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Evaluation of Furrow Irrigation System on Head Cabbage Yield and Water Use Efficiency in Arbegona Woreda, Ethiopia

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Abstract
Available fresh water resources are subjected to an ever-increasing pressure due to extensive agricultural water demand for irrigated lands. A long-term perspective in shortage of fresh water resources, especially in arid and semi-arid area, highlights an urgent solution for innovative irrigation strategies and agricultural water management. The experiment was conducted in Arbegona district, Sidama region of Ethiopia. This experiment was conducted to evaluate and demonstrate of Alternative, Fixed and Conventional furrow irrigations on Head Cabbage yield and water use efficiency. To achieve this objective the treatment were three furrow irrigation method (Conventional, Alternate and Fixed furrow) laid out in a random complete block design (RCBD) with three replications. The result shows that there is no significant difference between alternative and conventional furrow irrigation on Head cabbage yield. But, fixed furrow irrigation system reduces the yield significantly. The maximum yield (48407kg/ha and 43840kg/ha) was obtained from conventional and alternate furrow irrigation method, respectively. The minimum yield (35242kg/ha) was obtained under fixed furrow irrigation. Furrow irrigation method has no significant effect on plant height, head weight and head diameter of head cabbage. The highest water use efficiency was obtained from alternate furrow irrigation and shows significant difference between the other treatments. Therefore, to save water, labour and time without significant yield reduction alternate furrow irrigation is recommended in water scarce area of Ethiopia.

Keywords: Alternate, Head Cabbage, Fixed Furrow Irrigation Water Use Efficiency

1. Introduction

Cabbage is the second most important vegetable crop in Ethiopia in area coverage as well as level of production next to red pepper [1]. Vegetable production is becoming an increasingly important activity in the agricultural sector of the country mainly due to increased emphasis of the government on the commercialization of smallholder farmers [2].

Water scarcity and drought are the major factors constraining agricultural crop production in arid and semiarid area of the world. Consequently, improvements in management of agricultural water continue to be called for to conserve water, energy and soil while satisfying society's increasing demand for crops for food and fiber [3].

According to Canone et al. (2015) and Ronaldo et al. (2015) Furrow irrigation is often characterized by low irrigation efficiency [4, 5]. Nevertheless less water is usually applied in alternating and fixed furrow irrigation as compared to conventional furrow irrigation. Moreover alternate and fixed; furrow irrigation (AFI and FFI) greatly reduce the amount of surface wetted, leading to less evapotranspiration and less deep-percolation. Enhancing water use efficiency, both under rain-fed and irrigated agriculture is a high priority for agricultural improvement in developing countries. It is reported that AFI technique can save irrigation water by 25 to 35% compared to TFI with the increase or decrease in crop yield to the extent of 2 to 16% [6].

Alternate furrow irrigation (AFI) is considered to be one of the most effective tools to minimize water application and irrigation costs and produce a higher crop yield. The AFI method is a way to save irrigation water, improve irrigation efficiency, and increase corn yield [7, 8]. The effective use of irrigation water has become a key component in the production of high-quality vegetable crops in arid and semi-arid areas [9].

Alternate-row furrow irrigation (skipped furrow irrigation), which has a higher water use efficiency is one of the effective methods to minimize wastage of irrigation water [10]. Therefore, by considering the scarcity of irrigation water in the country and the high profitability per unit area and sensitivity of Head cabbage crop to moisture stress, this research aims to evaluate and appropriate irrigation method on Head cabbage yield and water use efficiency.

2. Materials and Methods

2.1 Description of the Study Area

This study was carried out in Arbegona district Sidama region of Ethiopia. The woreda (Arbegona) is located 360 km south of Addis Abeba and 50 km from south of Hawassa town and geographically lies between 6°35'18" to 6°56'37"N and 38°35'60" to 38°53'36"E with elevation of 2,521 m.a.s.l.

