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Evaluation of Wetting Front Detectors (WFD) for Irrigation Scheduling and Water Productivity; in Mychew Small Scale Irrigation Scheme (SSIS), Keih Tekli District, Tigray, Ethiopia

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

The principle **"**even a drop of water is matters**"** is essential for irrigation scheduling. Hence, this paper deals with three different methods of irrigation scheduling (Penman–Monteith equation, wetted front detector (WFD), and Modified Blaney – Criddle (B-C) (Modified B-C)) compared with farmer's practices. The experiment was conducted in Tigray, Ethiopia, with the objective of evaluating WFD for irrigation scheduling. The experimental design was a randomized complete

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block design (RCBD). The collected data subjected to one-way analysis of variance (ANOVA), while irrigation water related performance indicators were computed using equations. The amount of irrigation water applied through estimated based on the Penman-Monteith equation, WFD, modified B-C method, and farmers practice (FP) were 510.3mm season^{-1}, 489.6 mm season^{-1}, 528.9 mm season^{-1} and 816.48 mm season^{-1}, respectively. This indicated less irrigation depth was applied through WFD, and its irrigation interval was infrequent than the farmers' practices. The WFD method of irrigation scheduling revealed the highest yield and agronomic attributes of tomato. Additionally WFD had economic and productivity of irrigation water compared to farmers practice and other treatments. Likewise, this method of irrigation scheduling had saved 40% irrigation water over the farmers practice. As a conclusion, the WFD method of irrigation scheduling was found to be better for efficient irrigation water utilization while concurrently increasing tomato yield and yield components. More to the point, the method is easily manageable by farmers to properly manage their irrigation water. Accordingly, this irrigation-scheduling device is unreservedly recommended to be used for irrigation scheduling in the area.

Keywords: Irrigation water; irrigation water utilization; irrigation water saving; scheduling.

1. INTRODUCTION

Irrigation practices can meet its objectives if it is managed appropriately. Inappropriate utilization of irrigation water on-farm leads to the adverse effect of irrigation practices. When irrigation water is applied over field water requirements, it leads to erosion (irrigation soil erosion), poor water distribution, non-uniform crop growth, excessive leaching (decrease nutrient content of the soil), water logging (low aeration of the soil), etc. As a contradiction, when the application of less water than is required, it leads to sedimentation of reservoirs, insufficient leaching (leading to salinity buildup), etc.; therefore, over and less application of irrigation water decreases the yield per unit of land area and per unit of water applied [1].

To overcome these problems, there are different irrigation management technologies that improve irrigation efficiency and water productivity. These technologies include irrigation water application (IWA) methods and sensors for soil moisture indicators. The IWA methods are classified into low-energy precision application (LEPA), drip (micro-irrigation), sprinkler, and surface (flood, basin, border, and furrows) types of irrigation. From these, drip, sprinkler, and LEPA methods are known to be efficient in maximizing water utilization. Despite the fact that their initial investment costs are often expensive [2], consequently, these irrigation practices are not recommended for developing countries like Ethiopia (Tigray). Under such conditions, least initial investment and yet less precise IWA methods have to be considered.

Thus, the furrow irrigation method is the most widely used and is particularly suitable for irrigating row crops such as pepper (*Capsicum annuum*), onion (*Allium cepa),* tomato (*Solanum lycopersicum L.*), cabbage (*Brassica oleracea*), garlic (*Allium sativum*), sweet potato (*Ipomoea batatas (L.)*, beetroot (*Beta vulgaris*), lettuce (*Lactuca sativa*), carrot (*Daucus carota*), etc. The irrigation practiced by farmers is known to be less efficient [3]. The scheduling method in the scheme is an irregular or fixed irrigation scheduling method and also the farmers think that more irrigation water increases crop productivity [4]. Under current practices, there is likely to be over- or under-irrigation, leading to irrigation water scarcity. The shortage of irrigation water has become the source of conflict between head and tail irrigation water users [4].

