Journal of Water Resources and Ocean Science
2023; 12(3): 46-54
http://www.sciencepublishinggroup.com/j/wros
doi: 10.11648/j.wros.20231203.12
ISSN: 2328-7969 (Print); ISSN: 2328-7993 (Online)

On Farm Evaluation of Irrigation Water Levels with Mulch on Yield and Water Productivity of Hot Pepper (*Capsicum annum* L.) at Odo Shakiso District, Southern Ethiopia

Tesfaye Gragn*, Obsa Wolde

Oromia Agricultural Research Institute, Bore Agricultural Research Center, Bore, Ethiopia

Email address:
tgragn@gmail.com (Tesfaye Gragn)
*Corresponding author

To cite this article:
Tesfaye Gragn, Obsa Wolde. (2023). On Farm Evaluation of Irrigation Water Levels with Mulch on Yield and Water Productivity of Hot Pepper (*Capsicum annum* L.) at Odo Shakiso District, Southern Ethiopia. *Journal of Water Resources and Ocean Science*, *12*(3), 46-54. https://doi.org/10.11648/j.wros.20231203.12

Received: November 14, 2023; **Accepted**: December 13, 2023; **Published**: December 26, 2023

Abstract: Ineffective use of water consumption usually causes problems such as increased land salinity, waterlogging, land salinization, waterlogging, reduced crop productivity and water loss. This experiment was conducted to study the effects of irrigation levels and mulching materials on yield, yield components, and water productivity of hot pepper in Odo Shakiso district, Southern Oromia region during 2021-2022. The experiment was designed as a combination of nine treatments and was repeated three times under a completely randomized block design (RCBD). Treatments included three levels of irrigation application (100% ETc, 85% ETc, and 70%) and three types of mulch (no mulch, straw mulch, and white plastic mulch). The combination effect of irrigation levels with mulch type under convectional furrow irrigation has shown a highly significant ($p<0.01$) influence on plant height, number of pods per plant, marketable yield, total yield, and water productivity of green hot pepper. The highest marketable and the highest total yield of green pepper were obtained under 100% ETc and white plastic mulch treatment with 15.46 tons of green pepper per hectare and 15.54 tons of green pepper per hectare respectively. However, statistically, there is no significant difference among treatments of 100% ETc without mulch, 100% ETc with white plastic mulch, 100% ETc with straw mulch, 85% with white plastic mulch, and 85% ETc with straw mulch. Moreover, the maximum water productivity (4.74kg/m^3) was observed at irrigation application of 70% ETc with white plastic mulch which was statistically non-significant with irrigation application of 85% ETc with white plastic mulch and 85% ETc with straw mulch with the value of (4.61kg/m^3) and (4.46kg/m^3) respectively. Based on the partial budget analysis, the highest net benefit value of 839,438 birr/ha with marginal rate of return (1080) was obtained from irrigation water application of 85% ETc under straw mulch. This result revealed that applying irrigation of 85% ETc with straw mulch is economically feasible for green hot pepper production in the Odo Shakiso area of the Guji zone. In conclusion, the present study points out that irrigation application of 85% ETc with straw mulch is recommended for the Odo Shakiso district and other similar agro ecologies. However, as the trial was conducted in one location, conducting similar research over locations would be appropriate to get conclusive results for the best recommendation.

Keywords: Green Hot Pepper, Water Level, Mulch Material, Marketable Yield, Marginal Rate of Return

1. Introduction

Inadequate water resources and growing water demand for industrial and urban settlements have caused declines in the amount and quality of agricultural water use [24]. Water is usually considered a renewable natural resource. Still, improper distribution among the world and increasing demands can have an extreme effect on its availability and lead to significant freshwater scarcity. Recent scientific studies have predicted an increase in freshwater demands by up to eighty percent by 2050 [13], and the global population head for more than nine billion people by 2050 [11], which implies a high impact on agricultural water supply. In Ethiopia, irrigated agriculture is becoming main concern and powerfully known to ensure the food security which is taken as a means to increase food production and self sufficiency of the rapidly increasing population of the country. Ethiopia plans to irrigate more than 5 million hectares with existing water sources [3]. The growth of irrigation to feed the growing population on one hand, and the competition for water with other water use sectors on the other, required improved water use efficiency in irrigation to sustain production and conserve this scarce resource [22]. Improving water efficiency is one of the most important approaches to address future water scarcity challenges, especially in arid or semi- arid regions [20]. Deficit irrigation is the practice of using less irrigation water than the plant needs or the pasture needs. This type of irrigation is often used in conditions of inadequate water availability and drought, which can result in greater economic benefits by increasing water efficiency. The term ‘deficit irrigation’ is used to define an optimizing strategy in which crops are intentionally and systematically permitted to maintain a certain degree of water deficiency and yield reduction. Adopting a deficit irrigation strategy requires sufficient knowledge of the end-of-cycle condition (ETc), the crop’s response to different amounts of irrigation water (i.e. critical crop growth period), and the economic consequences of yield reduction policies.

Another method of conserving soil moisture is by applying mulch to the soil. Mulching is a practice that comprises covering the soil surface with organic or synthetic mulch around the plants to produce favorable circumstances for plant growth and efficient crop production [16]. Mulching improves plant growth and yield while also optimizing water use [30]. Mulches increase soil structure and aeration, regulate the temperature of the soil, conserve in-situ moisture, organic matter, and microbial flora, control weeds, minimize weed nutrient loss, and minimize soil erosion [6].

