

On Farm Evaluation of Low-Cost Drip Irrigation on Water and Crop Productivity Compared to Conventional Hand Watering System

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ABSTRACT

The efficient use of water is seen as a key to crop production in semi-arid and arid areas of Ethiopia. For smallholder farmers, low-cost drip irrigation systems provide a means of maximizing return on their cropland by increasing the agricultural productivity per unit of land; and through increasing cropping intensity during the dry season. The experiment was conducted in 2019-2020 cropping seasons in moisture deficit areas of Goro district Nere Negaya peasant association (PA), Southeastern Ethiopia. The study was conducted to evaluate and demonstrate low-cost drip irrigation system in moisture deficit areas and increase the productivity of farmers using harvested water with drip irrigation technology. The runoff water during rainy season was collected stored in the lined farm pond (Capacity of 60m³) with geomembrane then the water was lifted manually to water tanker for drip. Low-cost drip set which operates with gravity installed at 1m height above the ground level to supply water for the crop was obtained from Maki Batu Farmer Union. The highest Tomato yield of 40.8 t ha⁻¹ which is 64.8% higher over farmer practice was recorded under drip Irrigation with recommended practice at the study area. Whereas Conventional hand watering with recommended management practice gave the Tomato yield of 31.7 t ha⁻¹ (28%) Over farmer practice. The highest water use efficiency(3.76kg/m³) was obtained from Drip Irrigation with recommended managements and saves 10% water over farmer practice and lowest water use efficiency (2.06 kg/m³) was obtained from farmer practice. Consequently, an economic analysis shows that there is a significant difference, in terms of net income, between the various Irrigation method. Tomato was more valuable with Drip Irrigation, compared to hand watering and farmer practice. It can be concluded that Low-cost drip Irrigation with recommended management practice, saves labour and time and it provides uniform irrigation for Tomato production.

Keywords: low-cost, drip irrigation, water harvesting, water use efficiency and Tomato

INTRODUCTION

Agriculture is only possible when there is availability of sufficient water which can meet the plant need for growth, not only because plants need water for their physiological processes but also because water contains nutrients in solution. Lack of water in rain-fed areas limits crop production to one, possibly two crops per year. Access to irrigation, which provides the means to cultivate an additional crop, is viewed as one of the best ways to boost productivity of small scale, dry land farming systems (Postel, 1998).

Irrigation is the artificial application of water to the land to provide adequate moisture for crop production (Solomon, 1990). Phocaides (2000) also defined irrigation as the application of water, supplementary to that supplied directly by precipitation, for the production of crops. Generally, the risk of yield reduction due to drought is minimized with irrigation.

Irrigation is widely carried out through surface, sub-surface and pressurized systems, characterized by the mode of transport of the water onto the point of application (Keller and Bliesner, 1990).

Surface irrigation methods are utilized in more than 80% of the worlds irrigated lands yet the field level application efficiency is often only 40–50%. When water is applied on the surface, a considerable amount is lost through evaporation, run off and deep percolation making it less efficient. In contrast, drip irrigation may have field level application efficiencies of 70–90%, as surface runoff and deep percolation losses are minimized (Postel, 2000).

Drip irrigation may allow more crops per unit water to be grown and to allow crop cultivation in areas where insufficient water exists to irrigate by surface methods. Drip irrigation is defined as “the slow, frequent application of small volumes of irrigation water to the base or root zone of plants” (Smeal, 2007).

The system applies water slowly to keep the soil moisture within desired range for plant growth, minimizing such conventional losses as deep percolation, runoff and soil water evaporation. Drip irrigation is the most effective way to convey directly water and nutrients to plants and not only save water but also increases yields of vegetable crops (Tiwari et al., 2003). Drip irrigation is an efficient method for minimizing the water used in agricultural and horticultural crop production. Frequency of water application is one of the most important factors in drip irrigation management because of its effect on soil water regime, root distribution around the drip holes, the amount of water uptake by roots and water percolating beyond the root zone (Coelho and or 1999; Assouline, 2002; Wang *et al.* 2006). Because the drip irrigation is capable of applying small amounts of water where it is needed and to apply it with a high degree of uniformity and frequently, these features make it potentially much more efficient than other irrigation methods. For the above and many other reasons, drip irrigation is fast becoming popular in the developing world.