Therefore, to solve the irrigation water scarcity and conflict among the farmers and between the irrigation water committee and irrigation water users, irrigation scheduling based on the sensor of soil moisture is the main solution. Wetting front detector (WFD) is one of the different technologies commonly used to determine optimum irrigation scheduling and thereby improves irrigation water management. Hence, this study aimed to (i) determine an appropriate irrigation scheduling and (ii) evaluate the performance of wetting front detector regarding the tomatoes yield and water saves.

2. MATERIALS AND METHODS

2.1 Description of the Study Area

The field experiment was conducted in the Mychew small-scale irrigation scheme of Adiha Kebelle, Keih_Tekli district, central zone of Tigray regional state. Geographically, it is situated at a latitude of 13.76° North and a longitude of 39.098° East (Fig. 1), and the average elevation of the study area is 1640 meter above sea level [4].

The rainfall pattern of the district is mono-modal, with a wet season of about three months from mid-June to mid-September. Agro-ecologically, it is characterized as hot, warm, sub-moisture-low land (SM1–4b). The mean annual rainfall and temperature are 400–650 mm and 25–27 °C, respectively [5,6]. The dominant soil texture of the area is sand (75%), followed by loam (20%) and clay (5%) with low organic matter content [6] and the soil class that best fits this texture and composition is a Sandy Loam soil.

Based on Efriem and Mekonen [4], the major crops and plants grown in the area are: cereal crops (maize (*Zea mays*), *taff* (*Eragrostis tef),* sorghum (*Sorghum bicolor*), barely (*Hordeum vulgare),* and finger millet (*Panicum miliaceum*)), vegetables (tomato (*Lycopersicon esculentum Mill*), pepper (*Piper nigrum*), and onion (*Allium cepa)),* and fruit trees mainly mango (*Mangifera indica*) and orange (*Citrus sinensis*).

2.2 Experimental Design, Treatment Setup and Agronomic Management

The experimental design was laid out in randomized complete block design (RCBD) with three replications. There were four treatments which composed of different irrigation scheduling methods namely: 1) CWR (CROPWAT 8), 2) wetting front detector, 3) Modified Blaney–Criddle (B-C) and 4) farmers practice (Table 1). The plot size was 3.5 x 3 meters, with 1 meter and 0.5 meter spacing between blocks and plots, respectively.

Tomato (Roma VF) was used as an indicator crop. The inter- and intra-spacing was 70cm and 30cm, respectively according to Zemichael [7] recommendations. The experimental study was carried out for two years in 2017 and 2018

