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Response of Yield and Water use efficiency to different Irrigation Levels under Furrow systems of Soybean[1]

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Abstract

Introduction: Water management practice that is, deficit irrigation (DI) has a greater contribution to water-saving and increase crop water use efficiency (CWUE). DI is an approach where crops are exposed to a certain level of water stress either during a specific crop growth stage or in the course of the entire developing season. Furrow irrigation system requires a lower initial investment than other water application systems. However, it is usually associated with considerable runoff and excessive filtration at the upper portion of the furrow while it also causes insufficient application at the lower fields. The DI level to improve water productivity range is between 60 to 100% of full crop evapotranspiration (ET_c) needs in previous works. Enhancing water use efficiency of irrigated crops through field irrigation management is vital in water-scarce areas. The DI and furrow irrigation systems are alternatives to enhance CWUE in such areas.

Materials and Methods: This experiment has been executed in Jawi district of Amhara location. Jawi district is found at 602 km North West of Addis Ababa with a geographical

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location of 36° 29'17.58'' longitude and 11° 33'22.68'' latitude. It is characterized with hot to humid climate of low land area with high unimodal rain fall (1250 mm) from May to October. Jawi district is located in the lowland part of Awi zone and its altitude ranges from 700 to 1500 m.a.s.l with mean yearly temperature of 16°C to 32°C. The climate of Jawi is Kola according to Ethiopian agro ecological climate classification and is equivalent to hot humid climate. The average annual potential evapotranspiration of Jawi is 5.52 mm day^{-1}. A field experiment was worked out in Jawi district of Amhara region of Ethiopia with the objective of investigating the performance of various furrow irrigation techniques and DI levels to enhance the grain yield and CWUE of soybean. Split-plot design with RCBD arrangement in 3 replications was used and contains 3 furrow irrigation methods (Conventional Furrow Irrigation (CFI), Alternative Furrow Irrigation (AFI), and Fixed Furrow Irrigation (FFI)) as main plot and three DI levels (100%ETc, 75%ETc, and 50%ETc) as sub-plot.

Results: The result showed that DI had a significant effect on soybean above ground biomass and a very high significant ($P<0.001$) effect on grain yield. The advanced grain yield of 1944 kg/ha was obtained from CFI at 100% of ET_c and the minimal one was recorded in FFI at 50% ET_c. The highest CWUE of 1.17 kg/m^3 was obtained from AFI at 100% ET_c. The highest yield reduction in this experiment was obtained at AFI at 100% of the crop water application which showed 7.46% yield reduction and also saved 47.9% irrigation water as compared to CFI. Using this saved water, 35% grain yield was obtained under an AFI compared to CFI.

Conclusions: It could be reported that enhanced water saving and CWUE might be achieved using 100% ET_c at AFI system solving water shortage problem. It can be concluded that, in areas where water is scarce alternative furrow irrigation saves 50% irrigation water in comparison to conventional furrow irrigation method. Hence, additional land could be irrigated with the saved irrigation water in similar water scarce areas. This finding could make certain the possibility of irrigation improvement in the study area and other comparable agro-ecology like the study area.

Keywords: Water Productivity, Crop water use efficiency, Deficit irrigation, Furrow irrigation systems, Soybean.

1. Introduction

The United Nations estimates the need for a 30% increase in irrigation water to provide food in 2025 (Tabatabaee & et al., 2022). Ethiopia is the second populous country in Africa next to Nigeria (Awulachew & et al., 2007) where about 82% of the population is dependent in farming for their livelihood (Bank, 2014). Agriculture in Ethiopia is dominantly rain-fed which is accompanied by low crop productivity and few irrigation practices (Gayanilo & et al., 2005). Generally, the country's water potential is underutilized so that developing and effectively utilizing it will enable the country to become food self-sufficient in a short period of time.The adoption of water-saving strategies helps to optimize yield and may contribute more to food security (Topçu & et al., 2007). Water management practice that is, deficit irrigation (DI) has a greater contribution to water-saving and increase crop water use efficiency (CWUE) (Akele, 2019; Eck & et al., 1987). DI is an approach where crops are exposed to a certain level of water stress either during a specific crop growth stage or in the course of the entire developing season (Pereira & et al., 2002).

Furrow irrigation system requires a lower initial investment than other water application systems (Mebrahtu & et al., 2018). However, it is usually associated with considerable runoff and excessive filtration at the upper portion of the furrow while it also causes insufficient application at the lower fields. Fereres & Soriano (2007) recently reviewed that the DI level to improve water productivity range between 60 to 100% of full crop evapotranspiration (ET_c) needs.

Soybean crop was selected for this study due to its higher economic benefits and greater area coverage in the region. Smallholder farmers in Metekel zone of Benshangul Gumuz and Awi zone in Amhara regional states have cultivated soybean as the primary source of revenue and subsistence (CSA, 2018). Besides, the crop is the primary source of edible oil globally with the maximum gross output of vegetable oil through the cultivated plant with whole cultivated area of 117.7 million ha (FAOSTAT, 2015) then the current price of oil is very expensive. In solving this problem, the government of Ethiopia has given attention to produce more oil crops locally. Soybean is a drought-resistant crop that requires a hot environment and can grow under low to medium altitudes such as low lands of Amhara and Benshangul Gumuz regional states (CSA, 2018). Yet, there is no research about the application of DI and the routine of irrigation systems in this region where related information is lacking. The goal of this observes was to investigate the response of yield and crop water productivity to distinct irrigation levels under furrow systems of soybean.

