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Evaluation of Different Furrow Irrigation Systems and Water Levels on Potato at Oda Sirba Scheme

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Abstract

Water availability is becoming a critical issue in Ethiopia so that preferable irrigation technologies need to be developed and water productivity of irrigated crops through water management is a vital option in water shortage areas. Hence, the objective of the study was to improve potato tuber production through the application of different irrigation system and deficit irrigation application under highland climatic condition. Field experiment was carried out at farmer field of Oda Sirba scheme for three consecutive years with three furrow irrigation system and one deficit irrigation 80% Evapotranspiration of crop (ETc) and control irrigation 100% ETc replicated three times in a split plot design. Obtained results revealed that, the highest seasonal water requirement value of 497.8 mm was at Conventional furrow irrigation (CFI) with full irrigation application while, the lowest value of 199.2 mm was by Alternative furrow irrigation (AFI) with 80% ETc. The analysis of variance indicated that there was significant ($P \leq 0.05$) difference obtained for yield and water use efficiency (WUE) of potato tuber. The highest yield of 36.12 t ha^{-1} was obtained from control treatment with CFI while FFI at deficit application had the lowest yield of 26.3 t ha^{-1}. The nearest yield of 34.22 t ha^{-1} was obtained by AFI method with full irrigation application. Higher WUE was observed at AFI method at a control treatment and higher than at 80% ETc but there is no significant variation between them. Applied water in AFI was reduced by 50%. AFI at full irrigation application appears to be a hopeful alternative technology with negligible reduction in yield.

Keywords

Water level, Alternate furrow irrigation, Conventional furrow irrigation, Fixed furrow irrigation, Water use efficiency

Introduction

In Ethiopian irrigated agriculture traditional and small-scale irrigations cover the lions share [1] where the main sources of water for irrigation are diversion from rivers, spring development, and surface reservoirs, whereas the common method of water application for irrigation is furrow irrigation [2].

The challenge that Ethiopia faces in terms of food insecurity is associated with both inadequate food production even during good rain years (a problem related to inability to cope with growth of population) and natural failures due to erratic rainfall. Therefore, increasing arable land or attempting to increase agricultural yield by, for instance, growing higher yielding varieties of crops offers limited scope to provide food security in Ethiopia [3].

Farmers in the country seem to have awareness about the benefits of irrigation and proven ability to organize themselves to manage small scale irrigation systems. However, it lacks scientific management; they either over or under irrigate their fields [4]. One of the irrigation management practices which could result in water saving is through deficit irrigation [5].

Irrigating with an optional irrigation method of alternate furrows saved water, provided comparable yield, and enhanced water productivity and economic benefit [6]. It has been reported by [7] that 97.8% of irrigation in Ethiopia is done by surface methods of irrigation especially by furrow system in farmer's fields and majority of the commercial farms. Proper furrow irrigation practices can minimize water application and irrigation costs, save water, control soil salinity build up and result in higher crop yields [8].

Alternate furrow irrigation (AFI) method with appropriate irrigation interval is suitable irrigation method; for humid climate where soil is dominated by clay soil and water is liming factor for potato crop production [9] and alternate furrow

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irrigation with full irrigation application increases water use efficiency and can solve a problem of water shortage [10].

Alternate furrow irrigation is the innovation that involves irrigating only one part of the root of the crop in each irrigation event, leaving another part to dry to certain soil water content before rewetting by shifting irrigation to the dry side and also improve storage and application efficiency [11].

Deficit irrigation is an optimization strategy in which irrigation is applied during drought-sensitive growth stages of a crop. Outside these periods, irrigation is limited or even unnecessary if rainfall provides a minimum supply of water [12].

Potato (*Solanum tuberosum L.*) is the world's most important root and tuber crop worldwide. It is grown in more than 125 countries and consumed almost daily by more than a billion people. Hundreds of millions of people in developing countries depend on potatoes for their survival [13].

Material and Methods

Field experiment was carried out at Bekoji Negeso during the dry cropping season for three consecutive years. The experimental site (7°53'N, 39°25'E, 2780 meters above sea level) located in the Arsi Zone. The long-term average annual rainfall at Bekoji is 1098 mm, 62% of which falls between the months of June and October, and the mean maximum and minimum temperature are 19 °C and 6.8 °C respectively (Figure 1).

