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Effect of Drip Irrigation System on Yield and Water Use Efficiency (WUE) of Tomato at Bako Agricultural Research Centre

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Abstract: Drip irrigation is one of the modern irrigation methods which aimed to distribute water near the roots, in small quantities, in a concentrated and hesitant manner in order to maintain the soil moisture needed for the plants. In addition, drip irrigation is suitable for all types of soils, certified agriculture, the conditions of available water and the land shapes. The utilization of drip irrigation methods could reduce the manpower, when using automatic instruments, thus, that one person can manage all the irrigation process. Drip irrigation system performance evaluation was conducted in Bako Agricultural Research centre for two consecutive years. The uniformity parameters, Emission Uniformity (EU %) and Uniformity Coefficient (UC %) were determined for the drip irrigation system installed over a year of performance. The procedures are based on taking measurements of emitter discharge along selected driplines on a sub-main. Results indicated that the uniformity of water application was 90% indicating that the emitter was still good after a year of installation. The average discharge rate was 1.33 l/h. The uniformity coefficient (UC %) for the drip irrigation system was 95%, indicating excellent water application uniformity and was quite significant for the evaluation of the uniform distribution of water for the design. The expansion of this irrigation method in rural communities could contribute to relevant water savings in most areas of the r West Part of Ethiopia.

Keyword: Application uniformity, Uniformity coefficient, Distribution uniformity and Wetting pattern

INTRODUCTION

Ethiopia is the country which endowed with abundant water resources and huge irrigable lands for irrigation agriculture (EPCC, 2015). Despite this, much of the available irrigation water is applied through the conventional surface irrigation method, where the efficiency of water is very low. The low irrigation water-use efficiency not only reduces the anticipated outcomes from investments in the water resources sector of the country, but also creates environmental problems, such as lowering of the water table due to over-exploitation of sub-surface water resources, water logging and soil salinity, thereby affecting the yields adversely. Technologies such as drip irrigation can improve WUE and decrease evaporation while maintaining or increasing yields (Phuntsho *et al.,* 2011). Water use efficiency (WUE) is a measure of a crop's capacity to convert water into plant biomass. Drip irrigation is one of the modern irrigation methods for irrigation, a technique aimed to distribute water near the roots, in small quantities, in a concentrated and hesitant manner in order to maintain the soil moisture needed for the plants (Paul *et al.,* 2013). In surface irrigation techniques and sprinkler irrigation techniques, the plants are supplied with water to meet its requirements for a long period, sometimes exceeding more than one week. Therefore, that the plants take advantage of it excessively in the first days after irrigation, which leads to reduce in the quantity and quality of the product in addition to the significant loss of water and fertilizer. In case of drip irrigation, water is distributed according to the daily requirements of plants in small quantities and concentrated in the roots zoon, which helps to obtained abundant product and with the high quality (Wu *et al.,* 2014). The high efficiency of drip irrigation is not only produced by the equipment's of drip irrigation, but also resulted from the two of main factors: a) the first factor is according to the water reaches to the plants roots with minimum evaporation and infiltration into the soil depth; b) the second factor is related to the water distributed according to the daily requirements for crops rather than tracking irrigation cycle. In addition, drip irrigation is suitable for all types of soils, certified agriculture, the conditions of available water and the land shapes. The utilization of drip irrigation methods could reduce the manpower, when using automatic instruments, thus, that one person can manage all the irrigation process. Tomato is one of the most popular and widely grown vegetables in the world.

