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Growth, Yield, Water use Efficiency and Economic benefit for Brinjal as Influenced by Drip Irrigation in Western Ganga Catchment

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ABSTRACT

This study was conducted in the College of Agriculture Sciences and Engineering, IFTM University, Moradabad, Uttar Pradesh (India). Drip irrigation, a relatively new technology in the world, has increased in vegetable crops. In India, eggplant, also known as brinjal, is cultivated across approximately 0.72 million hectares of land. The study included various drip irrigation treatments: T1 (1 hour every day), T2 (2 hours every two days), T3 (3 hours every three days), T4 (4 hours every four days), and T5 (Control with furrow irrigation). The findings showed that the best outcomes in terms of plant height, growth, yield, water use efficiency (WUE), benefit-cost ratio (B:C ratio), and economic returns were observed in T2, whereas T5 had the lowest values. The highest water use efficiency (WUE) was recorded in T2 at 327.29 kg/ha-mm through drip irrigation, while the lowest WUE in T5 was 169.88 kg/ha-mm through flood irrigation method. The maximum net return was obtained in treatment (T2) 163306 Rs/ha, while compared lowest net return at (T5) 101624 Rs/ha. Overall, the study underscores the significance of adopting modern irrigation technologies, particularly drip irrigation, to enhance agricultural productivity, conserve water resources, and improve the economic viability of vegetable crop cultivation, as evidenced by the superior results obtained in the treatment (T2).

Key words : *Drip Irrigation, Irrigation Scheduling, Water Use Efficiency.*

Introduction

Drip irrigation is considered to be the most advanced and efficient technology for delivering water precisely to a plant's root zone, ensuring optimal growth and yield. It has been predicted that by 2050, there will be an 11% increase in water consumption and a doubling of the need for more food (UNESCO-WWAP, 2003). Therefore, drip irrigation is expected to play a pivotal role in meeting the rising demands for both food production and water resources.Drip irrigation is a precision irrigation method that delivers water directly to the root zone of plants through a network of emitters (Fanish *et al.*, 2011). It is one of the most efficient irrigation methods available, and it has been shown to have a significant positive impact on crop yield and water efficiency (Olamide *et al.*, 2022). Drip irrigation is also one of the most water-efficient irrigation methods available. It can save up to 50% of the water used by other irrigation methods, such as furrow irrigation or sprinkler irrigation (Biswas *et al.,* 2016). This is because drip irrigation delivers water directly to the root zone of plants, where it is most needed. It also helps to reduce water losses due to evaporation and runoff (Hanson and May, 2007). The water efficiency of drip irrigation is especially important in areas where water resources are scarce. Drip irrigation is considered the most advanced and efficient method of irrigation system for supplying water precisely to the root zone of plants as per their requirement resulting in enhancement of yield (Mohanty *et al.,* 2016).

In the research area, the flexibility, effectiveness and even distribution of water across the irrigation system are utilized to evaluate its performance (Pruitt *et al.,* 1984). The uniform water distribution factor evaluates how well an irrigation system distributes the same amount of water across its surface, whether it is an individual emitter in a drip system (Yohannes and Tadesse, 1998). If the distribution is inconsistent, it is difficult to successfully irrigate while saving water. When employing drip irrigation, it is critical to apply water consistently (Burt *et al.,* 1997; Camp *et al.,* 1997). Deep percolation losses occur in the area that receives more water, whereas poor plant development and yields occur in the area that receives less water. This is primarily influenced by pressure variations and the hydraulic characteristics of the emitters. The hydraulic parameters of emitters include the emitter design, discharge rate, water quality and temperature, and so on. The pressure change in the laterals produced by friction loss affects the flow rate of emitters (Lameck *et al.,* 2011).

