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Evaluation of Alternate, Fixed and Convectional Furrow Irrigation Under Different Water Application Level on Cabbage Growth Parameters and Yield Component in Eastern Oromia

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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. Experiment was conducted at Kombolcha ATEVT Collage, farm site in eastern Ethiopia. The aim of this study was to compare and evaluate alternate with convectional furrow irrigation under deficit water application on growth and yield response of cabbage crop. Field experiment was designed as a two factor factorial experiment in RCBD, replicated three times. The two factors were 3 irrigation methods (IMs); (AFI, FFI and CFI) and 3 deficit or water application levels (ALs) (100%, 75%, 50% ETc of full crop water requirement. Hence study focuses on the effect alternate furrow irrigation on agronomic (growth parameters) and yield response of cabbage crop. Plant height was highly significantly ($P<0.01$), influenced by both IMs and (ALs) at all growth (initial, development, mid-season and late stage. Number of outer leaf per plant of at development was significantly ($p<0.05$) influenced by IMs, while ALs shows highly significant effect at ($p<0.01$). At mid stage both IMs and ALs shows highly significant ($p<0.01$) affected by number of outer leaf per plant. Similarly leaf area index at all stages was highly significantly ($p<0.01$) affected by both IMs and ALs. In case of yield related parameter, the result cabbage irrigated under AFI and FFI with 100% and 75% ETc shows less impact on agronomic and yield parameters when compared to CFI with same water ALs. Thus, under limited water resources where water is precious, alternate furrow irrigation is a viable option to increase water productivity, at acceptable yield reduction. Therefore, the study recommended that farmers should observe equally serving deficit alternate furrow irrigation methods as better option in limited water environment.
Keywords: Alternate and fixed furrow irrigation, Application levels, Cabbage, Growth, Yield parameters

1. Introduction

Globally, more than 40% of annual food production comes from irrigated land, and agriculture is the largest consumer of water, up to 70% of all freshwater withdrawals (FAO, 2007). As water scarcity becomes more acute in many parts of the world, increasing the effectiveness with which agricultural water resources are used is a priority for enhanced food security. The world population is predicted to grow beyond 7.5 billion and food demand to increase by 50% by 2030 (FAO, 2012).

Water scarcity and drought are the major factors constraining agricultural crop production in arid and semi-arid zones 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 (Kassam *et al.* 2007).

Furrow irrigation is often characterized by low irrigation efficiency. 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. According to Canone *et al*. (2015) and Ronaldo *et al.* (2015) 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% (Reddi and Reddy, 2009). In the 21st century, irrigated agriculture in many parts of the world should be more effective, productive, profitable and sustainable under increasing global pressures on climate variability and change, financial investments, water use and other natural resources (Lenton 2015). Thus, new irrigation strategies must be established to use the limited water resource more efficiently. Alternate partial root-zone irrigation (APRI) or partial root-zone drying (PRD) has been raised, which is inexpensive and an alternative choice compared with expensive methods of irrigation such as sprinkler or drip irrigation technique. Hence the objective this study is to examine the effect different furrow irrigation water management and application levels practices on growth and yield, parameters of cabbage in semi-arid climatic condition of eastern Ethiopia.

2. Materials and Methods

2.1. Description of the study area

The experiment was conducted at Kombolcha AETVT farm site in Kombolcha woreda, Eastern Hararge Zone Oromia Regional State during dry season (September 2015 to April 2016). Kombolcha is situated at 09^0 26′ 0″ – 09^0 35′ 0″ North latitude and 42^0 05′ 0″ – 42^0 13′ 0″ East longitude and at an altitude of 2161 m a.s.l. The site receives bi-modal rainfall characteristics with a mean annual rainfall of 650 mm, which was erratic and uneven distribution and mean minimum and maximum temperatures of 10 ^{0}C and 27.8 ^{0}C respectively. The major field crops grown in the study area at main season is maize, sorghum, haricot bean and groundnut. Horticultural crops include cabbage, pepper, tomato, lettuce and potato were dominantly produced under irrigation. The source of irrigation water mainly hand dug well.

2.2. Experimental design and treatments

The experiment had two factors, factorial design arranged in Randomized Complete Block Design (RCBD) with three replications. The two factors were namely three furrow irrigation methods and three application levels, total of nine treatments. The three irrigation methods were, Alternative Furrow Irrigation (AFI), Fixed Furrow Irrigation (FFI) and Convectional Furrow Irrigation Methods (CFI). The three levels of water applications were, full irrigation (100% of ETc) and ¾ (75% of ETc) and half (50% of ETc) of the irrigation requirement. The experiment was conducted on individual plot size of 4 m x 3 m (12 m^2) with 27 number of such plot. The spacing between the blocks and plots were kept as 2.5 m and 1 m respectively. The treatment was randomly applied to area of each of the blocks (replications) and each treatment was assigned in the blocks.

A test crop cabbage (*Brassica oleraceacapita L.*) seeds (cultivar: Golden quality Gloria F1 Variety with net-weight of 250 gram packed on September, 2015 having expiry date on September, 2017 produced in Netherland: with a purity test of 98%, and having germination percentage of 85 was purchased from Haramaya Farmers' Union Agricultural Input Supplier Shop. Five weeks after germination seedlings were transplanted on December 10, 2015 to experimental plots.