Odo shakiso is a district of Guji Zone in the Southern Oromia Region where, because of low and variable rainfall, ongoing drought and water scarcity are commonly noted, causing agricultural productivity to hurt. There was competition for water consumption among residents for livestock and agriculture cultivation. However, farmers of the study area do not have enough knowledge and awareness on small scale irrigation technologies and less irrigation water management practices for efficient irrigation water use and agricultural production improvement. Therefore, this study was initiated in view of the existing problem to evaluate the effects of deficit irrigation and mulch types on yield, yield component and water use efficiency of hot pepper for optimal crop production and economic water resource uses.

2. Materials and Methods

2.1. Description of the Study Area

The field experiment was conducted in the Guji zone of Oromia Regional State, at Odo Shakiso District. The district is found at a distance of 139 km from the zonal capital Negele and 490 km from Finfinne. The District has a geographical location of 5°2'29”-5°58'24” northing latitudes and 38°35'0”- 39°13'38” easting longitudes with an elevation ranging 1500-2000 m a.s.l. The district is characterized by three agro-climatic zones, namely highland (Bada), accounting for about 33%, midland (Bada dare), accounting for about 47%, and lowland (Gamoji), accounting for about 20% of district area coverage. The mean annual rainfall is about 900mm) and the annual temperature of the district 25°C.

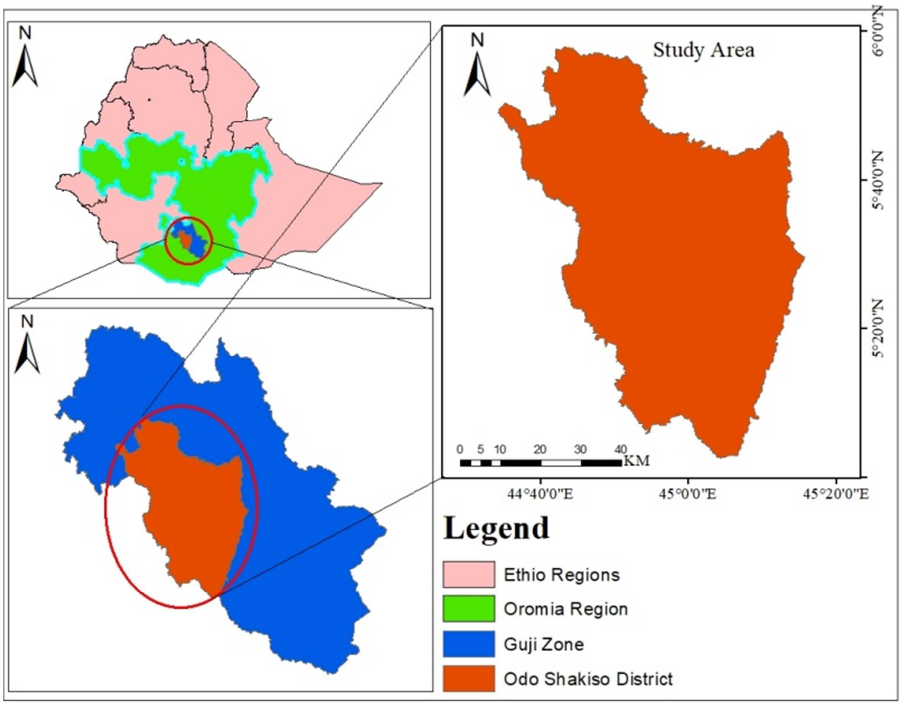

Figure 1. *Location Map of the study area.*

2.2. Soil Sampling and Analysis

The representative composite Soil sample was taken from different plots randomly and diagonally across the experimental field using an auger before planting to determine the physical properties of soil (textural class, bulk density, FC, PWP, and TAW) and chemical properties of soil (pH, organic matter (OM), organic carbon (OC) and electrical conductivity (EC)). The soil samples were collected with depths of 0 –20cm, 20 – 40 cm, and 40 – 60 cm. The particle size distributions in the soil profiles were determined using a hydrometric method [27]. Soil pH was measured in 1:2.5 soil: water mixture by using a pH meter. Organic carbon content was determined by titration method using chromic acid (potassium dichromate + H_2SO_4) digestion [29]. Field capacity and permanent wilting point of the soil were analysed through a pressure plate apparatus in the laboratory with a pressure of 1/3 bar (for field capacity) and 15 bars (for permanent wilting point). The bulk density of the soil was determined using undisturbed soil samples using a core sampler having a dimension of 2.5 cm diameter and height of 2.5cm (12.27 cm^3). Then the bulk density was calculated as the ratio of the dry weight of the soil to the known cylindrical core sampler volume as the following (Eq. 1).

$$Bulk\ Density = \frac{Weight\ of\ Dry\ Soil\ (g)}{Volume\ of\ Core\ Sampler\ (cm^3)} \quad (1)$$

2.3. Treatment and Experimental Design

The experimental design was in randomized complete block design (RCBD) design with three replications. Treatments included three levels of deficit irrigation applications (100% ETc, 85% ETc, and 70% Etc) and three mulch types (No mulch, Straw mulch, and white plastic mulch). Full crop water requirement (100% Etc) computed with the aid of the CROPWAT program was applied as a control irrigation application. The experimental arrangement was a factorial arrangement resulting in 9 treatment combinations (Table 1). The treatments were assigned randomly to the experimental plots.