Drip irrigation, a relatively new technology in the world, has increased vegetable crop agriculture. This interest stems from the technology'sability to reduce water usage while potentially increasing crop yields (Jain *et al.,* 2000). It has proven to be superior to conventional irrigation approaches, particularly when used to irrigate fruit and vegetable crops, due to the system's precise and concentrated water delivery directly to the root zone. This method reduces the need for fertilizers while also conserving water. Furthermore, it can boost agricultural output while using minimum irrigation water (Yohannes and Tadesse, 1998).

In India, eggplant, also known as brinjal, is cultivated across approximately 0.72 million hectares of land, constituting roughly 10% of the total area devoted to vegetable crops, according to data from the National Horticulture Board. This places India second in terms of eggplant cultivation area, trailing only China (Wang, 2012). However, the yield of eggplants in India is comparatively low at 18.6 tons per hectare, which is only half of the yield seen in China. This disparity in yield can be attributed to various factors, with one of the primary reasons being the inconsistent and inadequate supply of irrigation water. Vegetables, including eggplants, are particularly vulnerable to water stress due to their fleshy nature and sensitivity to changes in water availability. They require regular and timely irrigation, especially during critical growth stages, as highlighted by (Chauhan *et al.,* 2013). Insufficient water supply can lead to delays in crop maturity, resulting in poor-quality produce and reduced overall yield. However, it's crucial to acknowledge that farmers face significant challenges in providing consistent irrigation due to the prevailing issue of acute water scarcity. This concern has been documented and studied by various sources, including the Ministry of Water Resources (MOWR) in 1999, (Seckler *et al.,* 1999), the Central Water Commission (CWC) in 2010, and (Amarasinghe and Smakhtin, 2014).

Eggplant (*Solanum melongena L.*) is a very common and popular vegetable in India and many other places in the world. India is the second-largest producer of eggplants after China. Using drip irrigation and fertigation methods is very helpful in saving water and nutrients while increasing the amount of vegetables produced. This is beneficial for various crops, including eggplants (Patel *et al.,* 2006; and Kumar and Kumar, 2018). Vegetable crops, like eggplants, are easily affected by not having enough water or nutrients in the soil. Drip irrigation and fertigation help solve these problems and make it easier to grow more eggplants. So, we did a field study to figure out the best schedules for drip irrigation and fertigation to use resources efficiently and get the most eggplants from the plants (Nileema *et al.,* 2021).

Materials and Methods

Experimental site

The experiment was carried out in an area College of Agriculture Sciences and Engineering, IFTM University, Moradabad (Uttar Pradesh) at coordinates 28.83°N latitude, 78.78°E longitude and it had an elevation of approximately 205.67 meters above mean sea level (MSL) shown in Fig. 1. The experi-

