*Journal of Engineering Research and Reports*

*18(2): 30-37, 2020; Article no.JERR.58107*
*ISSN: 2582-2926*

# Effect of Deficit Irrigation under Different Crop on Crop Productivity and Water Use Efficiency- A Review

**Dessie Gieta Amare[1*] and Zigijit Kassa Abebe[1]**

[1]*Department of Natural Resources Management, Debre Markos University, P.O.Box: 18, Ethiopia.*

***Authors' contributions***

*This work was carried out in collaboration between both authors. Author DGA designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author ZKA managed the analyses of the study. Both authors read and approved the final manuscript.*

***Article Information***

DOI: 10.9734/JERR/2020/v18i217204
*Editor(s):*
(1) Dr. Grzegorz Sierpiński, Silesian University of Technology, Poland.
*Reviewers:*
(1) Emad Mohamed Mohamed Salem, Desert Research Center, Egypt.
(2) Riani Muharomah, Sriwijaya University, Indonesia.
(3) Khushboo Chandra, Dr. Rajendra Prasad Central University India.
Complete Peer review History: http://www.sdiarticle4.com/review-history/58107

***Review Article***

***Received 10 April 2020***
***Accepted 17 June 2020***
***Published 06 November 2020***

## ABSTRACT

Deficit irrigation is a strategy which could be applied to utilize water efficiently. The goal of the article was to review and examine different irrigation deficit to compare its crop morphological characters, yield, water productivity and water use efficiency under different crop type. The overall idea and results are very actual and useful over the world in the semi-arid and arid area interms of water managment and better economic return per applied water.The maximum production in dryland, tomato should be irrigated using drip irrigation system with 100%ETc watering amount [17]. On the other hand 85%, 75% and 30% are also effective in terms of water saving and yield. 85%ETc irrigation level water applied system appears to be a promising alternative for water conservation and labor saving with negligible trade-off in yield of maize [15]. The application of deficit irrigation (75%ETc) could be adopted in lettuce production [16]. Form the review I have seen that The WP increased as the irrigation level reduced.

*Keywords: Crops; irrigation; deficit; yield and its component; water productivity.*

**Corresponding author: Email: dessiegt@gmail.com, kebiekassa@gmail.com;*

## 1. INTRODUCTION

The limited fresh water is a severe problem throughout the world and especially in arid and semi-arid regions, which is considered the major constraint to crop production [1]. The efficient use of water by modern irrigation systems is becoming increasingly important in arid and semi-arid regions with limited water resources [2]. Adequate water and nutrient supply are important factors affecting optimal plant growth and successful crop production [3]. Accordingly, irrigation is one of the major agricultural activities and throughout the production season. Its importance increases as the climate gets drier [4]. Water deficit is one of the most important restricting factors in crop production in the world [5,6,7]. Deficit irrigation is a strategy which could be applied to utilize water efficiently. The adoption of deficit irrigation implies appropriate knowledge of crop transpiration, crop responses to water deficits, yield reduction, its impact on water use efficiency and the economic impacts of yield reduction strategies [8]. Deficit irrigation (DI) has been practiced in different parts of the world [9,10,11]. Partial root-zone irrigation (PRI) or partial root-zone drying is a further development of DI. In alternate PRI, half ofthe root zone is irrigated while the other half is dried, and then the previously well-watered side of the root system is allowed to dry while the previously dried side is fully irrigated [12]. So far PRI has already been investigated on some vegetable crops [13]. Many investigations have been conducted to gain experiences in irrigation of crops to maximize performances, efficiency and profitability. However, investigations in water saving irrigation still are continued [14].

### 1.1 Objective

The goal of the article was to review and examine different irrigation deficit to compare its crop morphological characters, yield, water productivity and water use efficiency under different crop type. The overall idea and results are very actual and useful over the world in the semi-arid and arid area interms of water managment and better economic return per applied water.

