SJIF IMPACT FACTOR: 4.110 CRDEEPJournals
International Journal of Basic and Applied Sciences Mandefro & Kokobe Vol. 4 No. 4 ISSN: 2277-1921
International Journal of Basic and Applied Sciences Vol. 4. No. 4 2015. Pp. 229-234

Full Length Research Paper

Effect of Irrigation Application Levels on Yield and Water Productivity of Drip Irrigated Lettuce (*Lactuca sativa* L.), Gedio Zone, Southern Ethiopia.

Mandefro Chala[1], Kokobe W/Yohannes[2]
[1] *Dilla University, Department of Water Resource and Irrigation Management, Dilla, Ethiopia.*
[2] *Dilla University, Department of Horticulture, Dilla, Ethiopia.*

**Corresponding author: Mandefro Chala*

Abstract
A field experiment was conducted at Dilla University; southern Ethiopia to evaluate the effect of irrigation application levels on yield and water productivity of drip irrigated lettuce. The experiment was laid out in randomized complete block design with three replications with the help of drip irrigation system. 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. Results from variance analysis revealed that yield and yield related parameters such as plant height, number of leaves and plant diameter were significantly affected by different water 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 (25.7t/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 (16kg/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.

Keywords: *Drip irrigation, lettuce, deficit irrigation, water productivity*

Introduction

Lettuce is the most popular vegetable with the highest consumption rate and economic importance throughout the world. It is most often used for salads, although it is also seen in other kinds of food, such as soups, sandwiches and wraps; it can also be grilled. (Coelho *et al*., 2005). Water availability is generally the most important natural factor limiting the widespread and development of agriculture in arid and semi-arid regions. Efficient water use by irrigation systems is becoming increasingly important especially in arid and semi-arid regions with limited water resources. Nowadays, full irrigation is considered a luxury use of water that can be reduced with minor or no effect on profitable yield (Kang and Zhang, 2004). New innovations for saving irrigation water and thereby increasing crop water use efficiency (WUE) are especially important in water-scarce regions (Gencoglan *et al*., 2006). Scheduling water application is very critical to make the most efficient use of drip irrigation system, as excessive irrigation reduces yield, while inadequate irrigation causes water stress and reduces production (Yazgan *et al*., 2008).Deficit irrigation and partial root-zone drying irrigation are the water-saving irrigation methods that cut down irrigation amounts of full irrigation to crops. The amount of irrigation reduction is crop dependent and generally accompanied by no or minor yield loss that increases the water productivity (Ahmadi *et al*., 2010b).

Deficit irrigation (DI) has been practiced in different parts of the world (Zhang, 2004; Payero *et al*., 2006; Bekele and Tilahun, 2007; Ali *et al*., 2007). Partial root-zone irrigation (PRI) or partial root-zone drying is a further development of DI. In alternate PRI, half of the 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 (Stoll *et al*., 2000). So far PRI has already been investigated on some vegetable crops (Shao *et al*., 2008). 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 (Sleper *et al*., 2007). To increase agricultural production and living standards in dry lands of Ethiopia, greater priority must be given to enhancing efficiency of water collection and utilization (Hillel, 2001; Sandra *et al*, 2001; Hune and Paul, 2002).

A number of researches (Kadayıfc *et al*. 2004; Acar *et al*. 2008; Yazgan *et al*. 2008; Bozkurt *et al*. 2009) based on water-yield relationship of lettuce cultivars were performed in different parts of the world. Sanchez (2000) demonstrated that lettuce yield increased in response to water and nitrogen. On the other hand, excessive application of irrigation water and nutrients result in some serious problems (Türkmen *et al*., 2004). Capra *et al*. (2008) found that the highest marketable yield of lettuce was recorded for plots receiving 100% of ETc and for deficit irrigated plots, reductions in crop production were ascribed to a decrease in lettuce weight. Karam *et al*. (2002) investigated the impact of deficit irrigation regimes on lettuce yield and water savings.

However, local information in Ethiopia on the response of lettuce yield and yield components with drip irrigation is scarce, especially dealing with the effect of limited water allocations. Therefore, the objective of this experiment was to investigate the effect of irrigation application levels on yield and water productivity of lettuce with the help of drip irrigation system.