Analysis of sampled soil

Representative composite soil samples were collected from (0-15, 16-30, 31-60) cm soil depths for Textural, FC, PWP, ECe, pH, Organic Carbon and OM analysis. Bulk density of the field was determined from undisturbed soil samples using core sampler. Samples were oven dried for 24 hours at temperature of 105 °C to obtain dry soil sample. Hence, the bulk density (BD) was computed following Eq. (1).

$$BD\left(\frac{g}{cc}\right) = \frac{weight\ of\ dry\ soil\,(g)}{volume\ of\ core\ sampler\,(cm^3)} \quad (1)$$

Experimental treatment and design

Field experiment was conducted for three consecutive years to evaluate the effect of irrigation methods and irrigation levels on yield and water productivity of potato. The experimental field was separated into 18 plots of 5 m by 5 m to accommodate a plot having seven ridges and eight furrows and representing a single treatment. The plots and replications had a buffer zone of 1.5 m and 3 m length respectively from each other to eliminate influence of lateral flow of water. The crop was established at a plant and row spacing of 30 cm and 83 cm respectively. The experimental treatments include

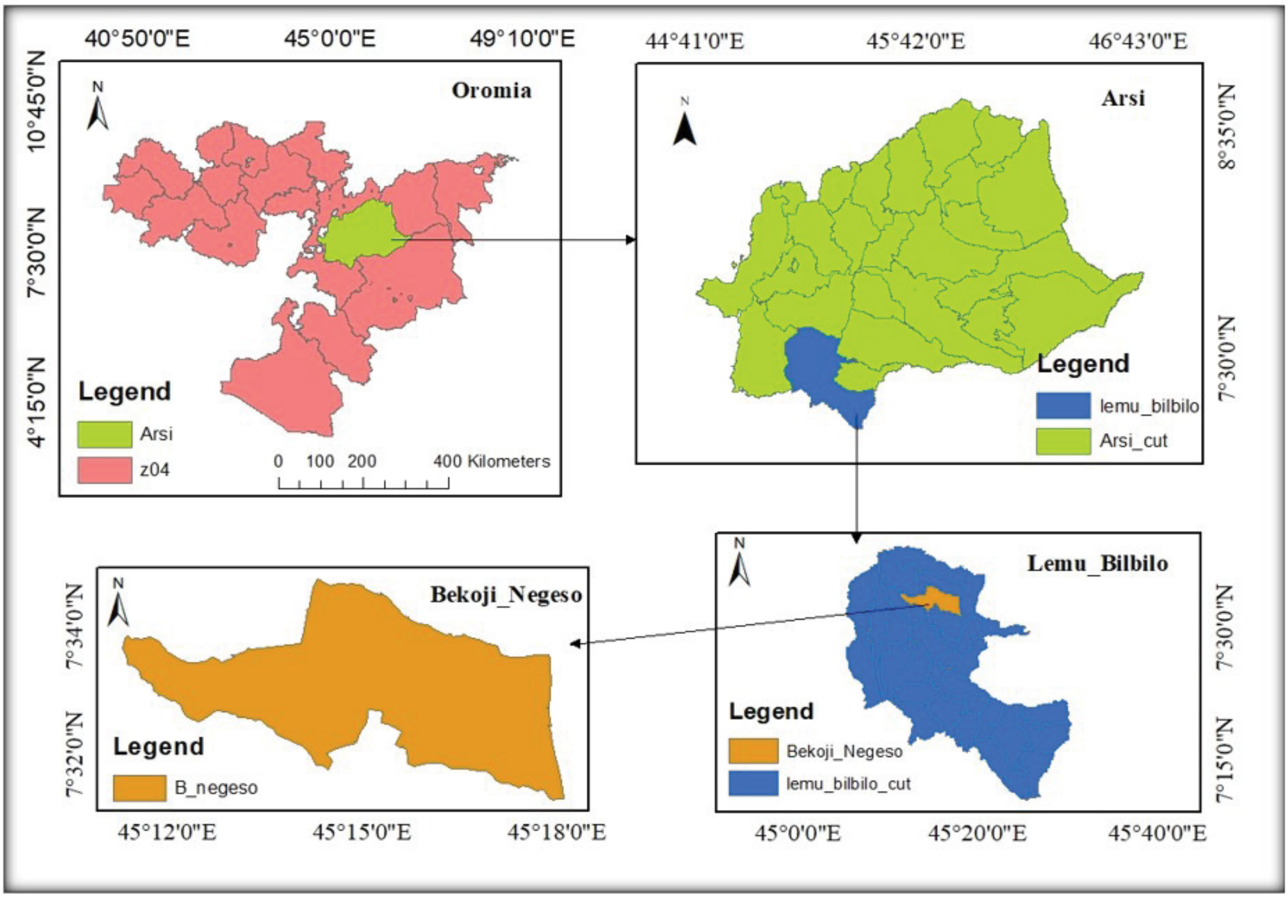

Figure 1: Map of the study area.

three irrigation systems, viz., the Alternate furrow irrigation (AFI), fixed furrow irrigation (FFI), conventional furrow irrigation (CFI) and one deficit irrigation application levels, viz., 80% ETc, and a control irrigation of 100% ETc application. The experimental design was a split plot design with three replications. The irrigation system was used as main plots and irrigation water levels as sub-plots (Table 1).

Crop water requirements and irrigation water management

Crop water requirement: Reference evapotranspiration, ETo was estimated using FAO Penman-Monteith equation from long term meteorological data collected from Meraro meteorological station with the help of CROPWAT 8.0 model software. Seasonal crop water requirements, ETc was estimated by multiplying long term ETo value with the established Kc value (Eq. 2).

$$ETc = ETo \ x \ Kc \quad (2)$$

where, ETc is Crop evapotranspiration (mm/day); ETo is Reference crop evapotranspiration (mm/day), and Kc is Crop coefficient (fraction).

Kc [14] for potato crop under Bokoji climatic condition which is considered as semi-humid used was as shown in Table 2.

