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Evaluation of Deficit Irrigation Effect on Water Use Efficiency and Yield Response for Onion and Potato at Ketar Scheme

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Abstract: In the situation of improving water productivity, there is increasing interest in deficit irrigation practice whereby water supply is reduced below maximum levels and mild stress is allowed with minimal effects on yield. For this authorize, the study was conducted during the dry season for three years from December 2017 to May 2019 to study the effect of deficit on application efficacy, storage efficiency, distribution uniformity and irrigation water use efficiency of potato and onion. The deficit water level used were 75 and 50% CWR lined with full irrigation 100%. From the result, average of application efficiency (Ea), storage efficiency (Es) and distribution uniformity (DU) of the three water levels (100%, 75% and 50%) were 60.97%, 70.27%, 75.4%, 55.45%, 62.84%, 88.68%, 88.24%, 87.61% and 89.89% for potato and 60.06%, 70.81%, 85.64%, 65.03%, 60.24%, 66.02%, 88.49%, 87.89% and 86.24% for onion respectively. The highest Ky of 0.98 and 0.85 was attained at 50% CWR for potato and onion respectively and the lowest was 100% CWR for both crops. This show the highest yield reduction was registered under 50% CWR. The application efficiency, storage efficiency, distribution uniformity and yield response of 75% CWR is slightly low from full irrigation water level. So it is recommended to use 75% CWR for both crops in saving water as it has low yield reduction. Therefore, to implement deficit irrigation on farm participatory training should be given for application of right amount of water.

Keywords: Deficit, Potato, Onion, Efficiency, Yield Response

1. Introduction

Food production and water use are inextricably linked. Water has always been the main factor limiting crop production in much of the world where rainfall is insufficient to meet crop demand. With the ever increasing competition for finite water resources worldwide and the steadily rising demand for agricultural commodities, the call to improve the efficiency and productivity of water use for crop production, to ensure future food security and address the uncertainties associated with climate change, has never been more urgent [7].

The pressure on agriculture is increasing due to population growth thereby creating a need to improve agricultural production and productivity. Water has been identified as one of the scarcest inputs, which can severely restrict agricultural production and productivity unless it is carefully conserved and managed. There is a growing recognition that increases in food production will largely have to originate from improved productivity per unit water and soil [6, 13].

The increase in water demand has resulted in new methods of saving water worldwide with about 70% of water being used in agriculture globally; water saving techniques has to be practiced. Irrigation technologies and irrigation scheduling may be adopted for more effective and rational uses of limited supplies of water. Deficit irrigation is one of the methods designed to ensure the optimal use of allocated water. It maximizes water use efficiency for better yields per unit of irrigation water applied through; exposing the crops to a certain level of water stress either during a particular period or throughout the growing season [14].

At present and more so in the future, irrigated agriculture will take place under water scarcity. Insufficient water supply for irrigation will be the norm rather than the exception, and irrigation management will shift from emphasizing production per unit area towards maximizing the production per unit of water consumed, the water productivity. To cope with scarce supplies, deficit irrigation, defined as the application of water below full crop-water requirements (evapotranspiration), is an important tool to achieve the goal of reducing irrigation water use. While deficit irrigation is widely practiced over millions of hectares for a number of reasons from inadequate network design to excessive irrigation expansion relative to catchment supplies it has not received sufficient attention in research.

In order to ensure successful deficit irrigation, it is necessary to consider the water retention capacity of the soil. In sandy soils plants may undergo water stress quickly under deficit irrigation, whereas plants in deep soils of fine texture may have ample time to adjust to low soil water matric pressure, and may remain unaffected by low soil water content. Therefore, success with deficit irrigation is more probable in finely textured soils [5].

Deficit irrigation has been suggested as an alternative strategy for making better use of irrigation water. Deficit irrigation provides a means of reducing water consumption while minimizing adverse effects on yield. In this method, the crop is exposed to a certain level of water deficit either during a particular period or throughout the whole growing season [4].