Materials and Methods

Description of the Study Area

The field experiment was conducted in Gedeo Zone, Dilla Zuria Woreda, at Dilla University. Geographically, the area is located in Southern Ethiopia at 6^0 18' 11" to 6^0 25' 32" N latitude and from 38^0 17' 4^{0}" to 38^0 23' 43" E longitude with an altitude about 1476 m.a.s.l. The mean annual daily maximum and minimum air temperature is 28.4 ^{0}C and 12.8 ^{0}C, respectively. (Demelash 2010).

The agro ecology of the area is characterized as '*Weyna Dega'* (sub-humid) and '*Moist Kola*' (semi-arid). However, most of the area is found in the semi-arid agro ecology zone, with bi-modal rainfall characteristics. The topography is characterized by flat, gentle to steep slopes (Temesgen, 2010). The major field crops grown in the study area are maize, sorghum, haricot bean, and groundnut. Horticultural crops include cabbage, pepper, tomato, lettuce and sweet potato.

Experimental Design and treatments

The experiment was laid out with factorial arrangement at randomized complete block design (RCBD) with three replications per treatment with the help of drip irrigation system. 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) irrigating one part of the root zone in each irrigation event. The treatments were randomly applied to each block. Each experimental plot had 1.5 m by 5 m with 0.5 m free space between plots and 1 m wide road between replication. Each plot had four rows of lettuce plants. Spacing between plants and rows was 0.4 and 0.4 m respectively.

The seed were sown on 15, Oct, 2014 in plots and seedlings were transplanted to the experimental site after two weeks when the plants showed some permanent leaves. The entire plots were uniformly pre-irrigated prior to starting treatment applications using drip irrigation system to stabilize the soil water content in effective root depth.

A common recommended fertilizer rate was applied manually in the experimental plots. All plots received the same amounts of fertilizer consisted of 150 kg ha^{-1} of urea and 100 kg ha^{-1} of P_2O_5 (DAP) .No pesticide was applied. The irrigation water used in the study was obtained from a well. According to the results of the analyses, the water salinity level was 1.486 dS m^{-1} and had no serious harmful effect on plant growth. Crop water requirements was estimated using the CROPWAT computer software program using climatic, soil and crop data as inputs. The treatment application started on 2, Nov, 2014 and irrigation was terminated two weeks before harvesting, Dec 25, 2014.

The amount of water trickles out of the emitters was measured using measuring gauge and time of application was intensively monitored using stopwatch during each irrigation. The duration of time for the emitters to deliver the desired depth was calculated using the following relationship (Phocaides, 2000).

$$t = \frac{0.8Dr^2}{360q} \quad (1)$$

Where;

D = depth of water applied (cm) t = application time (hour)

q = emitters discharge rate (1/sec) r = radius of effective wetted area (m)

Crop Water Requirement

In this experiment, the reference evapotranspiration (ET_o) and crop water requirement (ETc) was estimated from long years climatic data collected from Dilla meteorological station, Awasa branch. FAO's CROPWAT computer model version 8.0 was used to estimate the values. 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.

Table 1. Some climatic data of the experimental site

Month	Min T.(deg.C)	Max T.(deg.C)	Mean	Humidity (%)
Oct	14.5	28.2	21.35	76.2
Nov	12.4	29.6	21	70.1
Dec	11.0	31.5	21.25	64.3

Soil Analysis

Soil samples from the experimental area were taken to analyze bulk density, texture, organic matter content, pH, ECe, moisture content at filed capacity and permanent wilting point from the field at three points along the diagonal of the experimental plot up to the depth of 45 cm. The results are as follows.

Table 2. Physical and chemical properties of experimental soil

Texture	Bulk density	FC (%)	PWP (%)	EC (µs/cm)	pH (1 : 2.5; Soil : Water)	Organic matter content (%)
Sandy clay loam	1.45	32.1	17.3	1.61	6.3	2.9

Water Productivity Estimation

Water productivity (WP) is generally defined as marketable yield/ET but economists and farmers are most concerned about the yield per unit of irrigation water applied. (Zhang, 2003).Thus, in this study, the water productivity was determined by dividing the yield of lettuce to the amount of water consumptively used by the crop.

$$WP = Y/WA \qquad (2)$$

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

Lettuce Yield and Components

For measurements of investigated parameters at the end of the experiment, six plants per treatment from the central row were selected randomly from each plot. Plant weight was determined by weighing above ground of the plants using sensitive digital balance. Plant diameter (cm) (two repetition in both east-west and north-south directions) and plant height (cm) were measured by ruler and calculated as the average of measured values. Total leaf numbers were determined by counting the leaves of randomly selected six plants and the dry weights were recorded after oven drying the plant samples at 70°C for 72 h.