## 2. LITERATURE REVIEW

### 2.1 The Effect of Irrigation Amount on Maize Crop under Conventional Furrow Irrigation

To identify the level of deficit irrigation for achieving optimum crop yield and water productivity of maize crop in the mid rift valley of Ethiopia, conventional furrow irrigation systems were used with three deficit levels and control which are 50%ETc, 70%ETc and 85%ETc and a control irrigation of 100%ETc making a total of four treatments in RCD with three replications. The analysis of variance for the result of the study indicated highly significant ($P \leq 0.05$) differences for yield, yield components and WUE's. The highest yield of 4.52 t/ha was obtained from the control with 100%ETc which was not significantly ($P \leq 0.05$) different to the 85%ETc irrigation level. In terms of irrigation and water use efficiency, 50%ETc deficit irrigation application gave the highest IWUE which was significantly different from all other treatment combinations. Yield and water use efficiency based comparison had shown that there was a significant difference between the yield, CWUE and IWUE obtained in the treatment. Therefore, it can be concluded that increased water saving and associated water productivity through the use of 85%ETc with Conventional furrow irrigation, can solve the problem of water shortage which improve WUE without significant reduction of yield. 85%ETc irrigation level water applied system appears to be a promising alternative for water conservation and labor saving with negligible trade-off in yield [15].

### 2.2 Effect of Irrigation Amount on Yield and Water Productivity of Drip Irrigated Lettuce

Water productivity (WP) is generally defined as marketable yield/ET but economists and farmers are most concerned about the yield per unit of

**Table 1. Effects irrigation amount on grain yield, dry matter (DM), CWUE, and IWUE [15]**

| Treatment | Grain yield (kg/ha) | DM t/ha | CWUE $kgm^{-3}$ | IWUE $kgm^{-3}$ |
|---|---|---|---|---|
| 100% ETc | 4522.80 a | 8.49ab | 0.77d | 0.54d |
| 85% ETc | 4237.40 a | 8.89a | 0.94c | 0.66c |
| 70% ETc | 4073.30 b | 8.08b | 1.12b | 0.78b |
| 50% ETc | 3668.80 b | 8.04b | 1.37a | 0.96a |

*CWUE = Crop Water Use Efficiency, IWUE = Irrigation Water Use Efficiency, DM = dry matter* irrigation water applied [9]. During the review what we understand the researcher was done a field experiment was conducted at southern Ethiopia to evaluate the effect of irrigation application levels on yield and water productivity of drip irrigated lettuce crop. The experiment design was laid out in randomized complete block design with three replications with the help of drip irrigation. The treatments consisted of full crop water requirement (FI), 75% of FI, 50% of FI and 100%ETc irrigating one part of the root zone in each irrigation event (PRD100), 75% of FI (PRD75) and 50% of FI (PRD50) following the same strategy as PRD100. CROPWAT computer model version 8.0 was used to estimate the reference evapotranspiration ($ET_o$) and crop water requirement ($ET_c$). The total water received for the 100%ETc treatment was 304 mm and the other deficit irrigation treatments were taken 75% and 50% of the maximum (100%ETc) irrigation treatment, which were 228 mm and 152 mm respectively [16].

The water productivity was determined by dividing the yield of lettuce to the amount of water consumptively used by the crop [16].

$$WP = Y/WA$$

Where; Y is Yield per unit area (Kg/ha), WA is Water used to produce the yield ($m^3$ /ha)

The result of investigation indicated that yield and yield related parameters such as plant height, number of leaves and plant diameter were significantly affected by different water deficit levels. However, Irrigation levels had no significant influence on dry weight. The highest yield was recorded from FI (42 t/ha) whereas the lowest yield was obtained from PRD50 treatment (25.7 t/ha). Moreover, it was found that the water productivity (WP) was significantly affected by irrigation treatments. The WP increased as the irrigation level reduced. The highest values were obtained under the PRD50 treatment (21.5 kg/$m^3$), while the lowest values (16 kg/$m^3$) occurred under full irrigation treatment. Overall, it can be concluded that lettuce yield is highly dependent on the amount of water applied. However, under limited water supply condition application of deficit irrigation (75%ETc) could be adopted [16].

### 2.3 Effect of Irrigation Amount on Tomato

Two irrigation systems (drip and furrow) with three irrigation watering amount: (100%, 75% and 50%ETc of tomato crop), were used. The experiment was arranged in a split plot design with three replicates. The irrigation systems were allocated to the main plots and the amounts of irrigation water were assigned to the subplots. The crop water requirement was estimated by CROPWAT computer model. The deficit irrigation treatment was assessed under both irrigation systems (Table 4). The maximum values of aforementioned parameters were obtained with 100%$ET_c$, followed by 75%Etc and 50%ETc (Table 3). This may be due to fact that water applied at 100%$ET_c$ adequately meets the crop water requirement. For maximum production in dryland, tomato should be irrigated using a drip irrigation system with 100%ETc watering amount [17].