2. Materials and Methods

2-1. Description of the Study Area

This experiment has been executed in Jawi district of Amhara location from 17 February to 12 May 2021. Jawi district is found at 602 km North West of Addis Ababa with a geographical location of 36° 29'17.58'' longitude and 11° 33'22.68'' latitude (Figure 1). It is characterized with hot to humid climate of low land area with high unimodal rain fall (1250 mm) from May to October. Jawi district is located in the lowland part of Awi zone and its altitude ranges from 700 to 1500 m.a.s.l with mean yearly temperature of 16°C to 32°C (JDAO, 2018). The climate of Jawi is Kola (<1500 m a .s.l) according to Ethiopian agro ecological climate classification and is equivalent to hot humid climate. The average annual potential evapotranspiration of Jawi is 5.52 mm day^{-1}.

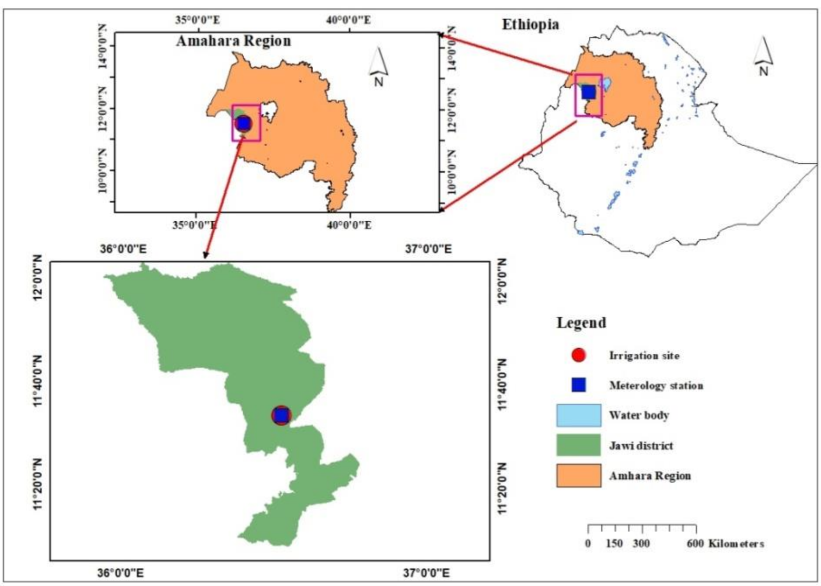


Fig. 1. Location map of the study area and Jawi meteorological station

2-2. Experimental Design and layout

The area test becomes organized in split-plot layout with RCBD arrangement in three replications. Split plot designs are advantageous for experimental units which are large by design that may be utilized to compare subsidiary treatments and increase precision over a randomized complete block design (Madhyastha & et al., 2020). The treatments consisted of two factors: (1) three furrow irrigation methods namely; alternate furrow irrigation (AFI), fixed furrow irrigation, (FFI) and conventional furrow irrigation (CFI), and (2) three deficit irrigation (DI) application levels namely; 100% ETc, 75% ETc, and 50% ETc. The three DI levels were arranged in the sub plots while the furrow irrigation methods were applied on the main plots. The combination two factors included a total of nine treatments (Table 1).

Table 1: Two factors used to develop nine treatments over this experiment

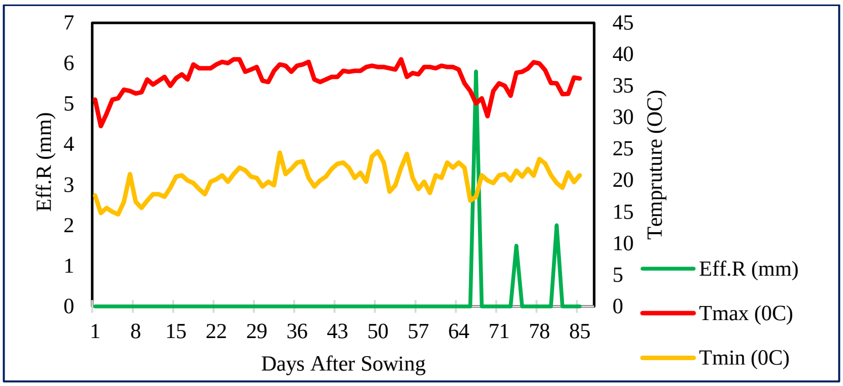
Main plot	Sub plot (ETc)	Treatments
Conventional furrow (CFI)	75%	T_1
	50%	T_2
	100%	T_3
Alternative furrow (AFI)	100%	T_4
	75%	T_5
	50%	T_6
Fixed furrow (FFI)	100%	T_7
	75%	T_8
	50%	T_9

The plot extent was 3 m by 3 m (9 m^2) and the spacing between each block and plot was 3 and 2 meters, respectively, used to control the seepage of irrigation water between plots and blocks. The spacing among rows and plants was 60 cm and 5cm, respectively. Plowing was made using a disk plough tractor and the seedbed was prepared manually. The improved variety (Awassa 95) of Soybean seed (Glycine max L.) was sowed on February 17, 2021 (Figure 3). Thinning was done after germination using local practices to keep the distance between plants consistent.

Fig. 2. Sowing and first water application

2-3. Data collection

The daily values of metrological data like rainfall, minimal and most temperature, wind speed, relative humidity, and sunshine hours of Jawi district were used for crop water requirement estimation using FAO-Penman Monteith equation (Allen & et al., 1998). These data were obtained from Jawi Belles research center meteorological station.



