SJIF IMPACT FACTOR: 4.402 CRDEEPJournals
International Journal of Life Sciences Mandefro & Shoeb Vol. 4 No. 4 ISSN: 2277-193x
International Journal of Life Sciences Vol. 4. No. 4. 2015. Pp. 232-239

Full Length Research Paper

Effect of Deficit Irrigation on Yield and Water Productivity of Garlic (*Allium Sativum* L.) under Drip Irrigation and Mulching at Wolaita Soddo, Ethiopia.

Mandefro Chala[1] and Shoeb Quraishi[2]
[1]Dilla University, College of Agriculture and Natural Resources, Dilla, Ethiopia
[2]Haramaya University, School of Natural Resources and Environmental Engineering, Haramaya, Ethiopia

*Corresponding author: Mandefro Chala

Abstract
To cope with the current water shortage, it is necessary to adopt water-saving agriculture countermeasures. Hence, this experiment was conducted to study the effect of deficit irrigation on yield and water productivity of garlic under drip irrigation and mulching. The experiment was laid out using factorial arrangement in randomized complete block design with three replications. The first factor was three different water application levels as 100%, 80% and 60% of ETc (Crop evapotranpiration) and the second factor was two levels of mulch as wheat straw mulch and no mulch. Mean values of yield showed that 100 % ETc and 80 % ETc irrigation levels provided higher values of total and marketable yield which was significantly different from 60 % ETc treatments. The analysis of variance revealed that there was also a significant difference on yields between wheat straw mulch and no mulch treatments. Mean bulb weight and mean clove weight of garlic responded highly significantly to the effects of both irrigation levels and mulching (P < .01). On the other hand, there was a significant difference on water productivity values under different irrigation application levels and wheat straw mulch and no mulch treatments. Based on the findings of this research, application of 80%ETc could be suggested to generate comparable garlic yield to that of full irrigation and Wheat straw mulch can be effectively used to save water in order to harvest improved yield.

Keywords: *Drip irrigation, Garlic, Water deficit, Management strategy, Evapotranspiration, WUE*

Introduction

Garlic is one of the main Allium vegetable crops known worldwide with respect to its production and economic value. It is used as a seasoning in many foods worldwide; without garlic many of our popular dishes would lack the flavor and character that make them favorites (Salomon R.2002). It has higher nutritive value than other bulb crops in addition to containing antibiotics like garlicin and allistatin (Maly L.*et al* 1998).

Garlic (*Allium sativum* L.) is the most widely used crop next to onion and has a wide range of climatic and soil adaptation (Dessalegn L. and E. Herath. 1994). It can be produced in areas where about 600mm rain is received in its growth cycle. It cannot tolerate too hot or too cold climates. Relatively high temperature up to 30^{0}c is required for optimum bulb development but cooling conditions in the early stages favors vegetative grown. Excessive humidity and rainfall are detrimental to both vegetative growth and for bulb formation. Garlic thrives well on fertile, well drained sand or silt loam soils with good moisture retaining properties. (Sovovo M. and Sova P.2004). In Ethiopia, the Allium groups (onion, garlic and shallot) are important bulb crops produced for home consumption and are sources of income to many farmers in many parts of the country (Metasebia M. and Shimelis H 1998). The bulk of garlic for domestic market is produced in homestead gardens of subsistence farmers. Moreover, it has been produced by state farms mainly as a cash crop and the country used to earn foreign currency by exporting it to Europe, the Middle East and USA (Tabour G. and Zelleke A. 2000).

Garlic requires regular watering throughout growth for best production. Water needs are critical since rooting depth in garlic is shallow. The most critical stage for watering is during bulbing. Lack of irrigation or rainfall during this stage will result in smaller bulbs and earlier maturity. Drought stress during growth will decrease yield and reduce bulb size. Excess water as the crop matures causes bulb splitting, delays curing and may cause storage problems (Drost, D.2010). In garlic, flood irrigation is widely practiced, which results in inefficient use of irrigation water due to losses in deep percolation, distribution and evaporation. Micro irrigation ensures higher water use efficiency (English *et al*., 1990). Many investigations have been carried out worldwide regarding the effects of deficit irrigation on yield of mainly horticultural crops. (F. J. Olalla *et al*.2004, C. Fabeiro Cortés *et al* .2003, Fereres E and Soriano MA. 2007) However, few studies on water use and water management of garlic exist.