Tomato is one of the high value crops which can grow under drip irrigation. With the use of drip irrigation, tomato growers benefit from higher yields, soluble solids (good quality) as well as savings on water, energy and labor (Netafim USA's, 2003)

In Ethiopia drip irrigation is largely restricted to the large-scale commercial farming community and has evolved to become a knowledge intensive, technology-oriented operation such that smallholder farmers have not adopted it extensively. Hence, this study aims to popularize this advantages' technology to smallholder farmers of tomato growers in Goro district of Bale Zone. The general objective of this was to increase agricultural water, use efficiency by using water saving irrigation technology with the following specific objectives

Specific Objectives

- To evaluate the feasibility of drip irrigation system at the farmer's circumstances
- To efficiently utilize the scarce water resources and maximize crop yield and quality at smallholder farmers conditions home garden.

MATERIALS AND METHODS

Description of the Study Area

The experiment was conducted at Goro (Nere Negeya PA) district of Bale Oromia Region. The study areas lie at Latitude $6^{\circ} 58'56.9''$ N and Longitude $40^{\circ} 31'51.0''$ E while the elevation of the study area varies between 1600 m, a.s.l and 2000 m.a.s.l (Figure 1). The rainfall pattern of the study area is bimodal type, which divide the year into two main seasons: a main rainy season Kiremt (June to October) and short rainy season Belg (March to May). The mean annual rainfall of the study area is between 600 and 1000 mm with Mean maximum annual temperature 26.5°C and mean minimum temperature 12.4°C (Figures 2).