The controlled, direct irrigation on the soil with the drip irrigation system prevents the entire plant from wetting, thus avoiding an increase in humidity in the leaf apparatus and in the fruits in tomato production. Tomato production using drip irrigation in high temperature prevents fungal, bacterial and viral diseases by absence of leaf moisture. Studies have shown that drip irrigation can increase tomato yield by 20–90 per cent, depending on the region and growing conditions. With an improved water-to-air ratio in the soil and a much more precise application of water and fertilizers, the crop can more easily reach its genetic yield potential. Drip irrigation systems can save up to 50 per cent more water than traditional irrigation methods such as furrow, making it an environmentally friendly option. With low flow rate

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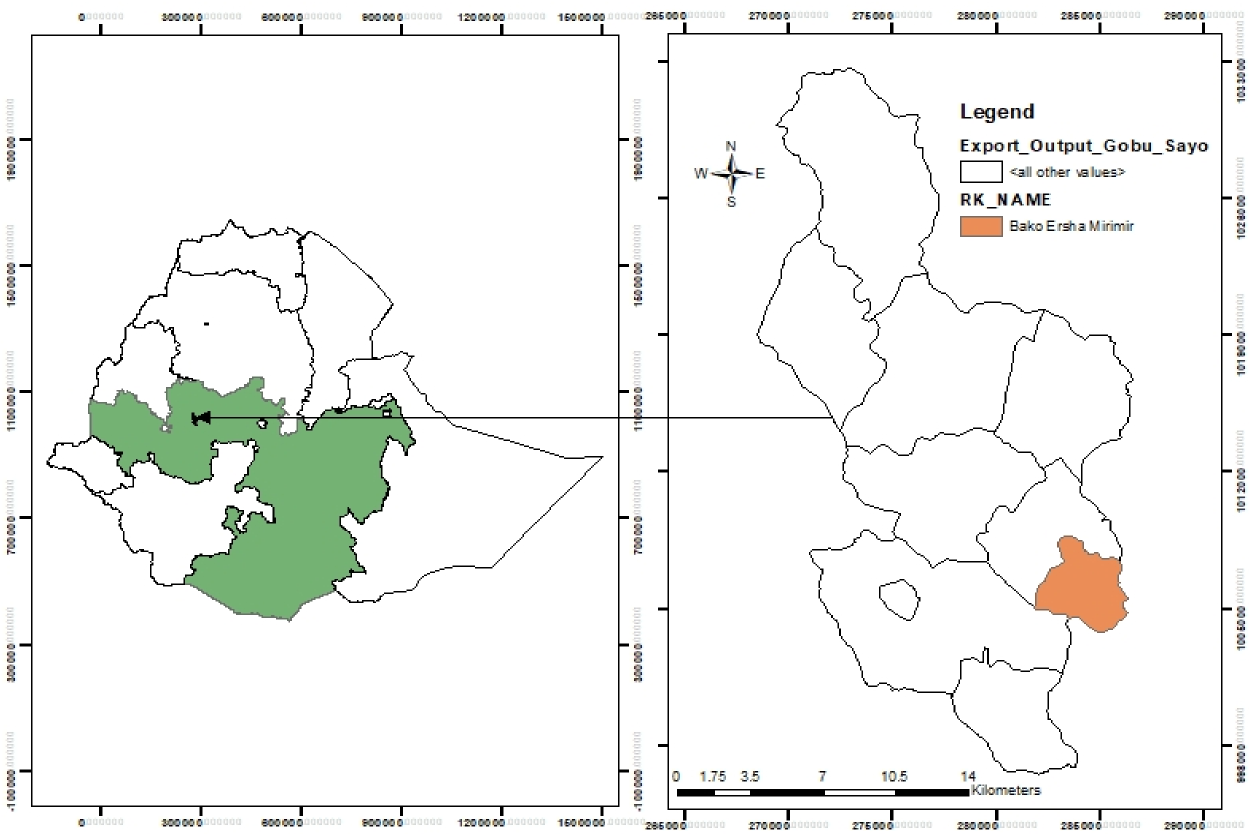
emitters, water is applied according to plants' needs, and exactly where it is needed. Without unintentional wetting of the area between the rows and without water logging or leaching, the plant's environment is brought closer to optimum. Drip irrigation allows for the precise application of fertilizers, ensuring that nutrients are delivered directly to the root zone, resulting in better nutrient uptake and reduced fertilizer wastage. The objective of this study was to evaluate the performance of drip irrigation system for tomato production. The specific objectives were to assess the drip irrigation emitter discharge rate along the dripline and to assess drip irrigation emission uniformity (EU %) and uniformity coefficient (UC %).

