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Journal of Agricultural Science and Food Research

Research Article

Participatory Evaluation and Demonstration of Onion Response to Deficit Irrigation at Gibe Woreda, Ethiopia

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ABSTRACT

Water scarcity has become a challenge for agricultural production in the arid area of Ethiopia, particularly in areas characterized by high evaporative demand and low and irregular rainfall. One of the options that can help to save irrigation water under these conditions is the adoption of deficit irrigation by farmers. This study aims participatory evaluation of the deficit irrigation level on onion yield and water use efficiency. To achieve this objective, the experimental was arranged in a randomized complete design with three levels of irrigation treatments and five replications. The treatment was three deficit irrigation levels (70%, 80% and 100% ETc). The results showed that, deficit irrigation level have a significant difference in plant height, bulb weight, bulb diameter and total yield of onion and water use efficiency. Onion yield has significant difference between 100% ETc and 70% ETc, but there is no significant difference between 100% ETc and 85% ETc. The highest water use efficiency was obtained under 70% ETc with significant yield reduction. Therefore, in an area where a sufficient amount of water is available full irrigation is recommended to obtain maximum yield, but in water-scarce areas applying 85% ETc is recommended with non-significant yield reduction.

Keywords: Deficit; Onion; ETc; Water use efficiency

Abbreviations: (DI): Deficit Irrigation; (WP): Wettable Powder; (ETc): Evapotranspiration.

INTRODUCTION

Onion (*Allium cepa L.*) is the most important, widely grown vegetable crop throughout the world [1]. It is widely cultivated as a source of income by many farmers in many parts of the country. It is also one of the most important vegetable crops in Ethiopia.

Water scarcity is a progressively important issue in many parts of the world. Climate change forecasts of increase in temperature and decrease in rainfall mean water will become even scarcer [2].

Under conditions of scarce water supply, the application of deficit irrigation could provide greater economic returns than maximizing yields per unit of water. The DI has been considered worldwide as a way of maximizing Water Use Efficiency (WUE) by eliminating irrigation that has little impact on yield [3].

In conditions of scarce water and drought, deficit irrigation can lead to greater economic gain by maximizing water use efficiency. The term water use efficiency is used to describe the relation between crop yield and water use [4,5]. The response of onion to water deficit has been reported by that showed deficit irrigation to increase the water use efficiency of onion [6]. Deficit Irrigation practices deliberately allow crops to sustain some degree of water deficit, sometimes with light yield loss and with a significant reduction in irrigation water use [7].

Partial root zone water application and deficit irrigation has more water saving and WP enhancement potential with tolerable level of yield reduction [8].

The growing water shortage in developing countries, increasing agricultural water management strategies is of paramount importance to reduce food insecurity [9].

DI is considered to be a sustainable practice and has been developed to improve water productivity, minimize yield losses and even improve product quality [10,11].

DI was used long time ago as a technique that irrigates the entire root zone with less evapo-transpiration and leads to reduce the irrigation water use with maintaining farmers' net profits [12]. As

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Received: 03-Nov-2023, Manuscript No. JBFBP-23-26907; **Editor assigned:** 06-Nov-2023, Pre QC No. JBFBP-23-26907 (PQ); **Reviewed:** 21-Nov-2023, QC No. JBFBP-23-26907; **Revised:** 28-Nov-2023, Manuscript No. JBFBP-23-26907 (R); **Published:** 05-Dec-2023, DOI: 10.35248/2593-9173.23.14.163

Citation: Kifle T, Mengist D, Gebre T (2023) Review on Handling, Hygienic Practices and Microbial Qualities of Raw Milk in Ethiopia. J Agri Sci Food Res. 14:163

long as the soil fertility is favorable and the crops are applicable for the DI strategy, DI enhances WP in comparison with full irrigation [13,14].

