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Participatory Evaluation of Alternative, Fixed and Conventional Furrow Irrigation on Head Cabbage Yield and Water Use Efficiency at Gibe Woreda

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Abstract: The experiment was conducted at Lintalicho irrigation scheme, Gibe Woreda of Centeral Ethiopia Region. This study evaluated the impact of three irrigation methods. The treatments were Alternate Furrow Irrigation (AFI), Fixed Furrow Irrigation (FFI), and Conventional Furrow Irrigation (CFI) on the growth performance and yield of head cabbage. To achieve this objective the treatment were three furrow irrigation techniques (conventional, alternate and fixed furrow) laid out in a random complete block design (RCBD) with five replications. Data were collected and analyzed using SAS software in probability of 5% confidence level. Parameters such as plant height (PH), head length (HL), head diameter (HD), marketable yield (MY), unmarketable yield (UMY), total yield (TY), and water use efficiency (WUE) were assessed. CFI produced the highest plant height (25.65 cm), head diameter (6.96 cm), and total yield (19.18 t/ha), while AFI demonstrated superior water use efficiency (9.675 kg/m³). Significant differences were observed in PH, HD, and WUE. The results suggest that while CFI maximizes biomass and yield, AFI provides an efficient option for water-limited conditions without substantial yield loss, offering a practical balance for sustainable head cabbage production.

Keywords: Water use Efficiency, Head cabbage, Alternative, Fixed, Conventional.

Research Paper

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INTRODUCTION

Head Cabbage (Brassica oleracea L. var. capitata) belongs to the family cruciferae and it is a biennial crop with a very short stem supporting a mass of overlapping leaves from a compact head. It originated from wild non-headed type 'colewart' (crambecordifolias) from Western Europe and northern shore of Mediterranean (Semuli, 2005). Water is the major limiting factor for crop diversification and production. More than 80% of water resources have been exploited for agricultural irrigation (Sitta, 2011). Different techniques of saving agricultural water use have been investigated globally. Various researchers (Hodges *et al*., 1989; Graterol *et al*., 1993; Stone and Nofziger, 1993) have used wide spaced furrow irrigation or skipped crop rows as a means of improving WUE. Kang *et al*., (2000) evaluated the alternate furrow irrigation (AFI), fixed furrow irrigation (FFI) and conventional furrow irrigation (CFI) with different irrigation amounts for maize production. They reported that yield reduction in AFI was not significant unlike FFI. Traditional irrigation is very old in Ethiopia (Awulachew *et al*., 2007). As reported by Graterol *et al*., (1993), the great evapotranspiration and deep percolation in the CFI system did not increase yields. This may be so because a greater portion of the evapotranspiration and deep percolation (Dp) could be due to non-productive water losses arising from evaporation from the higher amount of wet soil surface or from deep percolation.

Conventional furrow irrigation (CFI), where every furrow is irrigated during consecutive watering, is known to be less efficient particularly where there is shortage of irrigation water. CFI usually causes excessive deep percolation at the upper part of the furrow, insufficient irrigation at the lower part and considerable runoff, resulting in low application efficiencies and distribution uniformities. Proper furrow irrigation practices can minimize water application and irrigation costs, save water, control soil salinity build up and result in higher crop yields (Booher, 1974).

Considering the scarcity of irrigation water in the country and the high profitability per unit area and sensitivity of onion crop to moisture stress, this research aims to evaluate and demonstrate appropriate irrigation method on onion yield and water use efficiency.

MATERIALS AND METHODS

Description of the Study Area

The study was conducted in Gibe Woreda, Hadeya Zone of central region of Ethiopia. Gibe Woreda is located 300 km south of Addis Abeba and 73 km from south of the Hosaena town. The experimental site was located at an altitude of 1600m.a.s.l, latitude of 7°45′36" N and longitude 37°45'36"E.

Experimental Design and Treatment

The experiment was laid out in randomized complete bock design with three treatments and five replications (farmers were used as replication). The treatments were alternate furrow irrigation (AFI), fixed furrow irrigation (FFI) and conventional furrow irrigation (CFI). The size of each plot was 10m by 10m and space between the plots 1m. The recommended space between the plant and the row (40cm and 60cm) respectively was applied.

Soil Data

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.

Climate Data

The average climatic data (Maximum and minimum temperature, relative humidity, wind speed, and sun shine hours) on monthly basis of the study area were obtained from the new claim software. The potential evapotranspiration (ETo) was estimated using CROPWAT software version 8.

Long term monthly average climatic data of the experimental are

Month	Min Temp °C	Max Temp °C	Humidity %	Wind km/day	Sun hours	ETo mm/day
January	7	25.7	81	130	8.2	3.58
February	8.3	27.1	79	130	7.6	3.85
March	10	27.2	83	130	7.7	4.06
April	10.8	24.2	90	130	7	3.59
May	9.3	24.1	93	130	7.6	3.53
June	9.5	22.3	95	147	5.9	2.93
July	9.8	21.3	95	104	3.6	2.49
August	9.8	21.2	92	86	4.2	2.71
September	9.3	22.6	98	112	5.2	2.89
October	7.9	23.7	87	112	7.2	3.38
November	8.1	24.7	90	138	8.9	3.51
December	7	26	78	138	8.3	3.62
Average	8.9	24.2	88	124	6.8	3.34

Crop Data

Head cabbage crop data required for CWR determination. Head cabbage has total growing period 125days, root depth 0.5m, depletion factor 0.45 and Crop coefficient(kc) is 0.9 FAO 56(Allen et al., 1998).