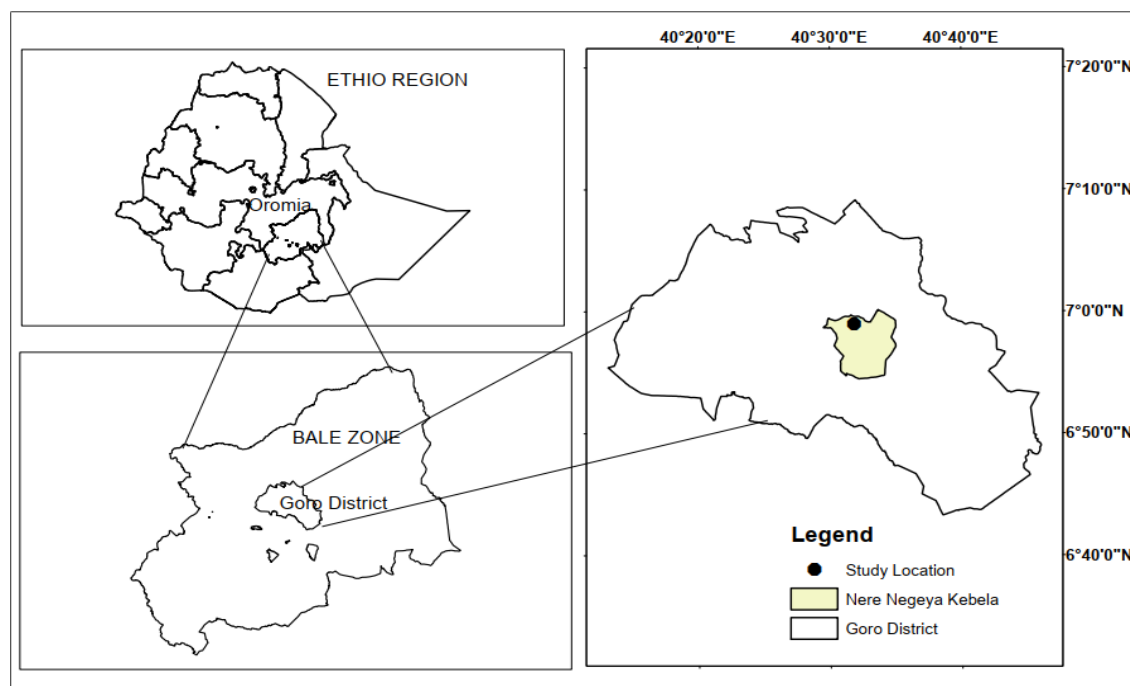


Figure1: Map of the Study area

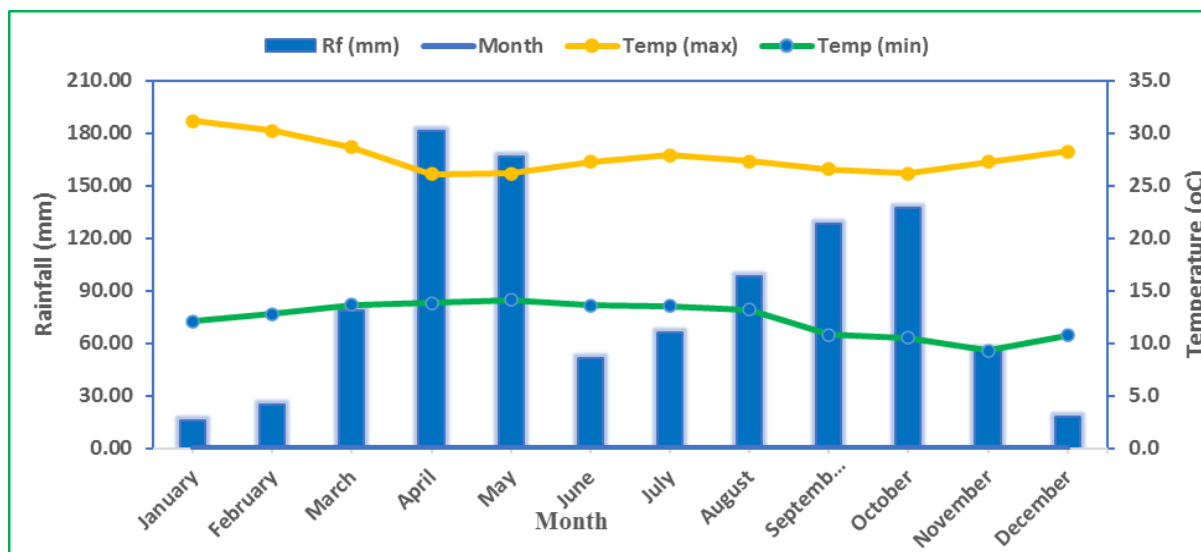


Figure 2: Mean monthly rainfall and maximum and minimum temperature of the study at Goro.