Other experiments with onion showed that deficit irrigation throughout the growing season of onion as 50 and 75% of ETc reduced yields from full irrigation and resulted in the highest water saving and crop water use efficiency [15]. Kumar, et al., investigated also the impact of deficit irrigation strategies on onion yield and water savings.

Considering the scarcity of irrigation water in the region and the sensitivity of onion crops to moisture stress this research aimed to identify the level of deficit irrigation on onion yield and water use efficiency. [16]

MATERIALS AND METHODS

Description of the experimental site

The study was conducted in Gibe Woreda, Hadiya Zone of Southern nation nationality and peoples of Ethiopia. Gibe Woreda is located 300 km south of Addis Abeba and 73 km South of Hosanna town. The experimental site was located at an altitude of 1600 m.a.s.l, a latitude of 7°45'36'' N and longitude of 37°45'36'' E.

Experimental design and treatment

The experiment was laid out in a randomized complete block design with three treatments and five replications (farmers were used as replication). The treatments (100% ETc, 85% ETc and 70% ETc) were applied at the same irrigation interval. The size of each plot was 10 m by 10 m and the space between the plot was 1 m. The recommended space between the plant and the row was applied as 10 cm* 20 cm* 40 cm.

Soil data

The soil was analyzed in the laboratory and the gravimetric method, Potential of Hydrogen (pH) meter method and soil and water ratio method were used to determine soil moisture content, pH value and electrical conductivity respectively (Table 1).

Climate data

The average climatic data (maximum and minimum temperature, relative humidity, wind speed and sunshine hours) on monthly basis were obtained from the meteorological station. The potential Evapotranspiration (ETo) was estimated using Crop Water and Irrigation Requirements Program (CROPWAT) software version 8 (Table 2,3).

Table 1: Soil data of the study area.

Soil property		Soil depth in (cm)				
		0-20	20-40	40-60	60-80	Average
Particle size distribution	Clay %	50	54	58	56	54.5
	Sand %	32	28	30	26	29
	Silt %	18	18	12	18	16.5
Textural class		clay	clay	clay	clay	Clay
BD (g/cm^3)		1.18	1.22	1.37	1.32	1.27
% Moisture		22.7	20.48	16.28	12.87	18.08
pH		5.58	5.56	5.49	5.62	5.56
EC (ds/m)		0.98	1.04	1.02	0.98	1.005

Note: BD: Bulb Diameter; EC: Soil electrical conductivity; pH: Potential of Hydrogen

Table 2: Average climatic data of the experimental site.

Month	Minimum temperature (°C)	Maximum temperature (°C)	Humidity (%)	Wind (km/day)	Sun(hours)	Radiation ($MJ/m^2/day$)	ETo mm/day
January	7	25.7	81	130	8.2	19.9	3.58
February	8.3	27.1	79	130	7.6	20.2	3.85
March	10	27.2	83	130	7.7	21.2	4.06
April	10.8	24.2	90	130	7	20.3	3.59
May	9.3	24.1	93	130	7.6	20.6	3.53
June	9.5	22.3	95	147	5.9	17.7	2.93
July	9.8	21.3	95	104	3.6	14.4	2.49
August	9.8	21.2	92	86	4.2	15.7	2.71
September	9.3	22.6	98	112	5.2	17.3	2.89
October	7.9	23.7	87	112	7.2	19.7	3.38

November	8.1	24.7	90	138	8.9	21.1	3.51
December	7	26	78	138	8.3	19.6	3.62
Average	8.9	24.2	88	124	6.8	19	3.34

Note: ETo: Evapotranspiration.

Table 3: Onion crop data is required for crop water requirement determination.