Table 1. *Treatment's combinations of the experiment.*

Treatment	Description
T1	100%Etc with no mulch
T2	100%Etc with white plastic mulch
T3	100%Etc with straw mulch
T4	85%Etc with no mulch
T5	85%Etc with white plastic mulch
T6	85%Etc with straw mulch
T7	70%Etc with no mulch
T8	70%Etc with white plastic mulch
T9	70%Etc with straw mulch

Figure 2. *Pictures of No Mulch (NM), Straw Mulch (SM), and white plastic Mulch (WPM) of treatments.*

2.4. Experimental Plots Preparation and Transplanting

The trial field plot was cultivated using oxen, levelled, and prepared by separating the field into 27 plots for transplanting. The plot area was 2.8 m x 3.0 m = 8.4 m^2, with 1m spacing between adjacent plots and 1.5 m between replications. Each plot of the experimental unit included five rows in which the three central rows were considered for data collection and the two side rows were used as buffer rows to minimize border effects. Hybrid hot pepper (*Capsicum annum* L.) variety vigro was used as a test crop. The seedlings were transplanted to field plots on the second week of November 2021 and 2022 for two consecutive years. Transplanting was done late in the afternoon to reduce the risk of poor establishment. The spacing between plants within a row and between rows was 30 cm and 70 cm, respectively. All other agronomic practices were kept normal and uniform for all the treatments including pre-irrigation and one irrigation after germination.

2.5. Application of Mulches

Two types of mulching materials, namely white plastic and straw mulch was used for the experiment. The mulching rate of 6 t ha^{-1} wheat straw [1] and white plastic mulch with 8 microns thickness was applied. Both White Plastic and straw mulch were applied after transplanting Hot pepper seedlings. White plastic mulch was applied by making small holes at the desired intra-row spacing while wheat straw mulch was applied under transplanted hot pepper seedlings by covering the ridge of the rows. Transparent plastic mulch was selected because it provides more yields than black plastic mulch and it is characterized by the occurrence of higher soil temperature that permits early germination, bulbing, increases water use efficiency, and harvesting than black plastic mulch [25].

2.6. Water Requirement and Irrigation Scheduling

2.6.1. Determination of Crop Water Requirement

Reference Evapotranspiration (ETo) was estimated using Long-term daily weather data collected from Shakiso meteorological station. Climatic parameters that were used were maximum temperature (Tmax), minimum temperature (Tmin), sunshine hours (hrs), relative humidity (H), and wind speed at two meters. The ETo was estimated by the CROPWAT software version 8.0 using the FAO Penman-Monteith approach [2].

The crop coefficient was collected from FAO Irrigation and Drainage Paper 56 for Pepper given by [2] as 0.35 for the initial stage, 0.35<Kc<1.05 for the crop developmental stage, 1.05 for the mid-season stage, and 0.9 the for the late season stage. For seasonal crop water requirements, ETc was estimated by multiplying the long-term ETo value with the established Kc value (Eq. 2).

$$ETc=ETo*Kc \quad (2)$$

Where, ETc = Crop evapotranspiration (mm/day), Kc = crop coefficient, and ETo = reference crop evapotranspiration (mm/day).

2.6.2. Irrigation Scheduling

The total available water (TAW), stored in a unit volume of soil, was determined by taking the difference between the water content at field capacity (FC) and at permanent wilting point (PWP) using the following equation [2].

$$TAW = \frac{(FC-PWP)}{100} * BD * DZ \quad (3)$$

Where TAW=Total available Water (%), FC and PWP in % on weight basis, BD= Bulk density of the soil (gm cm^{-3}) and DZ= maximum effective root zone depth (mm)

Readily Available Water (RAW) is the amount of water that crops can extract from the root zone without experiencing any water stress. The RAW was computed from the expression in Eq. (4).

$$RAW = TAW * p \quad (4)$$

Where, RAW is the readily available water or net irrigation depth, IRn (mm), p is allowable permissible soil moisture depletion fraction and TAW is total available water in the root depth (mm).

Whenever there is rainfall between irrigation, the IRn was calculated based on [2] as follows

$$IRn=ETc-Pe \quad (5)$$

Where, IRn =Net irrigation requirement (mm), ETc = crop evapotranspiration (mm) and Pe = effective rainfall (mm) which is part of the rainfall that enters into the soil and makes available for crop production. The effective rainfall (pe) was estimated using the following expression [2].

Pe = 0.6 * RF – 10/3 for RF month <= 70 mm or

$$Pe =0.8*RF–24/3 \text{ for RF month} > 70mm \quad (6)$$

Where, Pe (mm) = effective rainfall and P (mm) = actual monthly rainfall. The gross irrigation requirements account for losses of water incurred during conveyance and application to the field. This is expressed in terms of efficiencies when calculating project gross irrigation requirements from net irrigation requirements. Daily gross irrigation was estimated using the following equation [17]:

$$IRg = \frac{ET_c}{E_a} \quad (7)$$

Where, IRg= gross irrigation requirement (mm), ETc = crop evapotranspiration (mm/day)/net irrigation water requirement and Ea= irrigation efficiency

Irrigation interval, f, was estimated using the following (Eq. 8).

$$f = \frac{IRn}{ET_c} \quad (8)$$

Where, f is irrigation interval (day), IRn =Net irrigation requirement (mm) and ETc is mean daily crop water requirement (mm day^{-1}).