MATERIALS AND METHODS

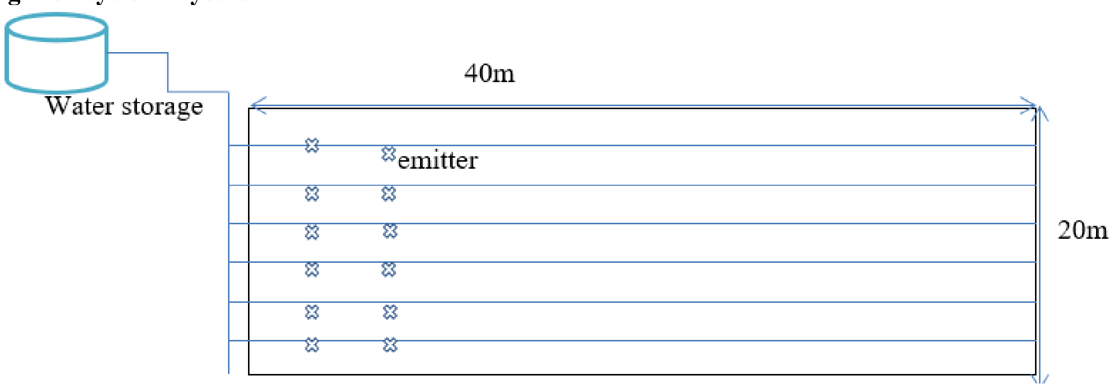
Study Area



Soil Sample Collection and Characterization

Soil physical properties and analysis were carried in the laboratory. Soil samples were collected at 40cm soil depths before and after planting placed in different moisture content cans labelled 1 and 2, 3, and 4. Soil samples were tested for Moisture Content, Soil texture, Dry Bulk Density and Total Available Moisture Capacity.

Drip irrigation system layouts



Evaluation Procedure

The evaluation was carried out according to Raphael *et al.* (2018). These procedures are based on taking measurements of emitter discharge along selected lateral lines on a sub-main. Five positions were tested on each lateral line which is 20 m long each: one located on

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the first emitter point close to the inlet, one at the far end, and one in the middle one at one-third and one two-thirds positions. Each lateral line was identified as L1, L2, and L3… L21. Emitter position on each lateral line was identified as A, B, C, D and E starting from the emitter point near the submain line spaced at equal distances of 0.3m on the lateral line. Thus, the catch can was identified as L1A, L1B, L1C, L1D and L1E, same for L5A to L5E, L10A to L10E and L15A to L15E and L20A to L20E. This gives a total of 25 measurement positions as there were 5 driplines.

The depth was estimated in the field by digging into the soil and then measuring the depth using a field tape from the top of the soil to the dry layer zone of the soil. Four different measurements were made and their average values gave the wetting depth of drip irrigation system. The effective wetting diameter was estimated in the field by measuring the diameter of their moisture spread. Four different measurements were made and their average values gave the wetting diameter of drip irrigation system.

Emitters Discharge Rates

The average discharge rates of the sampled emitters measured by volumetric method in which a disposable plastic cup was attached to five emitters and discharged water collected into a measuring cup for an hour during sample collection. The following parameters were used to evaluate the drip system based on the measured data in the study and were as follows:

Average Emitter Discharge Rate (q_a)

The mean amount of water released by each dripper per unit time is the average emitter discharge rate (q_a). It is obtained by using the equation of Zamaniyan *et al.*, 2014

$$qa=\frac{1}{n}\sum_{i=1}^{n} qi \quad (1)$$

where: q_i = flow rate of the emitter i m^3/s or (l/h);

n = total number of emitters.