2.2 Experimental Design and Treatment

The experiment was laid out in randomized complete bock design with three treatments and three replications. The treatments were alternate furrow irrigation (AFI), fixed furrow irrigation (FFI) and conventional furrow irrigation (CFI). The size of each plot was 4 m by 5 m and space between the plots 1m, the block 1.5m and the recommended space between the plant and the row (40 cm and 50 cm) respectively.

2.3 Climate Data

The average climatic data (Maximum and minimum temperature, relative humidity, wind speed, and sun shine hours) of the study area were obtained from meteorological station. The potential evapotranspiration (ETO) was estimated using CROPWAT software version 8.

Month	Min Temp (°C)	Max Temp (°C)	Humidity (%)	Wind (km/day)	Sun (hrs)	Rad (MJ/m?/day)	ETo (mm/day)
January	7.6	20	75	104	8.2	20.2	3.33
February	8.1	18.2	70	104	8	21	3.48
March	8.3	18.2	76	130	7.4	20.9	3.48
April	8.8	18	86	104	7.5	21	3.38
May	8.8	17.5	88	104	7.2	19.9	3.18
June	7.8	15.8	91	138	6.4	18.2	2.75
July	7.6	14.8	89	104	4.6	15.8	2.48
August	6.5	15	88	104	5.3	17.3	2.65
September	7.5	15.8	92	69	6.2	18.9	2.9
October	7.8	16.5	81	69	7.1	19.7	3.1
November	7.5	16.7	80	86	8.6	20.9	3.16
December	6.9	17.7	68	95	8.2	19.7	3.12

Table 1: Average climatic data of the experimental area

2.4 Crop Data

Maximum effective root zone depth (RZD) of Head cabbage ranges between 0.4 - 0.5m, total growing period 100 – 150 days, seasonal crop water requirement 350 – 500 mm and has allowable soil water depletion fraction (P) of 0.45. Head cabbage average Kc would be taken after adjustments have been made for initial, development, mid and late season stage to be 0.5, 0.8, 1.1 and 1.0, respectively.

2.5 Soil Data

Soil physical and chemical properties like textural class, bulk density, field capacity, permanent wilting point and infiltration rate, acidity, electric conductivity of the soil was measured in the field and laboratory. The soil was analyzed in laboratory, gravimetric method; pH meter method, soil and water ratio method were used to determine soil moisture content, pH value and electrical conductivity respectively.

2.6 Crop Water Determination

Crop water requirement refers to the amount of water that needs to be supplied, while crop evapotranspiration refers to the amount of water that is lost through evapotranspiration (Allen et al., 1998). For the determination of crop water requirement, the effect of climate on crop water requirement, which is the reference crop evapotranspiration (ETO) and the effect of crop characteristics (Kc) are important. The long term and daily climate data of the study area were collected to determine reference evapotranspiration. Crop data like crop coefficient, growing season and development stage, effective root depth, critical depletion factor of Head cabbage and maximum infiltration rate and total available water of the soil was determined to calculate crop water requirement using CropWat model.

$$ETc = ETo \times Kc$$

Where; - ETc= crop evapotranspiration, Kc = crop coefficient, ETo = reference evapotranspiration.

2.7 Irrigation Water Management

The total available water (TAW), stored in a unit volume of soil was determined by the expression.

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

For maximum crop production, the irrigation schedule should be fixed based on readily available soil water (RAW). The RAW could be computed from the expression:

$$RAW = (TAW * p)$$

Where; - RAW in mm, p is in fraction for allowable/permissible soil moisture depletion for no stress and TAW is total available water in mm.

The depth of irrigation supplied at any time can be obtained from the equation

$$Inet(mm)=(ETc_{mm}-Peff_{mm})$$

The gross irrigation requirement was obtained from the expression:

$$GI = \frac{NI}{Ea}$$

Ea= application efficiency of the furrows (60%)

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

$$t = \frac{(l*w*dg)}{6Q}$$

Where: dg = gross depth of water applied (cm), t = application time (min), l = furrow length in (m), w = furrow spacing in (m), and Q= flow rate (discharge) (l/s)

2.8 Data Collection

Climate data was collected to calculate crop water requirement. To determine physical and chemical properties of soil, samples were collected gravimetrically. Amount of applied water per each irrigation event was measured using calibrated parshall flume. During harvesting plant height, head weight, head diameter, marketable yield and unmarketable yield were measured from the net harvested area of each plot.