2.7. Irrigation Water Application

Irrigation water applied to each experimental plot was measured using a standard (3-inch) Parshall flume and installed 10 m away from the first plot of the first block. Calculated gross irrigation was finally applied to each experimental plot based on the treatment proportion. The volume of water applied for every treatment was determined from plot area and depth of gross irrigation requirement. The time required to irrigate each treatment was calculated from the ratio of the volume of applied water to the discharge-head relation of the 3-inch Parshall flume. The time required to deliver the desired depth of water into each furrow was calculated using the following equation [23].

$$T = \frac{A*d}{6*q} \quad (9)$$

Where, T= Application time (min), A= Area to be irrigate

(m^2), d= gross irrigation depth of water to be applied (cm) q= Flow rate of Discharge (l/s)

2.8. Data Collection and Analysis

The data collection was made on the three middle rows, leaving two outer rows in order to avoid border effects. Five plants were taken randomly from the three middle rows of each experimental plot for recording observations on growth and yield parameters. The collected parameters were Plant height (cm), number of pods per plant, pod length (cm), marketable yield (kg ha^{-1}), unmarketable yield (kg ha^{-1}), and water use efficiency (Kg m^{-3}).

1) Plant height (cm): plant height was measured as the distance in centimeter from the soil surface to the top most point of the sample plants at the last harvesting time. It was determined by randomly taking the height of five plants in each plot from three central rows using meter tape.

2) Average pod number per plant: pod number per plant was counted from each five randomly selected plants in the central row of each plot. The total pod number then divided by plant number from which sample was taken (ten).

3) Pod length: ten marketable pepper's pods from each plot were collected. Pod's length was measured by using meter tape.

4) Marketable yield: marketable yield was recorded as the weight of marketable fruits collected from the central three harvestable rows. Green peeper fruits were sorted by color, shape, presence of surface defects due to insect or diseases, damages and size as pictorial parameters for marketable grade and their weight was recorded and converted to kg/ha.

5) Unmarketable yield: unmarketable yield was recorded as weight of fruits collected from the central three harvestable rows. Unmarketable fruits were sorted out of the total fruits depending on diseased fruit, discolored, cracked, damaged by insect, birds and sunburn and wasted shape.

6) Total fruit yield: it is the sum of marketable and unmarketable yield. The yield collected from each plot; weighed and the mean for the same treatment converted to kg/ha.

Data collected was statistically analyzed using Genstat software 18th edition. Mean separation using least significant difference (LSD) at 5% probability level was employed to compare the differences among the treatments mean.

2.9. Water Use Efficiency

Water Use Efficiency was determined based on the ratio of crop yield per hectare to the net irrigation depth (mm) [8].

$$Water\ Use\ Efficience = \frac{Total\ yield\ of\ green\ pepper\ \left(\frac{kg}{ha}\right)}{Water\ Delivered\ up\ to\ harvesting\ \left(\frac{m^3}{ha}\right)} \quad (10)$$

2.10. Partial Budget Analysis

To assess the costs and benefits associated with mulch materials the partial budget technique as described by [9] was applied on the yield results. The variable expenses included were the cost of water pumping fuel, labor, irrigation water, plastic and straw mulch. The net income (NI) was calculated by subtracting total variable cost (TVC) from total Return (TR) as follows:

$$NI = TR - TVC \quad (11)$$

Marginal analysis compares the net benefits with the total variable cost of different treatments. Marginal rate of returns (MRR) were calculated by percentage change in benefit over change in total variable cost in moving from a lower cost treatment to a higher one using (equation 12). Local market price of green hot pepper was assessed during the harvest time and was changed to hectare bases.

$$MRR\ (\%) = \left(\frac{MNB}{MC}\right) * 100 \quad (12)$$

Where, MRR = Marginal rate of return, MNB = Marginal net benefit, MC = Marginal cost

3. Result and Discussion

3.1. Soil Characterization of Experimental Site

3.1.1. Soil Physical Properties

The result of the soil textural analysis from the experimental site is presented in Table 2. The average bulk density of the study area was 1.42 g/cm^3, which is below the critical threshold level 1.45 g/cm^3, and it was suitable for crop root growth [19] According to the USDA soil textural classification system, the soil of the experimental field could be classified as clay loam, sandy clay loam, and clay at a depth of 0 – 20 cm, 20 – 40 cm, and 40 – 60 cm, respectively.

Table 2. Bulk densities, field capacity, permanent welting point and TAW of the soil.

Depth (cm)	Bulk Density (g/cm^3)	FC (%)	PWP (%)	TAW (mm/m)	Particle size distribution (%)			Textural class
					Sand	Silt	Clay	
0-20	1.4	26.5	18.4	113.4	44	23	33	Clay loam
20-40	1.51	26.1	20.2	89.1	48	25	22	Sandy clay loam
40-60	1.36	28.7	20.0	118.3	12	23	65	Clay
Average	1.42	27.1	19.5	107.9	34.7	23.7	40.0	Clay loam

The basic infiltration rate in this experiment was found to be 8 mm/hr which is in the range of clay loam soil (2-15mm/hr) [15]. This means that a water layer of 8 mm on the soil surface will take one hour to infiltrate. In dry soil, water infiltrates rapidly and as more water replaces the air in the pores, the water from the soil surface infiltrates more slowly and eventually reaches a basic infiltration rate.