Emitters Discharge Uniformity

Emission uniformity (EU) is determined as a function of the relation between the average flow emitted by 25% of the emitters with the lowest flow and the mean flow emitted by all emitters, as shown in Equation Zamaniyan *et al.*, 2014.

$$EU = 100\frac{q25\%min}{q} \quad (2)$$

Where: EU = Emission Uniformity (%); q = average of 25% of the lowest values of flow rate (l/h); q = average discharge rate of all sampled emitters (l/h). The evaluated system is classified according to the EU values, following Merriam and Keller (1978).

Uniformity Coefficient (UC)

The water application uniformity of drip irrigation system was evaluated using the uniformity coefficient formula reported by (Asif *et al.,* 2015):

$$UC=100[1-\frac{1}{nqa}\sum_{i=1}^{n}|qi-qa|] \quad (3)$$

Where: n = number of emitters under consideration;

Coefficient of variation (CV)

The coefficient of variation is used to measure the variability of flow in the drip irrigation system by using the following equation (Madramootoo, 1988).

$$CV = \frac{\text{Standard devation}}{\text{mean of sampled number}} \quad (4)$$

Water application uniformity (AU)

The water application uniformity depends on the uniformity of water discharge.

$$AU= (1-CV) X100 \quad (5)$$

Water use efficiency (WUE)

Water use efficiency (WUE) was calculated as the ratio between the yields harvested (kg) and the total volume of water applied (m^3

Vertical & Horizontal wetting Front

Four laterals were selected to take wetting front data. One emitter from each of selected laterals was selected and set to feed water to the plant. Then the water was for one hour to flow. Exactly after, 1hr the wetting diameter was measured with a tape. Similarly the data was taken for 2hr and 3hr from selected emitters. Next, the vertical wetting section of four emitters was cut with a spade and by a measuring taped the reading was taken. The positions of the moving wetting front on the surface and in the vertical plane of the substrate were recorded visually. Measuring tape was used to measure the distance covered. To evaluate the wetting patterns during the infiltration, the depth and radius of the wetting front was visually recorded during the first irrigation.

Data management and analysis

The recorded flow rate of each sampled point in the system was arranged in ascending order (ranked) using an excel spreadsheet. From the result obtained, the outliers, the very smallest and highest flowrates not consistent with the rest of the recorded flowrates were left out. Data obtained from field was analysed using excel.

RESULTS AND DISCUSSION

Long term Climate data of the study site

Table 1: Long-term monthly climatic data of the experimental area

	Min.Temp (c°)	Max.Temp (c°)	Wind Speed (Km/hr)	Relative Humidity (%)
Jan.	12.68	31.48	2.31	53.35
Feb.	13.06	32.76	2.67	49.39
Mar.	14.29	32.70	3.06	50.05
Apr.	14.69	32.14	3.00	53.24
May.	15.00	30.06	3.10	58.18
Jun.	15.14	27.03	2.72	65.20
Jul.	15.30	25.41	2.11	70.73
Aug.	15.23	25.27	1.71	71.04
Sept.	15.00	26.40	1.62	68.56
Oct.	14.32	28.53	1.60	62.88
Nov.	12.96	29.90	1.76	59.11
Dec.	12.04	30.71	1.90	56.14

Physio-Chemical Soil Properties

The results of the physiochemical properties analysis of the soil sampled from the study area as presented in Table 2. The soil of the study field was found to be sandy loam with average bulk density of 1.40 g/cm at 40 cm of root zone depth of sampling. In this study, the core method was used in determining the dry bulk density of the collected soil samples. Several research findings have shown that, average soil bulk density for a cultivated sandy loam soil range between 1.1 g/cm to 1.4 g/cm (USDA-NRCS, 2018). The average field capacity was 25% at 40 cm of root zone depth in the experimental field. The permanent wilting point (PWP) was obtained as 13.7%. Thus, root zone depth moisture distribution shows that, at lower depths, the available water was 11.3% for the soil type at site.