Patel *et al*. (1996) found a linear relationship between the amount of water applied with drip irrigation and garlic yield under drip irrigation. Panchal *et al*. (1992) found that water applications of 1.2 times the cumulative pan evaporation resulted in higher yields compared with less water. Similar results were reported by Sadaria *et al*. (1997). Other experiments with onion (S. Bekele and K.

Tilahun 2007) 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. Kumar et al. (2007) investigated also the impact of deficit irrigation strategies on onion yield and water savings. On the other hand, Results of different kinds of mulching indicated increased plant growth, yields, and improved bulb size of onions. Many of these effects were attributed to the capacity of the mulch to conserve soil moisture (Adetunji I.A. 1994, Abu-awwad. 1999, Shock C.C. 1999)

Despite its importance and increased production, garlic productivity, in many parts of the world, is low due to genetic and environmental factors affecting its yield and yield related traits (Nonnecke, I.L. 1989) .In Ethiopia, where local varieties are widely used, yields are by far low not exceeding 3-4 tons/ha. But the two improved varieties (Tseday and Bishoftu netch) are reported to give as high as 8.5 tons per hectare (Desalegn L. 1998).Generally, deficit irrigation and mulch are known to individually save scarce water but there has not been a study made to use drip set in conjunction with surface covering for different climate and crop under moisture stress in Ethiopia. Therefore, in view of the existing low productivity and water shortage, this study was carried out with the main objective of evaluating the effect of deficit irrigation on yield and water productivity of garlic under drip irrigation and mulching.

Materials and Methods

Description of the Experimental Site

This experiment was conducted at Wolaita Soddo ATVET College, Wolaita Zone, and SNNPR. The experimental site is located at 6°34'N latitude, 37°43'E longitude and at an altitude of 1854 meter ASL.The site has a bimodal rainfall distribution pattern with average annual rainfall of 1200 mm. The rainy season covers from April to October and the average minimum and maximum air temperatures are 14.6 ^{o}C and 25.4 ^{o}C, respectively (National Meteorology Agency, Awassa soddo branch). The soil type is sandy clay loam (Wolaita Zone soil laboratory). The major crops grown in the area are maize, sweet potato, *teff*, banana, haricot bean, onion, tomato and other vegetables.

Experimental Design and Field Layout

The experiment was laid out using factorial arrangement in randomized complete block design (RCBD) with three replications under drip irrigation system. The experiment consisted 6 treatments combinations: Control and two deficit irrigation, two mulch treatments with and without mulch, resulting in a total of 18 plots (Table 1). The first factor was three different water application levels as 100 %, 80 %, 60 % of ETc and the second factor was two levels of mulch as wheat straw mulch at 4 tons/ha and no mulch. 100 % irrigation implies the amount of irrigation water applied in accordance with the computed crop water requirement with the aid of CROPWAT software. 80 % and 60 % irrigation depths meant 80 % and 60 % of full irrigation requirement.

Table 1. Treatment combinations

Number	Treatments	Description
1	T1	100 % of crop water requirement without mulch.(Control)
2	T2	80 % of crop water requirement without mulch.
3	T3	60 % of crop water requirement without mulch.
4	T4	100 % of crop water requirement with mulch.(Control)
5	T5	80 % of crop water requirement with mulch
6	T6	60 % of crop water requirement with mulch.

Size of each plot was 1.2 m x 5 m. A total of four rows were kept on each plot. Spacing between each treatment and block was kept as 1m. Spacing between plants and rows of garlic was 10 cm and 30 cm respectively. Fertilizer application rate of 100 kg/ha of nitrogen and 92 kg/ha of P_2O_5 (DAP) was applied manually as per Ethiopian research centers recommendation to each plot. DAP was applied at planting time while urea was applied by split application (50 % of urea were applied two weeks after planting and the remaining 50 % after 45 days. A local garlic cultivar '*Tummo*" was used for the experiment.