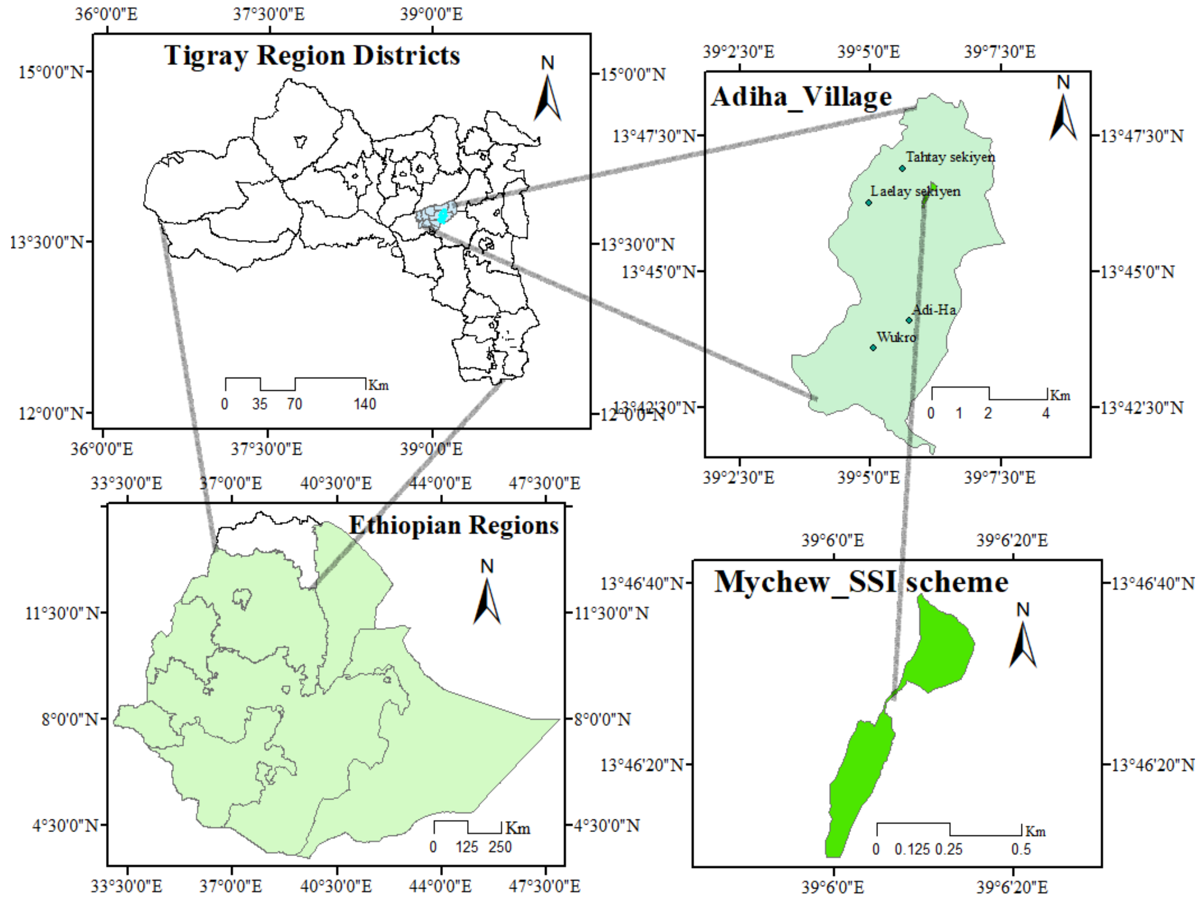

Fig. 1. Map of the study area

irrigation seasons. Healthy and vigorous tomato seedling with age of forty five days was transplanted on January 21, and finally harvested on April 25, in both years. Each experimental plot had 5 rows with 10 plants per row. Blended fertilizer of NPSZnB (17Nitrogen (N), 34Phosphorus (P_2O_5), 7Sulfur (S), 2.2Zinc (Zn), and 0.67Boron (B)) with a rate of 200 kg ha^{-1} was applied during transplanting. Moreover, one third of urea (100 kg ha^{-1}) was also applied during transplanting and the remaining two thirds at the flowering stage. Plants were initially irrigated uniformly to have suitable root development and a favorable plant stand. The watering system used in this experiment was conventional furrow or every furrow method.

2.3 Determination of Crop Water Requirement (CWR) and Irrigation Scheduling

There are four indirect methods (Blaney-Criddle (B-C), Stewart-Rouse, deBruin, and Penman-Monteith) of estimating crop water requirements. For this experiment, the Penman-Monteith and modified B-C methods were used for estimating reference ETo. Because all of these formulas except the modified B-C method have theoretical formulations based somewhat on Penman's derivations but with different simplifying assumptions [8]. According to Zhan and Lin [8], the modified B-C method is able to estimate PE with improved accuracy and is applicable to a wide range of climate conditions. It measured ETo varies from 300 – 4,000 mm/year, annual average RH varies from 25 – 85 per cent, annual wind speed varies from calm wind (2 m/s) to strong wind (8 m/s), and site elevations range from 400 – 4,000 m above sea level.