2.9 Statistical Analysis

Data were analyzed using SAS 9.0 statistical software at probability of 5% confidence level. The factor of the experiment was considered as single factorial Randomized Complete Block Design (RCBD) during the analysis.

3. Result and Discussion

3.1 Physical and Chemical Properties of Soil

According to the USDA soil textural classification, the average results of soil textural class of experimental site were sandy loam. The top soil surface had slightly lower bulk density (1.2g/cm3) than the subsurface (1.32g/cm3). Bulk density typically increase with increasing soil depth since subsurface layers are more compacted and have less organic matter, less aggregation, and less root penetration as compared to surface layer, therefore contain less pore space. The bulk density shows slight increase with depth. This is because of slight decrease of organic matter with depth and compaction due to the weight of the overlying soil layer (Brady and Weil, 2002). In general, the average soil bulk density of study site (1.26 g/cm3) is below the critical threshold level (1.4 g/cm3) and was suitable for crop root growth. The acidity (pH) of the study site soil is 5.73, thus the United States Department of Agricultural National Resources Conservation Service groups soil pH values 5 – 6.0 range is very slightly acid.

	Soil depth in (cm)		
Soil property	0-20	20-40	40-60
Textural class	Sandy loam	Sandy loam	Sandy loam
Bulk density (g/cm3)	1.2	1.26	1.32
FC (Vol %)	13.8	14	16
PWP (Vol %)	6.2	6	8
TAW (mm/m)	87.4	100.8	105.6
pH	5.68	5.73	5.79
infiltration rate = 12mm/hr			

Table 2: Soil Result of the Study Site

3.2 Head cabbage response to furrow irrigation method

The table indicated that the maximum yield (48407kg/ha and 43840kg/ha) was obtained from conventional and alternate furrow irrigation method, respectively. The minimum yield (35242kg/ha) was obtained under fixed furrow irrigation. Furrow irrigation method has no significant effect on plant height, head weight and head diameter of head cabbage. The highest water use efficiency was obtained from alternate furrow irrigation and shows significant difference between the other treatments.

Treatments	PH	HW	HD	CWUI	IWUI	MY	UMY	TY
Alternate furrow irrigation	15.7	1.5	35.8	17.1a	22.5a	43691.7a	148.3	43840a
Fixed furrow irrigation	16.1	1.2	29.3	13.8b	18.1b	35100b	142.3	35242b
Conventional furrow irrigation	17.6	1.8	38.2	9.5c	12.4c	48275a	132.5	48407a
Cv (%)	13.9	40.7	33.7	8.5	8.4	9.0	17	8.9
Lsd (0.05)	NS	NS	NS	1.42	1.86	4761.2	NS	4768.4

PH = plant height, HW= head weight, HD = head diameter, CWUI = crop water use efficiency, MY = marketable yield, UMY = unmarketable yield, TY = total yield

Table 3: Effect of Furrow Method on Head Cabbage Yield, Yield Component and Water Use Efficiency

4. Conclusion and recommendation

Alternative furrow irrigation improve water use efficiency and save 50% of irrigation water relative to conventional furrow irrigation without causing a significant effect on Head cabbage yield. There is no statistical difference on treatments alternate and conventional furrow irrigation method on Yield of Head cabbage. The plant height, head weight and head diameter of head cabbage not affected by furrow method. Compared to conventional furrow irrigation alternate and fixed furrow irrigation systems save 50% irrigation water and labor. Therefore, in water scarce area alternate furrow irrigation is recommended to obtain maximum water use efficiency and to save water, time and labor without significant yield reduction.

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