The Irrigation schedule was set taking the size of the water container and maximum daily crop water requirement into account. It was set to be every three days. The duration of irrigation was determined based on the volume of water applied and the application rate of the irrigation system. Prior to starting treatment applications, the entire experimental plot was uniformly pre-irrigated (30 mm) for better establishment of the plant. The crop was planted on December 20, 2011 at a depth of 3 cm by hand. The irrigation was terminated two weeks before harvesting, April 5, 2011. Harvesting was done when the leaves fell over on April 20, 2011.

Drip System Installation and Mulching

The stand for placing water container having a capacity of 200 litres was constructed from locally available material. The container was placed at a height of 1.5 m above the ground surface. The mainline was connected to the inlet valve and to the sub mainline. The filter was attached to the mainline to supply clean water to the sub main and manifold. Control valve was connected to the lateral to control the water flow. The laterals were connected to the manifold at 30cm spacing with emitters spaced at 20cm interval. The end of the sub main and the laterals were closed with end caps. Each plot had four rows of garlic plants. Wheat straw mulch was collected from the local farmers, and dried before application in the plots. According to Lal (1981), mulch was weighed and applied uniformly at a rate of 4 tons/ha over the surface while leaving space around the plant.

Data Collection Techniques
Data collected through secondary sources included 17 years of climatic data, which were collected from National Meteorology Station, Hawassa branch. The climatic data used for determination of reference evapotranspiration (ETo), and crop water requirement (ETc) were mean monthly, minimum and maximum temperatures, mean monthly rainfall, relative humidity, wind speed and sunshine hours.

Other secondary data on the crop parameters like depth of the plant root, the crop coefficient, management allowable depletion, crop spacing, growth stages and period etc…were obtained from FAO guideline (Doorenbos and Kassam, 1992; Allen et al., 1998). The primary data collected included soil characteristics (texture, bulk density, infiltration capacity, field capacity, and permanent wilting point, pH, ECe, Organic matter content); emitters discharge rate, water use efficiency, application efficiency and yield.

Soil Analysis and methods
Table 2. Physical and chemical properties of experimental soil (0 - 45 cm)

Particulars	Value	Methods
Sand (%)	56.0	**Hydrometric method**
Silt (%)	23.3	
Clay (%)	20.7	
Bulk density, Kg m^{-3}	1.38	**Core Sampler**
FC (%)	30.3	**Pressure plate apparatus**
PWP (%)	18.7	
TAW(mm/m)	116.7	
EC (µs/cm)	1.40	
pH (1 : 2.5; Soil : Water)	6.10	**Soil pH Meter**
Organic matter content (%)	3.16	**Titration method**

Crop Water Requirement
In this experiment, the reference evapotranspiration (ET_O) and crop water requirement (ETc) was estimated from seventeen years climatic data (1995-2011) collected from Wolaita Soddo meteorological station, Awassa branch. FAO's CROPWAT computer model version 8.0 was used to estimate the values.

Table 3. Monthly reference evapotranspiration (ETo)

Month	**Min T.**	**Max T.**	**Humidity**	**Wind Spd.**	**Sun Shi.**	**Solar Rad.**	**ETo**
	(deg^{o}C)	(deg^{o}C)	(%)	(Km/day)	(Hours)	(MJ/m^2/d)	(mm/day)
December	14.1	26.5	50	199	8.8	20.7	4.80
January	14.0	27.3	51	173	8.4	20.6	4.69
February	15.3	28.6	45	199	8.6	22.0	5.44
March	15.6	28.3	52	164	7.9	21.7	5.10
April	15.1	26.6	66	130	7.6	21.1	4.44

Crop water productivity
Water productivity (WP) is defined as crop yield per unit applied irrigation water that is looking into the efficiency of applied irrigation water (Zhang, 2003). In this study, the water productivity was determined by dividing the yield of garlic to the amount of water consumptively used by the crop.

$$WUE = Y/WY \qquad (2.1)$$

Where: Y is Yield per unit area (Kg/ha), WY is Water used to produce the yield (mm)

Yield per unit area was obtained from the yield that was collected from each plot of land and water used to produce yield was registered when applied to produce the yield during the growing season.

