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The Influence of Drip Irrigation with Mulch Cover on the Growth, Yield, and Water Use Efficiency of Black Tomato (*Solanum lycopersicum l.*) in Pots

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The field experiment was conducted at the Instructional Farm of Department of Agricultural Engineering, JISCE, Nadia, West Bengal in sandy loam soil to investigate the influence of drip irrigation with two mulches cover (polyethylene sheet and paddy straw) on growth, yield and water use efficiency of black tomato (*Solanum Lycopersicum L.*) in pots and conventional farming methods at different treatments. In the study, four irrigation treatments were applied with four

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replications. The different irrigation treatments were follows: (i) T_{1}- Conventional irrigation with 5 cm of water in each irrigation after disappearance of water, (ii) T_2 - 0.8 E_{pan} under drip irrigation @ 4 l/h at 1 day interval with plastic mulching, (iii) T_3 - 0.6 E_{pan} under drip irrigation @4 l/h at 1 day interval in pots, (iv) T_4 - 0.4 E_{pan} under drip irrigation @ 4 l/h at 1 day interval in pots with straw mulching. Results showed that the water requirements under drip irrigation for all treatments were lower compared to conventional (flooding) irrigation. The amount of irrigation water required under drip irrigation with straw mulch cover in pots at T_4 -0.4 E_{pan} treatments is the lowest, i.e, 150 mm, and the highest value was 562 mm at T_1 treatments i.e, in the conventional irrigation system. The amount of irrigation water required under T_2 and T_3 was 300 mm and 225 mm, respectively, over the 75 days. It was found that the average yield at T_1, T_2, T_3, and T_4 treatments was 80 t/ha, 112 t/ha, 96 t/ha, and 120 t/ha, respectively. It was observed that the water use efficiency was found to be the highest at the treatment of T_4 0.4 E_{pan} of drip irrigation with straw mulching in pots was 120 t/ha-cm. The study demonstrates that drip irrigation in combination with different mulch significantly increased the plant height, dry matter production, number of fruits per plant, fruit weight and finally raised the black tomato yield to 120 t/ha with 73 % water saving compare to conventional method of irrigation (flooding) practiced by most of the farmers.

Keywords: Conventional irrigation; pan evaporation; fruit yield; irrigation requirement.

1. INTRODUCTION

Tomato (*Solanum Lycopersicum*) is one of the most widely cultivated and consumed vegetables globally, including in India. The black tomatoes (*Solanum Lycopersicum L.*) are an emerging crop that gained attention in recent years due to its unique fruit characteristics and potential health benefits (Tóth & Hort, 2022). Renowned for its dark purple to almost black coloration, rich flavor, high nutritional value, and versatility, it has become a staple in various cuisines. Black Tomatoes are an excellent source of antioxidants, specifically phenolic compounds, vitamins A, C, and K, along with antioxidants like lycopene, which play a crucial role in reducing the risk of chronic diseases, cancer prevention, and reduction of cardiovascular disease (Gerszberg *et al*., 2014). Additionally, they provide essential minerals such as potassium and folate, contributing to overall health. Tomatoes are consumed in multiple forms: fresh, cooked, and processed, making them integral to the production of sauces, purees, ketchups, and other value-added products (Arulmani et al., 2022). The crop thrives in well-drained, fertile soil with moderate temperatures ranging between 20-30°C for optimal growth and yield (Anonymous[1]). Adequate irrigation, proper nutrient management, and pest control are essential for achieving high productivity. India is the second-largest producer of tomatoes globally, following China, contributing approximately 10-11% of the total world production (Anonymous[2]). In the 2020-2021 seasons, India's total tomato production reached around 21.181 million metric tons, with a cultivation area of approximately 845 thousand hectares (Anonymous[3]). The country's diverse climatic conditions enable year-round cultivation across multiple states, with major producing regions including Andhra Pradesh, Madhya Pradesh, Karnataka, Gujarat, Odisha, West Bengal, Chhattisgarh, Bihar, Telangana, Tamil Nadu, Uttar Pradesh, Maharashtra, Haryana, and Himachal Pradesh. Nowadays, the black tomato variety has a good market price in India and foreign markets. It needs to be cultivated commercially for more income for the farmer. But till now it is not so popular in farming in India.