The plant height, stem size and yield of tomatoes, irrigated by drip system have superiority over that irrigated by furrow system. The superiority of drip irrigation may be attributed to the fact that drip system distributes water evenly among plants and provides the crop with adequate water requirement as compared to furrow irrigation [17].

**Table 2. Effect of different irrigation amount on yield and yield components of lettuce [16]**

| Treatment | Plant height (cm) | Leaf number | Plant diameter (cm) | DW (gplant$^{-1}$) | Yield (tha$^{-1}$) | WP (Kgha-1) |
|---|---|---|---|---|---|---|
| FI | 26 | 31.3 | 27 | 10.5 | 42 | 16 |
| 75% FI | 24 | 26 | 24 | 10.2 | 36.3 | 17.7 |
| 50%FI | 21.7 | 22 | 22 | 9.8 | 29 | 18 |
| PRD 100 | 25 | 28.3 | 25 | 10.3 | 39 | 17 |
| PRD 75 | 22.3 | 24 | 23 | 10.1 | 32.3 | 19 |
| PRD50 | 20 | 21 | 20 | 9.5 | 25.7 | 21 |
| LSD0.05 | 1.33 | 0.8 | 0.88 | NS | 2.9 | 0.91 |

*PRD = Part Root Depth, FI = Full Irrigation*

**Table 3. Effect of irrigation amount on the growth parameters of tomato [17]**

| Irrigation system | Growth parameter | | |
|---|---|---|---|
| | Plant height (cm) | Stem size (cm) | Productivity t $ha^{-1}$ |
| 100% ETc | $72^a$ | $1.2^a$ | $24^a$ |
| 75% ETc | $69^b$ | $1^a$ | $22^b$ |
| 50% ETc | $50^c$ | $0.8^a$ | $12^c$ |

**Table 4. Effect of irrigation amount on the growth parameters of tomato [17]**

| Irrigation system | Growth parameter | | |
|---|---|---|---|
| | Plant height (cm) | Stem size (cm) | Productivity t $ha^{-1}$ |
| Drip | $70^a$ | $1^a$ | $23^a$ |
| Furrow | $58^b$ | $0.8^a$ | $12^b$ |

## 2.4 Effect of Different Irrigation Amount on the Performance of Wheat

The study was consists of five irrigations levels including control *viz.* control or no irrigation ($T_0$), one irrigation at 25 DAS ($T_1$), two irrigations at 25 and 40 DAS ($T_2$), three irrigations at 25, 40 and 55 DAS ($T_3$) and four irrigations at 25, 40, 55 and 70 DAS ($T_4$). The experiment was laid out in completely randomized block design (RCBD) with four replications. Among the studied morpho-physiological growth yield and yield contributing characters where three irrigations had more significant than that of other irrigation treatments and no irrigation. As a result, three irrigations ($T_3$) recorded significantly the tallest plant (76.86 cm) and maximum requiring days to anthesis (54.80 days) while four irrigations ($T_4$) obtained the statistically similar height of plant (73.76 cm). Similarly, maximum number of effective tillers (5.00 $hill^{-1}$) and grains (44.00 $spike^{-1}$) as shown in Table 3 were also obtained by three irrigation ($T_3$) treatments. The highest grain growth was obtained at $T_3$ (3.11 g at 36 DAS), $T_4$ continued grain growth till 44 DAS but grain growth was decreased than $T_3$, $T_2$ and $T_1$ completed their grain growth at 36 DAS which were less than $T_4$. Longest spike (17.28 cm) and higher weight of 1000-seed (50.16 g) were also found with three irrigation ($T_3$) treatment while both two and four irrigation treatment ($T_2$ and $T_4$) showed the statistically identical spike length (16.76 and 16.95 cm, respectively) and 1000-seed weight (47.96 and 49.62 g respectively). Among other studied characters, grain, straw and biological yield and harvest index had also higher (4.16, 5.89 and 10.05 t $ha^{-1}$ and 41.39%, respectively) with three irrigation treatments ($T_3$) where four irrigation treatments ($T_4$) showed the statistically identical harvest index as 41.39% and 41.37% respectively. Among the studied morphological and yield attributing characters, the lowest result were obtained by no irrigation such as shortest plant (48.57 cm), lowest LAI (2.50), minimum days to anthesis and maturity (53.00 and 91.00 days respectively), minimum effective tillers (3.60 $hill^{-1}$), minimum grains (35.38 $spike^{-1}$), shortest spike (12.00 cm), lowest weight of 1000-seed (38.00 g), lowest yield of grain, straw and biological (2.86, 4.74 and 7.60 t $ha^{-1}$, respectively) and lowest harvest index (37.63%) were obtained with no irrigation treatments ($T_0$) [18].