*Eff.R=Effective rain fall, T_{max}=Maximum temperature, T_{min}=Minimum temperature

Fig. 3. Daily weather data of study area

2-4. Soil Sampling and Analysis

The experimental soil sample was collected diagonally at five points using augur and core sampler across the experimental field to address the soil variation in the field. Soil sample was collected in the root zone depth ranges of 0.3m to 1m for the soybean. Disturbed composite soil samples were taken from the five points at four depths 0-30 cm, 30-60cm, 60-90 cm, and 90-100cm with the help of an auger. Undisturbed soil samples were taken at every regular 30 cm interval from the top soil up to the maximum root depth of the crop using 5 mm diameter by 5 cm depth core sampler. The soil analysis was conducted for the following soil properties which were used as input parameters for the CROPWAT model.

Analysis of soil samples for the main soil physical and chemical properties was carried out at Pawe Agricultural Research Center soil quality research laboratory. The soil texture with inside the soil profile become decided the usage of the hydrometer method (Bouyoucos, 1962) from the collected composite soil sample at five points and four depths. By using undisturbed soil samples, the bulk density was determined after oven drying at 105^{o}C for 24 hours until all the moisture was driven off. Then, the bulk density became computed by dividing the soil dry mass by the volume of the core sampler (Huang & et al., 2005)

2-5. Crop and Irrigation water Requirement

The total available water (TAW) was determined using the equation TAW= (FC−PWP)×1000×Zr (Allen et al. 1998), TAW is in mm; FC (field capacity) and PWP (permanent wilting point) are in %, and Zr is root depth in m. The fraction of TAW that a crop can extract from the root zone without suffering water stress is the readily available soil water (RAW). It was computed as $RAW = P \ x \ TAW$ (Allen et al. 1998), Where RAW is readily available water (mm) and P is in fraction for allowable soil moisture depletion by the crop (0.5).

The purpose if irrigation is to avoid this stress and to refill the RAW. The water requirement and irrigation schedule of soybean was computed for 85 days (Total length through the growing period). The crop water requirement was calculated by multiplying the daily vale of reference evapotranspiration (ET_O) with the daily vale of crop coefficient (Kc). The day by day crop coefficient of soybean (Kc) was calculated based on Allen et al. (1998) as 0.5 for the initial stage, 0.5<Kc<1.15 for the crop development stage, 1.15 for the mid-season stage, and 0.5<Kc<1.15 for the late season stage.

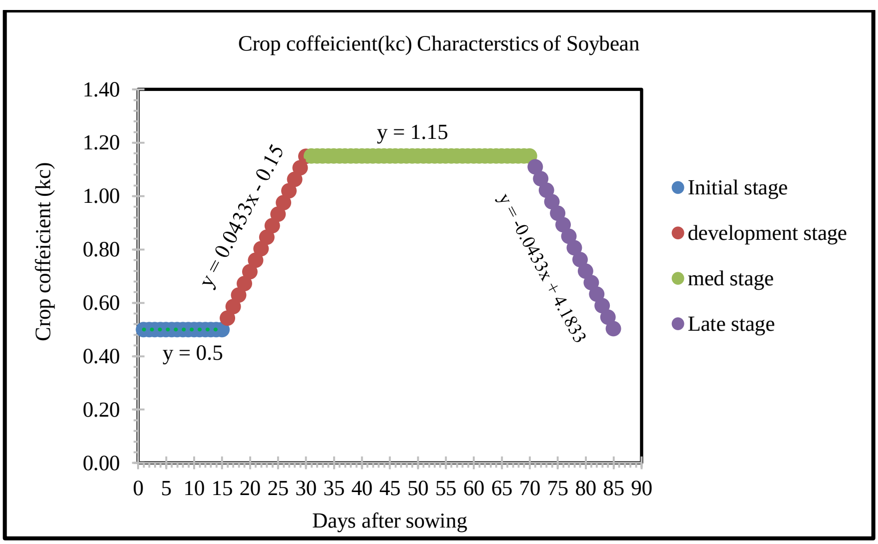


Fig. 4. Crop coefficient characteristics through the growing period

The net irrigation requirement was determined by subtracting the effective rainfall from subsequent irrigation amounts (Allen & et al., 1998). The effective rainfall was also estimated using FAO method (Allen & et al., 1998). According to Allen & et al. (1998) and Brouwer & et al. (1989), furrow irrigation application efficiencies generally vary from 40 to 60%. For this experiment, 60% application efficiency (Ea.) was used to estimate the gross irrigation requirement of surface irrigation methods (Chandrasekaran & et al., 2010).

2-6. Irrigation Water Application

Just after planting equal irrigation was applied for all plots prior to the start of treatments until the plant was established. The amount of irrigation water to be carried out at every irrigation application to the individual experimental plot was directed through channels from a river source and was measured using a standard 3-inch Parshall flume.

Fig. 5. irrigation water application systems: alternate furrow irrigation method (a), fixed furrow irrigation method (b) and CFI (c) after experimental establishment

2-7. Agronomic Data Collection

Crop parameters such as stand counts at emergency, flowering date, maturity date, plant height (cm), stand counts at harvesting, number of pods per plant; above-ground biomass, hundred seed weight (g), and grain yield were collected. Grain yield according to plot was measured using the instrument (electronic balance) and then adjusted to 12.5% moisture level lastly it was converted to hectare basis.

$$\text{Adjusted yield} = \frac{(100 - \text{Moisture Content})}{100 - 12.5} * \text{unadjusted yield}$$

The crop water use efficiency (CWUE) in Kg/m^3 was determined by evaluating the total yield of soybean crop per unit of water applied and the water consumptive use, throughout the growing season of the crop.