Data Analysis

All measured variables were subjected to analysis of variance appropriate for RCBD. The data were analyzed using Genstat statistical software. The mean separation was made using Least Significant Difference (LSD) method.

Results and Discussion

In this experiment, yield and yield components were the important parameters considered to measure the effects of treatments.

Yield related parameters

The analysis of variance showed that the effects of different water levels on plant height, leaf number and plant diameter were significant. From this finding it is clearly seen that as the irrigation level increases the plant height also increases. As depicted in table 3 the highest mean plant height was observed on FI (26 cm) while lowest plant height was obtained from PRD50 (20 cm). This finding is in agreement with Yazgan *et al*. (2008). They reported that the irrigation water levels in lettuce had significant effects on plant height and obtained the highest plant height values from full irrigation levels. Kirnak *et al*. (2002) also reported that lettuce plant height increased significantly with increasing irrigation water applied.

In case of number of leaves, decrease in the irrigation level from FI to PRD50 resulted with a reduction of mean leaf number per plant. The maximum mean number of leaves was observed in FI (31.3) treatments whereas the lowest leaf number (21) was obtained from PRD50 treatments. The present study is in conformity with findings of Karam *et al*.(2002).They found that water deficit reduced leaf number. Similarly, Kamel *et al* (2013) reported that FI-100 treatments gave the highest yield, plant diameter and number of leaves. In contrast with our results, Acar *et al*. (2008) reported that different irrigation levels did not significantly affect mean leaf number and plant diameter.

In addition, our results are in agreement with the results reported by Karam *et al*. (2002) and Bozkurt and Mansuroğlu (2011), who obtained higher yield, head diameter and leaf number with 100% ETc, full irrigation treatment. It seems that, water stress should be avoided during the period of head formation, the most critical period of lettuce for irrigation.

It was also observed that increases in the leaf number and plant head height under drip irrigation system might have resulted due to excellent soil-water-air relationship with higher oxygen concentration in the root zone (Gornat *et al*., 1993).

Table 3. Effect of different irrigation application levels on yield and yield components of lettuce.

Irrigation Treatments	Plant height(cm)	Leaf number	Plant diameter(cm)	Dry weight g plant-1	Yield t/ha	WP (kg/m^3)
FI	26	31.3	27	10.5	42.0	16.0
75%FI	24	26	24	10.2	36.3	17.7
50%FI	21.7	22	22	9.80	29.0	18.0
PRD 100	25	28.3	25	10.3	39.0	17.0
PRD75	22.3	24	23	10.1	32.3	19.0
PRD 50	20	21	20	9.50	25.7	21.5
$LSD_{0.05}$	1.33	0.8	0.86	NS	2.9	0.91

The analysis of variance showed that variation in irrigation water application level influenced the mean plant diameter. The highest plant diameter value was observed FI (27cm) treatments followed by PRD 100 (25cm) while the PRD50 treatment had the lowest plant diameters (20cm). Yazgan *et al*. (2008) declared statistically important differences for plant diameters of lettuce under different irrigation levels. In line with this result Karam *et al*. (2002) and Bozkurt and Mansuroğlu (2011) obtained higher plant diameter with full irrigation treatment. In a similar fashion, Kirnak *et al*. (2002) reported that lettuce canopy diameter increased significantly ($P<0.05$) with increasing irrigation water applied and evapotranspiration.
On the other hand, Irrigation levels did not affect the plant dry weight. In agreement with this result, Bozkurt *et al*. (2009) reported that water deficit did not produced significant differences in plant dry weight. Similarly, Gallordo *et al*. (1996) found that lettuce fresh weight was more sensitive than dry weight to reduction in water supply.