Tomato farming is a crucial part of West Bengal's horticultural sector, significantly contributing to the state's economy. In the 2020-2021 period, the state recorded a total production of approximately 1284.42 thousand tons. The cultivation area has expanded to 59.24 thousand hectares, with an average productivity of 21.68 metric tons per hectare (Anonymous[3]). Major tomato-producing districts include Bankura, Purulia, West Midnapore, East Midnapore, Nadia, Hooghly, Murshidabad, Birbhum, and East and West Burdwan. Despite the state's fertile alluvial soil and favorable climate, farmers face challenges such as nutrient deficiencies (calcium and magnesium), pest infestations (fruit borers, whiteflies, and aphids), and diseases like Tomato Leaf Curl Virus, Early Blight, and Bacterial Wilt. Unpredictable weather, such as unseasonal rainfall and high humidity, further affects production, often leading to fruit cracking and reduced shelf life. To overcome these issues, farmers need to adopt high-yielding hybrid varieties, drip irrigation with fertigation, and mulching techniques (Djaghrouri et al., 2024;

Mukherjee et al., 2023). Additionally, organic fertilizers, bio-fertilizers, and crop rotation are improving soil fertility, while post-harvest losses, which previously accounted for 15-20% of total production, are being minimized through investments in cold storage and processing units. The sector supports over 200,000 farmers, with tomatoes being sold at 10 - 40 per kg, depending on the season. Black tomato farming can increase the farmers' incomes. West Bengal also exports tomatoes to neighboring states like Jharkhand, Bihar, and Odisha, as well as Bangladesh, strengthening its agricultural economy.

Drip irrigation is a modern and highly efficient water-saving irrigation method that delivers water directly to plant roots through a network of pipes and emitters (Panigrahi et al., 2010). It offers a sustainable solution to water scarcity in farming. The field water use efficiency of drip irrigation is typically in the range of 90–95% when managed efficiently. One of its primary benefits is water conservation, as it minimizes evaporation and runoff, using 30–50% less water compared to traditional methods like flood irrigation (Shivani et al., 2019). This system ensures a consistent and precise water supply, leading to improved crop yield and better-quality produce. Applying water slowly and directly to the root zone prevents soil erosion and nutrient leaching, preserving soil health. Additionally, drip irrigation helps in weed and disease control by limiting excess moisture in non-crop areas, reducing weed growth and fungal infections. It is also energy-efficient since it operates at low pressure, consuming less energy than sprinklers or surface irrigation. Studying the effects of drip irrigation on black tomato cultivation in field experiments requires extensive infrastructure. An alternative approach is pot experiments, which offer the flexibility to include various soil types. Additionally, by protecting the pots from rain, experiments can be conducted year-round, significantly reducing the overall duration compared to open-field trials. When properly managed, pot experiments can also prevent drainage issues and the leaching of nutrients, a challenge that is often difficult to measure in field conditions (Singh et al., 2009). The study was conducted with the objectives (i) To determine the water requirements of black tomato under drip irrigation, (ii) To compare the water requirements of black tomato under drip and conventional (flooding) irrigation, (iii) To study the yield and economics of black tomato cultivation under drip irrigation with mulching in pots.

2. MATERIALS AND METHODS

The field experiment was conducted at the Instructional Farm of Department of Agricultural Engineering, JISCE, Kalyani, Nadia, West Bengal. The climate of Nadia is characterized by an oppressively hot summer, high humidity all year round, and well-distributed rainfall during the monsoon season. Winter begins in mid-November and lasts until the end of February. The rainfall during the monsoon months from June to September constitutes about 71% of the annual rainfall. The most rain occurs in July and August. The average temperature ranges from 37.6° C to 25.4° C during the summer months and between 23.7° C to 8.5° C during the winter months. Nadia district has 160-170 rainy days each year and an average rainfall of 1273 mm annually. The physical characteristics of the soil were analyzed, including bulk density, porosity, textural class, water holding capacity, and the relationship between soil moisture and tension. An heirloom variety black tomato, Indigo Rose, was selected for growing in the experimental plot with a drip irrigation system.

The soils were thoroughly blended with cow dung and dried in the sun before being used to fill pots. Containers of 12-inch size are used for this. Pots were filled with soil up to 2.5" to 3" below the top of the pots. Young seedlings with 15-20 cm height and 2-3 sets of true leaves only in each pot were transplanted in the afternoon. The row to row and plant to plant spacing was 62 cm and 66 cm, respectively. A row of tomato plants was covered with black plastic of 100 µm thickness (400 gauge) mulching, which is commonly used to retain moisture and control weeds. A row of tomato plants in pots filled with paddy straw at the rate of 1 kg/m^2 was mulched, a sustainable method that helps improve soil quality and moisture retention. The drip irrigation system was installed at the experimental site soon after transplanting the seedlings into pots. High-density polyethylene pipes of 5 cm diameter were used as main and sub-main lines, and 1.3 cm diameter low-density polyethylene pipes as lateral lines were laid from the sub-mainlines that were parallel to the plant roots in each pot. Emitters with a discharge of 4 lph were used in the lateral line for each plant.