Irrigation water management: Soil moisture level in all plots was brought to field capacity for each treatment in the last irrigation during the common irrigation time. Soil water availability in the experiment was tested from routine measurements of soil moisture content by the gravimetric method.

The wet soil samples were weighed and placed in an oven dry at a temperature of 105 °C and dried for 24 hours. The gravimetric water content was converted to equivalent depth (D) from Eq. (3).

$$D = \frac{Ww - Wd}{Wd} \ x \ BD \ x \ drz \quad (3)$$

Where, D is the depth of available soil moisture (mm); Ww is wet soil weight (gm); Wd is dry soil weight (gm); BD is the soil dry bulk density (gm cm^{-3}) and drz is the sampling depth within the crop root depth (mm).

The soil moisture depleted between irrigation was obtained from Eq. (4).

$$IRn = (FC - D) \quad (4)$$

Where, IRn is net irrigation requirement (mm), and FC is soil moisture content at field capacity (mm).

Irrigation scheduling: Total available water (TAW) was computed from the moisture content of field capacity and permanent wilting point using the following Eq. (5).

$$TAW = (FC - PWP) \ x \ BD \ x \ Dz \quad (5)$$

where, TAW is the total available water in the root zone (mm), FC and PWP are moisture content at field capacity and permanent wilting point (%) on weight basis respectively and Dz is the root zone depth of potato at times of each irrigation. For maximum crop production, irrigation schedule was fixed based on p-value. The p for potato that was used in this study was 35% of TAW (p = 0.35) [15].

Hence, RAW was computed from the Eq. (6).

$$RAW = TAW \times p \quad (6)$$

Where, RAW is the readily available water or net irrigation depth, IRn (mm), p is allowable permissible soil moisture depletion fraction and TAW is total available water in the root depth (mm).

Hence, the IRn of irrigation was computed from Eq. (7).

$$IRn = TAW * P \quad (7)$$

Where, IRn is net irrigation requirement (mm), and p. is depletion fraction.

Irrigation interval, f, was estimated using the following Eq. (8).

$$f = \frac{IRn}{ETc} \quad (8)$$

Where, f is irrigation interval (day) and ETc is mean daily crop water requirement (mm day^{-1})

Whenever there is rainfall between irrigation, the IRn could be obtained from the Eq. (9).

$$IRn = ETc - P_{eff} \quad (9)$$

Where, P_{eff} is effective rainfall (mm)

The effective rainfall, P_{eff} was estimated using the method given by [15] as,

$$P_{eff} = 0.6 \times P - \frac{10}{30/31} \ for \ month \leq \frac{70}{30/31} mm \quad (10)$$

Table 1: Treatment combination.