Crop data	Growth stage				
	Initial	Development	Mid	Late	Total
Growing period	20	30	30	15	95
Crop coefficient(kc)	0.7	-	1.05	0.95	-
Rooting depth(m)	0.3	-	0.6	0.6	-
Depletion level(p)	0.3	-	0.45	0.5	-
Yield response(ky)	0.8	0.4	1.2	1	-

Crop water determination

Crop water requirement refers to the amount of water that needs to be supplied, while crop evapotranspiration refers to the amount of water that is lost through evapotranspiration [17]. For the determination of crop water requirement, the effect of climate on crop water requirement, which is the reference crop Evapotranspiration (ETo) and the Effect of Crop Characteristics (Kc) are important [18]. The long-term and daily climate data such as maximum and minimum air temperature, relative humidity, wind speed, sunshine hours and rainfall data of the study area were collected to determine reference evapotranspiration, crop data like crop coefficient, growing season and development stage, effective root depth, critical depletion factor of onion and maximum infiltration rate and total available water of the soil was determined to calculate crop water requirement using CROPWAT model.

ETc = ETo x Kc

Where, ETc = Crop Evapotranspiration, Kc = Crop coefficient, ETo = Reference evapotranspiration.

Irrigation water management

The Total Available Water (TAW), stored in a unit volume of soil was determined by the expression:

TAW=((Fc-PWP)*BD*Dz)/100

TAW= Total Available Water (%), Fc= Field Capacity (kPa), PWP= Permanent Wilting Point (kPa), BD= Bulb Diameter (cm)

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

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

Inet= Depth of Irrigation (mm), ETc=Evapotranspiration (mm), Peff= Effective precipitation (mm)

The gross irrigation requirement will be obtained from the expression:

Ig=In/Ea

Ea= Application efficiency of the furrows (%), Ig= Gross Irrigation (m^3/ha)

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

t=(d*l*w)/(6*Q)

Where d= Gross depth of water applied (cm), t= Application time (min), l= Furrow length in (m), w= Furrow spacing in (m) and Q= Flow rate (m^3/s)

Data collection

Daily climate like maximum and minimum air temperature, relative humidity, wind speed, sunshine hours and rainfall data was collected to calculate crop water requirement. Soil moisture was determined gravimetrically. The amount of applied water per irrigation event was measured using calibrated pareshall flume. During harvesting and data collection 10 sample plants were randomly selected in each plot to measure plant height, bulb weight and bulb diameter and to measure yield of onion net harvested area of each plot were used.

Statistical analysis

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

RESULTS

Physical and chemical properties of soil

The critical value of bulk density for restricting root growth varies with soil type but the general bulk density greater than 1.6 g/cm^3 tend to restrict root growth [19,20]. Generally, according to United States Department of Agriculture (USDA) soil classification, soil with electrical conductivity of less than 2.0 dS/m at 25°C and pH less than 8.5 are classified as normal soil. The laboratory result shows that the experimental site soil textural class was clay according to USDA textural classification with an average composition of sand 29%, silt 16.5% and clay 54.5%. The average soil bulk density (1.27 g/cm^3) is below the critical threshold level (1.4 g/cm^3) and was suitable for crop root growth. The pH of the soil was slightly acidic with an average pH value of 5.56. EC critical value for agricultural use according to Hillel, et al. [21], is <2.0 ds/m. thus, the experimental site soil was less than this value (1.005 ds/m) so it is suitable for onion growth.

Onion response to deficit irrigation

The result showed that the application of a 70% deficit irrigation level significantly reduced plant height, bulb diameter, bulb weight and onion yield. The maximum yield was obtained from 100% ETc (32.27 t/ha) and the minimum yield was obtained from 70% of ETc (26.36 t/ha). there is no significant difference between applying 85% ETc and 100% ETc. Maximum and minimum water productivity were obtained from 70% ETc (7.8 kg/ m^3) and 100% ETc (6.1 kg/ m^3), respectively. The result obtained in this experiment was in agreement with Teferi who observed that irrigation water stress throughout the season significantly decreased onion bulb yield. Nazeer and Ali also discussed that different irrigation water depth affects onion yield and biomass (Table 4) [22,23].

Table 4: Onion response to Deficit Irrigation.