## 2.5 Effects of Different Irrigation Rates on Growth and Yield Parameters of Amaranth

Soil water deficit is a principal and biotic factor that limits plant growth and development. Amaranth is very sensitive to water stress. Foregoing research highlighted a reduced amaranth leaf area and dry matter, while others affirmed that water deficit impaired amaranth growth and yield. It was laid out as completely randomized blocs design, consisting of three treatments with different irrigation rates as treatment $T_1$ (10%), treatment $T_2$ (30%) and treatment $T_3$ (60%) with six repetitions for each. During the experiment, growth parameters (number of leaves, plant height, and leaf area and root growth) and production attributes (fresh and dry weight of leaves and roots) were measured. The irrigation levels effectively influenced yield with higher significance difference among the treatments. As can be seen in Table 6, a there were significant differences between treatments for fresh yield weight (FY). Specifically, treatment $T_2$, with 12288 kg/ha, got the maximum FY and highly differed from others with $P < 0.001$. It was followed by $T_3$ of 5605 kg/ha, while the minimum was recorded for treatment $T_1$ with 1059 kg/ha. Similarly, the DYW was effective and significantly (P <0.05) improved by treatment $T_2$ with optimum weight of 1684 kg/ha, followed by $T_3$ of 1104 kg/ha and lastly $T_1$ with a lowest value of 282 kg/ha. This treatment $T_2$ has also effectively enhanced RFW and RDW with highest value of 933 kg/ha and 229 kg/ha respectively, whereas $T_1$ got the minimum of 114 kg/ha and 38 kg/ha successively [19].

**Table 5. Effect of irrigation amount on days to anthesis, days to maturity and number of effective tillers hill$^{-1}$ [18]**

| Treatments | Days to anthesis (days) | Days to maturity | Number of effective tillers hill$^{-1}$ |
|---|---|---|---|
| $T_o$ | 53.00$^e$ | 91.00$^e$ | 3.60$^d$ |
| $T_1$ | 55.00$^d$ | 97.00$^d$ | 3.07$^e$ |
| $T_2$ | 57.00$^c$ | 102.00$^c$ | 4.25$^c$ |
| $T_3$ | 61.00$^a$ | 105.00$^a$ | 5.00$^a$ |
| $T_4$ | 59.00$^b$ | 109.00$^b$ | 4.73$^b$ |

*$T_o$= Treatment 0, $T_1$= Treatment 1, $T_2$ = Treatment 2, $T_3$ = Treatment 3, $T_4$ = Treatment 4*

**Table 6. Effect of irrigation amount on number of grains spike$^{-1}$, weight of 1000-seed and grain yield [18]**

| | Straw yield (tha$^{-1}$) | Weight of 100-seed (g) | Grain yield (tha$^{-1}$) |
|---|---|---|---|
| $T_o$ | 33.88$^d$ | 38.00$^d$ | 2.86$^e$ |
| $T_1$ | 37.38$^c$ | 44.40$^c$ | 3.08$^d$ |
| $T_2$ | 41.95$^b$ | 47.96$^b$ | 3.59$^c$ |
| $T_3$ | 44.00$^a$ | 50.16$^a$ | 4.16$^a$ |
| $T_4$ | 42.55$^b$ | 49.62$^a$ | 3.86$^b$ |