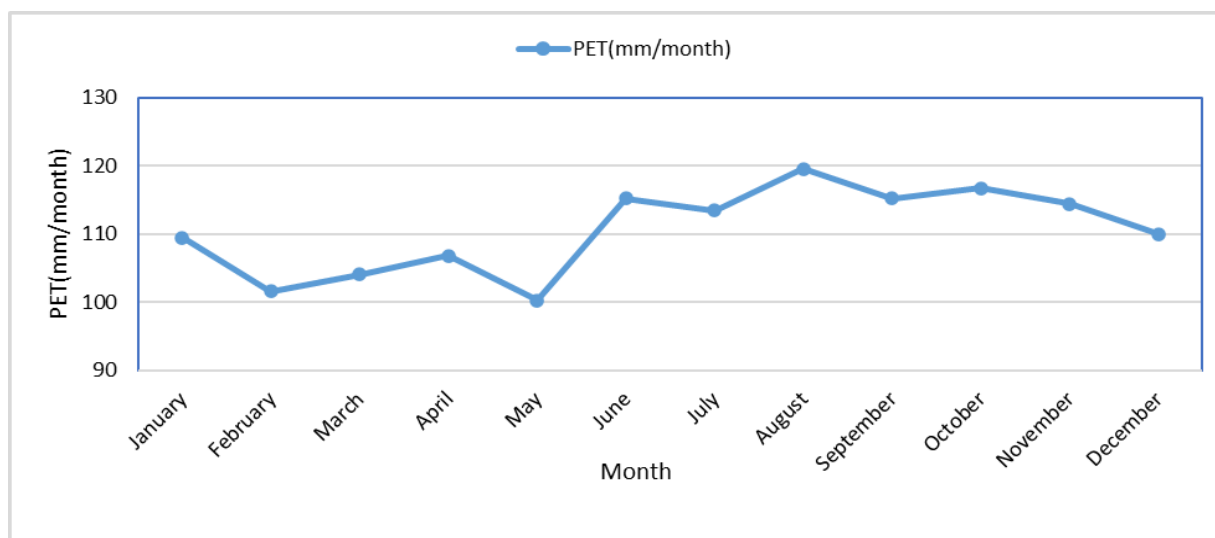


Figure 3: Monthly Potential Evapotranspiration (PET) of the study area

Experimental Design

The design used was RCBD in three replications. The treatments were Drip Irrigation system with recommended management (T1), Water Can with recommended management practice (T2) and Farmer practice as a control treatment (T3) that practiced commonly by farming community in the study areas. The demonstration and evaluation of Drip Irrigation from farm pond water harvesting for cultivating Tomato was made at Nere Negeya PA of Goro district-on farm, for two consecutive years (2019 up to 2020) on one farmer as a demonstration, where the farmer was having farm pond contracted by SARC and have suitable land near to the harvested water. The Pond is with side collectors, gutters (Chanel) were tied, stilling basin (to avoid direct entry of silt to ponds) and Geomembrane for lining of the ponds. The runoff water during rainy season was stored in the Pond (60m³ total capacity) for using during off-season for high value crop tomato (Cochoro variety) during two years of practice. The low-cost drip

set which operates with gravity installed at 1m height above the ground using barrel to supply water for tomato.

Data Collection

The data on yield (t ha^{-1}), total selling price (birr), water productivity (kg/m^3) and farmers' perception towards the technologies were taken. Effectiveness of the technology and farmers' preference toward the technology were collected through supervision and organizing mini field day. Farmers' and experts' opinion was collected at the time of field visit. To collect their real feeling and opinion, group discussion was undertaken and checklist was used for interviewing. Finally, the collected data (quantitative data) was analyzed by using descriptive statistics mean and standard deviation.

Mini-field day was arranged during the second year of practice which involved 40 participants. The discharge per m length of tape can be calculated by:

$$\text{Discharge (L/m/hr)} = \frac{\text{Discharge (L/emitter/ hr)}}{\text{Emitter spacing (m)}} \dots\dots\dots (1)$$

Duration of irrigation water application for a given drip system is computed as follows:

$$\text{Duration (hr)} = \frac{\text{Water requiriement(mm)}}{\text{Application rate (mm hr}^{-1}\text{)}} \dots\dots\dots (2)$$

Crop Water use efficiency for Tomato will be computed as follows;

$$WUE = \frac{YO}{\text{Total water used}} \dots\dots\dots (3)$$

Where YO: Yield of Tomato (kg/ha) and WUE-Water Use Efficiency

Economic Analysis

Economic analysis of the Irrigation system s was computed, based on investment, operation and production costs (CIMMYT ,1988). In this research, a partial budgeting approach based on economic evaluation of the product was used. To assess the economic viability of the drip irrigation system under variable irrigation, both fixed and operating costs were calculated (çetin et al. 2004). The net income for each treatment was computed by subtracting all the production costs from the gross incomes. All calculations were undertaken, based on a unit area of 1 ha, according to Koral and Altun (2000).