2-8. Yield Response factor

Yield response factor which links relative yield reduction to relative evapotranspiration deficit was determined. The connection between the evapotranspiration deficit $[1 – (ETa/ET_c)]$ and yield decrease $[1 – (Y_a/Y_m)]$ is always linear. The slope of this linear connection is called the yield response factor or crop response factor (K_y) **(**Kirda & et al., 2004). When ky > 1), crop response is very sensitive to DI with proportional large yield reductions corresponding to the reduced water. When ky < 1, the crop is more tolerant to DI, exhibiting less yield reduction with the reduced water. when ky = 1, the yield reduction is directly proportional to reduced water use (Steduto & et al., 2012). This relationship is expressed by the following equation.

$$[1- (Y_a/Y_m)] = K_y [1- (ET_a/ET_m)]$$

Where, Y_m (kg/ha) and Y_a (kg/ha) are the maximum and actual yields, respectively. While K_y is the yield response factor.

2-9. Statistical Analysis

The accumulated data were analyzed the usage of SAS statistical software program of model 9.4. Mean separation become finished the usage of the Least Significant Difference (LSD) check at 1% and 5% probability level. The collected yield, irrigation systems, and intensity of irrigation applied water for each treatment were compared.

3. Results

3-1. Physical and chemical properties of soil and water

The results of the experimental site soil laboratory analysis are shown (Table

2). The soil pH value of the experimental site was 5 where according to Ravikumar (2013) soils having a pH value of less than 6 are considered as acidic soils. Both high and low pH may limit yields in soybean (Doorenbos & Kassam, 1979).

Table 2: Physical and chemical properties of soil and water on the experimental *site*

Soil parameters	Unit	Values
Particle soil distribution		
Sand	%	43
Silt	%	6.33
Clay	%	50.7
Textural class	-	Clay
PH	-	5
OM	%	3.46
OC	%	2.01
ECe	dSm^{-1}	0.06
CEC	(meq/100g)	19.52
Irrigation water		
PH	-	6.86
ECw	dSm^{-1}	0.19

The top-soil has a barely decrease bulk density (1.2 g/cm^3) than the sub-soil (1.31 g/cm^3) which is probably due to high organic matter contents (Table 3). And also, the average soil moisture content on weight base at FC and PWP of Soybean root depth were 34.5% and 22.68%, respectively (Table 3). The total available water (TAW) was 140 mm per 1m and the result of readily available water (RAW), with an optimal depletion level of 50%, was 70 mm.

Table 3: Average Bulk Density (BD), Field Capacity (FC), Permanent Wilting Point (PWP) and Total Available Water (TAW) of the experimental site

Soil depth(cm)	Bulk density (g/cm^3)	FC (%)	PWP (%)	(FC-PWP) m^3/m^3	TAW (mm)
0-30	1.2	32.98	21.91	0.11	39.6
30-60	1.22	34.19	22.15	0.12	43.92
60-90	1.31	36.68	23.67	0.13	51.09
90-100	1.23	34.22	23.0	0.11	40.59
Average	1.24	34.5	22.68	0.12	43.8

3-2. Irrigation Water use

The effects of the study indicated that the highest amount of water was used across the pod formation of the Soybean. The result was likewise consistent with Boyhan & et al. (2001), that highest use of water mostly occurs during the latter stages of pod enlargement especially during periods of hot weather. The amounts of irrigation water practiced to every treatment plot are showed in Table (4).

Table 4: Amount of applied water through the growing season

Furrow system	Irrigation level (ETc)	Initial Stage	Development Stage	Mid stage	Late stage	Total
CFI	100%	73	140	361	131	705
	75%	62	105	271	98	536
	50%	51	70	181	66	368
AFI/FFI	100%	51	75	185	60	371
	75%	46	52	136	49	283
	50%	41	35	90	33	199

3-3. Soybean growth performance

Days to 50% flowering

Deficit irrigation (DI) levels showed a high significant (P<0.01) result on days to 50% flowering using analysis of variance (ANOVA). The highest flowering days were recorded with full irrigation (Table 5). This could be because less DI allowed the soybean to grow more quickly, resulting in longer days to flowering. On the other hand, the furrow irrigation method confirmed a relatively good sized (P<0.01) impact on days to 50% flowering (Table 5), since CFI system could evenly distribute irrigation water for all ridges enabling soybean to display better growth. Similar results were reported by Abate (2004) and Ahmed & et al. (2008) where a significant reduction in the quantity of days to flowering of Haricot beans and Faba beans were obtained under water stress. Plants under water stress prefer to finish their lifecycle quicker than the one beneath ordinary or excessive soil moisture conditions (Al-Suhaibani, 2009).

3-4. Days to maturity

As depicted from the ANOVA, the irrigation levels were significantly dissimilar from one another in maturity days (P≤0.01). The highest maturity days of 76 days were logged for 100% ETc of irrigation depth applied (Table 5). Besides, there was significantly high different (p<0.01) in maturity days between different furrow irrigation techniques. The delayed maturity days were found at CFI while the faster maturity days were seen at FFI.

Table 5: The effect of deficit irrigation and furrow irrigation method on flowering and maturity dates

Irrigation level	50% flowering days	95%maturity days
100% ET_c	41.78[a]	75.56[a]
75%ET_c	40.89[b]	74.89[b]
50%ET_c	40.11[c]	74[c]
Error	0.2	0.26
LSD (0.05)	0.65	0.56
CV (%)	1.1	0.68
Furrow method		
CFI	42.44[a]	76.1[a]
AFI	40.33[b]	74.3[b]
FFI	40.0[b]	74[b]
Error	0.09	0.48
LSD (0.05)	0.56	0.65
CV (%)	1.58	0.75

Numbers with the same letter(s) are statistically non-significant at 5% probability AFI= Alternative Furrow Irrigation, CFI=Conventional Furrow Irrigation, FFI=Fixed Furrow Irrigation, CV=coefficient of variance, LSD=List significant difference.