Deficit irrigation has been practiced in different parts of the world [2]. Deficit irrigation is a strategy which allows a crop to sustain some degree of water deficit in order to reduce irrigation costs and potentially increase revenues. English and Raja described three deficit irrigation case studies in which the reductions in irrigation costs were greater than the reductions in revenue due to reduced yields. Deficit irrigation can lead, in principle, to increased profits where water costs are high or where water supplies are limited. In these case studies, crop value was associated closely with yield, and crop grade and marketability were not germane.

The main objective of deficit irrigation is to increase the water use efficiency of a crop by eliminating irrigations that have little impact on yield. The resulting yield reduction may be small compared with the benefits gained through diverting the saved water to irrigate other crops for which water would normally be insufficient under traditional irrigation practices [5]. Therefor to overcome irrigation water shortage and increase water use efficiency, this study was conducted with the objectives of determining water use efficiency and yield response of potato and onion on three water levels under furrow irrigation.

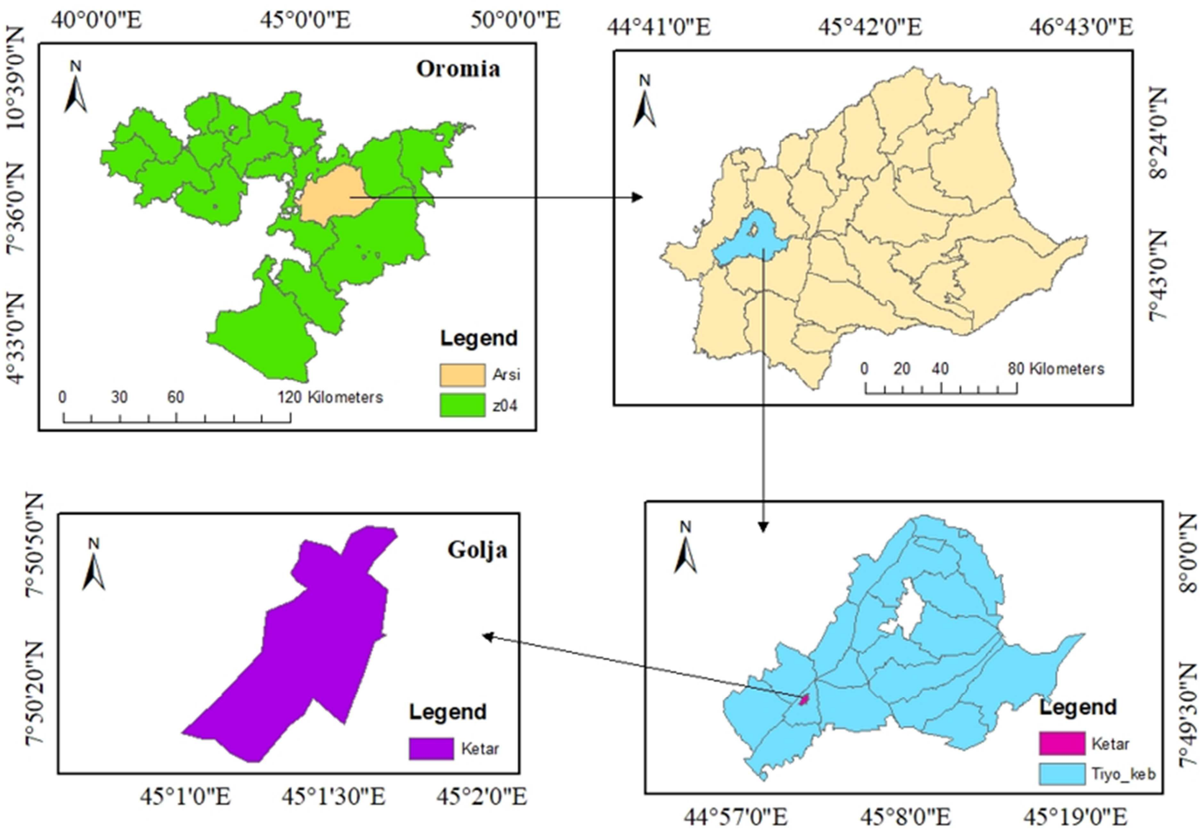

Figure 1. *Map of study area.*

2. Materials and Methods

2.1. Description of the Study Area

The study was conducted at Tiyo woreda, Arsi zone during dry season (December 2017 to May 2019) on Ketar irrigation scheme. The district is located at longitude and latitude of 7° 46’ 30" - 7° 54’ 0" N and 38° 55’ 30"-39° 4’ 30" E. The scheme was designed to irrigate around 430 ha of land, has discharge of 800 litir/s and was recommended as it can irrigate 795 ha if canal is lined (reduction of conveyance loss) and reduced over irrigation (deep percolation and tail water runoff loss) [3].