A common recommended fertilizer rate was applied manually in the experimental plots. All plots received the same amounts of fertilizer consisted of 150 kg ha^{-1} of urea and 100 kg ha^{-1} of P_2O_5 (DAP). The irrigation water used in the study was obtained from a well. Accordingly, the laboratory result, showed water salinity level was 0.40 dS m^{-1}. Crop water requirements was estimated using the CROPWAT computer software program using climatic, soil and crop data as input.

2.3. Crop water requirement

In this experiment, the reference evapotranspiration (ETo) and crop water requirement (ETc) was estimated from 15 years climatic data collected from National Meteorological Agency of Haramaya University branch Station. Based on FAO CROPWAT output, crop water requirement (ETc) of cabbage crop was found as 442.1 mm for growing periods of 120 days at full irrigation level (100% ETc). Accordingly, for treatment three-fourth (75% ETc) and half (50% ETc) irrigation levels crop water requirements were deduced as 331.5 mm and 221.0 mm, respectively.

2.3.1. Irrigation water requirement

Furrow irrigation is a standard practice in vegetable crop production like cabbage. Water needed per irrigation was determined as net depth of irrigation water that is required consumptively for crop production. It is the amount of irrigation water required to bring the soil moisture level in the effective root zone to field capacity. Thus, it was the difference between the field capacity and the soil moisture content in the root zone before starting irrigation. This is determined from relation between following parameters;

$$\text{Water need (d); } d = \frac{(\theta_{fc} - \theta_i)\rho_b * D_r}{100} \quad (1)$$

where; d is the net amount of water applied during irrigation (cm), θ_{fc} is the moisture content at field capacity in the root zone by volume (%), θ_i is field moisture content before irrigation in the root zone by volume (%), D_r is the depth of the root zone (cm) and bulk density of the soil in the root zone (g cm^{-3}).

The gross depth of irrigation water (I_g) equals the net irrigation depth (I_n) divided by the application efficiency (E_a). The following equation was used to compute gross irrigation water requirement.

$$\text{Gross irrigation water } I_g = \frac{I_n}{E_a} \quad (2)$$

The field water application efficiency for surface furrow irrigation is normally taken as 60%.

2.4. Soil analysis

Soil samples from the experimental plots were taken to analyze bulk density, texture, organic matter content, pH, ECe, moisture content at filed capacity and permanent wilting point from the field at three points along the diagonal of the experimental plot at two depth 0-30 cm and 30-60 cm and average value was described.

2.5. Agronomic parameters of cabbage

In this experiment the agronomic parameters of cabbage was collected to evaluate the effect of alternate and convectional furrow irrigation methods under different water application levels on physiological and yield response of cabbage. Hence different agronomic parameters were measured and collected as follows;

2.5.1. Growth components and physiological parameters

Plant height (cm): The height of randomly selected tagged plant was recorded in centimeter by measuring the height from ground level to the terminal growing point of the shoot, then mean height was worked out.

Number of outer leave per head: The total number of outer leaves were counted at 20, 45, 105, and 120 DAT (days after transplanting) and the average number of outer leaves per plant was calculated from tagged plant.

Leaf area (cm^2): The maximum length and breadth of the full expanded leaf was measured and area of individual leaf was calculated by using the following equation (Ranga, 1977), and expressed in cm^2.

$$A = aB^bL^c \qquad (3)$$

where A= leaf area (cm^2); a= 0.9817; B = breadth of leaf (cm); b = 1.1270; L = length of leaf (cm); c = 0.7503 (a, b and c are the constant values estimated by method of least square analysis)

Leaf area index: The leaf area index (LAI) is the ratio of leaf area per plant to land area occupied by plant and it was calculated by the formula as suggested by Sestak *et al*. (1971).

$$LAI = \frac{\text{Leaf area per plant } (cm^2)}{\text{Land area occupied by a plant } (cm^2)} \qquad (4)$$

2.5.2. Yield and yield related parameters

Fresh head weight (kg per plant): Cabbage head was harvested when they were firm, compact and attained physiological maturity. The fresh weight of heads (kg) were recorded and the average weight was calculated.

Marketable head yield ($t\ ha^{-1}$): The marketable head yield of 5 sample plants were randomly selected from the respective plot and weight of sampled plants were measured at harvesting stage was recorded and converted to ($t\ ha^{-1}$).

Unmarketable head yield ($t\ ha^{-1}$): The yield which was obtained by sorting the disease, discolored, shrunken shape and small size, totally unwanted by consumers from marketable fresh head was recorded at each harvest and converted to ($t\ ha^{-1}$).

Total head yield ($t\ ha^{-1}$): The weight of total (marketable and unmarketable) head of yields per plot at harvesting from the sample plants were recorded and summed up to estimate yield per hectare.