Statistical 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

Crop Water Requirement of Garlic

The total water received for the 100 % ETc treatment was 576 mm and the other deficit irrigation treatments were taken 80 and 60 % of the maximum (100 % ETc) irrigation treatment, which were 461 mm and 346 mm respectively. As the experimental period was dry season, the share contributed by rainfall was insignificant. It was determined by using the following empirical formula.

$$P_e = P-(C * P) \quad \text{or} \quad Pe = f * P \qquad (3.1)$$

Where: P = daily rainfall (mm)

f and C = constant and their respective values are 0.2 and 0.8.

Crop Yield

Yield is the important component of plant performance under a set of growing condition. Any agronomic parameter at a given stage of growth would be of further use only when its effect is reflected on yield either way. The analysis of variance revealed that the effect of the applications of different irrigation levels and mulch significantly affected the total dry bulb yield (Table 4)

Table 4. Effects of irrigation and mulching on total yield, mean bulb weight, mean clove weight and clove number per bulb of garlic

Treatments	Total Yield (qt/ha)	Bulb weight (g)	Clove wt. (g)	Clove number
Irrigation app				
100	70.83a	37.30a	3.28a	11.83a
80	68.07a	35.62a	3.10a	12.00a
60	58.22b	28.43b	2.55b	12.33a
LSD 0.05	3.43	1.731	0.117	NS
Mulching				
WSM	68.59a	34.83a	3.1a	12.11a
NM	62.82b	32.73b	2.8a	12.00a
LSD 0.05	2.8	1.413	0.15	NS
CV (%)	4.1	3.6	4.9	9.7

WSM-Wheat straw mulch, NM-no mulch, LSD- Least significant difference and CV- coefficient of variation. a and b means with different superscripts in the same column are statistically different.

As shown above in Table 4, each increment in amount of irrigation level brought about significant increase in bulb yield over preceding amount of irrigation application. Accordingly, the garlic crop irrigated with 100 % and 80 % ETc irrigation applications significantly ($P \leq .01$) out yielded on average (71 qt/ha) and (68.1 qt/ha) in the order of 18 % and 15 % over the less irrigated (60 % ETc) irrigation treatment, respectively. Such yield increment may be due to higher water application. On the effect of the amount of irrigation application, yield has significantly decreased when moisture at the root zone decreased. In general, yield showed a decreasing trend with decrease in the amount of irrigation application. However, the highest bulb yield was statistically at par with the yield obtained from 80 % ETc. This supports similar findings of Moges (2006).

In contrast to this study, Ayars (2008) reported that marketable yield and total weigh of garlic obtained from 50% and 75% irrigation levels were significantly different from the 100% irrigation level with no difference between the 100% and 125% levels. Smith also reported that both shortage and excess water affect the growth and development of onion directly and consequently its yields and quality (Smith, 1994). Excess irrigation water affects crop growth by influencing availability of nutrients. Water and other inputs interact with each other and improper combination retards growth and yield (Awulachew, 2009).
Moreover, Yenus (2013) reported that the highest total bulb yields were obtained at irrigation level of 120% ETc than 100%ETc. However, in the present experiment, the increased yield might be due to efficacy of mulch in conserving moisture during entire crop growth period which favored the growth attributes.

The above table reveals that application of wheat straw mulch influenced the mean yield of garlic, total yield from wheat straw mulch (WSM) (68.6 qt/ha) was significantly ($p < 0.05$) different from unmulched plots (62.8 qt/ha). Since increased yield is directly related with the plant availability of moisture in the root zone, it can be inferred that higher total yield of garlic obtained from wheat straw mulch treatments implies the effectiveness of wheat straw mulch to conserve moisture. This has an agreement with that of Uddin (1997) and Bhuiya et al (2003) who reported that the yield of garlic was found to be statistically significant due to the effect of mulching.

In addition, Past research with mulch versus no mulch conditions showed that higher onion yield on mulch treatments were also likely related to the conservation of moisture (Suh and Kim, 1991) and fertilizer (Adetunji I,1994) The yield enhancement found in mulched plots of the current study might also be associated with these factors.