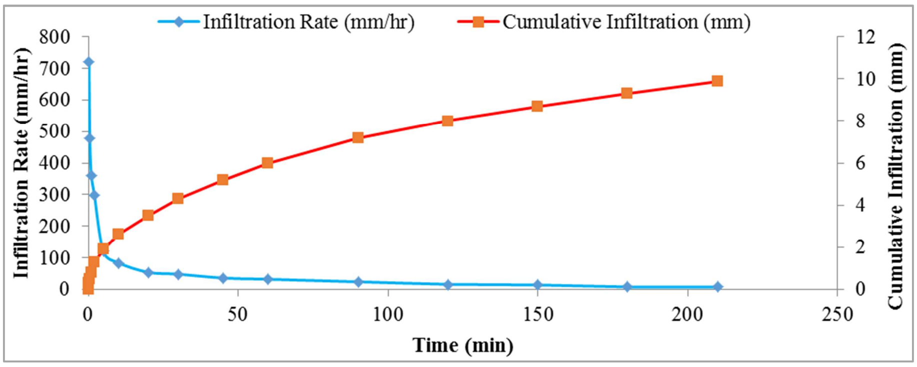

Figure 3. *Cumulative infiltration and infiltration rate curves.*

3.1.2. Soil Chemical Properties

As shown in Table 3, the average pH value of the experimental site through the analysed depth was found to be nearly neutral, with an average value of 6.73. The soil had an average electrical conductivity of 0.13 dS/m through a 60 cm profile which is below the threshold value for yield reduction, i.e. 1.2 dS/m [26]. The OM content and OC content of the soil had average values of 1.997% and 3.45%, respectively which indicates a high soil fertility level (OC > 1%) and is suitable for vegetable production [5].

Table 3. *Soil chemical properties of the experimental site.*

Depth (cm)	pH	EC (Ds/m)	OC (%)	OM (%)
0-20	6.2	0.092	2.34	4.04
20-40	6.7	0.140	2.14	3.69
40-60	7.3	0.159	1.51	2.61
Average	6.7	0.1	2.0	3.4

3.2. Effect of Irrigation Water Levels and Types of Mulches on Yield Components and Yield of Hot Pepper

3.2.1. Plant Height

The statistical analysis in Table 4 shows that average plant height was significantly (P=0.01) affected by irrigation water levels and types of mulches. The maximum plant height was recorded from the treatment of full crop water requirement (100% ETc) with white plastic mulch (48.97 cm) followed by full crop water requirement (100% ETc) with straw mulch (36.58 cm) whereas a minimum plant height was observed from the treatment of 70% Etc without mulch (37.1 cm). Furthermore, white plastic mulching with 100% ETc improved plant height by 2.7% than 100% ETc with no mulching. This might be due to white plastic mulch conservation of the available soil moisture through reducing evaporation. Similar findings were reported by [21], who stated that the plant height of maize was increased by 11.2% with plastic mulch when compared with no mulch condition.

3.2.2. Number of Pods Per Plant

The analysis of variance revealed that the different irrigation levels and types of mulch significantly ($p < 0.01$) influenced the number of pods per plant. The highest number of pods per plant (22.2) was recorded at 100 ETc with white plastic mulch, while plots treated with 70% ETc and no mulch produced the lowest number of fruits per plant (11.4) (Table 4). There was no statistical difference among 100% ETc with white plastic mulch, 100% ETc with straw mulch, and 100% ETc without mulch on the number of pods per plant. Similar findings were reported by [7], who reported that 100 micro linear low-density poly ethylene plastic mulching improves fruit set of chili peppers.

3.2.3. Marketable Yield

Irrigation levels and mulching types showed a significant effect on marketable green yield of hot pepper ($P < 0.01$). Irrigation application of 100% ETc with white plastic produced the highest marketable green yield of hot pepper with a value of 15.46 tone ha^{-1} followed by treatment of 85% ETc with white plastic mulch with a value of 14.19 tone ha^{-1}. On the other hand irrigation application of 70% ETc without mulch was recorded as the lowest marketable green yield of hot pepper with the value of 5.56 tone ha^{-1}. Moreover, 100% ETc with white plastic mulching enhanced marketable green yield of hot pepper by 11.2% than 100% ETc with no mulching. This result complies with that of [18], who stated that plastic mulch with full irrigation produces the maximum fruit yield of chili peppers. Moreover, [14] revealed that the maximum increase in marketable yield of hot pepper (12.81 tone ha^{-1}) was recorded at 100% ETc with 6 tones ha^{-1} of straw mulch. This might be due to mulching improving the moisture content of soil through the reduction of evaporation and saving water in the root zone.