$$T_{mean} = \frac{T_{max} + T_{mean}}{2} \qquad \text{Eq. 1}$$

where T_{mean} is monthly average temperature, $T_{max} = \frac{sum\ of\ all\ T_{max}\ values\ during\ the\ month}{number\ of\ days\ of\ the\ month}$ and $T_{min} = \frac{sum\ of\ all\ T_{min}\ values\ during\ the\ month}{number\ of\ days\ of\ the\ month}$

$$ET_0 = p * (0.46\ T_{Mean} + 8) \qquad \text{Eq. 2}$$

where, ET_0 is references or potential evapotranspiration, p is mean daily percentage of annual daytime hours for different latitudes (Table 4, https://www.fao.org/3/s2022e/s2022e07.htm) latitude of experimental site i.e. 13.76°N and month watering from January till April) since, estimation using interpolation method ($Y = \frac{Y_2 - Y_1}{X_2 - X_1}(X - X_1) + Y_1$).

$$ET_{0adj} = (0.58ET_0 - 1) * ET_o \qquad \text{Eq. 3}$$

where, ET_0adj is modified ET_0 through K i.e. the adjustment factor, ETo is calculated using Equation 2.

The second method for estimating crop water requirements was the Penman-Monteith equation using the CROPWAT 8.0 software. The net and gross irrigation water requirements to be applied to the field were determined using 65% irrigation efficiency [4]. And irrigation intervals were calculated for both the Blaney-Criddle and Penman–Monteith methods (Equation 4,5 and 6) based on Tukimat et al. [9].

Net IR or ASMDL = TAW x p Eq. 4
TAW = (FC – PWP) x BD x Rd x 10

where: Net Irrigation Requirement or ASMDL is available soil moisture depletion level or net irrigation requirement (mm), TAW is total available soil moisture (mm/m,) P is Allowable soil moisture depletion by the tomato (0.40), FC is field capacity of the soil in weight bases (%), PWP is permanent wilting point of the soil in weight bases (%) is BD is bulk density (g/cm^3) and Rd is Root depth (m),

$$\text{Irrigation interval (days)} = \frac{Net\ IR}{CWR} \qquad \text{Eq. 5}$$

$$\text{GI} = \frac{Net\ IR}{Ea} \qquad \text{Eq. 6}$$

Where; ETc is Crop Evapo-transpiration (mm/day), GI is gross amount of water (mm) and Ea is irrigation application efficiency (%).

2.4 Irrigation Water Management

The experimental plot was watered through the procedure, as the duration of water application for the field was divided by the number of furrows on the plot, and the duration of water application for the furrows was then controlled by the stopwatch for uniform application. Based on El-Halim [10], the amount of water for each furrow was added until it reached 95% of the average run length on the average of all furrows. Furrows subjected to irrigation were open-ended; however, water does not exceed the edge of the plot because it flows through the parallel furrows. Whereas other furrows not irrigated were closedended. The water in the channel was controlled through a minimum discharge from 5 cm to 10 cm head of the Parshall flume during the irrigation event.

2.5 Installation of Wetting Front Detector (WFD)

The Wetting Front Detector (WFD) was developed at the Commonwealth Scientific and Industrial Research Organization (CSIRO) in Australia in response to the low adoption of these existing irrigation tools [11,12]. This instrument is a very simple tool that helps to measure how deeply water has penetrated into the soil after an irrigation event and monitor nutrient losses in soils [12]. Additionally, with this tool, there are no wires, no electronics, and no batteries for the WFD to work. Studies show that WFD saved water [13], reduced labor, and increased crop yield [14]. In addition, the mechanical version has a float visible at the surface to provide the signal that a wetting front has reached the prescribed depth. Therefore, WFD was developed in an attempt to attain maximum simplicity for an irrigator, especially for illiterate farmers.

