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Verification and Demonstration of Low-cost Family Drip Irrigation System for Potato Production Under Smallholder Farmer's Condition at Jimma Zone

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Abstracts: Water scarcity is the major threats to global food production constraints as well as in Ethiopia. In addition river water is not accessible to all location due to topographic barriers. So, farmers far from river may accessible to hand dug wells, but its amount is low as compared to river water. Therefore, this low quantity of water requires effective utilization. Though, demonstration of low-cost and appropriate micro-irrigation system had been designed and carried out under agro-climatic condition of Jimma Zone, Dedo district, Waro-kolobo kebele at farmers field conditions for three consecutive years to evaluate the feasibility of drip irrigation system, efficiently utilize the scarce water resources and maximize potato yield. Drip irrigation and furrow irrigation methods were evaluated on 336 m^2, the area was divided equally into two parts, and each had an area of 168 m^2. The tuber yield data were collected and sorted into marketable and non-marketable yields. The maximum yield of potato was obtained from drip irrigation, while lowest from furrow irrigated fields. The drip irrigation had greater performance than furrow irrigations method in terms of yield. The higher water productivity was obtained from drip irrigation and lower from furrow. A total of 172 participants were attended training during three years, 132 male and 40 females. The maximum net benefit was recorded from drip irrigation. Therefore, drip irrigation method is better technology in study area where shortage of water exists or when source of water are limited as the case of shallow wells, and preferable in sloppy areas. So, for more accurate information and justifications it needs to be demonstrated and verified under varies climatic and soil condition of Jimma Zone.

Keywords: Drip Irrigation, Furrow Irrigation, Water Productivity, Water Saving, Potato, Tuber Yield

1. Introduction

Water scarcity is now the major threats for the global food productions [1]. Most farmers in Africa including Ethiopia lived in water limited areas. Even though water resource is abundant, the access of river water are constrained by topographic factors, however, some farmers used hand dug wells, the production of this well is quite low as compared to rivers. This small quantity of water requires greater saving to produce more yields per liter of water. So, the best irrigation technology is required to save this small quantity of water. Drip irrigation is among best alternatives to overcome such problems.

Drip irrigation is an irrigation method whereby small quantities of water drip directly to the root zone of crops through a network of plastic pipes, valves, emitters or drippers, and ancillary devices [2]. Drip irrigation technology is used to improve yields and irrigation efficiency [1], notably by maximizing irrigation uniformity and minimizing water deliveries [3].

A typical drip irrigation kit comprises of a screen filter, a main valve, several thin flexible plastic pipes of different lengths, and water emitters. Water is manually supplied to the reservoir or by using treadles or manual. A defining

difference between conventional high-tech drip irrigation and the low-cost version is the pressure in the drip lines. The pressure in the pipes of drip kits is delivered by gravity, typically 1 to 2 meters of head. The lower head provided by gravity reduces the costs of the material (pipes and drippers) and fuel to run the pump. The drip lines operate under low gravity as the water reservoir, which supplies water to them, is elevated by one or two meter [4]. The size of the area to be irrigated is depending on availability of irrigation material and farmers willingness.

Having the importance of drip irrigation method in the sustainable use of irrigation water, attempts are being made to introduce family drip irrigation in different parts of Ethiopia where shortage of water are prominent [5]. However, the technology is less adopted by smallholder farmers. Many farmers feel that the water drops are insufficient to satisfy crop needs as compared to the one traditionally used furrow irrigation. According to Gebrekiros et al. [5], the lower expansion of drip system utilization in country is mainly due to the lack of awareness including training and demonstration of the technology at field level under farmers' operating condition as farmers were not convinced with the significance of water drops to satisfy crop needs as furrow irrigation. In view of the limited water resource in the study areas, the long-term sustainability of drip irrigation system appears to depend on how much productivity improved after shifting from surface irrigation to drip irrigation. Hence, it is important to conduct a research and demonstrate in both irrigation methods at farmers' field where farmers can easily convinced with the amount of water saved and yield increased.