2.1 Treatment

Irrigation was carried out daily based on evaporation readings. The study included four irrigation treatments, each with four replications.

The different irrigation treatments and formulas were as follows:

1. T_1-Conventional irrigation with 5 cm of water in each irrigation after the disappearance of water.

At T_1- volume of water (V_1) = 5* (cm) * Kp *Kc * A

2. T_2- 0.8 ET under drip irrigation @ 4 l/h at 1 day interval with plastic mulching in soil.

At T_2- volume of water (V_2) = 0.8* Epan (cm) * A

3. T_3- 0.6 ET under drip irrigation @4 l/h at 1 days interval in pots.

At T_3- volume of water (V_3) =0.6* Epan (cm) * A

4. T_4-0.4 ET under drip irrigation @ 4 l/h at 1 day interval with straw mulching in pots.

At T_4- volume of water (V3) =0.4* Epan (cm) * A

Where, A= area of the pots = 7.5 m^2(3m x 2.5m)

Due to rainfall during the experiment, the irrigation interval was increased, and according to the amount of rainfall, the irrigation interval was changed.

2.2 Fruit Yield

The first picking was done 75 days after the planting, and thereafter, further pickings were done as the fruits mature at 3-4 day intervals. The fruits from observational plants were counted at each picking, and their average number was calculated. The total fruit weight per pot was determined by summing the yield from all pickings until the experiment concluded. The fruit yield was worked out for yield/plant, yield/ha, and water use efficiency. The estimated yields were calculated based on the crop period from March to May.

2.3 Water Use Efficiency

Water use efficiency was calculated by the following formula for different treatments and expressed as WUE =Yield of tomato (t/ha) ÷Water requirement (t/ha-cm).

3. RESULTS AND DISCUSSION

3.1 Soil Parameters

The Bouyoucous Hydrometer method were used for the determination of soil texture which revealed that the relative portions of silt particles for the examined sample were 62.8% of silt and clay content, 34.8% of clay content, 28% of silt content, and 37.5% of sand content. These percentages were located on a Soil Textural Triangle, and the soil was classified as clay loam. The analysis of physical soil characteristics using the Keen Raczkowski box yielded the following results: bulk density of 1.29 g/cm^3, particle density of 2.6 g/cm^3, porosity of 51.15%, and Maximum Water Holding Capacity of 52.3%.

3.2 Comparison between the Water Requirements of Black Tomato under Drip and Conventional (Flooding) Irrigation

“Drip irrigation can apply water both precisely and uniformly at a high irrigation frequency compared with conventional irrigation, thus potentially increasing yield, reducing subsurface drainage, providing better salinity control and better disease management since only the soil is wetted whereas the leaf surface stays dry” (Hanson *et al*., 2007). Similarly, in the field experiment it was found that Water requirements under drip irrigation for all treatments were less as compared to conventional (flood) irrigation (Table 1). The amount of irrigation water required under drip irrigation with straw mulch cover in pots at T_4 0.4 E_{pan} treatments is the lowest, i.e, 150 mm, and the highest value was 562 mm at T_1 treatments in the conventional irrigation system. The amount of irrigation water required under T_2 and T_3 was 300 mm and 225 mm, respectively, over the 75 days.

3.3 Comparison of Yield between the Drip and Conventional system

The fruit yields per plant and fruit quality was shown in Table 2. It is noticed that there were variations under different treatments. The maximum, 120 t/ha, was recorded on treatment T_4 under drip irrigation and straw mulching on pots, and the lowest was recorded in conventional irrigation treatment (T_1). It was found that the average yield at T_2 and T_3 treatments was 112 t/ha and 96 t/ha, respectively. “It was observed that in conventional irrigation system, water was applied less frequently, potentially causing a water deficit in the soil because an interruption in cell division and cell elongation” (Ilyas *et al*., 2017; Ullah *et al*., 2018; Chakma *et al*., 2021) which might be accountable for the diminution of plant height and leaf area so yield might be less in conventional irrigation system compare to drip irrigation system.