**Table 7. Effect of amount on straw yield, biological yield and harvest index [18]**

| Treatments | Straw yield (tha$^{-1}$) | Biological yield (tha$^{-1}$) | Harvest index (%) |
|---|---|---|---|
| $T_o$ | 4.74$^d$ | 7.60$^e$ | 37.63$^c$ |
| $T_1$ | 5.08$^c$ | 8.61$^d$ | 37.75$^c$ |
| $T_2$ | 5.51$^b$ | 9.10$^c$ | 39.45$^b$ |
| $T_3$ | 5.89$^a$ | 10.05$^a$ | 41.39$^a$ |
| $T_4$ | 5.47$^b$ | 9.33$^b$ | 41.37$^a$ |

**Table 8. Different irrigation amount effect on plant height (cm) [19]**

| Treatment | 12 d | 19 d | 26 d | 33 d |
|---|---|---|---|---|
| T1 | 11.76a | 11.9a | 12.27a | 12.41a |
| T2 | 12.58a | 18.37b | 25.97b | 33.67b |
| T3 | 15.86b | 21.77b | 28.00b | 32.53b |

**Table 9. Effects of irrigation amount on amarath leaf area (cm$^2$) [19]**

| Treatment | 12 d | 19 d | 26 d | 33 d |
|---|---|---|---|---|
| T1 | 10.09a | 10.60a | 9.60a | 10.00a |
| T2 | 12.51a | 26.9b | 28.70b | 29.5b |
| T3 | 14.98a | 24.4b | 28.00b | 28.9b |

**Table 10. Effect of irrigation deficit on the leaf number [19]**

| Treatment | 12 d | 19 d | 26 d | 33 d |
|---|---|---|---|---|
| T1 | 5a | 5a | 6a | 6a |
| T2 | 8b | 12b | 15b | 19b |
| T3 | 9b | 13b | 14b | 16b |

**Table 11. Effect of irrigation deficit on the yield component of amaranth [19]**

| Treatment | FYW ($Kgha^{-1}$) | DYW (Kg | 26 d | 33 d |
|---|---|---|---|---|
| T1 | 5a | 5a | 6a | 6a |
| T2 | 8b | 12b | 15b | 19b |
| T3 | 9b | 13b | 14b | 16b |

**Table 12. Effect of irrigation amount for the yield component of amaranth [19]**

| Treatment | FYW $Kgha^{-1}$ | DYW $Kgha^{-1}$ | YR (%) | RFW $Kgha^{-1}$ | RDW $Kgha^{-1}$ | RR | TDW $Kgha^{-1}$ | TFW $Kgha^{-1}$ | WUE $Kgm^{-3}$ |
|---|---|---|---|---|---|---|---|---|---|
| $T_1$ | 1059a | 282a | 3755a | 114a | 38a | 0.404 | 320a | 1455a | 4322a |
| $T_2$ | 12288b | 1684b | 7297b | 933b | 229b | 0.554 | 1913b | 14905b | 13740b |
| $T_3$ | 5605c | 1104c | 5077ab | 588c | 74a | 0.533 | 1178c | 7297c | 3363c |

*FYW = Fresh Yield Weight, DYW = Dry Yield Weight, YR = Yield Ratio, RR = Root Ratio*

## 2.6 Effects of Deficit Irrigation on Yield and Water Use of Grown Cucumbers

A series of greenhouse and open field experiments were conducted using a deficit irrigation program on cucumber crops under drip irrigation during 2007–2010 growing seasons. The layout of the experiment was a completely randomized design with four replicates. Irrigation treatments consisted of five levels of ETc (30, 40, 60, 80, and 100% of ETc) in addition to traditional practice by farmers. At 60 and 80%ETc treatments, deficit irrigation tested at different growth stages (development, mid, and late stages of the growth) for a total of 14 treatments at each experiment. The maximum amount of water applied to the crop was 332 mm for the 100%ETc treatment while the minimum water applied was 100 mm for 30%ETc treatment, and 600 mm for traditional practice by the farmers in the region. The calculated ETc ranged from between 95 and 316 mm for the different treatments. Water use efficiency (WUE) and water productivity (WP) represent the productivity of water related to yield. The T4-80 treatment was found to be the best treatment in terms of yield and water productivity, these values were 14.2 kg/m$^3$ and 48 kg/m$^3$ (Table 1); Moreover, decreasing irrigation water to 40% ET caused very high water productivity however decreases the final yield. Generally, the water use efficiency (WUE) and water productivity (WP) values increased when water amount decreased, these decreased values were 74.0 and 61.9 kg/m$^3$, and 48.9 and 42.3 kg/m$^3$ for WUE and WP in $T_{12}$ and $T_1$ treatments respectively, The results of cucumber yield for different treatments (Table 1) indicated that the highest yield was obtained in the treatment T1-100 (15.0 kg/m$^3$) and the lowest yield was in the treatment $T_{12\text{-}40}$ (9.1 kg/m$^3$). Treatment T1-100 had the highest yield and treatments T3, 4, 5, 6-80 and $T_{12\text{-}40}$ gave fairly good marketable yield with economically saving water. The result also indicated that the water productivity (WP) increased with decrease the amount of applied