The climate of the area is generally warm and temperate. The average annual temperature is 13.8°C at an average 15.1°C, April is the hottest month of the year at an average 12.7°C and december is the coldest month of the year. The rainfall here is 1118 mm. Precipitation is the lowest in December, with an average of 12 mm. In July, the precipitation reaches its peak, with an average of 187 mm. The woreda has an altitude of 2430m above sea level (a.s.l) [18].

2.2. Experimental Design and Treatments

The crops used for this experiment were potato and onion. For each crop experiment was done individually and the experiment was arranged in Randomized Complete Block Design (RCBD) with three replications. The treatments considered for the experiments were three irrigation water levels which are 100%, 75% and 50% CWR. The experiment was conducted on individual plot size of 5 m x 5 m (25 m^2) with 9 number of such plot for each crops. The spacing between the blocks and plots were kept as 2 m and 1.5 m respectively.

2.3. Soil Data

For soil texture, organic matter, pH and EC, disturbed soil samples were used and undisturbed soil for bulk density, moisture content at field capacity (FC) and permanent wilting point (PWP). Undisturbed soil samples were collected by core sampler and disturbed was by auger from two depths 0-30cm and 30-60cm at three points diagonally of the experimental sites and was taken to laboratory for analysis.

For textural analysis of the soil hydrometer method was used for analyzing particle size distribution and USDA textural triangle was used to identify the textural class. The organic matter content of the soil was determined by titration method. The soil was oxidized under standardized condition with potassium dichromate in sulphuric acid to determine the carbon content. The status of organic matter content was obtained by multiplying carbon content with 1.724 [16].

The soil bulk density was analyzed after oven drying the samples for 24 hours at 105°C and weighed for calculating dry density as given by [12].

$$\rho_b = \frac{M_s}{V_t} \tag{1}$$

Where: ρ_b = soil bulk density (gm/cm^3)

M_s=mass of dry soil (gm) and

V_t=total volume of soil in the core sampler (cm^3)

Soil pH was determined by using water suspension with soil to water ratio 1:2.5 by PH meter. EC was determined by method of water suspension with soil to water ratio 1:2.5 by electro conductivity meter.

The soil moisture content at field capacity (FC) and permanent wilting point (PWP) was determined after soil samples were saturated for one day (24 hrs) using the pressure plate apparatus. Field capacity was determined by exerting a pressure of 0.33 bars and permanent wilting point was determined by exerting a pressure of 15 bars until no change in moisture will be observed. The FC and PWP values were further used to determine total available water (TAW). To undertake the test of parameter three soil samples from each plot. Once FC and PWP determined TAW was determined as stated [1]:

$$\text{TAW}=\frac{(FC-PWP)}{100} * \text{BD*D} \tag{2}$$

Where: *TAW*=total available water (mm)

FC=field capacity (% by weight)

PWP=permanent wilting point (% by weight)

D=depth of root zone (mm)

BD=specific density of soil

$$\text{RAW=TAW * MAD} \tag{3}$$

Where: RAW is readily available water and MAD is management allowable depletion normally varies from 0.3 to 0.7 depending on soil type.

2.4. Climatic Data

The minimum and maximum temperature, relative humidity, wind speed and daily sunshine hour 20 years of the study area were collected from Ethiopia National Meteorological Agency to determine mean daily reference evapotranspiration (ETo).