2.6. Depth, discharge and time of water application

The total amount of water estimated using the CROPWAT model was diverted to the furrow with calibrated siphon of correction factor of (0.65) tubes having opening diameter of one and half inch at the sides of the ditch water supplied to each furrow was under controlled by the difference in depth between the water level in the feeder canal and free water level at the outlet at the furrow head. This was calculated as (Michael, 1997).

$$Q = 0.65 * 10^{-3} * a * \sqrt{2gH} \qquad (5)$$

where; Q is discharge from siphon tube ($l\ s^{-1}$), a is area of cross section, inside of tube (cm^2), g is acceleration due to gravity ($cm\ sec^{-1}$, $981 cm\ sec^{-2}$) and H is effective head causing flow (cm).

The effective head was calibrated to be 12 cm and hence the resulting discharge out of the siphon tube was 1.15 liters per second. This discharge was selected in order to avoid erosion, in accordance effective height and allowable maximum non erosive discharge as possible recommended by (FAO, 2002). The time required to deliver the desired depth of water in to each furrow was calculated using the equation recommended by Israelsen (1980):

$$t = \frac{D_{ap} * w * l}{360 * q} \qquad (6)$$

where; D_{ap} is depth of water applied (cm), t is application time (hr), l is flow length (m) q is flow rate ($l\ s^{-1}$) and w is furrow spacing (m).

2.7. Statistical analysis

All agronomic and yield parameters were subjected to ANOVA with appropriate (RCBD) design. The data were analyzed using Genstat 15th edition statistical software. The mean separation was made using fisher protected list significant difference (LSD) method.

3. Results and Discussion

3.1. Physical and chemical properties of experimental soil

Laboratory analysis of particle size distribution indicated that the soil texture was sand clay loam` throughout the depths of 0-30 cm and 30-60cm. The average soil bulk density of 0-60 cm soil depth was 1.14 g cm^{-3}. Average available soil moisture content for the top (0-30 cm) and lower (30-60 cm) soil depths were observed as 136 mm per 0 - 30 cm and 160 mm per 30 - 60 cm respectively. Representative value of TAW (148 mm m^{-1}) was obtained by considering the average of the upper 0 - 60 cm soil depth. The average OM of the soil was found as 1.97%. Representative value of the soil pH (1:2.5 soil to water) was 6.26.

Table 1: Physical and chemical properties of experimental soil

Averaged values of 0-30 and 30-60 cm depth)							
			Particle size distribution (%)				
			Sand	Silt	Clay	Textural class	
			53.4	13.9	32.8	Sandy clay loam	
BD (gcm^{-3})	FC (Vol. %)	PWP (Vol. %)	TAW (mm m^{-1})	OC (%)	OM (%)	ECs (dS m^{-1})	pH
1.14	34.88	20.8	148	0.09	1.14	0.4	6.26

Note: FC stands for field capacity volume base, PWP for permanent wilting point volume base, BD for bulk density, TAW for total available water, OC for organic carbon, OM for organic matter, ECs for electrical conductivity of soil, pH for power of Hydrogen (soil reaction at 1 : 2.5; soil: water)

The average electrical conductivity of the soil throughout profile depth was found was found as 0.40 dS m^{-1}. Field level infiltration test indicated that basic infiltration rate of the experimental area was 24 mm hr^{-1}

3.2. Gross irrigation water applied in growth stages for each treatments

Gross water applied for each stage was listed in Table 2. Comparison of irrigation water used in alternating furrow irrigation (AFI), fixed furrow irrigation (FFI) and conventional furrow irrigation (CFI) under three different application levels and water savings from each treatments.

Table 2: Water applied per growth stage and percent of water saved from each treatment

Treatment	Growth stage				I_{gross} (mm) Seasonal water applied	% of saved water
	Initial	Development	Mid	Late		
T_1	64.0	81.0	335.1	95.3	575.3	16.7
T_2	48.0	60.7	251.3	71.5	431.5	37.5
T_3	32.0	40.5	167.6	47.6	287.7	58.3
T_4	64.0	81.0	335.1	95.3	575.3	16.7
T_5	48.0	60.7	251.3	71.5	431.5	37.5
T_6	32.0	40.5	167.6	47.6	287.7	58.3
T_7	76.8	97.2	402.2	114.3	690.4	-
T_8	57.6	72.9	301.6	85.7	517.8	25.0
T_9	38.4	48.6	201.1	57.2	345.2	50.0

I_{gross} is gross irrigation in (mm), T_1, T_2 and T_3 for application level of (AFI) with 100%, 75% and 50% ETc respectively, T4, T_5 and T_6 for application level of (FFI) with 100%, 75% and 50% ETc respectively: T_7, T_8 and T_9 for application level of (CFI) with 100%, 75% and 50% ETc respectively

From practical point of view alternate furrow (AFI and FFI) water applied only two furrow at each successive irrigation event, so water saved from these irrigation methods was greater by saved water of neighbor furrow each event through growth season, even though, the yield obtained was less than full application

Hence the result indicated that water saved from treatment combination of AFI and FFI with 100% ETc, 75% and 50% ETc levels were 16.67 %, 37.5% and 58.33% of total net volume of irrigation water applied. Whereas CFI with 75% and 50% application obtained 25.0% and 50.0% respectively (Table 2). According to Shahnazari *et al*. (2007) comparative report of FI (full irrigation) with PRD (partial root drying) for field grown potato, PRD treatments saves 30% of water which increases water use efficiency of the crop.