Treatment	PH (cm)	BD (CM)	BW (gm)	TY (t/ha)	WUE (kg/ m^3)
100% Etc	69.27^a	5.92^a	82.36^a	32.27^a	6.1^b
85% Etc	58.12^b	5.37^{ba}	72.48^a	29.61^{ba}	6.1^b
70% Etc	49.64^c	4.93^b	60.44^b	26.36^b	7.88^a
CV (%)	6.076	9.88	10.08	7.78	13.27
LSD (5%)	5.23	0.7806	10.551	3.34	1.29

Note: PH: Plant Height; BD: Bulb Diameter; BW: Bulb Weight; TY: Total Yield; WUE: Water Use Efficiency; CV: Coefficient of Variation; LSD: Least Significant Difference; Etc: Evapotranspiration.

DISCUSSION

Although the ideal bulk density to limit root development varies depending on the type of soil, in general, bulk densities higher than 1.6 g/cm^3 likely to do so. In general, soil that has a pH of less than 8.5 and an electrical conductivity of less than 2.0 dS/m at 25°C is classed as normal soil by the United States Department of Agriculture (USDA). According to the USDA textural classification, the laboratory results indicate that the soil texture class of the experimental site was clay, with an average composition of 29% sand, 16.5% silt and 54.5% clay. The essential threshold level of 1.4 g/cm^3 is exceeded by the average soil bulk density of 1.27 g/ cm^3, indicating that the soil is adequate for crop root development. The average pH of the soil was somewhat acidic.

CONCLUSION

Water scarcity is the major limiting factor for increased production and productivity. Water is a scarce resource in the central rift valley of Ethiopia and is the major limiting factor for crop production. Onion is one of the major economically important vegetable crops grown in the southern region. Appling 85% of crop water requirement can save a substantial amount of water without significant yield reduction. Onion bulb yield increased when the irrigation level increased from 30% deficit irrigation to full application of 100% ETc. Therefore, DI practice is a suitable and most efficient practice for sustainable production in a water-scarce area.

DECLARATIONS

We authors of the manuscript entitled: Participatory Evaluation and Demonstration of Onion Response to Deficit Irrigation at Gibe Woreda, Ethiopia. Hereby declare that the above manuscript which is submitted for publication in International Journal of Water Resources Development. The manuscript is not published already in a part or whole in any journal or magazine for private or public circulation. We have read instructions to contributors and are fully aware of what plagiarism is. No part of this manuscript has been copied verbatim from any source. Before starting the study, our study was approved by the Southern Agricultural Research Institute's ethical approval committee and obtained all protocols from the Southern Agricultural Research institutional review board to confirm the study meets national guidelines for research. The committee set directions for the researchers to honestly report data, results, methods and procedures and publication status. Do not fabricate, falsify or misrepresent data, strive to avoid bias in experimental design, data analysis, data interpretation, personnel decisions, grant writing, expert testimony and other aspects of research. In this research all researchers were carefully and critically examine our work, share data, results, ideas, tools, resources and respect human dignity, privacy and autonomy.

COMPETING INTERESTS

We confirm that the manuscript has been read and approved by authors and that there are no other persons who fulfill the criteria for authorship but are not listed. We further confirm that we have approved the order of authors listed in the manuscript. We wish to confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome. We understand that the corresponding author is the sole contact for the editorial process (including editorial manager and direct communications with the office). He is responsible for communicating with the other authors about progress, submissions of revisions and final approval of proofs. We confirm that we have provided a current, correct email address which is accessible by the corresponding author.

AUTHORS' CONTRIBUTIONS

Tamirneh Kifle, Demeke Mengist and Temsgen Gebre have made substantial contributions to the conception and design, acquisition of data or analysis and interpretation of data. We were constructing an idea or hypothesis for research, planning methodology to conclude, taking responsibility for the execution of the experiments, patient follow-up and data management and reporting. We were reviewing the article before submission not only for spelling and grammar but also for its intellectual content. All authors read and approved the final manuscript.

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