Irrigation systems	Irrigation Level (sub-plot)	
(Main-plot)	100% ETc	80% ETc
Alternative furrow irrigation	T_1	T_2
Fixed furrow irrigation	T_3	T_4
Conventional furrow irrigation	T_5	T_6

Table 2: Potato growth stage and crop coefficient (Kc) under Bokoji climatic condition.

Growth stage	Initial	Development	Mid	Late
Development day	20	40	40	20
Kc value	0.43	0.73	1.1	0.88
Root depth (m)	0.30 - 0.42	0.43 - 0.60	0.6	0.6

$$Peff = 0.8 \times P - \frac{24}{30/31} for\ month > \frac{70}{30/31} mm \quad (11)$$

Where, P is daily rainfall (mm)

Field application efficiency and gross irrigation water requirement

Field irrigation application efficiency (Ea) is the ratio of water directly available in crop root zone to water received at the field inlet. Furrow irrigation could reach a field application efficiency of 70% when it is properly designed, constructed and managed. The average ranges vary from 50 to 70%. However, a more common value is 60% [16]. For this particular experiment, irrigation efficiency was taken as 60%, which is common for surface irrigation method in furrow irrigation. Based on the net irrigation depth and irrigation application efficiency, the gross irrigation water requirement was calculated based on eq. (12).

$$IRg = \frac{IRn}{Ea} \quad (12)$$

Where, IR_g the gross irrigation requirement (mm) and E_a is the field application efficiency (%).

Discharge measurement of parshall flume

Time required to irrigate each treatment was calculated from the ratio of volume of applied water to the discharge-head relation of 3-inch PF. Since discharge level might vary at field condition, time required was calculated from 5 to 15 cm head levels eq. (13).

$$t = \frac{A \times dgross}{Q} \quad (13)$$

Where: dg-gross depth (mm), t-application time (sec), A-plot Area (m^2) and Q-discharge (l/s)

Data collection

The sample locations were selected systematically in the central ridges randomly (4 m × 4.15 m). Yield data were collected from plants of net plot area (16.6 m^2). The collected parameters were marketable tuber yield (t ha^{-1}), unmarketable tuber yield (t ha^{-1}), total tuber yield (t ha^{-1}) and water productivity (Kg m^{-3}).

Marketable tuber yield (t ha^{-1}): - was done by weighing all the tubers per net plot area.

Total tuber yield (t ha^{-1}): - sum of the weights of marketable and unmarketable tubers from the net plot area and transformed into ton per hectare.

Water productivity (kg m^{-3})

The yield of potato (bulb yield per hectare) to the net irrigation depth plus effective rainfall used from establishment to harvest expressed as (kg) of bulb yield per (m^3) of water. It was calculated based on eq. (14)

$$WP = \frac{Ya}{Tw} \quad (14)$$

Where, WP-Water productivity (kg/m^3), Ya-Total tuber yield (kg/ha), Tw-Total water used (m^3/ha)

Economic water productivity

It was begun by considering the general relationship between the crop water use and crop yield per hectare of land at different irrigation application levels using the partial budget analysis. For economic evaluation of the total return, net benefit, marginal return rate and cost benefit ratio using the different amount of water applied, the Partial Budget Analysis (PBA) was used following the CIMMYT procedure [17].

According to (CIMMYT 1988), the average yield was adjusted down wards by 10%. The gross returns were computed by multiplying average market rate with the yield of respective treatments during the crop harvesting period. The variable costs of this experiment among treatments were cost of irrigation water and costs of labor for irrigating. The field price of potato during the harvesting season was 12 Birr kg^{-1}. The net revenue was calculated by subtracting total variable cost production from total return using eq. (15).

$$NI = TR - TVC \quad (15)$$

Where: NI-Net income, TR-Total income from sales, TVC-Total variable cost spent during production.

The marginal return rate is computed as using eq. (16)

$$MRR = \frac{\Delta NI}{\Delta VC} \quad (16)$$

Where: MRR-Marginal rate of return (%), ΔNI-change in net income, ΔVC-change in variable cost

Statistical analysis

Collected data were analyzed using R-software statistical package using procedure of general linear model for the variance analysis. Mean comparisons were executed using LSD at 5% probability level when treatments show significant difference to compare difference among treatments mean.