Potato is one of the most popular and the most cultivated vegetables in Ethiopia in general and in Jimma Zone in particular as it is considerably important cash crop. Farmers in the study area produce Potato as a cash vegetable crop and it is the first in area coverage, but its productivity is very low. Having the above facts, the specific objectives of this study was to evaluate the feasibility of drip irrigation system and efficiently utilize the scarce water resources and maximize potato yield at smallholder farmer's conditions.

2. Materials and Method

2.1. Description of the Study Site

The study was conducted at Waro-kolobo kebele in Dedo worada, Jimma Zone, southwest of Ethiopia. The site was located 360 Km from the capital Addis Ababa and about 14 Km west of Jimma town, the capital city of Jimma Zone. Geographically the experimental site is located at 7° 37' 03" North Latitude and 36° 50' 04" East Longitude with an altitude of 1708 m.a.s.l.

The site receives a mean annual rainfall of 1541 mm with an average minimum and maximum temperature of 11.5 and 25°C, respectively. The soil textural class of the experimental area is sandy clay loam.

Table 1. *Long term climate data of experimental site.*

Month	Min Temp	Max Temp	Humidity	Wind	Sunshine	Radiation	ETo
	°C	°C	%	km/day	hours	MJ/m^2/day	mm/day
January	6.3	29.8	72	48	7.4	18.8	3.52
February	8.4	31.6	65	67	8.1	20.9	4.15
March	10.8	31.7	65	73	8	21.7	4.47
April	13.5	29.9	74	67	7.8	21.5	4.35
May	12.4	28.2	84	70	8.9	22.6	4.29
June	13.3	27.2	88	63	6	17.8	3.47
July	13.5	24.8	81	46	3	13.5	2.71
August	14.1	26.6	84	44	4.6	16.3	3.18
September	14.1	27.6	79	52	6.4	19.1	3.78
October	10.7	26.6	73	47	8.3	21.4	3.88
November	12.7	27.7	76	58	8.4	20.4	3.75
December	9.9	29.4	63	60	8.3	19.6	3.74
Average	11.6	28.4	75	58	7.1	19.5	3.77

2.2. Experimental Procedures

The trial was carrying out for three consecutive years to evaluate feasibility of drip irrigation system on Gudane potato crop variety at two farmers' fields at Woro-kolobo kebele.

Land preparation and agronomic practice: The total area allotted for this experiment was 336 m^2 and was divided into two portions equally. One portion about 12 X 14 m was occupied by drip and the other portion about 12 X 14 m by furrow irrigation method. The lands were ploughed three times by oxen, leveled; furrows and ridges were prepared according to specified spacing. Pre-irrigations were provided before planting, to enhance tuber sprouting. The potato tubers were planted on ridges on first week of December, last December and mid December for 2016, 2017 and 2018 years, respectively. Fertilizers were applied to each plot as recommended by [6]. The full doze of DAP (150 kg/ha) was applied at planting time, whereas as Urea (180 kg/ha) was applied in two splits 90 kg during planting and the rest 90 kg at 25 days after planting. Other management practice like weeding, pest and disease control was performed according to recommended procedures.

Installation of family drip irrigation system: A family drip was used, which consist of water source (Tanker), control valve, filter, water pipe lines (mainline and sub-mainline) and lateral lines. The 40 liter capacity tank was placed 1.5 m

above the ground to obtain enough pressure and 32 mm diameter HDPE mainline pipe, deliver water from tank, connected to 25 mm HDPE pipe, sub-mainline, which was connected to 16 mm HDPE lateral line with 2.1 liter /hr drippers. Spacing between rows and plant was 0.75 and 0.3 m, respectively, as recommended by [6] for potato. In all total 16 laterals were laid on the ground surface along the lines of plants each 14 m long with 46 emitters. The source of water was hand dug wells and the tank was filled by treadle pump at two farmer's fields.

Irrigation Scheduling: Irrigation scheduling was performed using CROPWAT 8 model. The scheduling for furrow irrigation treatment was defined using irrigate at critical depletion criteria, which is when the readily available water is totally depleted. However, the timing for drip irrigation was defined using irrigate at fixed interval per stage criteria, accordingly, the irrigation water was applied each four days for all growth stages.

