18cm, bottom width of 8cm and depth of 12cm with determined flow rate) and lowest in T2. Generally T2 indicated better performance in both efficiencies and water productivity as well as yield and growth related parameters. Hence T2 is recommended for better irrigation efficiencies, water productivity and maize yields. It is recommended that further research covering all soil types should be conducted.

References

1. Awulachew, Yilma, Loulseged, Lois kandl, Ayana,and Alamirew. "Water resources and irrigation development in Ethiopia" *IWMI Working Paper 123. Colombo, Sri Lanka: International Water Management Institute* (2007).
2. Christian, Angelika, Christoph, Frank and Albrecht. "Genomic and metabolic prediction of complex heterotic traits in hybrid maize" *Nat. Genet* (2012)44:217–220.
3. Crevoisier, Popova, Ruelle. "Assessment of simulation of water and nitrogen transfer under furrow irrigation" *Agricultural water management* (2008)95:354-366.
4. Hazelton, Murphy. "Interpreting soil test results: What do all the numbers mean 2nd Edition" *CSIRO Publishing* (2007)152.
5. Jones. "Agronomic Handbook: Management of crops, soils, and their fertility" *CRC Press LLC, Boca Raton, Florida, USA* (2003) 482.
6. Legesu. "Evaluation of adaptability and yield performance of maize varieties at Bure district of Ilu Ababor zone" *south western Ethiopia* (2017).

How to cite this article: Habtamu Bedane*, AdisuTadese , Gudeta Genemo, Eshetu Mekonnen. Effect of furrow dimensions on yield and water productivity of maize in Sibu Sire district, Eastern Wollega, Ethiopia. *Irrigat Drainage Sys Eng* 10 (2021): 254.