Result and Discussion

Analyses of soil sample

Physical properties of soil: The laboratory results of the average soil physical properties of the experimental site were presented in Table 3 below.

The average result of physical properties from the experimental site showed that the composition of sand, silt and clay percentage were 27.56%, 29.78% and 42.67% respectively. Thus, according to USDA Soil textural classification, the soil is classified as Clay.

The weighted average bulk density of the experimental site was 1.05 g/cm^3. High value of TAW (188.00 mm/m) was found in subsurface soil, whereas lower values (178.00 mm/m) were found in the topsoil (Table 3). The average value of TAW was 181.67 mm/m [18].

Chemical properties of soil: The average pH value of the experimental site through the analyzed soil profile was

Table 3: Average soil physical properties of experimental site.

Depth	Bulk density (g/cc)	FC (%)	PWP (%)	TAW	TAW	Texture			
(cm)		(V/V)	(V/V)	(mm/m)	(mm)	% Sand	% Silt	% Clay	Class
0-15	0.95	37.3	19.5	178	26.7	27.33	28	44.67	Clay
16-30	1.07	37.6	19.7	179	26.85	29.33	31.33	39.33	Clay
31-60	1.14	39	20.2	188	56.4	26	30	44	Clay
Aver.	1.05	37.97	19.8	181.67	36.65	27.56	29.78	42.67	Clay

FC: Field Capacity; PWP: Permanent Wilting Point; TAW: Total Available Water

Table 4: Average chemical properties of soil at the experimental site.

Depth (cm)	pH	Total organic matter (% OM)	Total organic carbon (% OC)	ECe (ds/m)
0-15	5.27	3.15	1.83	0.1
16-30	5.13	3.19	1.85	0.12
31-60	5.13	3.24	1.88	0.09
Aver.	5.18	3.2	1.85	0.1

Table 5: Water applied per growth stage and percent of water saved from each treatment.

Treatment	Growth stage				IRg (mm)	Water saved (%)
	Initial	Development	Mid	Late		
AFI 100% ETc	27	40.6	124.95	56.35	248.9	50
AFI 80% ETc	21.6	32.48	99.96	45.08	199.12	60
FFI 100% ETc	27	40.6	124.95	56.35	248.9	50
FFI 80% ETc	21.6	32.48	99.96	45.08	199.12	60
CFI 100% ETc	54	81.2	249.9	112.7	497.8	0
CFI 80% ETc	43.2	64.96	199.92	90.16	398.24	20

AFI: Alternate Furrow Irrigation; FFI: Fixed Furrow Irrigation; CFI: Conventional Furrow Irrigation

found to be in recommended range with average value of 5.18% (Table 4). OM and OC content had an average value of 3.20%, 1.85% respectively over 60 cm depth of soil profile. An average electrical conductivity of the experimental soil is 0.10 ds/m. Soils that had ECe < 2 (ds/m) was non saline [19].

Irrigation water applied of potato tuber throughout the growth stages

From (Table 5) water saved from treatment combination of AFI and FFI with 100% ETc, and 80% ETc levels were 50%, and 60% of total net volume of irrigation water applied respectively. Whereas CFI with 80% obtained was 20.0%. According to [20] comparative report of full irrigation with partial root drying for field grown potato, partial root drying treatments saves 30% of water which increases water use efficiency of the crop. The optimum seasonal irrigation requirement was found to be 497.8 mm for every furrow irrigation method. For AFI and FFI, 248.9 mm of water was needed throughout the growing season of potato tuber (Table 5).

Effect of irrigation methods and irrigation water levels on yield of potato tuber

Crop yield collected from each treatment was further differentiated to total yield, marketable yield and unmarketable yields.

Marketable tuber yield (t ha^{-1}): ANOVA (Table 6) resulted that marketable tuber was significantly ($P < 0.05$) affected by irrigation methods (IMs) and irrigation levels (IL). The largest mean value of yield 31.51 t ha^{-1} was produced under CFI, but statistically the yield recorded by AFI and FFI were not significantly different. Accordingly marketable tuber yield was influenced by Irrigation application levels; the average potato yield perceived by 100% ETc was 30.37 t ha^{-1} and 23.32 t ha^{-1} under 80% ETc.