2.5. Crop Water Requirement and Irrigation Water Requirement

CROPWAT version-8 was used and climatic data were fed to calculate the reference evapotranspiration (ET_o) of the study area.

$$ET_c=ET_o \times K_c \tag{4}$$

Where: ET_c=crop evapotranspiration (mm/day)

ET_o=reference crop evapotranspiration (mm/day)

K_c=crop coefficient

Net-irrigation requirement for the crop was determined according to cropping pattern. Total irrigation water requirement for the crop was calculated using net-irrigation requirement of the crop, irrigated areas and irrigation efficiency.

Irrigation interval was calculated as;

$$I = \frac{d_{net}}{ET_c} \quad (5)$$

Where, I=irrigation interval (days)

D_{net}=net-depth of irrigation (mm)

ET_c=daily crop evapotranspiration (mm/day)

The depth of irrigation application is the depth of water that can be stored within the root-zone between the fields capacity and allowable level of the soil water depleted for a given crop, soil and climate. It is equal to the readily available soil water over the irrigate zone. The moisture deficit (d) in the effective root-zone is found out by determining contents at the field capacity and bulk densities of each layers of the soil.

$$d = \sum_{i=1}^{n} \frac{(FC_i - PWP_i)}{100} * \gamma_i * D_i * P \quad (6)$$

Where: FC_i=field capacity of the irrigation water layer on oven dry weight basis (%)

PWP_i=actual moisture content of the water layer on oven dry weight basis (%)

γ_i =apparent specific gravity of the soil of irrigation layer

D_i=depth of the irrigation layer (mm)

P=depletion fraction (%)

n=number of layers in the root zone

2.6. Soil Moisture Determination

For soil moisture determines gravimetric method was used. For this soil before and after irrigation were collected from two soil depths of the field. The samples were taken at 30 and 20 cm depth interval within the effective root zone, which was considered up to 60 cm for potato and 40cm for onion crops. The moisture status of the soil profile for each field was measured before and after each irrigation event. The samples collected from field using manually driven soil auger were placed in the air tight container and weighed prior to placing in an oven dry at 105°C for 24 [17]. The oven dried soil samples with container and cover was weighed again. After the soil moisture sampler collected and oven dried, the moisture was calculated as a percentage of dry weight of the soil sample (W) as

$$W = \frac{M_t - M_s}{M_s} * 100 = \frac{M_w}{M_s} \% * 100 \quad (7)$$

Where: W=weight of soil sample (gm)

M_t=weight of fresh sample (gm)

M_s=weight of over dried sample (gm)

M_w=weight of moisture (gm)

To convert these soil moisture measurements into volumes of water, the volumetric moisture content (θ) was calculated as

$$\theta = \frac{\rho_b * W}{\rho_w} \quad (8)$$

Where: θ =volumetric moisture content (%)

ρ_b = Soil bulk density (gm/cm^3)

W=moisture content on dry weight basis (%)

ρ_w =unit weight of water ($1gm/cm^3$)

2.7. Discharge Measurements at Field

The flow of water into the experimental flow was measured using 3" (3 inch) size parshall flume to be installed at its entrance. Discharge measurement was taken at 2/3A (two-third of length of converging section). Then the flow depth observed on the flume was converted to the corresponding discharge using equation (9) for 3" size parshall flume. Then the total volume of water applied (V_a) was calculated using equation (10) as stated [9] and the total depth of applied water was calculated based on the representative plot.

$$Q = C_f (KH)^{n_f}$$

For 3'' parshall flume, $Q = 0.1771H^{1.550}$ (9)

$$V_a = Q * \Delta t \quad (10)$$

Where: Q=discharge through the flume (l/s)

C_f=discharge coefficient from rated tables

K=unit constant (K=3.28 for H in m)

n_f=flow exponent from the tables

V_a=total volume of water applied (m^3)

Δt =flow time to the field

2.8. Determination of Irrigation Efficiency

2.8.1. Application Efficiency

It is expressed as:

$$E_a = \frac{V_s}{V_f} * 100 \quad (11)$$

Where: E_a=Water application efficiency (%)

V_s=Volume of irrigation water stored in the root zone (m^3/s or ha-m)

V_f=Volume of irrigation water delivered to farm or field (m^3/s or ha-m)

Volume of irrigation water stored in the root zone was determined by calculating available water in the root zone in either volume bases or weight bases by determining soil moisture content before and two days after irrigation by gravimetric or oven dry method for the selected plots. Volume of irrigation water delivered to plot was measured at field by parshall flume.