3.3. Effect of irrigation methods (IMs) and water application levels (ALs) on growth components and physiological parameters

3.3.1. Effect of IMs and ALs on plant height at different growth stages of the crop

Initial stage: The result shows that plant height at initial stage of cabbage was highly significantly ($P<0.01$) influenced by both irrigation methods (IMs) and application levels (ALs). The highest mean plant height 10.81cm was recorded by CFI, but FFI and AFI were not significantly different respectively. Under different application levels plant heights were significantly different in all application levels. The highest mean recorded by 100% ETc was 11.06 cm and lowest value was observed at 50% ETc application depth as 9.54 cm (Table 3).

Development stage: The ANOVA of plant height at development stage (Table 3) show that the plant height was highly significant ($p<0.01$) affected by both IMs and ALs. The highest plant height 26.72 cm and 27.5 cm recorded by CFI and 100% ETc respectively. Whereas the lowest plant height obtained at FFI and 50% ETc as 23.27 cm and 22.96 cm respectively.

Table 3: Effect of irrigation methods and water application levels on plant height (cm)

		Stages			
	Treatments	PH-I	PH-D	PH-M	PH-L
Irrigation method (MI)	CFI	10.81^{a}	26.72^{a}	32.68^{a}	33.69^{a}
	AFI	9.96^{b}	24.89^{b}	30.84^{b}	32.59^{b}
	FFI	10.02^{b}	23.27^{c}	29.87^{c}	31.33^{c}
Application level (AL)	100 ETc	11.06^{a}	27.52^{a}	33.66^{a}	34.46^{a}
	75% ETc	10.19^{b}	24.40^{b}	31.28^{b}	32.84^{b}
	50 % ETc	9.54^{c}	22.96^{c}	28.46^{c}	30.31^{c}
	LSD (5%)	0.4358	0.792	0.872	10.01

AFI, FFI and CFI: (Alternative, Fixed and Convectional) furrow irrigation method respectively, ETc: Evapotranspiration of crop, PH-I (cm): Plant height initial at stage, PH-D (cm): Plant height development stage, PH-M (cm): Plant height at mid stage, PH-L (cm): Plant height at late stage, Note: Mean followed by the same in columns are not significantly different

Mid-stage: The result showed that plant height was highly significantly ($P<0.01$) affected by both IMs and ALs. Conventional furrow irrigation method produces 32.68 cm followed by AFI and FFI as 30.84 cm and 29.8 cm respectively. Taller plant was found at 100% ETc and shorter plant was seen at 50% ETc (Table 3).

Late stage: Analysis of variance revealed that plant height was highly significantly ($P<0.01$) influenced by both irrigation methods and water application levels. The mean maximum and minimum plant heights 33.69 and 31.33 cm were recorded by CFI and FFI respectively. Accordingly, under different deficit levels the highest mean plant height produced by 100% ETc was 34.46 cm and, the lowest, 30.31cm was by 50% ETc water deficit treatment throughout irrigation season (Table 3).

Generally in all stages (initial development, mid and late stages) the result indicates furrow water application methods and levels had significant effect on plant height independently. Hence, from this finding it confirmed that plant height increased as application levels increases. In the same manner, irrigation methods also significant impact on plant height. This result was agreed with Mandefro and Kokobe, (2015), the study reported that plant height increased significantly with increasing water application level. Furthermore Ebisa, (2015) reported that plant height measured at initial stage was influenced significantly by different mulch types at ($p<0.05$).

3.3.2. Effect of furrow IMs and ALs on number of outer leaves per plant at different growth stages of the crop

Initial stage: Analysis of variance revealed that number of outer leaves per plant at initial stage was not significantly ($P<0.05$) affected by both furrow irrigation methods and application depths (Table 4). This is because of the cabbage was irrigated equal at nursery and during seedling establishment.

Development stage: In this stage ANOVA indicated that number of outer leaves per plant significantly ($p<0.05$) influenced by IMs; while application levels were highly significant at ($p<0.01$). The highest mean number of outer leaf recorded by CFI was 13.64, but AFI and FFI were no significantly different. With respect to ALs the highest mean number of outer leaf per plant observed in 100% ETc application level as 13.87, but mean produced by 75% and 50% ETc ALs were not statistically different (Table 4).

Table 4: Effect of IMs and ALs on number of outer leaves per plant

		Stages			
	Treatments	NL-I	NL-D	NL-M	NL-L
Irrigation Method (MIs)	CFI	5.472^{a}	13.64^{a}	14.24^{a}	13.12^{a}
	AFI	5.433^{a}	13.28^{b}	13.46^{b}	12.80^{a}
	FFI	5.400^{a}	13.35^{b}	13.77^{b}	12.77^{a}
Application level (ALs)	100% ETc	5.461^{a}	13.87^{a}	14.74^{a}	13.40^{a}
	75% ETc	5.422^{a}	13.31^{b}	13.48^{b}	12.67^{b}
	50% ETc	5.422^{a}	13.09^{b}	13.24^{b}	12.58^{b}
	LSD	0.1125	0.2913	0.4560	0.6628

NL-I: Number of leaf at initial stage, NL-D: Number of leaf at development stage, NL-M: Number of leaf at mid- stage, NL-L: Number of leaf at late stage Note: means followed by the same in column are not significantly different

Mid-season: The outcome of statistical analysis indicates that number of outer leaf per plant at mid stage was highly significantly ($p<0.01$) affected by MIs and ALs. Mean number of outer leaf per plant owned by CFI was 14.24, but AFI and FFI were not significant. Whereas effect of ALs in this stage, showed that, the highest mean number outer leaf was produced by 100% ETc application level as 14.74, but mean produced by 75% and 50% ETc application depth were not significantly different as shown in Table 4.