Total tuber yield (t ha^{-1}): From (Table 6) total tuber yield was significantly ($P < 0.05$) affected by irrigation methods (IMs) and irrigation levels (IL). The largest mean value of 33.49 t ha^{-1} was produced by CFI, and the total yield of AFI and FFI were significantly different ($P < 0.05$). Total tuber yield recorded for AFI and FFI were (30.51 t ha^{-1} and 29.00 t ha^{-1}) respectively. It was nearly the same in both (AFI and FFI). Accordingly, the yield was influenced by irrigation application levels; the average yield obtained by 100% ETc was 34.01 t ha^{-1} and 29.26 t ha^{-1} by 80% ETc irrigation level.

[21] found no difference in potato tuber yield between

(100% ETc) and (70% of water applied to full irrigation from tuber initiation to maturity) in a field experiment, which suggest that partial root zone drying could be an effective strategy to improve water productivity while sustaining yields provided partial root zone drying is optimized [22].

Combined effect of irrigation methods and irrigation water levels on tuber yield

From (Table 7) the interaction data of marketable yield and total tuber yield had significant effect (P < 0.05) due to Irrigation method (IM) and irrigation level (IL) and water use efficiency was not significantly affected.

Total potato tuber yield (t ha^{-1}): As shown from the result (Table 7), the difference observed among irrigation methods as combined with irrigation levels in terms of total tuber yield was statically significant (P < 0.05) effect. However, total tuber yield was nearly the same in both CFI and AFI irrigation methods at full irrigation application (100% ETc); whereas total depth of water applied under every furrow irrigation was almost double as compared with that of applied under alternate furrow irrigation. The maximum tuber yield was 36.12 t/ha at 100% ETc irrigation application under CFI. The nearest yield of 34.22 t ha^{-1} was obtained by AFI method at full irrigation application. Alternate furrow irrigation method produced total tuber yield of 33198 kg/ha which showed insignificant difference as compared with that obtained under every furrow irrigation (33369 kg/ha) (Figure 2) [23].

Therefore, by implementing alternative furrow irrigation technique at full irrigation level, the same tuber yield was obtained comparing with conventional furrow irrigation method. This result agreed with outcome obtained by [24] that alternate furrow irrigation can increase water productivity with no or minor yield loss.

Even though, fixed furrow irrigation method saves water it is not appropriate method to meet crop water requirement as per growth stage of the crop and yield was reduced significantly. The minimum tuber (26.30) t ha^{-1} was recorded at FFI method with 80% ETc irrigation level. This result agrees

Table 6: Effect of Irrigation method and Irrigation level on potato yield and WUE.

Irrigation Method (IM)	MY (t/ha)	TY (t/ha)	WP (kg/m)
AFI	24.84^{b}	30.5^{b}	13.6^{a}
FFI	24.18^{b}	29.00^{c}	12.97^{b}
CFI	31.51^{a}	33.49^{a}	7.98^{c}
S.Em ±	0.46	0.17	0.05
CV	2.97	0.93	0.77
LSD (5%)	1.81	0.67	0.2
Irrigation Level (IL)			
100% ETc	30.37^{a}	34.01^{a}	11.25^{a}
80% ETc	23.32^{b}	29.26^{b}	11.79^{a}
S.Em ±	0.26	0.22	0.11
CV	1.68	1.22	1.59
LSD (5%)	1.58	1.35	0.35

Means followed by the same letter (or letters) do not have significant difference at 5% level of probability.

Table 7: Interaction effect of Irrigation Systems and Irrigation Level on potato yield.

Interaction (IS × IL)	MY (t/ha)	TY (t/ha)	WUE (kg/m)
AFI × 100% ETc	30.01^{b}	34.22^{b}	13.75^{a}
AFI × 80% ETc	19.67^{d}	26.80^{d}	13.46^{ab}
FFI × 100% ETc	27.68^{c}	31.69^{c}	12.73^{c}
FFI × 80% ETc	20.68^{d}	26.30^{d}	13.21^{bc}
CFI × 100% ETc	33.41^{a}	36.12^{a}	7.2^{e}
CFI × 80% ETc	29.61^{bc}	34.69^{ab}	8.71^{d}
S. Em ±	0.47	0.44	0.18
CV	3.06	2.4	2.72
LSD (5%)	2.14	1.26	0.49

MY: Marketable Yield; TY: Total Yield; WP: Water use efficiency; CV: Coefficient of Variation; LSD: Least Significant Difference; S. Em: Standard Error of mean

Means followed by the same letter (or letters) do not have significant difference at 5% level of probability.