Plant height

There was a highly significant ($P \leq 0.01$) variance in plant heights among different DI levels. Significantly higher plant height was recorded for 100% of irrigation depth (Table 6). Plant height increased with reduced DI level. The findings of this observe also are consistent with Payero & et al. (2006) who determined that water stress shrinks crop height, which in flip impacts yield. Mebrahtu & et al. (2018) Stated that the plant tallness of onion decreased by increasing DI levels which is also similar to this result. Moreover, different furrow irrigation methods showed highly significant ($P < 0.01$) effects on plant height where the highest and the lowest plant height were obtained by CFI and FFI, respectively (Table 6), which are consistent with other scholars study (Payero & et al., 2006) and Kumar & et al. (2007).

Number of branches per plant

The statistical evaluation found out that, the number of branches per plant of soybean was significantly (P<0.05) affected by DI level. And also, the furrow irrigation techniques were highly significant ($P \leq 0.01$) dissimilar from one another on the number of branches per plant (Table 6). The ANOVA result showed a significant ($P \leq 0.05$) difference due to the interaction effect of furrow irrigation techniques and DI levels in the number of branches per plant of soybean (Table 7).

Stand Count at Harvest

The DI levels were highly significantly ($P \leq 0.01$) different from one another in the plant population during harvest. The study revealed that unlike levels of DI application highly significantly ($P \leq 0.01$) stimulated the plant population of the soybean crop. The maximum populace of soybean was counted at 100% ETc whereas the lowest population was recorded at 50% ETc of irrigation level (Table 6). The ANOVA result revealed that furrow irrigation techniques had a distinctly significant (P<0.01) result on the plant population (Table 6).

Table 6: Effect of furrow irrigation techniques and irrigation levels on plant height and number of branches per plant

Irrigation level (ETc)	PH (cm)	NBPP	SCHa
100%	45.44[a]	1.64[a]	168.8a[a]
75%	42[b]	1.44[ba]	163.7[b]
50%	37.67[c]	1.27[b]	156.2c
Error	6.43	0.07	1.94
LSD (0.05)	3.12	0.248	162.89
CV (%)	6.08	18.25	1.25
Furrow method	**PH (cm)**	**NBPP**	**SCHa**
CFI	50[a]	2.07[a]	172.8[a]
AFI	39.78[b]	1.47[b]	160.7[b]
FFI	35.33[c]	0.82[c]	155.2[c]
Error	19.70	0.03	1.94
LSD (0.05)	3.12	0.248	162.89
CV (%)	10.61	11.94	1.02

Numbers with the same letter(s) are statistically non-significant at 5% probability AFI= Alternative Furrow Irrigation, CFI=Conventional Furrow Irrigation, FFI=Fixed Furrow Irrigation, CV=coefficient of variance, LSD=List significant difference, PH=Plant Height, NBPP=Number of Branch per Plant, SCHa=Stand Count at Harvest.

The plant population of soybean was quite significantly (P<0.01) influenced by the interplay of DI tiers and furrow irrigation techniques (Table 7). This is probably because of the reality that plants beneath stress have a tendency to finish their lifestyles cycle, which allows their get away from damaging situations with the aid of using finishing their lifecycle a few days earlier than the ones beneath regular or excessive soil moisture situations.

Table 7: the interaction effect of deficit irrigation levels with furrow irrigation method on SCHa and NBPP.

Treatment	SCHa	NBPP
CFI 100%ETc	175[a]	2.53[a]
CFI 75%ETc	173.7[a]	2.13[a]
CFI 50%ETc	169.7[b]	1.53[b]
AFI 100%ETc	168.0[b]	1.67[b]
AFI 75%ETc	160.0[dc]	1.33[cb]
AFI50%ETc	154.0[e]	1.00[cd]
FFI 100%ETc	163.3[c]	1.40[cb]
FFI 75%ETc	157.3[de]	0.87[d]
FFI 50%ETc	145.0[f]	0.60[d]
LSD (0.05)	3.352	0.43
Grand mean	162.89	1.45
CV (%)	1.25	17.08

3-5. Effect of Deficit Irrigation level and Furrow Method on Soybean Yield and Yield Components

Number of pods per plant (NPPP)

Statistical analysis showed that DI amount had the highest significant ($P<0.001$) result on the mean NPPP. The highest NPPP (47) become acquired from treatments that obtained full irrigation water (Table 8). The decreases in NPPP were observed with an increase in DI. This result was in conformity with Comlekcioglu & Simsek (2011) who reported that NPPP were significantly decreased by reducing the amount of irrigation water. The furrow irrigation methods also showed a highly significant ($P\leq0.01$) difference from one another in NPPP (Table 8). The ANOVA resulted in NPPP showed a highly significant ($P\leq0.01$) distinction due to the interplay effect of furrow techniques with DI levels. From the interaction effect, significantly higher NPPP was recorded by CFI when it was applied with 100%, 75%, and 50% irrigation level respectively. 50% of irrigation levels with fixed furrow irrigation systems took the lowest NPPP (Table 10).