Late stage: The summary analysis result of cabbage growth components and physiological parameters indicated that mean numbers of outer leaves recorded by irrigation methods (AFI, FFI and CFI) were not significantly different ($p<0.05$), however, mean value produced by application levels were highly significantly different at ($p<0.01$). The maximum mean number of outer leaf recorded by 100% ETc was 13.40, but mean comparison between 75% and 50% ETc ALs showed that there were no significantly difference among them (Table 4).

In brief, the result indicated that more or less the mean number of outer leaves were significantly affected by both IMs and ALs. Even though both had significant effect, IMs had marginal effect as compared to deficit. On the other hand, ALs increasingly affect by reducing number outer leaves, leave size and height. According to Chung *et al.,* (1997) leaf and stem morphology are altered by water stress, and continuous water deficit results in fewer and smaller leaves, which have smaller and more compact cells and greater specific leaf weight. Similarly recent study on lettuce, by Mandefro and Kokobe, (2015) indicated that decrease in the irrigation level from FI (full irrigation) to PRD 50% (partial root drying) resulted with a reduction of mean leaf number per plant. Kamel *et al.,* (2013) reported that FI treatments gave the highest yield, plant diameter and number of leaves of tomato crop. In contrast of this study results, Acar *et al*. (2008) reported that different irrigation levels did not significantly affect mean leaf number and plant diameter.

3.3.3. Effect of furrow IMs and ALs on leaf area index

Leaf surface area decreases as the amount of water applied to the crop also decreases, as a result, leaf area index also decreases. At normal condition the leaf size of growing crop increases as stage of development increases. This directly envisages the leaf area index (LAI) also increases. The effect of IMs (irrigation methods) and ALs (application levels) on LAI described as follows:

Initial stage: LAI in this stage was highly significantly ($p<0.01$) affected by both irrigation methods and deficit levels. Under IMs, CFI significantly difference from both AFI and FFI by means of LAI of 0.1493, but when compared AFI and FFI individually they were not significantly different from each other. For deficit application levels, LAI shows highly significantly ($p<0.01$) affected under all application levels. The largest and smallest mean value were attained by full (100% ETc and 50% ETc) water application level treatment as 0.1671 and 0.0985 respectively (Table 5).

Table 5: Effect of furrow irrigation methods and application levels on leaf area index

		Stages			
	Treatments	LAI-I	LAI-D	LAI-M	LAI-L
Irrigation methods (MIs)	CFI	0.1493^{a}	1.801^{a}	4.586^{a}	3.749^{a}
	AFI	0.1270^{b}	1.559^{b}	3.889^{b}	3.116^{b}
	FFI	0.1118^{b}	1.557^{b}	3.659^{b}	2.915^{c}
Application levels (ALs)	100 ETc	0.1671^{a}	1.901^{a}	4.897^{a}	3.876^{a}
	75% ETc	0.1225^{b}	1.605^{b}	3.953^{b}	3.166^{b}
	50 % ETc	0.0985^{c}	1.412^{c}	3.285^{c}	2.738^{c}
	LSD (5%)	0.0160	0.1461	0.2624	0.1962

LAI-I: Leaf area index at initial stage, LAI-D: Leaf area index at development stage, LAI-M: Leaf area index at mid stage, LAI-L: Leaf area index at late stage Note: means followed by the same in column are not significantly different

Development stage: ANOVA result shows both irrigation methods and application levels were highly significant ($p<0.01$) effect on LAI. Accordingly, the highest mean leaf area index produced by CFI was 1.80, but FFI and AFI were statistically not significant from each other. The in the case of ALs, the largest LAI was observed in 100% ETc and the lowest was 50% ETc treatment Table 5.

Thus leaf area index directly related to leaf area which was affected by water stress at each stages of growth of cabbage.

Mid and late stage: The mid stage takes numerous growth period as a result cabbage needs ample amount of irrigation water because at this time crop starts heading and ball enlargement. Hence mid stage is the best stage of growth indicator to identify the effects of applied irrigation system. Accordingly, both stages (Mid and late) analysis of variance illustrated that LAI was highly significantly ($p<0.01$) affected by both irrigation methods and deficit levels. Maximum mean value recorded by 100 % ETc and CFI were 4.897 and 3.876, and 4.586 and 3.749 for mid and late stages respectively. Whereas minimum values were found by FFI and 50% water application level treatments correspondingly as shown in (Table 5). Leaf area index at mid-season stage was higher than late season stage. This may be due to as at head formation leaves form curl/folded and decreased at late stage.