Table 4. *Effect of irrigation water levels and mulch types on yield and yield component of hot pepper.*

Treatment	Plant Height (cm)	number of pods per plant	Pod length (cm)	Marketable yield (ton/ha)	Unmarketable yield (ton/ha)	Total yield (ton/ha)
100% ETc WM	47.64ab	19.1^{abc}	11.03	13.73^{ab}	0.081^{ab}	13.81^{ab}
100% ETc WPM	48.97a	22.2^{a}	12.59	15.46^{a}	0.083^{ab}	15.54^{a}
100% ETc SM	47.67ab	19.9^{ab}	12.42	13.81^{ab}	0.069^{b}	14.88^{ab}
85% ETc WM	41.75cde	13.1^{bcd}	10.34	9.65^{d}	0.075^{ab}	9.73^{d}
85% ETc WPM	42.95bcd	14.2^{bcd}	10.35	14.19^{a}	0.090^{a}	14.28^{a}

Treatment	Plant Height (cm)	number of pods per plant	Pod length (cm)	Marketable yield (ton/ha)	Unmarketable yield (ton/ha)	Total yield (ton/ha)
85% ETc SM	44.14abc	14.4bcd	9.50	13.72ab	0.092a	13.81ab
70% ETc WM	36.58f	11.4d	9.22	5.56e	0.068b	5.65e
70% ETc WPM	37.37ef	12.3cd	10.61	12.01bc	0.073ab	12.09bc
70% ETc SM	38.70def	13.4bcd	10.64	10.25cd	0.086ab	10.32cd
$LSD_{0.05}$	**	**	NS	**	*	**
CV (%)	9.8	34.0	29.60	13.0	18.40	31.6
Mean	42.9	15.54	10.74	12.04	0.08	9.58

Means followed by different letters in a column differ significantly and those followed by the same letter are not significantly different, ETc = Crop evapotranspiration, WM = without mulch, WPM = white plastic mulch, SM = straw mulch, NS = non-significant * = significant at p = 0.05, ** = significant at p = 0.01 and CV (%) = Coefficient of variation

3.2.4. Unmarketable Yield (ton/ha)

Statistical analysis showed that the interaction effect of deficit irrigation and mulch types had a significant ($p < 0.05$) effect on the unmarketable green yield of hot pepper (Table 4). The highest unmarketable green yield of hot pepper (0.092 t/ha) was obtained from experimental plots treated with 85% ETc with straw mulch and the lowest unmarketable green yield of hot pepper (0.068t/ha) was obtained from the treatment that received 70% ETc without mulch, however, there was no significant difference from plots treated with 100% ETc without mulch, 100% ETc with white plastic mulch, 85% ETc without, 85% ETc with white plastic mulch, 85% ETc with straw mulch, 70% ETc with white plastic mulch and 70% ETc with straw (Table 4).

3.2.5. Total Yield

The result revealed that the effects of irrigation level and mulch types resulted in a highly significant difference ($p < 0.01$) in the total green yield of hot pepper. The highest total green yield of hot pepper (15.54 t/ha) was obtained from full irrigation level (100% ETc) with white plastic mulch followed by plots that received 85% ETc with white plastic mulching (14.28 t/ha). On the other hand, the lowest total green yield of hot pepper (5.65 t/ha) was obtained from 70% ETc without mulch. This result showed that 100% ETc with white plastic mulch increased the total green yield of hot pepper by 11.13% than 100% ETc with no mulching which was applied as a control treatment. The reason for the reduction of total green yield with an increase in deficit level is that as the soil dries, the rate of absorption by roots falls, short of the transpiration rate by the plant, thus creating an internal water deficit, which affects photosynthesis and reduce food production [12]. The improvement of the net return of fruit crops through maximizing yield and water productivity with limited available water by the application of mulch was also reported by [28].

3.3. Water Productivity

The Interaction Effect of irrigation levels with mulch type under furrow irrigation has shown a highly significant ($p<0.01$) influence on the water productivity of green hot pepper (Table 5). Results indicated that the maximum water productivity (4.74kg/m^3) was observed at irrigation application of 70% ETc with white plastic mulch which was statistically non-significant with 85% ETc with white plastic mulch and 85% ETc with straw mulch with the value of (4.61kg/m^3) and (4.46kg/m^3) respectively. The minimum water productivity (2.20kg/m^3) was observed at irrigation water application of 70% ETc without mulching (Table 5). The higher amount of irrigation water application is associated with lower water productivity and the lower amount of irrigation water amount is related with higher water use efficiency. The lower water productivity might be attributed to higher irrigation water depth applied, much of which was lost through soil deep percolation. The results were similar to the findings of [4], who reported that a low irrigation regime reduced deep percolation and increased water use from the root zone.

Table 5. *Effect of irrigation water levels and mulch type on water productivity of hot pepper.*

Treatment	Water productivity (kg/m^3)
100% ETc WM	3.79c
100% ETc WPM	4.27abc
100% ETc SM	3.81c
85% ETc WM	3.14d
85% ETc WPM	4.61ab
85% ETc SM	4.46ab
70% ETc WM	2.20e
70% ETc WPM	4.74a
70% ETc SM	4.05bc
$LSD_{0.05}$	**
CV (%)	14.10
Mean	3.90

Means followed by different letters in a column differ significantly and those followed by the same letter are not significantly different at $p < 0.05$ level of significance, ns = non-significant at 5% probability level, LSD (%) = Least significant Difference at 5% of significance and CV (%) = Coefficient of variation

3.4. Economic Comparison of Treatments

The partial budget analysis showed that applying 85% ETc with straw had highest net benefit of 839,438 birr/ha with MRR of 1080 % and followed by 100% ETc without mulch treatment with a net benefit of 819,590 birr ha^{-1} and MMR of 3013 % (Table 6). The lowest net benefit 339,057 birr ha^{-1} was obtained from 70% ETc without mulch treatment. This result showed that applying irrigation with 85% ETc with straw mulch is economically feasible for hot pepper production in the Odo Shakiso area of the Guji zone.