Data collections: The potato tuber yield was collected and weighed from each plot. Marketable and non-marketable tuber yield were identified. The marketable tuber had weight greater than 25g as [7] recommendation. The tuber yield was then measured in ton/ ha for each drip and furrow irrigated plot.

Irrigation WUE (Kg/m^3): It was calculated dividing the total average tuber yield by the amount of water received by each irrigation methods.

Water saving: The water saving under drip over furrow irrigation system was calculated as:

$$Ws(\%) = \frac{(Wa - Wb)}{Wa} * 100$$

Where Ws=Water saving (in %), Wa=Total water used in furrow irrigation system (m^3/ha) and Wb=Total water used in drip irrigation system (m^3/ha)

Cost benefit analysis: To assess the profitability of drip irrigation as compared to furrow irrigation in potato production in irrigated area. The total cost, gross profit and rate of return were determined following [8] procedures. Both fixed cost and variable cost were taken into considerations. The fixed cost was the cost allotted for purchase of drip irrigation materials during first year only. The total cost paid for different items includes labor cost, material cost, fertilizer cost, and water cost which estimated based on prevailing local market conditions. The labor cost covers cost for land preparation, sowing, watering, weeding and harvesting activities. The average daily cost per labor was taken as 26 birr during the year of experimentation. The average prices of 100 kg DAP and 100 kg urea was 1400 birr and 1300 birr, respectively, during 2016, 2017 and 2018 G.c. The price of 1m^3 of water was assumed as 1birr (my own assumption). The gross profit was calculated as the product of mean yield and average price at farm gate. The net return calculated as the difference between gross profit and total cost. For each pair of treatments, marginal rate of return was calculated as the ratio of the difference in higher net benefit to lower benefit over the difference in higher total costs that vary to lower costs and expressed in percent.

3. Result and Discussion

3.1. Marketable Tuber Yield

The fresh tuber yield ranged from 19.10 to 24.86 ton/ha for furrow and drip irrigation methods during 2016, 2017 and 2018, respectively (Table 1). The tuber yield was low during 2016. Inspire of variation between years. The maximum yield was recorded with drip irrigation. Over all the mean tuber yield for all year drip and furrow irrigation were 23.8 and 19.5 ton/ha, respectively. Drip irrigation had 22.9 percent yield increment over furrow irrigation method. The yield reduction in furrow irrigation as compared to drip irrigation may probably due to nutrient leaching, and poor aeration that leads to fungal disease. However, drip irrigation reduces weed infestation and nutrient leaching, optimize soil aeration around plant root zone. Similar results were reported by different authors [1-13] under drip irrigation method higher yields recorded than furrow irrigated potato.

Table 2. *Potato tuber yield at Dedo site.*

Treatment	Yield (ton/ha)				Percentage of Increment
	2015/16	2016/17	2017/18	mean	
Drip irrigation	22.15	24.53	24.86	23.8	22.5
Furrow irrigation	19.10	19.12	20.21	19.5	-

3.2. Water Saving

The total mean volume water applied to potato crop under drip irrigation was 37.1 m^3, or 3026.9 m^3/ha. Similarly the mean total volume of water applied to crop for furrow irrigation was 4324 m^3/ha, or 59.77m^3. These results reveal that total volume of water used under drip irrigation system was less as compared to furrow irrigation method. The amount of water saved under drip irrigation system was found to be 49.5% and which helps to produce 0.50 ha of additional land.

Table 3. *The total volume of water applied considering 65%, and 90% efficiency for furrow and drip irrigation, respectively.*

	Drip	Furrow	Water saving % Under drip
Irrigation water (m^3/plot)	46.49	91.96	
Irrigation water (m^3/ha)	2767.33	5473.8	49.45
Saved water (m^3/ha)	2706.80	-	

3.3. Water Productivity

The maximum water productivity was obtained from drip irrigation (7.88 Kg/m^3), while the lowest (4.52 Kg/m^3) from furrow irrigated fields. The drip irrigation had 42.6% increment of water productivity over furrow irrigation. The lower water productivity obtained from furrow irrigation may due to lower irrigation efficiency and higher water loss as deep percolation, nutrient leaching, run off and evaporation. However, drip irrigation method had lower wetting diameter which reduce amount of irrigation water and reduce evaporative area. Our result is closely agree with others finding, drip irrigation significantly increase water use efficiency of potato as compared to other method [14-16].