Table 8: Effect of irrigation level and furrow system on NPPP, NSPP .BY (kg/ha) and GY (kg/ha)

Irrigation level	NPPP	NSPP	Furrow method	NPPP	NSPP
100% ETc	46.41[a]	92, 81[a]	CFI	49.13[a]	98.27[a]
75%ETc	43.27[b]	86.61[b]	AFI	39.23[b]	78.53[b]
50%ETc	36.42[c]	72.84[c]	FFI	37.73[c]	75.47[b]
Error	0.42	0.83	Error	0.61	0.83
LSD (0.05)	42.1	84.1	LSD (0.05)	42.1	84.1
CV (%)	0.792	0.76	CV (%)	1.47	1.47

Numbers with the same letter(s) are statistically non-significant at 5% probability AFI=Alternative Furrow Irrigation, CFI=Conventional Furrow Irrigation, FFI=Fixed Furrow Irrigation, CV=coefficient of variance, LSD=List significant difference, NPPP=Number of Pod per Plant, NSPP= Number of Seed per Plant.

Number of seeds per plant (NSPP)

The quantity of seeds from each plant were significantly ($P<0.05$) influenced by the interaction effect of DI level with the furrow system. The applications of full irrigation water combined with CFI were given the largest NSPP followed by 75% deficit irrigation level (Table 8).

Above Ground Biomass Yield

The ANOVA result confirmed that there was a highly significant ($p<0.01$) difference in the above-ground biomass yield of soybean under furrow irrigation method. Besides, CFI system was superior to AFI and FFI methods (Table 9). This finding is in keeping with the findings of Meskelu & et al. (2018) and Narayanan & Seid (2015) who revealed that above-ground dry biomass was higher for CFI systems than AFI and FFI systems. The above-ground dry biomass yield that obtained from CFI methods was better than for AFI and FFI methods (Gebreigziabher, 2020) which supports our current findings.

There become especially significant ($P<0.01$) distinctions among DI levels on the above-ground biomass yield of soybean (Table 9). From this experimental study, the tendency of above-ground biomass manufacture justly decreases as the amount of water implemented decreases. This finding is in line with the findings of Karam & et al. (2005). They described that, when the implemented irrigation water reduced, the dry matter accumulation also reduced. The ANOVA indicated that there was a highly significant ($P<0.01$)

distinction among the interplay of DI and water application system on above-ground biomass yield (Table10).

Table 9: Effect of irrigation level and furrow system on.BY (kg/ha) and GY (kg/ha)

Irrigation level	BY	GY	Furrow method	BY	GY
100% ETc	3586.42[a]	1549.114[a]	CFI	3991.77[a]	1611.96[a]
75%ETc	3187.24[b]	1364.58[b]	AFI	3316.87[b]	1331[b]
50%ETc	2773.66[c]	1166.27[c]	FFI	2238.68[c]	1136.98[c]
Error	78.6	15.96	Error	78.6	5.96
LSD (0.05)	3182.44	1359.98	LSD (0.05)	3182.44	1359.98
CV (%)	2.74	1.11	CV (%)	1.4	1.34

Numbers with the same letter(s) are statistically non-significant at 5% probability AFI= Alternative Furrow Irrigation, CFI=Conventional Furrow Irrigation, FFI=Fixed Furrow Irrigation, CV=coefficient of variance, LSD=List significant difference, BY=Biomass Yield, GY=Grain yield.

Grain yield

The total grain yield was with a relatively big difference ($p \leq 0.01$) at the interplay (interaction) effect of furrow irrigation methods and DI levels (Table 10). The end result revealed that highest grain yield was found in CFI with 100% ETc which is probably because of higher overall performance of the plant growth parameters. Different studies conducted on Soybean (Admasu & et al., 2019), maize Ko & Piccinni (2009), common bean Simsek & et al. (2011), and onion Enciso & et al. (2009) discovered that, by means of the moisture deficit level multiplied the manufacture of the crop was decreased, which decided with the current finding.

Table 10: Interaction effect of furrow irrigation techniques with irrigation levels on NPPP, NSPP, BY, and GY

Treatment	NPPP	NSPP	BY (kg/ha)	AGY (kg/ha)
CFI 100%ETc	51.27[a]	102.53[a]	4320.99[a]	1786.85[a]
CFI 75%ETc	49.47[b]	98.93[b]	4061.73[b]	1654.67[b]
CFI 50%ETc	46.67[c]	93.33[c]	3592.59[d]	1394.37[d]
AFI 100%ETc	44.55[d]	89.1[d]	3833.33[c]	1564.63[c]
AFI 75%ETc	40.82[f]	81.83[f]	3216.05[e]	1278.20[e]
AFI50%ETc	32.33[h]	64.67[h]	2901.24[f]	1150.16[f]
FFI 100%ETc	43.4[e]	86.8[e]	2604.94[g]	1295.86[e]

Treatment	NPPP	NSPP	BY (kg/ha)	AGY (kg/ha)
FFI 75%ETc	39.55^{g}	79.07^{g}	2283.95^{h}	1160.81^{f}
FFI 50%ETc	30.27^{i}	60.53^{i}	1827.16^{i}	954.28^{g}
LSD (0.05)	0.73	1.43	136.1	27.64
Grand mean	42.1	84.1	3182.44	1359.98
CV (%)	1.455	0.75	2.55	1.52

Numbers with the same letter(s) are statistically non-significant at 5% probability AFI= Alternative Furrow Irrigation, CFI=Conventional Furrow Irrigation, FFI=Fixed Furrow Irrigation, CV=coefficient of variance, LSD=List significant difference, SCHa=Stand Count at Harvest, NPPP=Number of Pod per Plant, NSPP= Number of Seed per Plant, BY=Biomass Yield, GY=Grain yield

3-6. Effects of irrigation level and furrow irrigation methods on water use efficiency

Irrigation water use efficiency (IWUE)

The ANOVA displayed that furrow irrigation methods as the primary effect motivated IWUE. From this experiment, higher IWUE values of 0.51 kg/m^3 was obtained from 50% ETc (Table 11). In the AFI method, an 18.9% higher value of IWUE was obtained as compared to that of FFI and 35.8% from that of CFI technique. IWUE appreciably modified when the DI level enhanced. This end result changed into an agreement with Ayana (2011) that with growing amount of water supply, the irrigation water use effectiveness reduce.