Quality of Garlic

The quality parameters for the garlic cultivar considered in the experiment were mean bulb weight (MBW), and mean clove weight (MCW) and mean cloves number (MCN). MBW of garlic has shown a highly significant difference to the effects of both irrigation level and mulching ($P< .01$) (Table 5). Bulb weight was highest (37.3 g) for the maximum amount of irrigation water application (100 % ETc) and lowest bulb weight (28.4 g) was obtained from the minimum amount of irrigation water application (60 % ETc). This is possibly due to the fact that the amount of irrigation application with 100 % ETc produced greater amounts of marketable bulbs than the bulbs obtained from the treatment plots irrigated with 60 % ETc.

Mean bulb weight also has shown a highly significant ($P< .01$) difference among mulching treatments. Treatments with wheat straw mulch produced heavier bulbs than the no mulch treatments (Table 5). This result is in agreement with the results obtained for onion (Umar *et al.,* 2000), shallot (Kebede, 2003), and garlic (Hossain et al.,2007). Similarly, Haque *et al* (2003) reported significant effect of mulching on mean bulb weight of garlic, but black polyethylene mulch being inferior to water hyacinth. The increased mean bulb weight under wheat straw mulch could be attributed to conserved soil moisture and organic matter contents, controlled weeds, and increased soil temperature (Tindall, 1991).

Mean clove weight (MCW) of garlic has shown highly significant ($P<.01$) difference to the effects of both irrigation and mulching ($P\leq .01$). It was observed that the influence of treatment on mean clove weight and increment trend in values of the parameter was more or less similar to that obtained for mean bulb weight. The highest mean clove weight (3.3 gm) was recorded at 100 % ETc which was statistically at par with the clove weight obtained at 80% ETc (Table 5). This result is in conformity with the findings of Bichi (1997) on garlic.

Mulching and irrigation application levels had no significant effect on mean number of cloves (MCN) per bulb (Table 5) which could be a result of inherited character of the garlic. This finding is in consistent with that of Moges (2006) and Hossain et al. (2007). who found no significant effect of irrigation application levels on clove number per bulb of garlic. In contrast, Mohsen *et al* (2012) reported that the variation in the number of cloves bulb $^{-1}$ due to the application of different mulching treatment was highly significant.

Water Productivity

Water productivity as affected by mulch and total irrigation application levels for bulb yield of garlic are presented in Table 6. The amount of water applied had an inverse relationship with crop water productivity. Statistically significant different WP values for bulb production were observed by application of different irrigation amounts and mulch. The WP for bulb yield were significantly ($P=.05$) influenced by different irrigation treatments. The irrigation water use efficiency differs considerably among treatments and generally tends to increase with a decline in irrigation (Howell et al., 2006).Water productivity probably will become more important as access to water become more limited (Shdeed, 2001).

The most deficient strategies often turn out to be the most efficient (Kirda and Kanber, 1999).Decreasing WUE was observed as the application of total irrigation increased from the minimum amount of irrigation application (60 % ETc irrigation treatment) to the highest amount of irrigation application treatment (100 % ETc), from 2.03 kg/ m^3 to 1.55 kg/ m^3 of water used.

In this experiment also decreasing WUE was observed as the application of total irrigation increased from the 60 % ETc deficit irrigation application to the highest irrigation application treatment (100 % ETc), i.e. in terms of efficiency from 1.84 kg/m^3 to 1.34 kg/m^3 of water used, respectively (Table 5). Similarly, Samson and Ketema (2007) reported that deficit irrigations (50 and 75% ETc) increased the WUE of onion. In contrast, Abbey and Joyce (2004) reported that WUE was significantly reduced due to water stress in onion plants.

Table 5. Effects of irrigation application levels and mulching on water productivity of garlic

Treatments	WP (kg/m^3)
Irrigation application (% ETc)	
60	1.84a
80	1.62b
100	1.34c
LSD 0.05	0.09
Mulch	
WSM	1.71a
NM	1.53b
LSD 0.05	0.07
CV (%)	4.2

WSM=Wheat straw mulch, a,b,c means with different superscripts in the same column are statistically different.