Table 6. *Partial budget analysis of green hot pepper under different treatments.*

Treatments	Marketable fresh yield (Kg ha^{-1})	Total Revenue (ETB ha^{-1})	TVC (ETB ha^{-1})	Net Benefit (ETB ha^{-1})	MRR (%)
70% ETc WM	5562	361530	22473	339,057	
85% ETc WM	9654	627510	29731	597,779	3565
85% ETc SM	13716	891540	52102	839,438	1080
70% ETc SM	10254	666510	65602	600,908	D
100% ETc WM	13730	892450	72,860	819,590	3013
100% ETc SM	13808	897520	87860	809,660	D
70% ETc WPM	12012	780780	352602	428,178	D
85% ETc WPM	14187	922155	394231	527,924	240
100% ETc WPM	15455	1004575	555860	448,715	D

ETB = Ethiopian Birr, TVC = total variable Cost, MRR = marginal rate of return, D = dominated treatments
Note: - The price of green hot pepper taken was 65 ETB Kg^{-1}.

4. Conclusion and Recommendation

The study was aimed at determining the yield, yield components and water productivity of hot pepper under different levels of deficit irrigation practice and mulch types during water stress without significant yield reduction. The experimental design was randomized complete block design with three replications.

According to the findings of this study, it was observed that the different irrigation levels and types of mulch significantly influenced plant height, number of pods per plant, marketable and total green hot pepper yield. The highest plant height, number of pods per plant, marketable and total green hot pepper yield were obtained under treatment of 100 ETc with white plastic mulch with values of 48.97 cm, 22.2, 15.46 ton ha^{-1}, and 15.54 ton ha^{-1} respectively. Based on marketable and total yield of green hot pepper, statistically there is no significant difference among treatments of 100% ETc without mulch, 100% ETc with white plastic mulch, 100% ETc with straw mulch, 85% with white plastic mulch and 85% ETc with straw mulch. Moreover, 100% ETc with white plastic mulching enhanced marketable green yield by 11.2% than 100% ETc with no mulching. On the other hand irrigation application of 70% ETc without mulch was recorded as the lowest marketable and total fresh yield of hot pepper with the value of 5.56 and 5.65 tone ha^{-1} respectively.

The Interaction Effect of irrigation levels with mulch type under furrow irrigation has shown a highly significant influence on water productivity of hot pepper. Results indicated that the maximum water productivity (4.74kg/m^3) was observed at irrigation application of 70% ETc with white plastic mulch which was statistically non-significant with 85% ETc with white plastic mulch and 85% ETc with straw mulch with the value of (4.61kg/m^3) and (4.46kg/m^3) respectively.

Based on the partial budget analysis, the highest net benefit value of 839,438 birr/ha with marginal rate of return 1080 % was obtained from 85% ETc with straw mulch followed by 100% ETc with no mulch treatment with net benefit of 819,590 birr ha^{-1} and marginal rate of return 3013 %. This result showed that applying irrigation with 85% ETc with straw mulch is economically feasible for green hot pepper production in the Odo Shakiso area of the Guji zone.

In conclusion, the present study points out that irrigation application of 85% ETc with straw mulch is recommended because of its higher water use efficiency and economical profitability compared to the other treatments around Odo Shakiso district and similar agro ecologies. However, as the trial was conducted in one location, conducting similar research over locations would be appropriate to get conclusive results for the best recommendation.

Acknowledgments

We would like to acknowledge Oromia Agricultural Research Institute for providing funds for the experiment and technical support. We provide special thanks to Bore Agricultural Research Center for providing necessary attention and follow up to conduct the research successfully.

Conflicts of Interest

Authors declare that there is no conflict of interest.

References

[1] Akhtar, K., Wang, W., Khan, A., Ren, G., Afridi, M. Z., Feng, Y. and Yang, G., 2019. Wheat straw mulching offset soil moisture deficient for improving physiological and growth performance of summer sown soybean. *Agricultural Water Management*, *211*, pp. 16-25.

[2] Allen, R. G. Pereira, L. S. Raes, D. and Smith, M. 1998. Crop evapotranspiration-Guidelines for computing crop water requirements-FAO Irrigation and drainage paper 56. Fao, Rome, 300(9): D05109.

[3] Awulachew, Selesh Bekele; Teklu Erkossa and Regassa Namara. 2010. Irrigation potentialin Ethiopia, constraints and opportunities for enhancing the system. IWMI, Colombo, Sri Lanka.

[4] Ayars J. E., Phene C. J., Hutmacher R. B., Davis K. R., Schoneman R. A., and Vail S. S., Mead R. M. (1999): Subsurface drip irrigation of row crops: A review of 15 years of research at the Water Management Research Laboratory. Agricultural Water Management, 42: 1−27.

[5] Basu, P. K. 2011. Methods Manual Soil Testing in India: Department of Agriculture and Cooperation Ministry of Agriculture Government of India New Delhi January, 2011.

[6] Bhanukar, M. S. S. Sindhu, Preeti and Prince. 2015. Effect of various mulches on growth, yield and quality of Kinnow. The Bioscan, 10(3): 1379-1382.