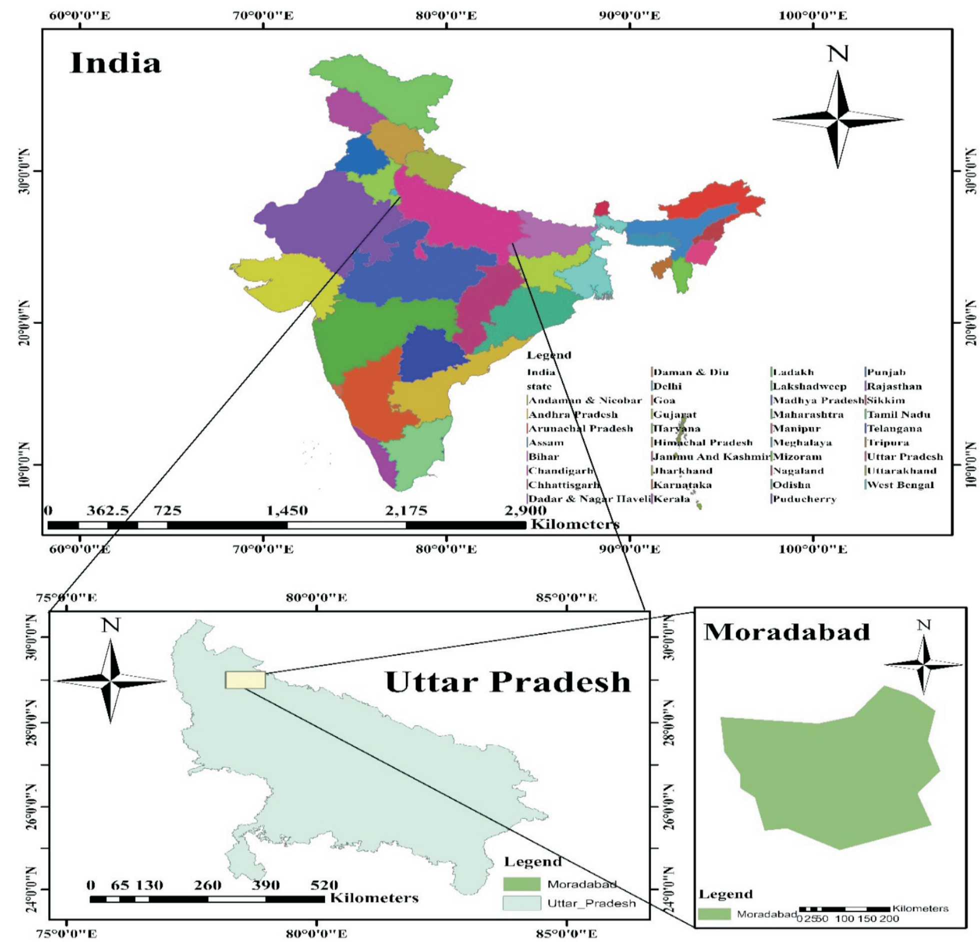

Fig. 1. Experiment site map

mental period extended from January to April 2018, and it involved a 200-square-meter plot cultivated with eggplants, specifically the *Pant Samrat*. Before transplanting, the soil was manually ploughed to a depth of 15 cm. One eggplant was transplanted about 2 cm away from each emitter.

Soil Characteristics

The soil at the experimental field was classified as loamy sand, composed of 81.3% sand, 7.5% silt, and 12.2% clay. Key soil properties included a field capacity of 15.6%, a wilting point of 4.7%, and a bulk density of 1.75 g/cm³. The soil had a texture resembling compact sandy clay loam with very little organic matter. Additionally, there was a hard layer of ferritic rock situated at a depth of 25–30 cm below the surface.

Layout and Design of drip Irrigation System

The experiment encompassed five different drip-irrigated treatments, which were determined based on varying soil matric potential thresholds (SMP). The size of each plot measured 10 m in length and 6 m in width, and within each plot, there were three beds, each with a width of 0.7 meters. In between furrowbeds the space dimension 0.4 meters wide and 0.25 meters deep.

The design of the drip irrigation system involves making decisions regarding the selection of emitters, laterals, manifolds, sub-mains, the mainline, and the necessary pumping unit. The sizing of the mainline, sub-mains, laterals, and pumps was determined based on the desired flow rate and pressure head required for the system. The estimation of pressure drop due to friction in the laterals and sub-mains was done using the Hazen-William empirical equation for multiple outlet pipes. The existing pumping system used by the farmers for irrigation, and the flow and pressure requirements were adjusted using control valves. To optimize the cost of installing the drip system for brinjal crops, we selected lateral spacing at 0.9 m and emitter spacing at 0.6 m based on the wetting zone in the soil for 4 liters per hour (lph) emitters.Water was pumped from the source using a 5 HP submersible pump and conveyed to the field through 63 mm diameter PVC pipes. Subsequently, sub-main lines of 63 mm and 50 mm diameter PVC pipes branched off from the mainline. Inline emitter lateral lines made of 16mm LLDPE pipes were installed on both sides of the field to irrigate the plots. The application of fertilizer to different treatments was regulated using control valves in the sub-main lines and flow control valves at the lateral off-takes.