Table 4. *Potato ETc, irrigation requirement and water use efficiency at Dedo disrict, Waro-kolobo kebele.*

Parameter	Year						Average	
	2016		2017		2018			
	Furrow	Drip	Furrow	Drip	Furrow	Drip	Furrow	Drip
ETc (mm)	400.9	280.6	436.1	305.27	460.3	322.21	432.4	302.69
IR.(mm)	324.3	227	359.3	251.51	383.7	268.59	355.8	249.03
WUE (Kg/m^3)	4.86	7.9	4.47	8.03	4.24	7.72	4.52	7.88
IWUE (Kg/m^3)	6.01	9.8	5.43	9.75	5.08	9.26	5.51	9.60

Assuming wetting pattern for drip irrigation is 70%, IR=irrigation

3.4. Cost Benefit Analysis

The results of the partial budget analyses revealed that the maximum net returns of Birr 65,086.6 were obtained from drip irrigation. However, the minimum net returns of Birr 56,946.6 were received from furrow irrigated. High net return from the drip irrigated could be attributed to high yield, even though drip irrigation associate with high cost during 1st year. Whereas the low net return was attributed to low yield in the case of furrow irrigation. Moreover, the maximum marginal rate of return of 114.3% was recorded in plot receiving drip irrigation, which is greater 50%. Thus, from the economic point of view drip irrigation which have greater marginal rate of return than furrow irrigation and, hence more profitable than furrow irrigations. Thus, the treatment which was non-dominated and having a marginal rate of return of greater or equal to 50% with the highest net benefit was taken to be economically profitable [8].

Figure 1. *Demonstration of family drip irrigation at farmers filed condition.*

Table 5. *Analyzed cost benefit of potato produced under drip irrigation technology and furrow irrigation at Dodo, Waro-kolobo kebele.*

Cost and Profit	Drip irrigation (Birr)		Furrow irrigation (Birr)	
	Per 168 m^2	Per ha	Per 168 m^2	Per ha
Variable cost				
Labor	1300	77,380.95	1500	89,285.71
Fertilizer (DAP + Urea)	70.56	4260	70.56	4260
Tuber seed cost	650	11700	650	11700
Water cost	46.49	2767.33	91.96	5473.84
Fixed cost				
Drip material	700	41,666.67	0	0
Total cost	2757.66	137,213.4	2280.33	108,803.4
Gross profit	3884.4	202,300	2784.6	165,750
Net profit	1126.74	65,086.6	504.27	56,946.6
MRR (%)		114.29	-	-

Table 6. *Training provided for farmers, DAs and Worada irrigation Experts.*

Sex	Training			
	2015/16	2016/17	2017/18	total
Male	56	59	17	132
Female	5	22	13	40
Total	61	81	30	172

MRR=marginal rate of return, DAs=development agents.

3.5. Training and Demonstration

Generally, training was provided for 172 participants who came from different Woredas of Jimma zone, that actively engage in irrigation activities. In this training different stakeholder were participated in training including small holder farmers, development agents and Woreda irrigation experts. Model farmers participated in training were selected from those majorly participated in irrigation activities. The training was provided on topic of irrigation water management, family drip irrigation technology and other important issues. After training the trainees were brought to Waro-kolobo kebele on farmer's field where family drip irrigation demonstration are carried out. At demonstration, participants of training observed and viewed the implemented family drip technologies, increase their awareness and finally rose as question and comment, the drip irrigation technology need to be demonstrated on different Woredas and kebeles in addition to Dedo Wareda, model farmers also indicated willing to adopt this technology on their own field.

4. Summary and Conclusion

The result shows that family drip irrigation is more advantages for smallholder farmers in terms of yields and water consumptions if water accessibility is limited. The maximum yield of potato was obtained from drip irrigated plots than furrow irrigated. Demonstration had been appreciated by model farmers and they have indicated their willingness to adopt drip irrigation technology. So, for more accurate information and justifications it needs to be demonstrated and verified under varies climatic and soil condition of Jimma Zone.

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