The analysis of variance revealed that maximum water productivity was recorded on wheat straw mulch treatment (1.71 kg/m^3) (Table 5), while it was minimum in unmulched treatment (1.53 kg/m^3). Higher WP with wheat straw mulch was due to reduction in evaporation and increase in yield. This result is in conformity with the findings of Boja (2006) and S. S. H. Shah *et al* (2015). The interaction effects of irrigation application level with mulching did not influence the water productivity of garlic yield significantly. Generally, the WP values ranges from the maximum 2.00 kg/m^3 of 60% ETc irrigation treatment for WSM to the minimum 1.3 kg/m^3 of 100% ETc irrigation treatment for NM treatment .

Table 6. Interaction effect of irrigation application levels and mulching on WP (kg/m^3)

	Irrigation application level		
Mulch	100 % ETc	80 % ETc	60 % ETc
WSM	1.38	1.68	2.00
NM	1.30	1.56	1.72
LSD	NS		
CV	4.2		

WSM = wheat straw mulch, NM = no mulch, NS = no significant difference.

Conclusion
Yield based comparison had shown that there was no significant difference between the yield obtained in 100 % and 80% ETc drip irrigation level. Mean values of yield showed that full and 80% ETc irrigation levels showed higher values of total and marketable yield which was siginificantly different from 60% ETc irrigated treatments. Applying of wheat straw mulch significantly improved garlic yield and saved applied water than no mulch treatment. Maximum water productivity was recorded on wheat straw mulch treatment while it was minimum in unmulched treatment. Decreasing water use efficiency was observed as the application of total irrigation increased from the 60 % ETc to the highest irrigation application treatment (100 % ETc). Therefore, deficit irrigation, application of 80%ETc could be suggested to generate comparable garlic yield to that of full irrigation and Wheat straw mulch can be effectively used to save water in order to harvest improved yield.

Acknowledgments
Our appreciation and gratitude go to Wolaita Soddo ATVET College, for providing us financial and material support for the research work, our special thanks goes to Mr. Daniel Desalegn, Dean of the college, Abebe Torchaso (Farm manager of the College) and Martha Mebratu for their unlimited effort in creating conducive environment to conduct this study.

References
Salomon R. (2002). Virus diseases in garlic and the propagation of virus free planting. In: Rabinwitch, H.D. and L. Currah (Eds.). Allium crop sciences: Recent advances. CAB International, Wallingford, UK.; 311-327.
Maly L, Bartos J, Hlusek J, Kopec K, Peteikova K,Rod J, Spitz P. (1998). Polni zelina_stvi. AgrospojPraha, 175-185.
Dessalegn L. and E. Herath. (1994) Agronomic Studies on Alliums (Garlic). In: Horticultural Research and Development in Ethiopia. Institute of Agricultural research and food and Agricultural Organization. Addis Ababa, Ethiopia.139-145.
Sovovo M. and Sova P. (2004). Pharmaceutical importance of garlic (*Allium sativum* L.) Hypolipemic effects in vitro and in vivo. Ceska Slov Farm,; 53 (3): 117 – 123.
Metasebia M. and Shimelis H. (1998) Proceedings of the 15th annual Research and Extention Review Meeting, Alemaya Research Center. Alemaya University of Agriculture Ethiopia. pp. 216-235.
Tabour G. and Zelleke A,(2000) .Achievements in Shallot and Garlic Research. Report Ethiopian Agricultural Research Organization, Addis Ababa Ethiopia.; No 36.
Drost, D., (2010).Garlic in the garden. http://extension.usu.edu/.
English MJ, J.T. Musick, VV.N. Murty. (1990) Deficit irrigation. In: Management of Farm Irrigation Systems. Hoffman J, T.A. Howell, and K.H. Solomon. (eds.). ASAE Monograph, Michigan. 631-663.
F. J. Olalla, A. Domínguez-Padilla, and R. Lópe)z, (2004 Production and quality of the onion crop (Allium cepa L.) cultivated under controlled deficit irrigation conditions in a semi-arid climate," Agricultural Water Management, 68 (1) : 77–89.
C. Fabeiro Cortés, F. J. Olalla, and R. López Urrea, "Production of garlic (Allium sativum L.) under controlled deficit irrigation in a semi-arid climate," Agricultural Water Management, 2003;59(2): 155–167.
Fereres E, Soriano MA, (2007)Deficit irrigation for reducing agricultural water use. J Exp Bot. 58: 147-159.
Patel,B.G.,Khanpara,V.D.,Malavia,D.D.,Kaneria,B.B. (1996) Performance of drip and surface methods of irrigation for garlic under varying nitrogen level. Indian J.Agron. 41 (1):174-176.
Panchal,G.N,Modhwadia,M,M.,Patel,J.C.,Sadaria,S.G.,Patel,B.S., (1992) Response of garlic to irrigation, nitrogen and phosphorous. Indian J.Agron. 37 (2):397-398.
Sadaria S.G.,Malavia D.D.,Khanpra,V.D.,Dudhatra,M.G.,Vyas,M.N.,Mathukia,R.K., (1997)Effect of nitrogen and phosphorous on garlic and their residual effect on groundnuts. indian J.Agron. 1997; 42(4): 653-656.