2.8.2. Distribution Uniformity

The distribution uniformity is more commonly used to characterize the irrigation water distribution over the field in surface irrigation systems. The low-quarter distribution uniformity (D_u) is defined as the average depth infiltrated in the low one-quarter of the field divided by the average depth infiltrated over entire field. It is expressed as:

$$D_u = \frac{D_{lq}}{D_{av}} * 100 \quad (12)$$

Where: D_u=Distribution Uniformity (%)

D_{lq}=Average depth of water infiltrated in the low one-quarter of the field (m)

D_{av}=Average depth of water infiltrated over the field (m)

For computing average depth of water infiltrated over the field, moisture content of the field was measured before and after irrigation and their difference and mean of their difference was calculated. The average depth of water infiltrated in the low one-quarter of the field, moisture content of the field was measured before and after irrigation and their difference was calculated for the least four from descending order and then mean of their difference was computed. From D_{av} and D_{lq} distribution uniformity (Du) was computed for the three plots (by dividing mean of difference of overall sample for mean of difference of least quarter).

2.8.3. Storage Efficiency

Soil water storage efficiency (E_s) is defined as the ratio of the volume of water stored in root to volume of water required filling the root zone to near field capacity and is expressed as

$$E_s = \frac{V_s}{V_{fc} - V_a} * 100 \quad (13)$$

Where: E_s=Soil water storage efficiency (%)

V_s=Volume of water stored in the soil root zones from an irrigation event (m^3/s)

V_{fc}=Volume of water at field capacity in the crop root zone (m^3/s or ha-m)

V_a=Volume of water in soil root zone prior to irrigation event (m^3/s or ha-m)

2.8.4. Water Productivity

The water utilization by crop is generally described in terms of water use efficiency (kg/ha, kg/m3 or q/ha) [11]. Water use efficiency (WUE) and irrigation water use efficiency (IWUE) are determined by dividing the yield to seasonal ET and total seasonal irrigation water (IW) applied [15].

$$WUE = \frac{Y_a}{ET_c} \quad (14)$$

Where: WUE=water use efficiency (kg/m^3)

Y_a=is actual yield (kg/m^2)

ET_c=seasonal crop evapotranspiration (m^3/m^2)

$$IWUE = \frac{Y_a}{IW} \quad (15)$$

Where, IWUE- irrigation water use efficiency (kg/m^3)

Ya=actual yield (kg/m^2)

IW=irrigation water applied (m^3/m^2)

2.8.5. Yield Response Factor of Crops to Deficit

When water supply does not meet the crop water requirements, the ETc will decrease. Under this condition, water stress will develop in the plant, which will adversely affect crop growth and, ultimately, crop yield. To predict the reduction in crop yield when crop stress was caused by a shortage of soil water:

$$(1-\frac{Y_a}{Y_m})=K_y(1-\frac{ET_a}{ET_m}) \quad (16)$$

where; Ya=actual yield (kg/ha); Ym=maximum yield (kg/ ha); ETa=actual evapotranspiration (mm); ETm=maximum evapotranspiration (mm), and Ky=yield response factor.

2.9. Statistical Analysis

The results were analyzed by descriptive statistically using Microsoft excel and compared averages result of parameters.

3. Result and Discussion

3.1. Physico-Chemical Properties of Soil

Table 1 below shows the physico-chemical property of the study area. From this soil pH values were found in range of 5.34-6.03 and have average of 5.49. This indicates moderate acidic soil. Electrical conductivity (EC) of the stations was in range of 0.10-0.32 mmhos/cm at room temperature (25°C). Average organic matter contents (OM) of the experimental site were 3.58. Soil texture class of study area was clay loam. The average values of pH, Electrical conductivity and organic matter were 5.49, 0.16 and 3.58 respectively. According to Classes of salinity and EC (1 dS/m=1 mmhos/cm; as adapted from USDA, soil which has electrical conductivity 0<2 mmhos.cm is non-saline soil.