Data Analysis

The data collected was statistically analyzed using statistical analysis system (SAS) software version 10 using the general linear programming procedure (GLM). Mean comparison was carried out using least significant difference (LSD) at 5% probability level to compare the differences among the treatments mean.

RESULT AND DISCUSSION

Soil Property

The soil is Clay texture with sand, silt and clay in proportion of 22%, 34% and 44% respectively and pH of the soil is 6.88. the following table show some physical and chemical property of the study area.

Table1: Some soil properties of the study area

Soil Parameters	Value
Soil pH	6.8
Organic Carbon (%)	1.43
Total N (%)	0.11
Available P	8.3
Sand	22
Silt	34
Clay	44
Textural Class	Clay
PWP (%)	38
FC (%)	20

Yield and Yield Component Analysis

Effect of the technology on yield and yield components of Tomato in the study area is indicated in Table 2. As indicated in the Table there were mean yield and yield component differences between farmer practice, water can with recommended practice as well as drip irrigation with recommended practice described well. Accordingly, Tomato with Drip Irrigation had the highest Plant height (PH), number of fruits per plant, fruit length fruit wight and Yield flowed by water can with recommended practice (Table 2).

Table2. Average yield and yield component of Tomato under different management practice

Treatments	Ph(cm)	No of branch/p lant	No of fruit/ Plant	Fruit length(cm)	Fruit weight(g)	Yield(t /h)	Water productivity (kg/hmm ⁻¹)
Drip Irrigation + RMP	53.8 ^a	6.7	32.3 ^a	5.3 ^a	77.56	40.8 ^a	3.76 ^a
Water Can + RMP	44.7 ^{ab}	5.1	28a ^b	4.5 ^b	70.53	31.7 ^{ab}	2.74 ^b
Farmer Practice	37.8 ^b	4.9	23.6 ^b	4.1 ^b	66.56	24.8 ^b	2.06 ^b
CV	10.56	21.5	8.16	8.1	12.6	14.7	14.4
LSD (0.05)	9.59	ns	4.56	0.75	ns	9.59	0.82**

Where: Ph: Plant height, CV: coefficient of variation, LSD (0.05): Least Significant Difference and RMP; Recommended Management Practice

Generally, Tomato growing using improved technology (Drip Irrigation system) techniques had better yield advantage as compared to farmers' practices. That means farmers' practices had the lowest yield and yield components, which is due to poor management practice effect on crop performance. In line with results of this study Shushay et al., 2014 and Satyendra et al., 2013 reported that yield of tomato under drip system was found higher as compared to the surface irrigation method.

The highest Tomato yield of 40.8 t ha⁻¹ which is 64.7% higher over the farmers' practice (poor management practice), was recorded under Drip Irrigation systems. Similarly, the highest Water productivity of 3.76 kghmm⁻¹ which is 9.6% water saved over the farmers' practice was obtained when the Tomato was grown using Drip Irrigation with improved management. Similarly, Shah S K, 2011 reported that 44 % yield increment and 79 % water saving under drip irrigation in tomato production than furrow irrigation system. The Irrigation with water can using improved management practice also gave significantly higher values of plant height, fruit length, fruit weight and Yield over farmer practice (Table 2). Studies revealed that, drip irrigation increased the yield of tomato and water use efficiency (WUE) by 19 and 20% (Fekadu and Teshome, 1997) as compared to other irrigation system; and others found it significantly reduced the irrigation water requirement of a crop as it supply water only to root zone of the crop (Postel et al., 2001). This indicates that the design and management of the system was very adequate and fundamental to application efficiency and irrigation uniformity. Our results agree with findings of researchers in other regions, who used a trickle irrigation system (Alva et al. 1999; Fares and Alva 2000; Zotarelli et al. 2009a, b)

Economic Analysis

Table 3 presents the Partial budget analysis of Tomato cultivation under various irrigation methods. The cultivation of Tomato will be profitable after the first harvest with both LCDI and HW irrigation methods. Although a farmer will generate greater profits in the first season of use with HW, farmers do choose LCDI rather than watering by hand for a variety of reasons. First, when labour costs are included, long-term profits (more than four crops) will be greater with LCDI. In addition, labour associated with hand watering is physically more demanding.