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 (Doorenbos and pruitt, 1977). The long term and daily climate data such as maximum and minimum air temperature, relative humidity, wind speed, sunshine hours, and rainfall 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.

Irrigation Water Management

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

$$TAW = \frac{(Fc - PWP) * BD * Dz}{100}$$

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

$$Inet(mm) = ETc(mm) - Peff(mm)$$

The gross irrigation requirement will be obtained from the expression:

$$Ig = \frac{In}{Ea}$$

Ea=application efficiency of the furrows (60%)

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

$$t = \frac{d*l*w}{6*Q}$$

Where: d= 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)

Data Collection

Daily climate like maximum and minimum air temperature, relative humidity, wind speed, sunshine hours and rainfall data was collected to calculate crop water requirement. Amount of applied water per each irrigation event was measured using calibrated pareshall flume. During harvesting, Plant Height, Head diameter, Head weight and Yield of Head cabbage were measured from the net harvested area of each plot.

Statistical Analysis

The collected data were analyzed using Statistical Agricultural Software (SAS 9.0) and least significance difference (LSD) was employed to see a mean difference between treatments and the data collected was statistically analyzed following the standard procedures applicable for RCBD with single factor. The treatment means that were different at 5% levels of significance were separated using LSD test.

RESULT AND DISCUSSION

Physical and Chemical Properties of Soil

In order to characterize soils of the study site, soil physical and chemical parameters were measured in the field and laboratory. The result of the soil analysis from the experimental site showed that, the soil of experimental area is clay soil. The average bulk density of the experimental site is 1.31gm/cm3 is below the critical threshold level (1.4 g/cm3) and was suitable for crop root growth. The critical value of bulk density for restricting root growth varies with soil type (Hunt and Gilkes,1992) but the general bulk density greater than 1.6 g/cm3 tend to restrict root growth (McKenzie *et al*., 2004). The moisture content of the soil is 22.18% per meter depth Soil. The pH of soil was 5.53 which is slightly acidic with average pH value of 5.56. EC critical value for agricultural use according to Hillel, (2004) is < 2.0 ds/m. thus, the experimental site soil were less than this value (1.005 ds/m) so it is suitable for Head cabbage growth.

Characteristics of soil in the experimental area

Soil properties		Soil depth in (cm)				
		0-20	20-40	40-60	60-80	average
Particle size distribution	Clay %	50	54	58	56	54.5
	Sand %	32	28	30	26	29
	Silt %	18	18	12	18	16.5
Textural class		Clay	clay	clay	clay	clay
BD (g/cm3)		1.14	1.32	1.42	1.34	1.31
% Moisture		19.05	25.31	28.21	16.14	22.18
pH		5.53	5.78	5.60	5.19	5.53
EC (ds/m)		1.00	0.91	0.95	1.22	1.02

Head Cabbage Response to Furrow Irrigation

The table shows that the irrigation treatments had varying effects on head cabbage growth and yield:

Plant Height (PH):

CFI resulted in the tallest plants (25.65 cm), followed by AFI (23.55 cm) and FFI (22.55 cm). The difference was statistically significant (LSD = 3.08 cm, $p < 0.05$), suggesting that full irrigation supports greater vegetative growth.

Head Length (HL):

No significant differences were detected among treatments for HL, with values ranging from 13.75 to 15.95 cm, indicating that irrigation strategy had limited impact on this trait.

Head Diameter (HD):

CFI had significantly greater head diameter (6.96 cm) compared to AFI (5.87 cm) and FFI (5.24 cm), with a statistically significant LSD value of 0.9023 cm. This suggests that better water availability under CFI supports improved head formation.

Yield Components:

Although CFI yielded the highest total yield (19.18 t/ha) and marketable yield (16.98 t/ha), followed closely by AFI (18.55 and 16.78 t/ha), the yield differences were not statistically significant. UMY was highest under CFI (2.19 t/ha), possibly due to overwatering effects or disease susceptibility.

Water Use Efficiency (WUE):

AFI achieved the highest WUE (9.675 kg/m^3), significantly better than FFI (8.525 kg/m^3) and especially CFI (3.775 kg/m^3). The LSD of 3.5562 kg/m^3 indicates that WUE differences were statistically significant, highlighting AFI's potential in water-scarce environments.

These results align with previous studies showing that deficit irrigation strategies like AFI can significantly improve WUE while maintaining competitive yields, making it an appealing option for sustainable crop production.

Treatment	PH(cm)	HL(cm)	HD(cm)	MY(t/ha)	UMY(t/ha	TY(t/ha)	WUE(kg/m3)
AFI	23.55ba	13.75	5.87b	16.78	1.76	18.55	9.675a
FFI	22.55b	13.75	5.24b	13.58	1.87	15.46	8.525a
CFI	25.65a	15.95	6.96a	16.98	2.19	19.18	3.775b
CV(%)	7.45	9.41	8.65	21.07	33.30	20.99	28.06
LSD(5%)	3.08	NS	0.9023	NS	NS	NS	3.5562

CONCLUSION AND RECOMMENDATION

Alternative and Fixed furrow has the potential to save 50 % of irrigation water relative to conventional furrow irrigation, greatly improving water use efficiency, without causing a significant effect on Head cabbage yield. The findings indicate that while CFI is most effective for maximizing plant growth and yield in head cabbage, it is significantly less water-efficient than AFI. AFI offers a favorable compromise by achieving high WUE and acceptable yields, making it a viable strategy for areas facing water scarcity. Thus, AFI stands out as a sustainable irrigation practice for head cabbage cultivation, supporting both productivity and resource conservation.

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