Yield and water productivity
The result of the analysis of variance revealed that effect of different water levels influenced yield and water productivity significantly. It was found that the lettuce yields were increased by increasing irrigation water levels. As depicted in the above table FI treatment gave the highest mean yield (42 t/ha) while the mean yield obtained from the PRD50 (25.7 t/ha) treatment was the least of all. Reducing irrigation had resulted in significant decrease of yield. It may be due to inadequate soil moisture in the root zone.
Results of this study are in agreement with the results reported by Kamel *et al* (2013) who reported that FI-100 treatments gave the highest yield. Karam *et al*. (2002) also reported that water deficit produced significant differences in fresh weight of individual heads ($P<0.05$). In addition, Bozkurt and Mansuroğlu (2011) obtained higher yield with 100% ETc, full irrigation treatment. It seems that, water stress should be avoided during the period of head formation, the most critical period of lettuce for irrigation.

Rolbiecki and Rolbiecki (2007) reported that irrigation significantly increased marketable yield of lettuce. Bozkurt *et al*. (2009) also reported that water deficit produced significant differences in yield and yield components. Coelho *et al*. (2005) and Yazgan *et al*. (2008) demonstrated similar results that the total maximum and marketable yields were obtained from 100% pan evaporation. Kirda C. *et al* (2004) reported that, in an experiment on fresh-market tomato, a partial root zone drying treatment with the restoration of 70% ETc, caused a yield reduction by 21% with respect to the full irrigated treatment.

Moreover, Shahnazari *et al*. (2007) for field grown potato showed that compared with FI, PRD treatment saved 30% of water and increased water-use efficiency. However, the results of (Liu *et al*., 2006b) showed that exposure of potato to PRD in early phase of growth) did not have similar advantage comparing to full or deficit irrigation. Similarly, Liu *et al* (2006a) reported that partial root zone drying has no advantages over deficit irrigation for potato. The observed yield difference in this experiment may be due to different resource allocation caused by repeated wetting and drying cycles in the root zone.

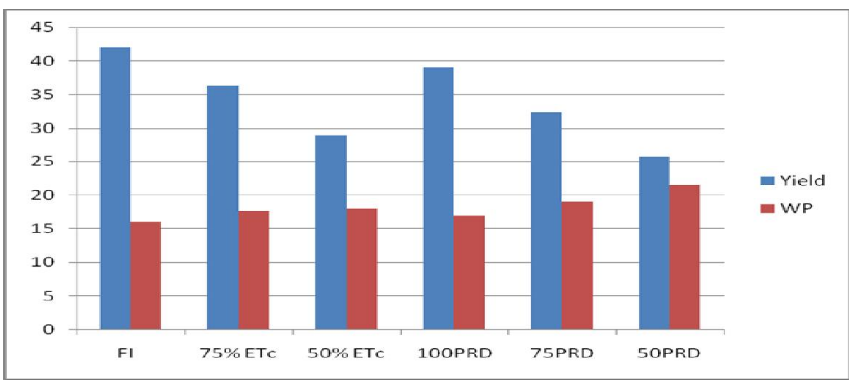

Fig 1. Effect of different irrigation application levels on mean yield and WP

The statistical analysis of variance shows that the difference in irrigation levels significantly influenced water productivity. In this experiment, we determined that the WP increased by the reduction of irrigation. WP under deficit irrigation ranged from a minimum of 16 kg m^{-3} in FI to a maximum of 21.5 kg m^{-3} in PRD50 level treatments. This indicates and confirms the water productivity under water shortage condition was higher than the full water applications. The increase in water productivity values under the water deficit irrigation practices could be attributed to the stomata closure. Furthermore, it was observed that there was no significant difference in water productivity between full irrigation treatment and 75% FI. Similar results on water productivity were reported for lettuce by others (Bozkurt *et al*., 2009; Gallardo et al., 1996). Kirnak *et al*. (2002) demonstrated similar results that IWUE increased with a decrease in irrigation water. In contrast to this study, Kadayifci *et al*. (2004) found that IWUE were highest in the full irrigated treatment. Karam *et al*. (2002) also reported that the water deficit treatments had lower water use efficiency than full irrigation. In general, differences between our study and previous studies may be due to differences in the plant variety used, region and cultivation periods.

Conclusion

Water scarcity and drought are the major factors constraining agricultural crop production in arid and semi-arid zones of the world. Innovations for saving water in irrigated agriculture and thereby improving water productivity are of paramount importance in water-scarce regions. This study investigated the effect of application of different irrigation level on yield and water productivity of drip irrigated Lettuce. Based on the findings of this study, the effect of the irrigation strategies applied in this study were statistically significant for yield, plant growth parameters and water productivity. It was found that yield components were higher in full irrigation treatments than those in deficit irrigation treatments. The Yield and yield related parameters such as plant height, number of leaves and plant diameter were significantly affected by different water 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). However, the water productivity increased as the irrigation level reduced. The highest values were obtained under the PRD50 treatments, while the lowest values occurred under full irrigation treatment. In addition, it was observed that there was no significant difference in water productivity between full irrigation treatment and 75% FI. Further work is suggested to evaluate the relative effect of deficit irrigation to substantiate the results.