According to Chung *et al.,* (1997) leaf and stem morphology are altered by water stress and continuous water deficit results in fewer and smaller leaves, which have smaller and more compact cells and greater specific leaf weight. The report of Yazgan *et al.* (2008) and Mandefro and Kokobe, (2015) declared that irrigation water application levels affected the mean plant diameter, thus statistically important differences for plant diameters of lettuce under different irrigation levels. Kirnak *et al.* (2002) also reported that lettuce canopy diameter increased significantly (P<0.05) with increasing irrigation water applied and evapotranspiration

3.4. Effect of irrigation methods (IMs) under different water application levels (ALs) on yield parameters

3.4.1. Fresh head weight per plant

Analysis of variance showed that fresh head weight of cabbage was highly significantly influenced (P<0.01) by IMs and ALs. The highest fresh head weight was recorded as 2.377 kg per plant by CFI, followed by AFI and FFI as 2.16 kg and 2.12 kg respectively Table 6. The average of observation indicate that as deficit levels increases from full (100% ETc) or no stressed treatment to half 50% ETc stressed treatment, cabbage fresh head weight shows decreasing trend. Hence, the head weight decreases from 2.451 kg per plant to 1.978 kg per plant Table 6. This result showed that fresh head weight of cabbage was seriously influenced by application depths than irrigation methods, which shows little variation on fresh head weight of cabbage. Karam *et al*., (2002) reported that water deficit produced significant differences in fresh weight of individual heads at (P<0.05). Similarly Acar *et al*. (2008) described that head weights were decreasing from treatments receiving 100% of the soil water depletion to 80% following 60% water applications respectively.

3.4.2. Marketable head yield

Analysis of variance showed that marketable head yield was significantly (P<0.05) affected by irrigation methods (IMs), while ALs shows highly significantly (P<0.01) influences. The largest mean value of 64.88 t ha^{-1} was produced under CFI, but statistically the yield recorded by AFI and FFI were not significantly different. Accordingly marketable head yield was influenced by ALs, the average yield perceived by (100% ETc) was 68.01 t ha^{-1} followed by 61.17 t ha^{-1} and 54.67 t ha^{-1} under 75% ETc and 50% ETc water application level correspondingly (Table 6). The result reveals that useful head yield was significantly affected by deficit treatment than furrow watering type. Considerably under ALs, the yield recorded by no stressed treatment had shown 13.34 t ha^{-1} greater yield over 50% stressed treatment. The reason may be due to cabbage need more water starting form head formation to maturity. Therefore reducing water or defecating during this stage had greatly affect head size and marketable head yield of cabbage.

Table 6: Effect of IMs under different water ALs on yield and yield components

	Treatments	FHW	MHY	UMHY	THY
Irrigation methods (MIs)	CFI	2.377^{a}	64.88^{a}	13.34^{a}	78.22^{a}
	AFI	2.160^{b}	60.06^{b}	11.99^{ab}	72.05^{b}
	FFI	2.120^{b}	58.91^{b}	11.72^{b}	70.63^{b}
Application levels (ALs)	100% ETc	2.45^{a}	68.01^{a}	13.02^{a}	81.03^{a}
	75% ETc	2.23^{b}	61.17^{b}	12.92^{a}	74.10^{b}
	50% ETc	1.98^{c}	54.67^{c}	11.11^{b}	65.78^{c}
	LSD (5%)	0.103	4.113	1.355	3.737

IM: Irrigation method, AL: Application level, FHW (kg per plant): Fresh head weight, UMHY (t ha^{-1}): Unmarketable head yield, MHY (t ha^{-1}): Marketable head yield, THY (t ha^{-1}): Total head yield, Note: means followed by the same in column are not significantly different

According to Kirda *et al*. (2004) report on an experiment of fresh-market tomato, a partial root zone drying treatment with the restoration of 70% ETc, caused a yield reduction by 21% with respect to the full irrigated treatment. Coelho *et al*. (2005) and Yazgan *et al.* (2008) also demonstrated similar result that total maximum and marketable yields were obtained from 100% pan evaporation.

3.4.3. Unmarketable head yield

Analysis of variance showed that unmarketable head yield was significantly (P<0.05) influenced by both IMs and ALs. The mean value observed for unmarketable head yield under irrigation methods were 13.34 t ha^{-1}, 11.99 t ha^{-1} and 11.72 t ha^{-1} for CFI, AFI and FFI respectively (Table 6), but statistically mean recorded by AFI was not significantly different from CFI and FFI treatment. Similarly the average unmarketable yield of 13.02 t ha^{-1}, 12.92 t ha^{-1} and 11.11 t ha^{-1} were recorded by full, three forth and half water application level by one-to-one expression. This result indicate that unmarketable yield (yield lose) was observed higher in normal or convection water application than alternate furrow depth of application. This shows more watering increases unwanted shoot or leaves other than producing marketable firmed head at a time of harvesting as observed on field.