Crop water use efficiency (CWUE)

ANOVA result shows that furrow irrigation method by means of the primary impact influenced crop water use efficiency. From this analysis, maximum CWUE was recorded from AFI with a value of 0.96 kg/m^3. Results display that AFI saved water through about 50%, as compared to CFI. These findings are in keeping with the finding of Abdel-Maksoud & et al. (2002), who decided that AFI enhanced crop water use efficiency for the crop beneath study. DI level was in its primary impact highly significantly enhanced CWUE ($P<0.01$) to an advanced CWUE value of 0.95 kg/m^3 with 50%ETc (Table 11). Generally, the effects associated with the efficiencies confirmed that once irrigation water is limited, 50% and 75% irrigation levels may be implemented through growing the water use efficiencies. Mansouri-Far & et al. (2010) stated that irrigation water may be preserved and yields maintained beneath water scarcity conditions.

Table 11: Effects of deficit irrigation and furrow irrigation methods on IWUE, and CWUE

Irrigation level	IWUE (kg/m^3)	CWUE (kg/m^3)
100% ET_c	0.37^c	0.63^c
75%ET_c	0.42^b	0.75^b
50%ET_c	0.51^a	0.95^a
Error	0.000112	0.00028
Grand mean	0.433	0.776
LSD (0.05)	0.011	0.017
CV (%)	2.45	2.15
Furrow method		
CFI	0.34^c	0.58^c
AFI	0.53^a	0.96^a
FFI	0.43^b	0.79^b
Error	0.000087	0.00034
Grand mean	0.432593	0.776
LSD (0.05)	0.0106	0.0166
CV (%)	2.16	2.38

Numbers with different letter(s) are statistically significant at 5% or 1% probability AFI= Alternative Furrow Irrigation, CFI=Conventional Furrow Irrigation, FFI=Fixed Furrow Irrigation, CV=coefficient of variance, LSD=List significant difference, IWUE=Irrigation water use efficiency, CWUE=Crop water use efficiency.

The ANOVA showed that crop water use efficiency (CWUE) was highly significantly influenced ($P<0.01$) by the interplay of DI level with furrow irrigation method in Soybean production (Table 12). The highest CWUE 1.173 kgm^{-3} was found under AFI at 50% ETc (Table 3.8). This result indicated that higher water utilization efficiency was found from treatments with higher DI. This result is lining with, Bekele & Tilahun (2007) who pronounced that deficit irrigations improved the water use efficiency of onion than filled irrigation. And also the other study Yazar & et al. (2009) reported that, Alternate furrow irrigation enlarged water use efficiency in a wheat-cotton rotation in Punjab, India. Generally, The finding of this experimental study is much like to the end result of the studies that decided AFI rises the water use performance with few or no yield reduction and saves a large amount of irrigation water (Gebreigziabher, 2020).

Table 12: The interaction effect of furrow irrigation methods and irrigation levels on CWUE (kg/m^3)

Furrow Techniques	DI level			
	100%	75%	50%	Mean
CFI	0.46000^{i}	0.56667^{h}	0.71000^{f}	0.57889
AFI	0.80667^{d}	0.90333^{c}	1.17333^{a}	0.96111
FFI	0.62667^{g}	0.76667^{e}	0.97333^{b}	0.78889
Mean	0.63111333	0.74555667	0.95222	0.776296
LSD (0.05)	0.0288			
Error	0.00012037			
CV (%)	1.414			

Numbers with different letter(s) are statistically significant at 5% or 1% probability AFI= Alternative Furrow Irrigation, CFI=Conventional Furrow Irrigation, FFI=Fixed Furrow Irrigation, CV=coefficient of variance, LSD=List significant difference, IWUE=Irrigation water use efficiency, CWUE=Crop water use efficiency.

3-7. Contribution of water saving and yield response factor

Increasing acreage

Irrigation water that saved through DI could be advantageous for irrigating additional cropland. The net extra irrigable land due to water saved from furrow system and application levels of Soybean production is projected as said by water applied for each treatment and the actual irrigated land of the soybean crop. As presented in Table 13, the end result displayed that the minimal yield reduction (7.46%) become from AFI 100% ET_c congruently saved 47.9% water from the obligatory amount of net irrigation for one hectare. Furthermore, making use of AFI 100%, will be able to irrigate the net area of 0.92 ha additionally per each hectare. The results clearly showed that the worth of residual yield generated was not influenced only by irrigation level but also by furrow irrigation systems.

Table 13: Additional area to be irrigated with the saved water based on the actual irrigated land.