Table1. Amount of irrigation of Black Tomato at conventional irrigation and under Drip Irrigation at different treatments

Treatment	Amount of irrigation (mm)
T_1	562
T_2	300
T_3	225
T_4	150

Table 2. Yield of Black Tomato at different irrigation treatments

Treatment	Plant height (cm)	Fruit length (cm)	Fruit diameter (cm)	Unit fruit weight (gm)	Fruit per plant	Average yield (t/ha)
T_1	106.3	47.30	63.32	105.11	27.13	80
T_2	117.5	51.29	67.43	107.23	38.21	112
T_3	110.7	49.34	64.23	106.52	31.32	96
T_4	125.4	53.27	69.60	118.43	43.23	120

Table 3. Water use efficiency in different treatment

Treatment	Water use efficiency(t/ha-cm)
T1	1.422
T2	3.733
T3	4.267
T4	8.000

3.4 Comparison of Yield between the Different Mulching and Conventional System

"Beneficial responses of vegetable crops to mulch in terms of growth and yield have been reported by many investigators" (Biswas, *et al*., 2016; Mahata & Sarkar et al., 2018; Olekar & Patil, 2019). The field experiment showed similar performance at all treatment. Mulches had a greater effect on tomato yield when compared to the conventional drip irrigation without mulch. The data of fruit yield per plant, unit fruit weight, were shown on the Table 2. It is noticed that there were variations under different treatments. The maximum fruit weight 118.43 gm was recorded on treatment T_4 under drip irrigation and straw mulch in pots and the lowest was recorded in T_1 conventional irrigation treatment.

3.5 Water Use Efficiency

In conventional irrigation system the whole season (115-120 days) consumes 7000-8000 m^3 on an average considering the way farmers apply irrigation water and the productivity is around 25 t/ha and it was observed that the water requirement in drip irrigation method of pot cultivation with straw mulching was 150 mm which revealed that almost 8.000 (t/ha-cm) water has been saved in pot cultivation (Soman, P. 2020). Similarly, from this experiment it was also observed that the water requirement in 0.8 E_{pan} of drip irrigation system in pot cultivation was 300 mm. Mulches with drip irrigation gave higher WUE over irrigation alone under all levels of irrigation. From the study, it was found that the water use efficiency was found to be the highest at the treatment T_4 (0.4 E_{pan}) and lowest at T_1 due to high water use in flood irrigation (Table 3). Drip irrigation with straw mulching in pots optimizes water retention and delivery and maximizes efficiency.

4. SUMMARY AND CONCLUSION

Now a day tomato has become one of the most important vegetables around the world. Recently, interest in the tomato has significantly increased because of its nutritional values as well as its anti-cancer and anti-oxidative properties. From the experimental data, it was found that the use of pot and mulching under a drip irrigation system in different treatments of black tomato cultivation gave higher yield with significantly less application of water as compared to conventional irrigation. In a drip irrigation system, usually less water is available to weeds, high efficiency in fertilizers use, less weed growth so low labor and relatively low operation cost and less evaporation losses of water as compared to conventional irrigation. In the experiment T_1 treatment under drip irrigation with mulch cover in pots at 0.4 Epan treatments has been found to be the lowest, i.e., 150 cm, and the highest value was 562 cm in the conventional irrigation treatments which show similar result to other researcher's work. Due to the application of different treatments, it can be said that the water saving in 0.4 Epan has found almost 73% in comparison to conventional tomato cultivation in pot culture. Similarly, yield was found highest at 0.4 Epan treatments, i.e., 120 t/ha, and water use efficiency was found highest at 0.5 Epan treatments, i.e., 8.0 t/ha-cm. Drip irrigation in black tomato in pots is found to be a much water-saving practice. It is concluded from this field experiment that drip irrigation itself is the most water-saving technique, and cultivating the crops in pots with mulch further add to water saving since there is the possibility of using entire rainwater and less evaporation loss. The pot practice does not require the cultivable land and management of an entire field. In consideration of all these aspects, drip irrigation in pots and black tomato in particular may be a good proposition for cultivation towards saving water and economic return.

5. RECOMMENDATION

Determining the effects of drip irrigation in black tomato cultivation in field experiments requires an elaborate infrastructure. Pot experiments appear to be a viable alternative, as they can incorporate various soil types. A further advantage will allow experiments to be continued throughout the year if the pots are sheltered from rain. This approach shortens the experiment duration compared to open-field trials. When conducted properly, pot experiments can prevent drainage and minimize the leaching of nutrients. In the present study, the experiment was carried out in a very small area for experimental purposes. If the study were carried out with large areas, where water is not available all the time with good and proper management, it may give better results.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby 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 this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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