Table 2: Soil physiochemical property of study site

	Parameter	
Physical Properties	Sand	55
	Clay	20
	Silt	25
	Texture	Sandy loam
	FC (%)	25
	WP (%)	13.7
	Bd	1.40
Chemical Properties	pH	5.48
	%OM	4.3
	%OC	2.5
	%T.N	0.22
	AvaP(ppm	6.4
	Na me/100g	0.01
	Mg me/100g	0.43
	Ca me/100g	3.2

Drip Irrigation System Performance

The cumulative average discharge rates for the sampled laterals of the drip irrigation system for two years are shown in table 3 and 4. The emitter average discharge rate along the laterals at different point of the drip irrigation system range between 0.98 l/hr to 1.55 l/hr from sample discharge collected for hour duration during study years. The average discharge rate for the system under study was found to as 1.33 l/hr from combined data of two years. This finding agree with previous studies by Raphael *et al.*, 2018) who reported an average discharge rate of 0.5 to 0.6 l/h. From sampled collect little discharge variation was observed. This may be due to head variation of water stored in water storage tanker during filling of water.

Table 3: Emitter discharge at different locations along selected laterals

Sampling time	Sampling point along lateral 1					Sampling point along lateral 5				
	1	2	3	4	5	1	2	3	4	5
IS	1.53	1.43	0.99	1.54	1.55	1.44	1.54	1.45	1.52	1.44
DS	1.49	1.23	1.56	0.98	1.54	1.23	1.43	1.46	1.46	1.55
MS	1.34	1.55	1.33	1.44	0.99	0.98	1.05	1.06	1.06	1.35
LS	1.34	0.98	0.98	1.55	0.98	1.55	1.46	1.55	1.36	0.98

Note: IS; Initial Stage, DS: Development stage, MS; Maturity Stage, LS: Late Stage

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Table 4: Emitter discharge at different locations along selected laterals

Sampling time	Sampling point along lateral 10					Sampling point along lateral 15					Sampling point along lateral 20				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
IS	1.54	1.54	1.35	1.28	1.55	1.44	1.25	1.55	1.55	1.28	1.36	1.45	1.18	1.29	1.35
DS	1.06	1.35	1.26	1.36	1.07	1.26	1.55	1.28	1.26	1.36	1.55	1.07	1.08	1.48	1.06
MS	0.98	0.99	1.46	1.46	0.98	0.98	1.46	0.98	1.36	0.98	1.47	1.25	1.26	1.36	0.99
LS	1.55	1.54	1.55	1.46	1.45	1.55	1.34	1.36	1.46	1.06	1.39	1.45	1.24	1.46	1.26

Performance of drip irrigation system was evaluated on tomato crop cultivation. Discharges at emitters were measured by using collecting bottles and measuring cylinders. The coefficient of variation (CV) is used to measure the variability of flow in the drip irrigation system by using Equation 4. The obtained values in table 5 were used to classify the drip irrigation performance. Equation 5 was used to calculate water application uniformity (AU), where it depends on the uniformity of water discharge. This equation also gives information on how water distributed efficiently in the field. Water application uniformity obtained in table 5 was also used test uniformity water distributed through emitters. Table 5 illustrates the coefficient of variation (CV) and water application uniformity (AU) values drip irrigation in tomato production at Bako Agricultural Research Centre. In general, CV value was classified as very good and acceptable performance of drip irrigation system during study conditions. Little Variation was observed along lateral lines. This may be due to frequent flushing of water by opening of end cups at every irrigation. As reported by (Bargués *et al.*, 2010) flushing was needed to remove the accumulation of sediments in the lateral before emitters become completely clogged. Therefore, it is vital to flush the laterals as frequent flushing reduces water variation along the lateral lines. Water application uniformity (AU) express how evenly the uniformity of water is spread over the irrigated area used. Application Uniformity between laterals was found to be in the range of 85 t0 90 % with an overall average of 90 %. This value was classified as good application uniformity of drip irrigation system during study conditions.