As illustrated in Fig. 2, two wetting front detectors were used for every treatment that was irrigated through the instrument, so one WFD was installed at the entry and the second WFD was installed at the outlet of the experimental plot. The installation depth for WFD is estimated based on Cook et al. [15] the guidelines for wetting front detector, i.e., with a yellow flag installed at 1/3rd of the effective root and wetting the front detector with a red flag installed at 2/3rd of the root depth. So for this experiment, the funnel was buried in the soil within the root zone at 20 cm for the yellow flag and 40 cm for the red flag, which is an effective root zone in the soil.

2.6 Data Collection

Both primary and secondary data were collected to fulfill this experimental study. Primary data collected from the experimental station includes soil infiltration rate, soil samples, irrigation depth, irrigation interval, agronomic data, and crop yield and yield components. Moreover, all secondary data such as climate data, crop data and soil data were collected from different sources. Climate data were collected from the Ethiopian National Meteorological Agency. Likewise, crop characteristics (root depth, growing period, Kc) and soil data mainly field capacity and permanent wilting point were collected from related literature and the district office.

Table 1. Treatment setting

Method of Irrigation Scheduling	Treatments
Penman–Monteith methods estimation of Crop water requirement (CWR)	T_1
Wetting front detectors (WFD)	T_2
Modified Blaney–Criddle (B-C)	T_3
Farmers practice (FP)	T_4

Fig. 2. Installation of WFD at the field level and its performances

2.6.1 Soil sampling and measuring the field infiltration rate

The composite soil samples were collected from each corner and one from the middle of the experimental area at a depth of 0–50 cm using a soil auger. Undisturbed soil samples were collected using a soil core sampler for the determination of soil bulk density. physico-chemical parameters of the collected soil samples were analyzed at Mekelle soil research center laboratory case team. The soil moisture content of the experimental plots was estimated directly by using volumetric soil moisture contents through the adoption of the procedures written in Novák and Hlaváčiková [16]. Furthermore, the soil infiltration rate was measured using the double-ring infiltro-meter (Fig. 3) at the field level before the land gets plowed.

2.6.2 Agronomic data collection

The agronomic data, which was very sensitive through different methods of irrigation scheduling (plant height (cm), fruit number per plant, fruit diameter (cm), and fruit length (cm), as well as marketable, unmarketable, and total fresh yield (kg ha^{-1}), were collected. These parameters were taken from the middle of the experimental plots (1 m x 1 m) to minimize the boarder effect and change into hectare using Equation 7.

$$\text{Yield (kg ha}^{-1}\text{)} = \text{yield obtained per square meter (kg)} * 10^4 \qquad \text{Eq. 7}$$

2.6.3 Discharge measurement and water application duration

The estimated gross irrigation water (Dap) and watering practices of the farmers were conveyed to experimental plots through a two-inch Parshall flume, which was installed at the entrance of the supply ditch. A two-inch Parshall flume was used to measure the amount of irrigation depth for all plots. Based on Efriem and Gebrekiros [3], the water application duration was computed (Equation 8). The total amount of irrigation water applied by farmers was measured using the Parshall flume in time and convert into discharege. Therefore, for the seasonal amount of water applied to the field for the fresh yield of tomatoes, both the Blaney-Criddle (B-C) and Penman-Monteith methods were used in Equation 9.

$$T = \frac{D_{ap} * L * W}{60 * Q} \qquad \text{Eq. 8}$$

$$\text{CWR (m}^3\text{)} = \text{Dap (mm)} * 10 \qquad \text{Eq. 9}$$

2.7 Performances Indicators

The amount of water applied to the field so as to gain the fresh yield (gross irrigation applied) of tomato and its yield (marketable yield), the performance of different irrigation scheduling systems was evaluated using the following performance indicators:

2.7.1 Irrigation water productivity (IWP) (Kg m^{-3})

Different researchers [15,17,18] explained that, agricultural water productivity is a measure of the output of a given system in relation to the water it consumes, so it is the net return for a unit of water used. Therefore, this is quantified according to Equation 10 [3].