Figure 2: Potato tuber at planting and maturity stage.

with outcome obtained by [25] in concluding that improper irrigation depth and frequency can substantially reduce yields by increasing the proportion of rough, distorted tubers.

Effect of irrigation methods and irrigation water levels on water productivity

Decreasing irrigation water application results in an increase in crop water productivity and the reverse is also true.

Table 6 showed that WP had significant ($P < 0.05$) difference due to irrigation methods (IMs) and not significantly affected by irrigation levels (IL). The largest mean value of 13.61 kg m^{-3} was recorded by AFI, and also that of FFI and CFI were (12.97 and 7.50) kg m^{-3} respectively. Water productivity was nearly the same in both AFI and FFI due to less irrigation water application. The result indicated that higher yield treatments had low water use efficiencies.

Water productivity was not significantly affected by the combination of irrigation methods (IM) and Irrigation levels (IL). The highest mean value of WUE (13.75 kgm^{-3}) was recorded at AFI with full irrigation application and the minimum mean value 7.26 kgm^{-3} was obtained under CFI with full irrigation application (Table 7). The highest mean irrigation production efficiency of 15.67 kg/m^3 is recorded when crop growing season is applied at 50% of irrigation schedule, because yield reduction is less as compared with seasonal water applied.

Water productivity obtained between AFI and FFI was statistically non-significant. The same amount of irrigation water was applied for alternate furrow and fixed furrow irrigation techniques. However, alternative drying of root zone under alternate furrow irrigation method showed higher water productivity than fixed drying of root zone under fixed furrow irrigation method. This is due to uniform water distribution between ridges in alternate furrow than fixed furrow irrigation. Uniform water distribution between ridges in alternate furrow irrigation method enhanced root growth and improved nutrient uptake of crop which increases the yield than fixed furrow irrigation method.

Water supply-yield relationship

Water supply-yield relationship is also known as water production function shows that, increasing the amount of irrigation level, yield production function also increased (Figure 3). The slope of the regression line ($R^2 = 1$) indicates that the increment of irrigation water level increases tuber yield. Large application of irrigation water for CFI increase yield as compared with other method but consumes large water.

Crop yield and water use efficiency can be increased if sufficient amount of water is added and also as the type of furrow method varies the yield and water production also varies. Alternate furrow irrigation gives optimum yield and water production at full irrigation application.

As indicated in Table 8, the result showed that the minimum yield reduction 3.96% was from CFI 80% ETc. However, it consumes large amount of water. AFI × 100% ETc result in yield reduction of 5.26% correspondingly saves 50% water from the required amount of gross irrigation. Accordingly, additional area able to be irrigated with saved water. It is clearly seen that value of the net yield generated was not influenced only by water applied but also furrow irrigation methods. The volume of water needed to irrigate one hectare area in CFI system is enough to irrigate two hectares area of land in AFI system. So, when the area to be irrigated becomes double in AFI system using the saved volume of water, the yield obtained also becomes double.

Economic water productivity

The field price of potato during the harvesting season 12 Birr kg^{-1} and 3.8 Birr m^{-3} value for water were taken [26].

The detail evaluation of the economic analysis of

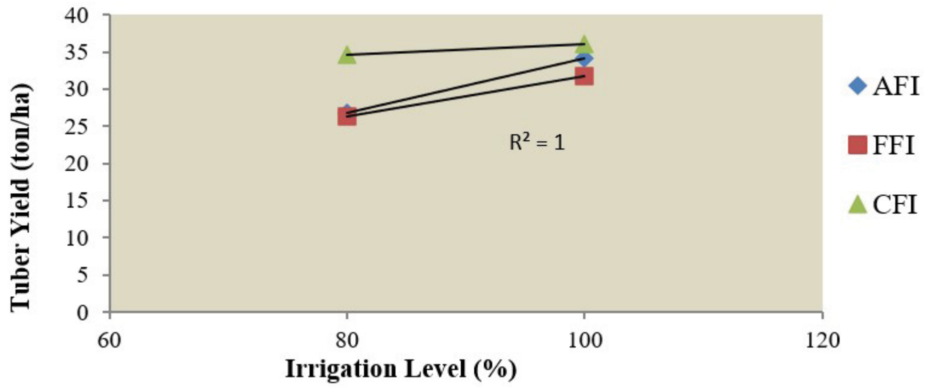

Figure 3: Irrigation water level versus Potato tuber yield.