S. Bekele and K. Tilahun, (2007) "Regulated deficit irrigation scheduling of onion in a semiarid region of Ethiopia," Agricultural Water Management,. 89(1-2): 148–152.
S. Kumar, M. Imtiyaz, A. Kumar, and R. Singh, "Response of onion (Allium cepa L.) to different levels of irrigation water," Agricultural Water Management. 2007; 89 (1-2): 161–166.
Adetunji, I.A. (1994). Responses of onion to soil solarization and organic mulching in semi-arid tropics. Scientia Horticulturae, 60: 161-166.
Abu-awwad, A.M., (1999) Irrigation water management for efficient water use in mulched onion. Journal of Agronomy Science, 187: 1-7.
Shock C.C., L.B. Jensen, J.H. Hobson, M. Seddigh, B.M. Shock and L.M. Saunders. (1999) Improving onion and Market grade by mechanical straw application to irrigation furrows. Hort Technology, 9: 251-253.
Nonnecke, I.L. (1989)Vegetable Production, New York. 657p.
Desalegn L. (1998) .Seed production guideline for Tomatoes, onion and hot paper. Institute of Agricultural Research. Addis Ababa, Ethiopia.
Lal R, Soil management in the tropics (1981). In: D.G. Greenland Characterization and Management. Oxford University press, UK.
Doorenbos J, Pruitt, W.O. (1992).Guidelines for predicting crop water requirements. Irrigation and Drainage Paper. Rome: FAO. 24(5): 69-79.
Allen, R., Pereira, L.A., Raes, D. and Smith, M. 19(98). Crop evapotranspitation: guidelines for computing crop water requirements. Irrigation and Drainage Paper No. 56. FAO, Rome.
Zhang H. Improving water productivity through deficit irrigation: Examples from Syria, the north China Plain and Oregon, USA. In: Water Productivity in Agriculture: Limits and Opportunities for Improvement (Kijne, J.W., Barker, R., and Molden, D. eds). (2003).CABI publishing, 332 p.
Moges F. (2006) Evaluating small-scale drip irrigation system: an option for water harvesting-based smallholder farmers' vegetable production in amhara region. An MSc Thesis presented to the school of graduate studies, Haramaya University. 40-54.
Ayars, J.E. (2008).Water requirement of irrigated Garlic. American Society of Agricultural and Biological Engineers. 51(5): 1683-1688.
Smith M., (1994). CLIMWAT for CROPWAT, a climate database for irrigation planning and management. FAO irrigation and drainage paper 49, Rome, 113pp.
Awulachew, S.B., Philippe Lemperiere, Tulu Taffa, (2009).Irrigation methods: Drip irrigation-Options for smallholders. International Livestock Research Institute, Addis Ababa, Ethiopia.
Yenus O, (2013) Effects of irrigation and nitrogen levels on bulb yield, nitrogen uptake and water use efficiency of shallot (Allium cepa var. ascalonicum Baker).AJAR. 8(37) : 4637-4643.
Uddin,M.A., (1997). Effects of mulching and fertilizer management practices on the growth and yield of garlic.M.Sc thesis.department of horticulture,BAU.Mymensingh,Bangladis,.pp 31.
M.A.K Bhuiya,M.A Rahim and M.N.A chowdhury. (2003) Effect of planting time ,mulch and irrigation on the growth and yield of garlic.Asian J.of plant sc.;2(8)639-643.