Table 1. *Soil pH, EC, OMC and texture determination of experimental site.*

Sample No	P^H	EC (mmhos/cm at 25°C)	OC%	OM	Soil texture			
					Sand%	Silt%	Clay%	Class
1	5.47	0.1	1.97	3.4	30	32	38	CL
2	5.34	0.24	2.04	3.52	26	36	38	CL
3	6.03	0.21	2.19	3.77	25	37	38	CL
4	5.39	0.32	1.98	3.41	34	24	42	C
5	5.29	0.12	1.94	3.34	29	35	36	CL

Sample No	P^H	EC (mmhos/cm at 25°C)	OC%	OM	Soil texture			
					Sand%	Silt%	Clay%	Class
6	5.57	0.11	2.15	3.71	30	36	34	CL
7	5.34	0.13	2.23	3.84	32	35	33	CL
8	5.51	0.11	2.13	3.67	36	30	34	CL
9	5.47	0.14	2.09	3.6	34	22	44	C
Average	5.49	0.16	2.08	3.58	31	32	37	CL

CL=Clay loam C=Caly

3.2. Irrigation Water Requirement

Table 2 show the average seasonal irrigation water applied for potato crop. For the three water levels (100, 75 and 50% CWR) the average of seasonal irrigation water applied per plot was 16.55, 12.41 and 8.27 m^3 respectively. From this the average of seasonal irrigation water need per hectare of potato crop for the three water levels (100, 75 and 50% CWR) were 6620, 4963.6 and 3309.2 m^3 respectively. The water saved per hectare using two water level which are (75 and 50% CWR) were 1656.4 and 3310.8 m^3 reference to 100% CWR. From this result, using deficit more water was saved to expand commend area of scheme.

Table 2. *Average Seasonal water application of water on potato experimental plot.*

Irrigation Day	Gr. Irr (mm)	Gross Irrigation depth (m)	Plot Area (m^2)	Average Volume of SWA (m^3)		
				(100% CWR)	(75% CWR)	(50% CWR)
1	37.3	0.04	25	0.93	0.70	0.47
2	22.1	0.02	25	0.55	0.41	0.28
3	27.3	0.03	25	0.68	0.51	0.34
4	37.3	0.04	25	0.93	0.70	0.47
5	40.1	0.04	25	1.00	0.75	0.50
6	53	0.05	25	1.33	0.99	0.66
7	46.7	0.05	25	1.17	0.88	0.58
8	47	0.05	25	1.18	0.88	0.59
9	53.3	0.05	25	1.33	1.00	0.67
10	53.5	0.05	25	1.34	1.00	0.67
11	51.1	0.05	25	1.28	0.96	0.64
12	56.2	0.06	25	1.41	1.05	0.70
13	64.4	0.06	25	1.61	1.21	0.81
14	72.5	0.07	25	1.81	1.36	0.91
15	0	0	25	0.00	0.00	0.00
Total				16.55	12.41	8.28

CWR=Crop water requirement SWA=Sessional water applied

The average of seasonal irrigation water applied for onion crop was illustrated under table 3 for the three water levels (100, 75 and 50% CWR). From this table the average of seasonal irrigation water applied per plot were 14.93, 11.20 and 7.47m^3 and seasonal irrigation water need per hectare of onion crop for the three water levels (100, 75 and 50% CWR) were 5972, 4480 and 2988 m^3 respectively. The water saved per hectare using two water level which are (75 and 50% CWR) were 1492 and 2984 m^3 reference to 100% CWR. From this result, using deficit more water was saved to expand commend area of scheme.