[7] Bhardwaj, R. L., Sundria, M. M., Kumhar, S. R. and Kumar, N., 2018. Effect of irrigation methods and mulching on growth and yield parameters of chilli (*Capsicum annum* L.) in arid condition. Journal of Spices & Aromatic Crops, 27(1).

[8] Chandrasekaran B, Annadurai K, and Somasundaram E. 2010. A textbook of agronomy. New Age International. New Delhi, India.

[9] CIMMYT (International Maize and Wheat Improvement Center). 1988. From Agronomic data to Farmer Recommendations: An Economics Training Manual. Completely Revised Edition. Mexico. D. F.

[10] English, M., & Raja, S. N. (1996). Perspectives on deficit irrigation, 32(96), 1–14.

[11] FAO (Food and Agricultural Organization). 2016. Coping with Water Scarcity in Agriculture. Food and Agriculture Organization of the United Nations, 1–12.

[12] Farooq, M., Wahid, A., Kobayashi, N., Fujita, D. and Basra, S. M. A. 2009. Plant drought stress: effects, mechanisms and management. Agron. Sustain. Dev. 29: 185-212.

[13] Flörke, M., Schneider, C., & McDonald, R. I. (2018). Water competition between cities and agriculture driven by climate change and urban growth. Environmental Science. Nature Sustainability. https://doi.org/10.1038/s41893-017-0006-8

[14] Hailu Demo, A., 2021. EFFECT OF DEFICIT IRRIGATION AND MULCH LEVELS ON YIELD COMPONENTS, YIELD, AND WATER USE EFFICIENCY OF HOT PEPPER (Capsicum annuum L.) IN HARAMAYA DISTRICT, EASTERN ETHIOPIA (Doctoral dissertation, Haramaya university).

[15] Hillel, D., (2004). Introduction to environmental soil physics. University of Massachusetts, ELESIVIER Academic Press. New York. 493p.

[16] Kader, M. A. Senge, M. Mojid, M. A. and Ito, K. 2017. Recent advances in mulching materials and methods for modifying soil environment. Soil and Tillage Research, 168: 155-166.

[17] M. H. Ali, Fundamentals of Irrigation and On-Farm Water Management, vol. 1, Springer, Berlin, Germany, 2010.

[18] Maida, P. and Kumar, U., 2020. Combination effect of mulch and irrigation schedule on performance of Chilli under drip irrigation condition. Journal of Pharmacognosy and Phytochemistry, 9(5), pp. 2639-2644.

[19] McKenzie, D., Gedalof, Z. E., Peterson, D. L. and Mote, P., 2004. Climatic change, wildfire, and conservation. *Conservation biology*, *18*(4), pp. 890-902.

[20] Mdemu, M. V. C. Rodgersa, P. L. G. Vleka and J. J. Borgadi. 2008. Water productivity (WP) in reservoir irrigated irrigation system in the upper east region (UER) of Ghana.

[21] Mebrahtu, Y. and Mehamed, A., 2019. Effect of different type of mulching and furrow irrigation methods on maize (Zea mays L.) yield and water productivity at Raya Valley, Northern Ethiopia. J. Biol. Agric. Healthc, 9, pp. 6-13.

[22] Mekonen Ayana. 2011. Deficit irrigation practices as alternative means of improving water use efficiencies in irrigated agriculture: Case study of maize crop at Arba Minch, Ethiopia. African J. of Agri. Res. 6(2): 226-235.

[23] Michael, A. M. 2008. Irrigation Theory and Practice", (revised and enlarged) Vikas Publishing House PVT. Ltd, Delhi, India.

[24] Osman, Y., Oner, C., Demet, U. and Hasan, B. 2001. Irrigation scheduling of Drip-irrigated Tomato using A pan evaporation, Turkey Journal of Agriculture, 26(2002) 171-178.

[25] Ramalan, H. N. and Oyebode, M. A. 2010. Effect of deficit irrigation and mulch on water use and yield of drip irrigated onions. Department of Agricultural Engineering, Federal Ministry of Agriculture and Rural Development, Ethiopia, 134, 47-49.

[26] Smith, R. Aguiar, J. L. Baameur, A. Cahn, M. Cantwell, M. De la Fuente, M. Hartz, T. Koike, S., Molinar, R. Natwick, E. and Suslow, T. 2011. Chile pepper production in California.

[27] Stanley, W. C. and Yerima, B. 1992. Improvement of soil services for agricultural development: guidelines for soil sampling and fertility evaluation. Ministry of Natural Resources Development and Environmental Protection, Addis Ababa, Ethiopia.

[28] Tesfaye Gragn Debele, Alemayehu Mamo Burayu and Obsa Wolde Dilgasa. 2023. Effects of Mulching and Amount of Water on Yield and Yield Components of Tomato (Solanum lycopersicum L.) under Drip Irrigation at Adola Rede District, Southern Ethiopia. Int. J. Curr. Res. Aca. Rev. 11(03), 32-44.

[29] Walkley, A. and Black, I. A., 1934. An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. Soil science, 37(1), pp. 29-38.

[30] Yu, Y. Y. N. C. Turner, Y. H. Gong, F. M. Li, C. Fang, L. J. Ge and J. S. Ye. 2018. Benefits and limitations to straw- and plastic film mulch on maize yield and water use efficiency: a meta-analysis across hydrothermal gradients. Eur. J. Agron., 99: 138–147.