**Table 13. Yield, water use efficiency (WUE) and water productivity (WP) as affected by deficit irrigation treatments at different growth stages of cucumber [20]**

| Treatments | Average days per season | Yield $kgm^{-2}$ | WUE ($kgm^{-3)}$ | WP ($kgm^{-3}$) |
|---|---|---|---|---|
| T1 - 100 | 108 | 15.0 a | 48.9 | 42.3 |
| T2 -80 | 108 | 13.8 bc | 56.3 | 48.8 |
| T3 -80 | 108 | 13.2 d | 51.6 | 44.7 |
| T4 -80 | 108 | 14.2 b | 54.8 | 47.5 |
| T5 -80 | 108 | 14.6 ab | 54.3 | 47.2 |
| T6 -80 | 108 | 13.5 cd | 51.9 | 45 |
| T7 -60 | 108 | 11.4 f | 62 | 53.5 |
| T8 -60 | 108 | 11.7 f | 57.4 | 49.6 |
| T9 -60 | 108 | 12.4 e | 59 | 51 |
| T10 -60 | 108 | 12.7 e | 54..7 | 47.6 |
| T11 -60 | 108 | 11.5 f | 54 | 46.7 |
| T12 -40 | 180 | 9.1 g | 74 | 61.9 |
| T13 - Trad | 108 | 14.2 b | 46.3 | 19.7 |

water, the WP were 42.3 and 61.9 $kgm^{-3}$ for T1-100 and T12-40, respectively. However the traditional irrigation treatment gets the lowest value of WP (19.7 kg $m^{-3}$). Although lack of irrigation as in treatments T12-40 led to very high water productivity however it also led to poor quantity and quality of yield [20].

## 3. CONCLUSION

The deficit of irrigation is depends the climatic condition, crop type, soil and methods of irrigation. From the review the study indicates some of investigation is more productive in full irrigation level. The maximum production in dry land, tomato should be irrigated using a drip irrigation system with 100%ETc, watering amount [17]. On the other hand 85%, 75% and 30%, are also effective in terms of water saving and yield. 85%ETc irrigation level water applied system appears to be a promising alternative for water conservation and labor saving with negligible trade-off in yield of maize [15]. The application of deficit irrigation (75%ETc) could be adopted in lettuce production [16]. Form the review I have seen that The WP increased as the irrigation level reduced.

## 4. RECOMMENDATION

1. During investigating the effect of deficit irrigation investigator should consider different factors of that affecting crop water requirement such as climatic condition, soil type, crop type (depth of root), growth stage of the crop, agro ecology of the environment and soil depth.
2. The investigator care on measuring parameters such as soil measure measurement before and after irrigation and flow measurement.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