Table 3. *Average seasonal water application of water on onion experimental plot.*

Irrigation day	Gross Irign Depth (m)	Plot Area (m^2)	Volume (m^3)		
			100% CWR	75% CWR	50% CWR
1	0.05	25	1.32	0.99	0.66
2	0.03	25	0.77	0.58	0.39
3	0.03	25	0.87	0.65	0.44
4	0.04	25	0.97	0.73	0.49
5	0.05	25	1.25	0.93	0.62
6	0.06	25	1.39	1.04	0.70
7	0.06	25	1.51	1.13	0.76
8	0.06	25	1.50	1.13	0.75
9	0.06	25	1.61	1.21	0.81
10	0.06	25	1.51	1.13	0.75
11	0.09	25	2.24	1.68	1.12
12	0.00	25	0.00	0.00	0.00
Total			14.93	11.20	7.47

3.3. Application Efficiency (Ea)

Table 4 shows the application efficiency of the experimental site were calculated using depth of water stored to crop root zone divided by depth of water applied to field. The average of application efficiency of the three water levels for potato and onion were 60.97%, 70.27%, 75.4% and 60.06%, 70.81% and 85.64% respectively. The water application efficiency of the two water levels (75% and 50%) was greater than the full irrigation (100%) even though the amount of water application was lower. This is due to properly used water and applied to field without more loss. The three application efficiency of the potato crop and two water levels (100% and 75%) were fall in the interval of recommendation for surface irrigation 50-80% as stated by [10]. But the average application efficiency of water level of 50% of onion crop was greater than 80% which are better than recommendation.

Table 4. *Average of application efficiency of selected crops.*

Applied water level	Application efficiency	
	Potato	Onion
100	60.97	60.06
75	70.27	70.81
50	75.4	85.64

3.4. Water Storage Efficiency (Es)

Table 5. *Average of water storage efficiency of selected crops.*

Applied water level	Storage efficiency	
	Potato	Onion
100	55.45	65.03
75	62.84	60.24
50	88.68	66.02

According to [12] the importance of determining storage efficiency is that, when water supplies are limited or when excessive time is required to secure adequate penetration of water into the soil. Table 5 shows water storage efficiency of study experimental sites for potato and onion crops. The average storage efficiency of potato were 55.45%, 62.84% and 88.68% and for onion were 65.03%, 60.24% and 66.02% respectively for the 100%, 75% and 50% of irrigation water level. Water stored efficiency was found as less than 100% due to the water applied was lost in form of deep percolation and runoff.

3.5. Distribution Uniformity (DU)

From Table 6 DU of the three irrigation water level (100%, 75% and 50%) were 88.24%, 87.61% and 89.89% for potato and 88.49%, 87.89% and 86.24% for onion respectively. According to [8] DU less than 60% low and DU greater than 75% recommended. So the DU of the three irrigation schemes was greater than 75% so it is under recommended percentage for the three water levels.

Table 6. *Average Distribution uniformity.*

Applied water level	Distribution Uniformity (DU)	
	Potato	Onion
100	88.24	88.49
75	87.61	87.89
50	89.89	86.24

3.6. Irrigation Water Use Efficiency (IWUE)

From table 7 the average of irrigation water use efficiency calculated were the highest at 50% water level for the two crops and the lowest were calculated at 100%CWR water levels. The 75% water level is the medium of the two water levels.

Table 7. *Average of irrigation water use efficiency.*

Applied water level	Average IWUE	
	Potato	Onion
100	1.76	2.26
75	1.82	2.93
50	2.38	4.22

IWUE=Irrigation water use efficiency

3.7. Yield Response

Yield response factor of potato crops to deficit water was described under table 8. From this table average Ky value rage were 0 - 0.98 and the highest Ky of 0.98 was attained at 50% CWR and the lowest was 100% CWR. This show the highest yield reduction was registered under 50% CWR. The deficit by 25% or 75% CWR is no more yield reduction therefor it is recommended.

Table 8. *Yield response factor of potato crop to deficit irrigation water.*

Water level (%)	Y_a (kg/ha)	ET_a	Y_a/Y_m	ET_a/ET_m	$(1-Y_a/Y_m)$	$1-(ET_a/ET_m)$	$K_y=(1-\frac{Y_a}{Y_m})/(1-\frac{ET_a}{ET_m})$
100	22093.2	3.76	0.97	1	0.03	0	-
75	22800	2.82	1.00	0.75	0.00	0.25	0.00
50	12060	1.88	0.53	0.5	0.47	0.5	0.94
50	11760	1.88	0.52	0.5	0.48	0.5	0.97
100	16800	3.76	0.74	1	0.26	0	-
75	21576	2.82	0.95	0.75	0.05	0.25	0.21
75	16080	2.82	0.71	0.75	0.29	0.25	1.18
50	10984	1.88	0.48	0.5	0.52	0.5	1.04
100	22712	3.76	1.00	1	0.00	0	-

Ya=actual yield (kg/ ha); Ym=maximum yield (kg/ ha); ETa=actual evapotranspiration (mm); ETm=maximum evapotranspiration (mm), and Ky=yield response factor.