$$\text{IWP (kg)} = \frac{Yield\ (kg)}{water\ aplied} \qquad \text{Eq. 10}$$

2.7.2 Economical irrigation water productivity (EIWP) (ETB m^{-3})

As explained in Kana [19], the economic irrigation water productivity (EWP) relates to the economic benefits per unit of water used, so the note was taken in Ethiopian birr so as to understand our farmers and quantified using Equation 11.

$$\text{EWP} = \frac{Yield\ (EBR)}{water\ aplied} \qquad \text{Eq. 11}$$

2.7.3 Amount of irrigation water saved (IWS)

Based on Cook et al. [15], the amount of water saved from the different treatments was evaluated Equation 12. This is done through the procedure of subtracting the water used by a particular irrigation scheduling method from the farmer's practices. The farmer’s watering practice was considered a control for each treatment.

$$\text{WS (\%)} = \frac{Control\ irrigation\ scheduling - other\ treatments}{Control\ irrigation\ scheduling} \qquad \text{Eq. 12}$$

2.7.4 Additional Irrigable Land (AIL)

Based on Cook [15] and [3], the more irrigable land was estimated using Equation 13.

$$\text{AIL} = \frac{Control\ irrigation\ scheduling - other\ treatments}{Control\ irrigation\ scheduling} * 1\ \text{ha}$$

or

$$AIL = WS * 1ha \qquad \text{Eq. 13}$$

2.8 Statistical Analysis

All statistics were performed with the program IBM SPSS Statistics 20 [17]. One-way analysis of variance (ANOVA) was used to determine statistically significant differences between groups. LSD was used for the mean separation ($P < 0.05$) between treatments.

3. RESULTS AND DISCUSSION

3.1 Crop Water Requirement and Irrigation Scheduling

The irrigation depth and its irrigation interval of application through WFD were less than the farmer's practices (Table 2). Based on Desalegn Tegegne [17,18] reported similar results to this findings. In their study, they concluded that the total irrigation water application was higher in the FAO method than in the WFD and Tensiometer methods. As a result of this, the application of irrigation water through the sensor of the WFD was considered proper compared with the farmer's practices. Hence, the irrigation intervals using the WFD were 3-days, 5-days, 5-days, and 6-days for the initial, development, mid-season, and late-season stages, respectively. The irrigation depth or seasonal irrigation water requirement for tomatoes in the Mychew small-scale irrigation scheme (SSIS) was 489.6 mm/season.

3.2 Effects of different Irrigation Scheduling Methods on Tomato Yield and Yield Components

As illustrated in Table 3, the different irrigation scheduling methods had a significant effect on the yield and yield components of tomatoes. Contrarily, fruit weight had no significant response to the different irrigation scheduling methods in these two years. In the irrigation scheduling, WFD had the highest plant height, fruit diameter, marketable and total yield. This agrees with Mosisa and Haileslassie [20]. The farmer's practice and WFD revealed the highest and least unmarketable yields, respectively (Table 4). This was consistent with the reports in Yismaw [18].

Fig. 3. Measuring infiltration rate using double ring infiltrometer

Table 2. Results of irrigation scheduling through different treatments

Treatment	Average Irrigation depth (mm/season)	Irrigation interval			
		Initial Stage	Development Stage	Mid-Season Stage	Late-Season Stage
T_1	510.3	3	5	5	6
T_2	489.6	3	5	5	6
T_3	528.9	3	5	5	6
T_4	816.48	3	4	5	5

where T_1 is the crop water requirement (CWR) estimated based on the Penman-Monteith equation, T_2 is the amount of irrigation water and its interval recorded using wetting front detectors (WFD), T_3 is the CWR estimated using the modified Blaney-Criddle method, and T_4 is the CWR recorded based on the watering and irrigation interval system of the farmers, i.e., farmers practice (FP)