Table 3: Partial budget Analysis of the management practice on the basis of Unit area 1 h

Treatment	Total Cost that Varies per h	Average Yield (kg/h)	Adjusted Yield(kg/h)	Gross Benefit (ETB/h)	Field Net Benefit (ETB/h)
Farmer Practice	85500	24800	22320	446400	360900
Water Can + RMP	142500	31733.3	28560	571200	428700
Drip Irrigation + RMP	200000	40833.3	36750	735000	535000

Where; **RMP**: Recemented management practice

This is not reflected in this analysis, as the cost of labour was considered equivalent irrespective of the degree of physical effort. Furthermore, hand watering requires a methodological and

diligent application procedure, easy for a researcher, but considerably more difficult for a farmer managing a complex portfolio of livelihood options. The greater long-term profitability and reduced labour costs favour the use of LCDI over hand watering and Farmer practice. Other Studies also revealed that, low-cost drip irrigation has high net benefit when compared to Hand watering and farmer practice (Stefanie von W et al.,2003).

Farmer's Preference of the Technology

Mini-field day was organized to collect the preference of the technology by the farmers and other stakeholders at the end of the season. Accordingly, a total of 40 (30 male, 10 female) participants consisting of farmers, extension agents, experts and researchers were participated on the field day event. Yield advantage, crop performance and Cost effectiveness were criteria's set by participants to aid selection process of the best technology. The feedback of the field day participants toward the technology are as indicated in Table 4.

Table 4. Participants Feedback (N=40)

Irrigation method	Cost effectiveness of the technology		Easy to use (Easiness)		Crop performance		Yield advantage	
	N	%	N	%	N	%	N	%
Drip Irrigation +RMP	5	12.5	30	75	25	62.5	26	65
Conventional hand watering +RMP	15	37.5	5	12.5	10	25	9	22.5
Farmer practice	20	50	5	12.5	5	12.5	4	10

RMP: Recommended managements Practice

From farmer's feedback assessment, it is revealed that the yield of Tomato crop by Drip Irrigation is much advantageous than farmer practice and conventional hand watering. Farmers were also reported that Drip Irrigation enhance easy to use and better crop performance. Even though the cost effectiveness of the farmer practice is higher, farmers prefer Drip Irrigation because of the low yield. Generally, 90% of the participants were selected Drip Irrigation as best irrigation method technology options to cultivate tomato in the study area.

CONCLUSION AND RECOMMENDATION

Water saving irrigation technologies need to be tested under local environments and particular agricultural production systems. Thus, the main challenge confronting both rain fed and irrigated agriculture is to improve WUE and sustainable water use for agriculture. Drip irrigation was found increased fruit yield of tomato and improved WUE due to consumption of less water. Generally, practicing rain water harvesting and using the collected water as supplementary or as complementary irrigation for double cropping is the better way of increasing agricultural crop production in moisture deficit areas of Southeastern Ethiopia, as low rainfall amount, high rainfall variability in space and time and decrease in reliability is the major impediment to the productivity of rural poor in these areas.

As this study reveals, water harvesting technology combined with water saving drip irrigation system is found effective in moisture deficit areas like Goro district and similar agro ecologies; especially for producing high value crops (onion, tomato etc) which have high return per plot of land and per drop of water during off-season or to supplement rain fed crops. But it needs careful planning for wise use of harvested water (increasing water use efficiency) to ensure increased production.

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