Acknowledgments

We gratefully acknowledge Dilla university research and dissemination office for providing financial support and additional inputs to carry out the experiment. We also wish to extend our profound sense of gratitude to Mr.Lidet Befikadu for his unreserved support during the fieldwork.

References

Acar B, Paksoy M, Türkmen O, Seymen M, 2008. Irrigation and nitrogen level affect lettuce yield in greenhouse condition. African Journal of Biotechnology 7(24): 4450-4453

Ahmadi, S.H., Andersen, M.N., Plauborg, F., Poulsen, R.T., Jensen, C.R., Sepaskhah, A.R., Hansen, S., 2010b. effects of irrigation strategies and soils on field grown potatoes: Yield and water productivity. Agri.Water Management. DOI 10.1`016/j.agwat.2010.07.007.

Ali MA, Hoque MR, Hassan AA, Khair A (2007). Effects of deficit irrigation on yield, water productivity, and economic return of wheat. Agric. Water Manage. 92: 151-161.

Bekele and Tilahun (2007). Regulated deficit irrigation scheduling of onion in a Semi-arid region of Ethiopia. Agric. Water Manage. 89:148–152.

Bozkurt S, Mansuroğlu GS, 2011. The effects of drip line depths and irrigation levels on yield, quality and water use characteristics of lettuce under greenhouse condition. African Journal of Agricultural Research. 10(17): 3370-3379.

Bozkurt S, Mansuroğlu GS, Kara M, Önder S, 2009. Responses of lettuce to irrigation levels and nitrogen forms. African Journal of Agricultural Research 4(11): 1171-1177

Capra A, Consoli S, Russo A, Scicolone B, 2008. Integrated Agro-Economic Approach to Deficit Irrigation on Lettuce Crops in Sicily (Italy). J Irrig Drain Eng. 134 (4): 437-445.

Coelho AFS, Gomes EP, Sousa AP, Gloria MBA, 2005. Effect of irrigation level on yield and bioactive amine content of American lettuce. Journal of Science Food Agriculture 85:1026–1032

Demelash Wondimeneh. 2010. Characterization and Classification of the Soils of Upper Sala Watershed in Dilla Zuria District of Gedeo Zone, Southern Ethiopia. MSc Thesis, Haramaya University, Haramaya, Ethiopia.

Gallardo M., Jackson L.E., Schulbach K.F., Snyder R.L., Thompson R.B., Wyland L.J.,1996. Production and water use in lettuces under variable water supply, Irrig Sci 16, 125–137. doi:10.1007/BF02215620.

Gencoglan C, Altunbey H, Gencoglan S, 2006. Response of green bean (P. Vulgaris L.) to subsurface drip irrigation and partial rootzone-drying irrigation. Agric Water Manage. 84(3): 274-280.

Gornat B, Goldberg D, Rimon D, Asher Ben J (1993). The physiological effect of water quality and method of application on tomato, cucumber and pepper. J. Am. Soc. Hort. Sci. 98(2): 202-205.

Hillel, D., 2001. Small-scale irrigation for arid zone. FAO Development series 2, Rome, Italy.

Hune Nega and Paul M. Kimeu, 2002. Water harvesting techniques. RELMA, Ministry of Agriculture, Addis Ababa, Ethiopia.

Kadayıfcı A, Tuylu GI, Uçar Y, Çakmak B, 2004. Effects of mulch and irrigation water amounts on lettuce's yield, evapotranspiration, transpiration and soil evaporation in Isparta location, Turkey. Journal of Biological Science 4(6):751-755

Kamel N, Fathia E, Mohamed M , Netij Ben .Soil salinity, yield and water productivity of lettuce under irrigation regimes with saline water in arid conditions of Tunisia. International journal of Agronomy and Plant Production. Vol., 4 (5), 892-900, 2013.