## REFERENCES


1. Panigrahi P, Srivastava AK, Huchche AD. Effects of drip irrigation regimes and basin irrigation on Nagpur mandarin agronomical and physiological performance. Journal of Agricultural Water Management. 2012;104:79-88.
2. El-Hendawy SE, Abd El-Lattief EA, Ahmed MS, Schmidhalter U. Irrigation rate and plant density effects on yield and water use efficiency of drip-irrigated corn. Agriculture Water Management. 2008;95:836-844.
3. Ashraf M, Nawazish S, Athar HR. Are chlorophyll fluorescence and photosynthetic capacity potential physiological determinants of drought tolerance in maize (*Zea mays* L.). Pak. J. Bot. 2007;39(4):1123-1131.
4. Naor A. Irrigation scheduling and evaluation of tree water status in deciduous orchards. In: Horticultural Reviews, (Ed.): J. Janick. 2006;32:111-165. ISBN: 0-471-73216-8.
5. Akram NA, Shahbaz M, Ashraf M. Relationship of photosynthetic capacity and proline accumulation with the growth of differently adapted populations of two potential grasses (*Cynodon dactylon* (L.) Pers. and *Cenchrus ciliaris* L.) to drought stress. Pak. J. Bot. 2007;39(3):777-786.
6. Jabeen F, Shahbaz M, Ashraf M. Discriminating some prospective cultivars of maize (*Zea mays* L.) for drought tolerance using gas exchange characteristics and proline contents as physiological markers. Pak. J. Bot. 2008;40(6):2329-2343.
7. Ashraf M. Inducing drought tolerance in plants: Recent advances. Biotechnol. Adv. 2010;28:169-183.
8. Pereira LS, Oweis T, Zairi A. Irrigation management under water scarcity. Agriculture Water Management. 2002;57:175-206.
9. Zhang Y, Eloise K, Qiang Yu, Liu C, Shen Y, Sun H. Effect of soil water deficit on evapotranspiration, crop yield and water use efficiency in the North China Plain. Agriculture Water Management. 2003;64:107–122.
10. Bekele, Tilahun. Regulated deficit irrigation scheduling of onion in a Semi-arid region of Ethiopia. Agric. Water Manage. 2007;89:148–152.
11. Ali MA, Hoque MR, Hassan AA, Khair A. Effects of deficit irrigation on yield, water productivity, and economic return of wheat. Agric. Water Manage. 2007;92:151-161.
12. Stoll M, Loveys B, Dry P. Hormonal changes induced by partial root zone drying of irrigated grapevine. Journal of Experimental Botany. 2000;51:1627-1634.
13. Shao GC, Zhang ZY, Liu N, Yu SE, Xing WG. Comparative effects of deficit irrigation (DI) and partial root zone drying (PRD) on soil water distribution, water use,

growth and yield in greenhouse grown hot pepper. Scientia Horticulture. 2008;119: 11–16.

14. Sleper DA, Fales SL, Collins ME. Foreword. In: Irrigation of Agricultural Crops (R.J. Lascano and R.E. Sojka, Eds.), 2nd Edition, Agronomy Monograph no. 30. ASA-CSSA-SSSA Publishing. 2007;664.
15. Zelalem Shelemew Furgassa. The effect of deficit irrigation on maize crop under conventional furrow irrigation in Adami Tulu Central Rift Valley of Ethiopia. Applied Engineering. 2017;1(1):1-12. DOI: 10.11648/j.ae.20170101.11
16. Mandefro Chala, Kokobe W. Yohannes. Effect of irrigation application levels on yield and water productivity of drip irrigated lettuce (*Lactuca sativa* L.). International Journal of Basic and Applied Sciences. 2015;4(4):229-234.
17. Adam Bush Adam, Ali Widaa Mohamed Elamin, Amir Bakheit Saeed, Amir Mustafa Abd Eldayi, Tawfeeg Mahmoud Elsheikh. Effect of irrigation systems and watering amount on tomato (*Lycopersicon esculentum*) production under semi-arid conditions. International Journal of Scientific Engineering and Applied Science (IJSEAS). 2016;3(2). ISSN: 2395-3470.
18. Islam ST, Haque MZ, Hasan MM, Khan ABMMM, Shanta UK. Effect of different irrigation levels on the performance of wheat. Progressive Agriculture. 2018;29(2):99-106.
19. Kwizera Chantal, Basil T. Iro Ong, Niyonzima Hermenegilde, Ntunzwenimana Melance, Bucumi Eliphase. Effects of different irrigation rates on growth and yield parameters of Amaranth. International Journal of Advances in Scientific Research and Engineering (IJASRE). 2018;4(9). E-ISSN: 2454-8006.
20. Alomran M, Luki II. Effects of deficit irrigation on yield and water use of grown cucumbers in Saudi Arabia. WIT Transactions on Ecology and the Environment. 2012;168. ISSN 1743-3541.



*Peer-review history:*
*The peer review history for this paper can be accessed here:*
*http://www.sdiarticle4.com/review-history/58107*