Table 9 show yield response factor of crops to deficit water was described. From this table average Ky value rage were 0 - 0.85 and the highest Ky of 0.85 was attained at 50% CWR and the lowest was 100% CWR. This show the highest yield reduction was registered under 50% CWR. The deficit by 25% or 75% CWR is no more yield reduction therefor it is recommended.

Table 9. *Yield response factor of onion crop to deficit irrigation water.*

Water level (%)	Y_a (kg/ha)	ET_a	Y_a/Y_m	ET_a/ET_m	$1-(Y_a/Y_m)$	$1-(ET_a/ET_m)$	$K_y=\{(1-(Y_a/Y_m)/(1-ET_a/ET_m))\}$
100	12200	662	0.80	1	0.20	0	-
75	13000	496.5	0.86	0.75	0.14	0.25	0.58
50	8520	331	0.56	0.5	0.44	0.5	0.88
50	8400	331	0.55	0.5	0.45	0.5	0.89
100	15200	662	1.00	1	0.00	0	-
75	13120	496.5	0.86	0.75	0.14	0.25	0.55
75	13400	496.5	0.88	0.75	0.12	0.25	0.47
50	9240	331	0.61	0.5	0.39	0.5	0.78
100	13200	662	0.87	1	0.13	0	-

4. Conclusion and Recommendation

4.1. Conclusion

In this study, an attempt was made to evaluate deficit irrigation deficit or three water levels (100, 75 and 50% CWR) using application efficacy, storage efficiency, distribution uniformity and irrigation water use efficiency of the potato and onion crops. Laboratory result of soil data shows that texture class of soil in study area was clay loam. The average values of pH, Electrical conductivity and organic matter were 5.49, 0.16 and 3.58 respectively.

For the three water levels (100, 75 and 50% CWR) the average of seasonal irrigation water applied per plot and per hectare of potato crop were 16.55, 12.41 and 8.27 m^3 and 6620, 4963.6 and 3309.2 m^3 respectively. For onion were 14.93, 11.20 and 7.47m^3 and 5972, 4480 and 2988 m^3 respectively. The water saved per hectare using two water level which are (75 and 50% CWR) were 1656.4 and 3310.8 m^3 for potato and 1492 and 2984 m^3 for onion reference to 100% CWR respectively.

The average of application efficiency (Ea), storage efficiency (Es) and distribution uniformity (DU) of the three water levels (100%, 75% and 50%) were 60.97%, 70.27%, 75.4%, 55.45%, 62.84%, 88.68%, 88.24%, 87.61% and 89.89% for potato and 60.06%, 70.81%, 85.64%, 65.03%, 60.24%, 66.02%, 88.49%, 87.89% and 86.24% for onion respectively. The irrigation water use efficiency calculated was the highest at 50% water level for the two crops and the lowest were calculated at 100%CWR water levels.

The highest Ky of 0.98 and 0.85 was attained at 50% CWR for potato and onion respectively and the lowest was 100% CWR for both crops. This show the highest yield reduction was registered under 50% CWR. The deficit by 25% or 75% CWR is no more yield reduction therefor it is recommended.

4.2. Recommendation

It is highly recommended to use 75% CWR for both crops in saving water as it has low yield reduction in from water reduced. Before implementing a deficit irrigation program, it is necessary to know crop yield responses to water stress, either during defined growth stages or throughout the whole season. To implement deficit irrigation on farm participatory training should be given for application of right amount of water. As this water saving technology (deficit irrigation) is best for water stress areas it is strongly recommended to conduct further research works for other schemes particularly at highland areas as it has less evapotranspiration than that of lowlands.

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