Kang, S.Z., Zhang, J.H., 2004. Controlled alternate partial root-zone irrigation: its physiological consequences and impact on water use efficiency. *Journal of Experimental Botany*, 55: 2437-2446.

Karam F, Mounzer O, Sarkis F, Lahoud R, 2002. Yield and nitrogen recovery of lettuce under different irrigation regimes. J Appl Hort. 4(2): 70-76.

KARAM F., MOUNZER O., SARKIS F., LAHOUD R., 2002.Yield and nitrogen recovery of lettuce under different irrigation regimes. J Appl Hort 4, 70-76.

Kirda, C., Cetin, M., Dasgan, Y., Topcu, S., Kaman, H., Ekici, B., Derici, M. R., and A. I. Ozguven (2004). Yield response of greenhouse-grown tomato to partial root drying and conventional deficit irrigation. Agr. Water Manag. 69, 191-201.

Kirnak H., Demir S., Tas I., Cakmakli M., 2002.Response of different irrigation water applications on yield and growth of lettuce grown in greenhouse. J Agric Fac Harran Uni 6(1-2), 47-54.
Liu, F., Shahnazari, A., Andersen, M.N., Jacobsen, S.E., Jensen, C.R., 2006b. Effects of deficit irrigation (DI) and partial root drying (PRD) on gas exchange, biomass partitioning, and water use efficiency in potato. Sci. Hortic. 109, 113–117.

Liu, F., Shahnazari, A., Andersen, M.N., Jacobsen, S.E., Jensen, C.R., 2006a. Physiological responses of potato (Solanum tuberosum L.) to partial root-zone drying: ABA signaling, leaf gas exchange, and water use efficiency. J. Exp. Bot. 57, 3727–3735.
Payero JO, Melvin SR, Irmak S, Tarkalson D (2006). Yield response of corn to deficit irrigation in a semiarid climate. Agric. Water Manage. 84: 101–112.
Phocaides, A., 2000. Technical hand book on pressurized irrigation techniques. FAO, Rome, Italy.
Rolbiecki R., Rolbiecki N., 2007. Effects of micro-irrigation systems on lettuce and radish production. Acta Hort 729, 331-335.
Sanchez CHA (2000). Response of lettuce to water and nitrogen on sand and the potential for leaching of nitrate-N. Hort Science. 35(1): 73-75.
Sandra Postel, Paul Polak, Fernando Gonzales and Jack Keller, 2001. Drip irrigation for small farmers. Water international, 26:1, 3-13, DOI: 10.1080/0250806018686882.
Shahnazari, A., Liu, F., Andersen, M.N., Jacobsen, S.E., Jensen, C.R., 2007. Effects of partial root zone drying (PRD) on yield, tuber size and water use efficiency in potato under field conditions. Field Crop Res. 100, 117–124.
Shao, G..C., Z.Y. Zhang, N. Liu, SE. Yu, W.G. Xing, 2008. 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 119, 11–16.
Sleper, D.A., Fales, S.L., Collins, M.E., 2007. Foreword. In: Irrigation of agricultural crops (R.J. Lascano and R.E. Sojka, eds.), 2nd edition, Agronomy Monograph no. 30. ASA-CSSA-SSSA publishing, 664p.
Stoll, M., Loveys, B., Dry, P., 2000. Hormonal changes induced by partial root zone drying of irrigated grapevine. *Journal of Experimental Botany*, 51: 1627-1634.
Temesgen Kebede. 2010. Evaluation of Different Mulch Types for Soil Moisture Conservation and Yield of Tomato (*Lycopersicon esculentum Mill*.). MSc Thesis, Haramaya University. Haramaya, Ethiopia.
Türkmen Ö, Bozkurt MA, Yıldız M, Çimrin KM (2004). Effect of nitrogen and humic acid applications on the head weight, nutrient and nitrate contents in lettuce. Adv. Food Sci. 26(2): 59-63.
Yazgan S, Ayas S, Demirtas C, Buyukcangaz H, Candogan BN, 2008. Deficit irrigation effects on lettuce (Lactuca sativa var. Olenka) yield in unheated greenhouse condition. J Food Agric Environ. 6(2): 357-361.
Zhang Y, Eloise K, Qiang Yu, Liu C, Shen Y, Sun H (2004). Effect of soil water deficit on evapotranspiration, crop yield, and water use efficiency in the North China Plain. Agric. Water Manage. 64: 107– 122.