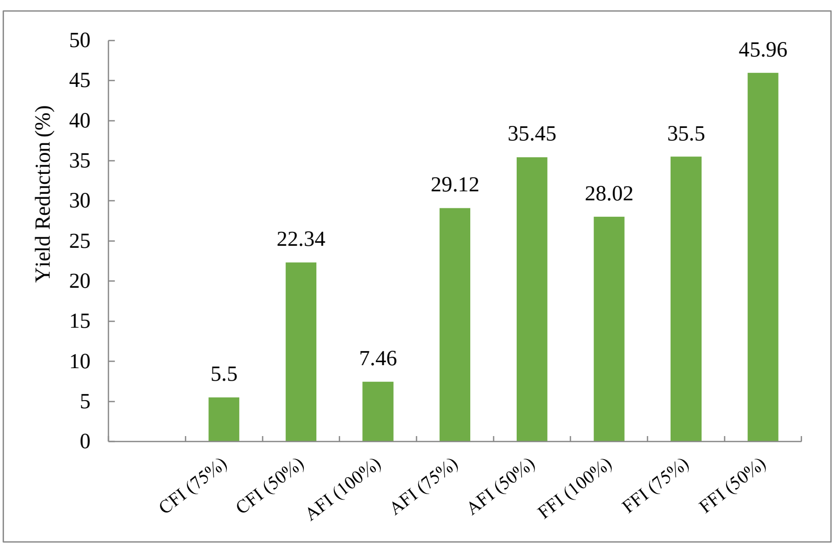
Treatment	Adjusted Grain yield (kg/ha)	Yield Reduction (%)	Water applied (m^3/ha)	Water saved (m^3/ha)	Water saved (%)	Additional area to be irrigated (ha)
CFI (100%)	1818.90	0	7040.50	0	0	0
CFI (75%)	1718.90	5.5	5362.20	1678	0.31	0.31

Treatment	Adjusted Grain yield (kg/ha)	Yield Reduction (%)	Water applied (m^3/ha)	Water saved (m^3/ha)	Water saved (%)	Additional area to be irrigated (ha)
CFI (50%)	1412.61	22.34	3674.80	3366	47.80	0.92
AFI (100%)	1589.74	7.46	3680.00	3361	47.73	0.91
AFI (75%)	1289.17	29.12	2831.00	4210	59.79	1.49
AFI (50%)	1174.02	35.45	1987.00	5054	71.78	2.54
FFI (100%)	1309.25	28.02	3681.00	3360	47.72	0.91
FFI (75%)	1172.73	35.5	2833.00	4208	59.76	1.49
FFI (50%)	983.02	45.96	1990.00	5051	71.73	2.54

Yield Response Factor

From this experiment study the average crop response factor was 0.49. The lowest yield response factor was observed under treatment received 100%ETc with AFI. With the value of Ky<1, the crop is greater tolerant to DI, and recovers in part from stress, showing much less than related decreases in yield with decreased water use (Steduto & et al., 2012). Based on this, the worth of yield response factor of the experiment indicated that the Soybean crop can tolerate some levels of moisture strain in its developing environment

The finding is in agreement with (Ayas & Demirtaş, 2009), who reported that when crops have Ky values which are decrease than one, they may be taken into consideration to be tolerant of water deficiency.



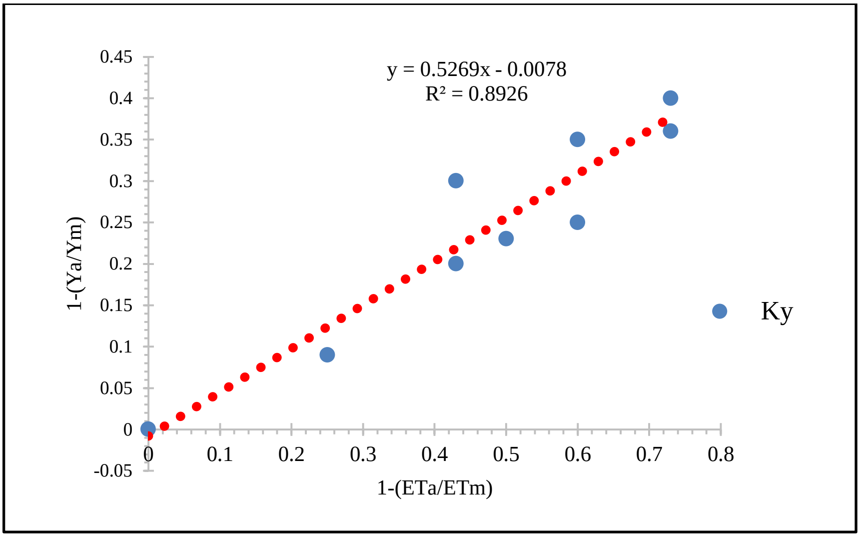


Fig. 6. Yield Reduction due to deficit irrigation and, the relationship between relative yield reduction and relative evapotranspiration deficit

4. Conclusion

This research was proposed to study the effect of Deficit Irrigation (DI) under different furrow irrigation methods on yield and water productivity (water use efficiency) of Soybean. The effects discovered that the primary and the interplay outcomes of DI with furrow irrigation system exerted a highly significant effect on the plant growth, the yield parameters (grain yield), and the water use efficiency of soybean. The grain yields of Soybean were enhanced as applied water increased. There were significant variations in grain yield as applied irrigation water minimized from 100%RTc to 50% ETc for different furrow irrigation techniques. The maximum grain yield was acquired from conventional furrow irrigation and then, by alternate furrow irrigation. In terms of water use efficiency, alternative furrow irrigation was much better than the conventional furrow irrigation. Even though equal amount of irrigation water was applied to both alternative furrow irrigation with 100%ETc and conventional furrow irrigation with 50%ETc, the alternative furrow irrigation with 100%ETc gave maximum grain yield. The effects show that DI in soybean is conceivable and indicates the clear benefit of alternate furrow irrigation over conventional furrow irrigation method. Therefore, it can be concluded that, in areas where water is scarce alternative furrow irrigation saves 50% irrigation water in comparison to conventional furrow irrigation method. Hence, additional land could be irrigated with the saved irrigation water in similar water scarce areas. This finding could make certain the possibility of irrigation improvement in the study area and other comparable agro-ecology like the study area.

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