3.4.4. Total head yield

Analysis of variance of indicated that total head yield was highly significantly influenced (P<0.01) by both furrow irrigation methods and water application levels. The mean value computed in (Table 6) shows that, maximum total head yield was recorded by CFI as 78.22 t ha^{-1} and minimum yield of 70.63 t ha^{-1} was found at FFI, but statistically mean observed under FFI and AFI were not significantly different. While the result under ALs lied in between 81.03 t ha^{-1} and 65.78 t ha^{-1} for full and half water application levels in decreasing order respectively. This shows that water application depths or levels have remarkable effect on total head yield. Xu and Leskovar, (2014) reported that both marketable and total yield of cabbage at 75% and 50% ETc deficit irrigations were significantly reduced as compared to 100% ETc water application level. Bozkurt *et al.* 2009) also reported that water deficit produced significant differences in yield and yield components of lettuce crop.

3.4.5. Combined effect of irrigation methods and water application levels on yield and yield components

Fresh head weight per plant: The analysis of variance indicated that interaction of irrigation methods (IMs) and application levels (ALs) had no significant effect at (P<0.05) on fresh head weight of cabbage. Even though, interaction effect was statistically not significant for the purpose of comparison but each mean value of furrow irrigation methods with their application levels had significant difference. For instance treatment combination of AFI with 100% ETc was recorded higher mean fresh head weight cabbage than both AFI with 75% and 50% ETc. This is synonym for remaining treatments FFI and CFI with same application levels) as described in Table 7.

Marketable head yield: The result shows interaction effect of irrigation methods (IMs) and application levels (ALs) was statistically not significant at (P<0.05) on marketable head yield of cabbage. However, the observed result revealed that treatment received 100% ETc, 75% and 50% ETc for CFI, AFI and FFI shown an average marketable head yield in decreasing order (Table 7)

Table 7: Interaction effect of irrigation methods under different water application levels on yield and yield components

Treatment combination	FHW	MHY	UMHY	THY
CFI 100% ETc	2.66^{a}	72.07^{a}	14.80^{a}	86.87^{a}
CFI 75% ETc	2.42^{b}	66.38^{ab}	13.67^{ab}	80.04^{b}
CFI 50% ETc	2.05^{de}	56.20^{c}	11.56^{bc}	67.76^{de}
AFI 100% Etc	2.35^{bc}	65.30^{ab}	12.60^{abc}	77.90^{bc}
AFI 75% ETc	2.08^{de}	60.33^{bc}	12.62^{abc}	72.96^{cd}
AFI 50% ETc	1.93^{e}	54.56^{c}	10.74^{c}	65.30^{e}
FFI 100% ETc	2.34^{bc}	66.66^{ab}	11.66^{bc}	78.31^{bc}
FFI 75% ETc	2.19^{cd}	56.81^{c}	12.48^{abc}	69.29^{de}
FFI 50% ETc	1.95^{e}	53.26^{c}	11.02^{c}	64.28^{e}
LSD (5%)	NS	NS	NS	NS
SED	0.084	3.361	1.107	3.053

Note: means within a column followed by the same letter are not significantly different

Total head yield: Interaction of irrigation methods (IMs) and application levels (ALs) statistically had no significant effect at (P<0.05) on total head yield. But obviously for treatment combination with its factor i.e., each combination, for example CFI with 100% ETc ALs produce higher total head yield of 6.83 and 19.11 t ha^{-1} difference was observed as compared to 75% and 50% ETc respectively. The yield variation also shown for treatment combination of AFI and FFI with same application levels as described in (Table 7).

4. Conclusion and Recommendation

This study was aimed to evaluate effects of three different furrow irrigation methods under different water application levels on cabbage (*Brassica oleraceacapita. L.)* growth parameters and yield component in Eastern Oromia. Accordingly the parameters for experimentation include growth components and physiological parameters: such as plant height, outer leaf number per plant and leaf area index, yield parameters include fresh head weight, marketable and unmarketable head yield, total head yield.

At crop development, mid-season and late season stage, plant height was highly significantly (P<0.01), influenced by both irrigation methods (IMs) and application level (ALs). Number of outer leaf per plant at initial stage was not significant. At development it was significantly (p<0.05) influenced by IMs but ALs highly significant at (p<0.01) and mid stage both IMs and ALs shows highly significant (p<0.01) effect on number of outer leaf per plant. Similarly leaf area index at all stages (initial development, mid and late stages) was highly significantly (p<0.01) affected by both irrigation methods (IMs) and application level (ALs),

Fresh head weight per plant and total head yield were highly significantly (P<0.01) affected by both irrigation methods (IMs) and application levels (ALs). Marketable head yield was significantly (P<0.05) affected by IMs, but highly significantly (P<0.01) by influenced ALs, for unmarketable head yield both IMs and ALs shows significant effect at (P<0.05). However overall for yield and yield components were not significantly (P<0.05) affected by interaction both IMs and ALs.

The finding indorses that farmers can practice either alternate or fixed furrow irrigation with 100% water application level or CFI with 75% ETc as a best and first option. Since this was identified as negligible yield difference of less than 10% when compared with every furrow irrigation or convectional furrow irrigation with the same ALs which able to save 16.67% to 37% of the irrigation water.