Suh JK. and YB. Kim,(1991) Study of improvement of mulching culture method in onion. Influence of mulch materials and times on growth and yield. Res.Rpt.Rural Devel. Admin. Hort., 33: 31-36.
Adetunji IA. (1994). Responses of onion to soil solarization and organic mulching in semi-arid tropics. Scientia Horticulturae.; 60(2): 161-166.
Umar MS, C.O. Muoneke, M.D. Magaji,. (2000) Effect of intra-row spacing and mulching materials on growth and yield of onion (*Allium cepa* L.). Nigeria Journal of Agriculture and environment.;1(2): 29-39.
Kebede W. Shallot (*Allium cepa* var. ascalonicum) (2003).Responses to Plant Nutrients and Soil Moisture in a sub-humid Tropical Climate. Doctoral Thesis. Swedish university of Agricultural Sciences, Alnarp.
Hossain, A.K.M.M., M.J. Islam, F. Khanam, U.K. Majumber, M.M. Rahman and M. saifur Rahman,. (2007) Effect of mulching and Fertilization on Growth and Yield of Garlic at Dinajpur in Bangladesh. Asian J. of Sciences. 6(1): 98-101.
Haque Md. S, Md. Rezaul Islam, M. Abdul Karim and M.D. Abdul Halim Khan. (2003) Effects of Natural and Synthetic Mulches on garlic (*Allium sativum* L). Asian Journal of plant Sciences. 2 (1): 83-89.
Tindall, J.A.(1991)Mulch Effect on Soil Properties and Tomato Growth Using Micro irrigation. Agron. J., 83(2): 128-130.
Bichi AM. Response of garlic (*Allium sativum* L.) to varying levels of phosphorus and nitrogen. B.Sc. project submitted to the department of Agronomy, ABU, and Zaria. 1997; 22(2):36-43.
Hossain, A.K.M.M., M.J. Islam, F. Khanam, U.K. Majumber, M.M. Rahman and M. saifur Rahman,.(2007) Effect of mulching and Fertilization on Growth and Yield of Garlic at Dinajpur in Bangladesh. Asian J. of Sciences. 6(1): 98-101.
Mohsen M, Alireza A, Abdolmahdi B and Amin L. (2012) Evaluation of the effects of different mulch material on quantity and quality yield of garlic populations. International Journal of Agriculture and Crop Sciences. IJACS/2012/5-22/2660-2665
Howell TA, (2006) .Challenges in increasing water use efficiency in irrigated agriculture. In the Proceedings of International Symposium on Water and Land Management for Sustainable Irrigated Agriculture, April, Adana, Turkey.
Shdeed,K. (2001) Economic and Technical Assessment of On-farm Water Use Efficiency. United Nations, New York, USA. 2 (1): 33-39.
Bozkurt S, Mansuroglu GS, Kara M, Onder S (2009). Responses of lettuce to irrigation levels and nitrogen forms. Afr. J. Agric. Res. 4(11): 1171-1177.

Samson B, Ketema T. (2007) Regulated deficit irrigation scheduling of onion in a semiarid region of Ethiopia. Agric. Water Manag. 89:148-152.

Abbey L, Joyce DC. (2004). Water deficit stress and soil type effects on spring onion accumulation and partitioning in two potato cultivars. J. Plant Nutr. 25:1621-1630.

Boja M. (2006) Evaluation of straw and plastic mulch on water use efficiency of drip irrigated pepper. MSc Thesis presented to the school of graduate studies, Haramaya University. 44-47. (In press).

S. S. H. Shah, S. B. Ahmad, S. H. H. Shah, (2015) Mulching Effects on Water Productivity, Maize Yield and Soil Properties in Bed and Flat Sowing Methods. Int j.plant & soil science. 8(1): 3-4.