Table 3. Agronomic characteristics of tomatoes in two experimental years

Treatment	Year	Plant height (cm)	Fruit diameter (cm)	Fruit weight (g)	Marketable yield (ton/ha)	Un marketable (ton/ha)	Total yield (ton/ha)
T1	2017	52.8	4.99	44.21	54.2	7.6	61.8
	2018	53.6	5.45	45.13	55.7	7.84	63.54
	Average	53.2^{b}	5.22^{b}	44.67	54.95^{b}	7.72^{ab}	62.67^{b}
T2	2017	57.9	5.92	44.2	63.94	4.32	68.26
	2018	59.5	6.58	44.86	65.98	4.36	70.34
	Average	58.67^{a}	6.25^{a}	44.53	64.96^{a}	4.34^{d}	69.3^{a}
T3	2017	50.9	5.2	45.49	58.15	5.75	63.9
	2018	51.9	6.14	45.57	59.59	5.77	65.36
	Average	51.4^{bc}	5.67^{b}	45.53	58.87^{b}	5.76^{c}	64.63^{b}
T4	2017	49.2	5.12	46.55	38.14	8.33	46.47
	2018	50.8	5.36	46.65	43.92	7.91	51.83
	Average	50^{c}	5.24^{b}	46.6	41.03^{c}	8.12^{a}	49.15^{c}
Sig (0.05)		0.021	0.03	0.24	0.035	0.033	0.012
SE (+)		1.55	0.17	0.6	3.41	0.6	3.78

Where T_1 is the crop water requirement (CWR) estimated based on the Penman-Monteith equation, T_2 is the amount of irrigation water and its interval recorded using wetting front detectors (WFD), T_3 is the CWR estimated using the modified Blaney-Criddle method, and T_4 is the CWR recorded based on the watering and irrigation interval system of the farmers, i.e., farmers practice (FP).

Table 4. Irrigation water productivity and its water saving in two experimental years

Treatment	Year	Marketable Yield (kg/ha)	Irrigation Depth (mm)	Irrigation Water (m^3)	IWP (kg/m^3)	IWS (%)	AIL (ha)
T1	2017	54200.00	505.19	5051.90	10.73	38.13	0.38
	2018	55700.00	515.41	5154.10	10.81	36.87	0.37
	Average	54950.00	510.30	5103.00	10.77	37.50	0.38
T2	2017	63940.00	479.90	4799.00	13.32	41.22	0.41
	2018	65980.00	499.30	4993.00	13.21	38.85	0.39
	Average	64960.00	489.60	4896.00	13.27	40.04	0.40
T3	2017	58150.00	524.50	5245.00	11.09	35.76	0.36
	2018	59590.00	533.30	5333.00	11.17	34.68	0.35
	Average	58870.00	528.90	5289.00	11.13	35.22	0.35
T4	2017	38140.00	813.90	8139.00	4.69	0.00	0
	2018	43920.00	819.06	8190.60	5.36	0.00	0
	Average	41030.00	816.48	8164.80	5.02	0.00	0.00

where Wp is water productivity, IWS is irrigation water saving, AIL is additional irrigable lands, T_1 is the crop water requirement (CWR) estimated based on the Penman-Monteith equation, T_2 is the amount of irrigation water and its interval recorded using wetting front detectors (WFD), T_3 is the CWR estimated using the modified Blaney-Criddle method, and T_4 is the CWR recorded based on the watering and irrigation interval system of the farmers, i.e., farmers practice (FP).