Table 5: The parameter values that indicate the performance of lateral line in drip irrigation system

Sampled Laterals	Mean Discharge l/h	SD	CV	AU	Classification of CV	Classification of AU
1	1.32	0.03	0.1	90	Very good	Good
2	1.35					
3	1.34					
4	1.32					
5	1.3					
Average	1.33					

Emission Uniformity (EU)

The absolute emission uniformity was found to be 90% for the drip irrigation system table 6. Hence the drip irrigation system in water distribution uniformity is very good. The general ratings of EU values as indicated by (Kumari *et al.,* 2018) illustrates that, a drip irrigation system with EU of 84% - 90% is very good. Slight variation in the uniformity of emitter flow was observed between emitters. This may be resulted from leakage at joint between lateral line and submain line.

Uniformity Coefficient

Christiansen's coefficient of uniformity (UC%) for the tested drip irrigation system was 95%, indicating excellent fair water application uniformity and was quite significant for the evaluation of the uniform distribution of water for the design table 6. The water uniformity coefficient of the drip irrigation system under study from emitters was 97% and this value of the water uniformity coefficient was found to be within the acceptable uniformity level.

Emitter Wetting Patterns

The wetting depth ranged from 10.2 cm to 26.34 cm and the average wetting diameter was 23.59 cm. Results obtained from the study showed that, after an hour, the drip recorded diameters of wetting zone of 11.2 cm to 14.8 cm. Diameters observed after two hours of irrigation wetting zones were 15.6 cm to 19.7 cm. Diameters ranging from 21.6 cm to 26.34 cm after three hours of irrigation. This wetting circumference for 3 hours irrigation period was in line with the findings of in Isikwue *et al.* (2016) that wetted diameter for a single dripper in light, medium and fine textured soils.

Table 6: The parameter values that indicate the performance of lateral line in drip irrigation system

Sampled Laterals	Mean Discharge L/h	Wetting Diameter cm	EU %	UC%	Classification of EU	Classification of UC
1	1.32	23.59	90	95	Very Good	Excellent
2	1.35					
3	1.34					
4	1.32					
5	1.3					
Average	1.33					

Yield and Water use efficiency

Tomato yield and water use efficiency monitored during both season for each irrigation method are listed in Table 7. Drip irrigation method showed significant yield difference when compared with furrow irrigation. The furrow irrigation method used the higher amounts of water than drip irrigation method. Water use efficiency of drip-irrigated plot was higher furrow-irrigated plot in both growing season. The furrow irrigation method showed higher unmarketable yield when compared with drip irrigation system. Drip irrigation system can save water and maintain yield with good quality yield. The total fruit yield of 50.7tha^{-1} was recorded from drip irrigation system. Similarly, variations in total fruit yield per hectare ranged from 33 to 71 ton ha-1 were observed under open field growing conditions (Yeshiwas *et al.,* 2016).

Table 7: effect of irrigation systems on yield and water use efficiency

Irrigation system	Days to 50% flowering	Days 50% maturity	Yield t/ha		Total Yield t/ha	WUE (kg/m^3)
			Marketable	Unmarketable		
Drip Irrigation	57	95	45	5.7	50.7	15.8
Furrow Irrigation	63	102	33.4	10.43	44.1	8.5

CONCLUSION AND RECOMMENDATION

Drip irrigation system Performance for tomato production in the study area was successfully evaluated. The evaluation was done by comparing drip irrigation system with furrow irrigation method in the study condition. High irrigation water distribution uniformity is essential for the drip-irrigation system to reduce water losses in fields and maximize farmer's returns. In this study, the performance of the emitter with the low-pressure (gravity) drip-irrigation system was found significant for a 1.2 m overhead tank. The uniformity of water application was 90% indicating that the emitter was were still good after a year of installation. The average discharge rate was 1.33 l/h. The uniformity coefficient (UC %) for the drip irrigation system was 95%, indicating excellent water application and was quite significant for the evaluation of the uniform distribution of water. These results demonstrated good water application uniformity and very good water coefficient variation between laterals lines .Generally, all of the lateral lines performed well and need to be monitored periodically, especially during the growing process to prevent clogging to the dripping system. This irrigation method has many advantages and is easy to install. The expansion of this irrigation system for farmers could contribute to relevant water savings in most areas of the western part of Ethiopia.