Table 8: Extent of saved water and yield reduction.

Treatment	Total Yield (tha^{-1})	Yield Reduction (%)	GIrr (mm)	water saved (mm)	Water saved (%)
AFI × 100% ETc	34.22	5.26	248.9	248.9	50
AFI × 80% ETc	26.8	25.8	199.12	298.68	60
FFI × 100% ETc	31.69	12.26	248.9	248.9	50
FFI × 80% ETc	26.3	27.19	199.12	298.68	60
CFI × 100% ETc	36.12	-	497.8	-	-
CFI × 80% ETc	34.69	3.96	398.24	99.56	20

Table 9: Partial budgeting MRR and B/C analysis for economic potato production.

Treatments	TC (ETB/ha)	UTY (kg/ha)	ATY (kg/ha)	GB (ETB/ha)	NB (ETB/ha)	B/C	MRR (%)
T_1	7,565.66	34,220	30,798	3,69,576	3,62,010.34	47.85	
T_2	6,052.53	26,800	24,120	2,89,440	2,83,387.47	46.82	5,196.03
T_3	7,565.66	31,690	28,521	3,42,252	3,34,686.34	44.24	3,390.24
T_4	6,052.53	26,300	23,670	2,84,040	2,77,987.47	45.93	3,747.12
T_5	15,131.33	36,120	32,508	3,90,096	3,74,964.67	24.78	1,068.17
T_6	12,105.06	34,690	31,221	3,74,652	3,62,546.94	29.95	410.33

TC: Total Cost; UTY: Unadjusted Total Yield; ATY: Adjusted Total Yield; GB: Gross Benefit; NB: Net Benefit; B/C: Benefit Cost ratio; and MRR: Marginal Return of Rate

treatments has shown that there was increasing trend of net benefit (NB) for increase in water application level (Table 9). It is clear that water saving at high application level is very low, though CFI treatment (T_5) has the highest NB.

The highest MRR was 5.196.03% obtained at T_2. This means that for every 3.8 birr invested on applied water of 199.12 mm, farmers can expect to recover 3.8 birr and obtained additional of 51.96 birr. This shows that T_2 can be the most preferable type of irrigation treatment to all other tested irrigation treatments as it can generate more profit per extra addition investment in water limited areas. The highest B/C ratio (47.85, and 46.82) was obtained from T_1 and T_2 respectively (Table 9). This result generally revealed that AFI gave high net income as compared to the other furrow methods for furrow irrigated total tuber yield of potato.

Conclusion and Recommendation

Conclusion

AFI and FFI save 50% of water. In alternative furrow irrigation method, the minimum mean tuber yield reduction was happened. In fact, this yield reduction was not statistically significant with CFI treatments. Even though, the highest yield was obtained at CFI at full irrigation application it consumes large amount of water. Using irrigation water at 100% ETc with AFI, can solve problem of water shortage which improve water productivity without significant reduction of yield. AFI system at full irrigation application appears to be a promising technology for utilization of irrigation with negligible reduction in yield.

Recommendation

Based on the findings obtained from the experiment, the following recommendations are made

- Irrigation water management through deficit irrigation strategies should be declared with appropriate irrigation level restriction during growth stages to achieve optimum yield and save water.
- Suggestion of practicing irrigation with different irrigation method save irrigation water and it increases frequency of cultivation, additional command area to be irrigated or use for other purpose of income generation.
- Thus, it is recommended that all possible efforts be made to introduce the technology to the farming community since the use of AFI method saves reasonable amount of water without affecting the production in moisture deficit areas. Nonetheless, further studies should be made to identify potentially suitable crops for these three furrow irrigation methods.

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