Table 5. Economic irrigation water productivity (EIWP) under different irrigation scheduling

Treatment	Year	Marketable Yield (kg ha^{-1})	Unit price per kg (ETB)	Total benefits (ETB)	Irrigation Water (m^3)	EIWP (ETB m^{-3})
T1	2017	54200	8.5	460700	5052	91.19
	2018	55700	8.5	473450	5154	91.86
	Average	54950	8.5	467075	5103	91.53
T2	2017	63940	8.5	543490	4799	113.25
	2018	65980	8.5	560830	4993	112.32

Treatment	Year	Marketable Yield (kg ha^{-1})	Unit price per kg (ETB)	Total benefits (ETB)	Irrigation Water (m^3)	EIWP (ETB m^{-3})
	Average	64960	8.5	552160	4896	112.78
T3	2017	58150	8.5	494275	5245	94.24
	2018	59590	8.5	506515	5333	94.98
	Average	58870	8.5	500395	5289	94.61
T4	2017	38140	8.5	324190	8139	39.83
	2018	43920	8.5	373320	8191	45.58
	Average	41030	8.5	348755	8165	42.71

N.B; the unit price of tomato for 1kg in 2020 on averagely was 8.5 ETB

where EIWP is the economic irrigation water productivity, T_1 is the crop water requirement (CWR) estimated based on the Penman-Monteith equation, T_2 is the amount of irrigation water and its interval recorded using wetting front detectors (WFD), T_3 is the CWR estimated using the modified Blaney-Criddle method, and T_4 is the CWR recorded based on the watering and irrigation interval system of the farmers, i.e., farmers practice (FP).

3.3 Irrigation Water Productivity (IWP)

The highest irrigation water productivity was obtained from the WFD method of irrigation scheduling (Table 4). On the contrary, farmer practices revealed the least water productivity. The WFD method of irrigation scheduling demonstrates that 13.27 kg of tomatoes could be gained from 1 m^3 of water. This indicates the WP is an important element in improving water management for sustainable agriculture, food security, and healthy ecosystem functioning.

The findings of Schmitter [14] and [21] reported higher irrigation water productivity using WFD as an irrigation scheduling method, particularly compared with farmer’s practices. Based on Schmitter [14], the reported water productivity of 1.01 and 20.88 kg m^{-3} tomatoes. The result of our study was in this range (Table 4). The literature in general revealed that the WP of the WFD is higher than the farmer's practices.

3.4 Irrigation Water Saving (IWS)

Based on this experiment, the wetting front detector saved more than 40.04% of irrigation water compared to the farmer’s practice (Table 4). Similarly, the Penman-Monteith equation and the modified B-C method of irrigation scheduling gained more than 37.5% and 35.2% irrigation water over the farmer’s practice. As the results of Mosisa and Haileslassie [20] show, farmers saved 16% of irrigation water using WFD compared with FAO. Similarly, [22] saved 14% of irrigation water using WFD compared to farmer's practices (FP). The saved water can irrigate additional irrigable land (Table 4).

3.5 Economic Irrigation Water Productivity (EIWP)

Irrigated through the scheduling of a sensor of soil moisture, i.e., WFD, the EIWP was higher than the other treatments, followed by Penman-Monteith and the modified B-C method (Table 5). Based on [14], similar reports were reported in Meki, with higher economic returns from WFD and the least from farmer practices.

4. CONCLUSION AND RECOMMENDATIONS

While irrigation intervals were similar, irrigation depths significantly varied with the method of irrigation scheduling. The WFD method of irrigation scheduling had the highest yield and yield components of tomatoes with a 489.6 mm/season irrigation depth. Apart from this, the WFD method of irrigation scheduling had the highest water productivity (WP), irrigation water saving (IWS), and economic irrigation water productivity (EIWP) compared with other treatments, particularly farmers practices.

On top of the above merits, WFD is very important for uneducated farmers by showing its sign flag. While the other treatments, modified B-C methods, require knowledge about their environment temperature and some calculations, the FAO method, i.e., the Penman-Monteith equation, requires a meteorological station and digital or computer skill. Based on our investigations, regardless of its price, WFD is so important that farmers could even manage it easily. Hence, opportunities should be created to manufacture these tools from plastic materials in the homeland.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

We are declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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