REFERENCE

1. Asif, M., Ahmad, M., Mangrio, A. G., Akbar, G., & Wahab, A. (2015). Design, evaluation and irrigation scheduling of drip irrigation system on citrus orchard. *Pakistan Journal of Meteorology, 12*, 37–48.
2. Awullachew, S. B., Lambisso, R., Asfaw, G., Yilma, A. D., & Moges, S. A. (2010). Characterizing, assessing of performance and causes of underperformance of irrigation in Ethiopia. *Ethiopian Journal of Development Research, 32*(1), 55–80.
3. Bargués, J., Arbat, G., Elbana, M., Duran-Ros, M., Barragan, J., Cartagena, R., & Lamm, F. R. (2010). Effect of flushing frequency on emitter clogging in surface and subsurface drip irrigation. *International Conference on Agricultural Engineering*, Clermont-Ferrand, France.
4. Ethiopian Panel on Climate Change (EPCC). (2015). *First assessment report, Working Group II; Climate change impact, vulnerability, adaptation and mitigation IV. Water and Energy*. Ethiopian Academy of Sciences.
5. Isikwue, M. O., Ochedikwu Anthea, E. F., & Onoja, S. B. (2016). Small farm gravity drip irrigation system for crop production. *Greener Journal of Science, Engineering and Technological Research, 6*, 48–54.

https://doi.org/10.15580/GJSETR.2016.2.061416105

6. Kumari, C. P., Bhagat, E. I. B., & Neeraj, K. (2018). Emission uniformity evaluation of installed drip irrigation system. *International Journal of Chemical Studies, 6*, 1651–1654.
7. Madramootoo, C. A. (1988). Effect of pressure changes on the discharge characteristics of pressure compensating emitters. *Journal of Agricultural Engineering Research, 40*(2), 159–164.

   Solomon, K. (1979). Manufacturing variation of trickle emitters. *Transactions of the ASAE, 22*(5), 1034–1038.
8. Paul, J. C., Mishra, J. N., Pradhan, P. L., & Panigrahi, B. (2013). Effect of drip and surface irrigation on yield, water-use-efficiency and economics of capsicum (*Capsicum annum* L.) grown under mulch and non-mulch conditions in Eastern Coastal India. *European Journal of Sustainable Development, 2*, 99–108.
9. Raphael, O. D., Amodu, M. F., Okunade, D. A., Elemile, O. O., & Gbadamosi, A. A. (2018). Field evaluation of gravity-fed surface drip irrigation systems in a sloped greenhouse. *International Journal of Civil Engineering and Technology (IJCIET), 9*, 536–548.
10. Phuntsho, S., Shon, H. K., Hong, S., Lee, S., & Vigneswaran, S. (2011). A novel low energy fertilizer driven forward osmosis desalination for direct fertigation: Evaluating the performance of fertilizer draw solutions. *Journal of Membrane Science, 375*(1–2), 172–181.
11. USDA-NRCS. (2018). *Using soil textural triangle*. Soil Science Curriculum. University of Nebraska Institute of Agriculture and Natural Resources, CROPWATCH.
12. Wu, J., Guo, W., Feng, J., Li, L., Yang, H., Wang, X., & Bian, X. (2014). Greenhouse gas emissions from cotton field under different irrigation methods and fertilization regimes in arid northwestern China. *The Scientific World Journal, 2014*, Article ID 407832.
13. Yeshiwas, Y., Belew, D., & Tolessa, K. (2016). Tomato (*Solanum lycopersicum* L.) yield and fruit quality attributes as affected by varieties and growth conditions. *World Journal of Agricultural Sciences, 12*(6), 404–408.
14. Zamaniyan, M., Fatahi, R., & Boroomand-Nasab, S. (2014). Field performance evaluation of micro irrigation systems in Iran. *Soil and Water Research, 9*, 135–142.