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6. References

Acar B, M. Paksoy, O.Türkmen, M.Seym, 2008. Irrigation and nitrogen level affect lettuce yield in greenhouse condition. African Journal of Biotechnology 7(24): 4450-4453

Bozkurt S, G.S. Mansuroğlu, M. Kara, S. Önder, 2009. Responses of lettuce to irrigation levels and nitrogen forms. African Journal of Agricultural Research 4 (11): 1171-1177

Canone D, M. Previati, I. Bevilacqua, L. Salvai, S. Ferraris. 2015. Field measurements based model for surface irrigation efficiency assessment. Agric. Water Manage. 156:30-42

Chung, S.Y., J.R. Vercellotti and T.H. Sanders.1997. Increase of glycolytic enzymes in peanuts during peanut maturation and curing: evidence of anaerobic metabolism. Journal of Agricultural and Food Chemistry. 45: 16–21

Coelho AFS, E.P, Gomes A.P, Sousa, M.B.A., Gloria. 2005. Effect of irrigation level on yield and bioactive amine content of American lettuce. Journal of Science Food Agriculture 85:1026–1032

Ebisa Kenno. 2015. Effect of different types of mulching on soil moisture conservation and water productivity of cabbage (*Brassica oleraceacapita L.*) under drip irrigation at Assosa, Ethiopia. M.Sc. Thesis. Haramaya University, Haramaya

FAO (Food and Agricultural Organization). 2002. Deficit irrigation practices. FAO Water Report No. 22. Rome, Italy

FAO. 2007. Climate change and food security: a framework document. Rome

FAO. 2012. Statistical Yearbook 2012. World food and agriculture. Rome

Godfray, H.C.J., I.R., Crute, L., Haddad, D. Lawrence, J.F. Muir, N. Nisbett., J. Pretty, S. Robinson, C. Toulmin, R. Whiteley. 2010. The future of the global food system. Philosophical Transactions of the Royal Society B: Biological Sciences, Vol. 365, No.1554, (September 27, 2010), pp. 2769-2777

Israelsen, O.W., and V. E. Hansen. 1980. Irrigation Principles and Practices. Jonsen Wiley and Sons, Inc. New York, London

Kamel N, E. Fathia, M. Mohamed, Netij Ben. 2013. Soil salinity, yield and water productivity of lettuce under irrigation regimes with saline water in arid conditions of Tunisia. International journal of Agronomy and Plant Production. Vol., 4 (5), 892-900

Karam F., Mounzer O., Sarkis F., Lahoud R., 2002.Yield and nitrogen recovery of lettuce under different irrigation regimes. J Appl Hort 4, 70-76

Kassam A.H., Molden D., Fereres E., Doorenbos J. (2007): Water productivity: science and practice – introduction. Irrigation Science, 25: 185–188

Kirda, C., M. Cetin, Y. Dasgan, S. Topcu, H. Kaman, B. Ekici, Derici, M. R., and A. I. Ozguven. 2004. Yield response of greenhouse-grown tomato to partial root drying and conventional deficit irrigation. Agr. Water Manag. 69, 191-201.

Kirnak H., S. Demir, I. Tas, M. Cakmakli. 2002. Response of different irrigation water applications on yield and growth of lettuce grown in greenhouse. J Agric Fac Harran Uni. 6(1-2), 47-54

Lenton R. 2015. Irrigation in the twenty-frst century: Reflections on science, policy and society. *Irrigation and Drainage*, **63**, 154-157

Mandefro Chala and Kokobe W/Yohannes. 2015. Effect of irrigation application levels on yield and water productivity of drip irrigated lettuce (*Lactuca sativa l.*), Gedio zone, southern Ethiopia. International journal of basic and applied sciences vol. 4. No. 4 2015. Pp. 229-234 (online version available at: www.crdeep.com

Michael, A.M. 1997. Irrigation Theory and Practice. Pashurati Printers, Delhi

Ranga Rao V. 1977. E ect of root temperature on the infection process and nodulation in Lotus and

Stylosanthes. *Journal of Experimental Botany*, 28: 241-259.

Reddi G H S, Reddy T Y. 2009. *Effcient Use of Irrigation Water*. 1st ed. Kalyani Publishers, New Delhi-110002, India

Ronaldo S, G.A., Maria, M. C.Teresa, Z.M. Chrispim, M.Paula, CS Gerson. (2015).Water resource management: A comparative evaluation of Brazil, Rio de Janeiro, the European Union, and Portugal. Sci. Total Environ. 511:815-828

Sestak Z., J. Catsky and P.G. Jarris. 1971. Plant photosynthetic production manual of methods. Junk, W, N.V. publications, The Hungns, pp 373-381

Yazgan S, S. Ayas, C. Demirtas, H. Buyukcangaz, B.N. Candogan. 2008. Deficit irrigation effects on lettuce (*Lactuca sativa var. Olenka*) yield in unheated greenhouse condition. J Food Agric. Environ. 6(2): 357-361

Xu C., D.I., Leskovar. 2014. Growth, physiology and yield responses of cabbage to deficit irrigation. Hort. Sci. (Prague), 41: 138–146. Texas A &M University, USA