Plate 1. Layout of experimental field under drip irrigation system in brinjal crop

Growth and Yield Parameters

Five plants were randomly selected and categorized for each treatment group in a plant experiment. The height of these plants was measured from the base to the tip of the main stem at 30, 60 and 90 days after transplanting (DAT). The number of primary branches per plant was also counted for each treatment group. Each picking counted the amount of fruits collected from five plants. The average number of fruits harvested per plant was calculated by dividing the total number of fruits harvested throughout all pickings by five. After that, the fruits were weighed with an electronic balance. We divided the total weight of fruits taken from each plot by the total number of fruits obtained to get the weight of each fruit. The overall marketable fruit yield was calculated by adding all picking sessions' yields and expressing it in quintals per hectare.

Data Collection and Analysis

Water use efficiency (WUE) was calculated by considering the yield per unit volume of water used. A present worth analysis was conducted, taking into account initial investments, the cost of the water source with pumping equipment and drip irrigation systems, prevailing bank interest rates, inflation, yields, income, and other relevant factors for different treatments. Various economic indicators, including Net Present Value (NPV), Benefit-Cost ratio (B:C ratio) and Internal Rate of Return (IRR), were determined for all treatments.

Statistical Analysis

In this research, a one-way analysis of variance (ANOVA) was conducted using a Randomized Block Design (RBD) with three replications. The threshold for identifying statistically significant differences was set at an LSD level with a significance level ($P < 0.05$).

Results and Discussion

Growth character

The tallest average plant height of brinjal was found at 30 DAT in T2 (25.53 cm), followed by T1, T3, T4, and T5 with heights of plant 24.43, 23.54, 21.85and 19.54 cm, respectively. The maximum plant height of the brinjal plant was observed at 60 DAT, in T2 (57.46 cm) followed by T1, T3, T4, and T5, with heights of 55.56, 53.91, 48.34 and 45.34 cm, respectively. AT 90 DAT, plants in T2 recorded the greatest average height at 92.71 cm, while the other treatments had slightly shorter plants, with treatment T5 having the shortest at 72.16 cm. These differences in plant height among treatments were statistically significant, with T2 producing the tallest plants, followed by T1, T3, T4, and T5. Similarly, at 120 DAT significantly highest plant height was observed in treatment T2 (90.36 cm) and was found statistically followed by treatment T1 (88.41cm), T3 (85.91 cm), T4 (70.67 cm) and T5 (70. 31 cm), respectively shown in Fig. 2.

The maximum average number of branches per plant wasrecorded at 30 DAT in T2 (9.9), while T1, T3, T4, and T5, with values of 7.2, 6.4, 5.9 and 4.9, respectively. At 60 DAT, the highest observed number of branches per plant in T2 (15.1), in terms followed by T1 (13.9, T3 (12.5), T4 (11.7), and T5 (10.3), respectively. This pattern persisted at 90 DAT, with T2 having the maximum number of branches per plant recorded (27.1), while the minimum number

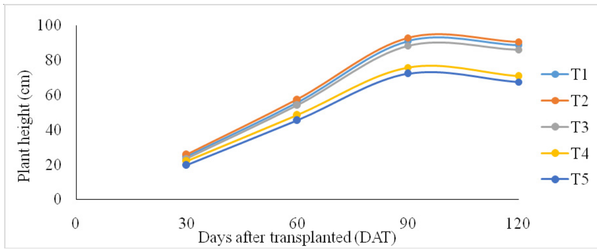

Fig. 2. Plant height as influenced by drip irrigation and irrigation scheduling

of branches per plant at T5 (15.8). The differences in the number of branches per plant among treatments were statistically significant. Similarly, at 120 DAT significantly highest maximum number of branches per plant was recorded was observed in treatment T2 (25.5) followed by the values of treatments T1, T3, T4 and T5 (20.7, 19.8, 17.2 and 14.7), respectively as shown in Fig.3. Drip irrigation has been shown to improve yield and quality, while also reducing disease and pest pressure (Chauhan *et al.*, 2013; Mohanty *et al.*, 2016).

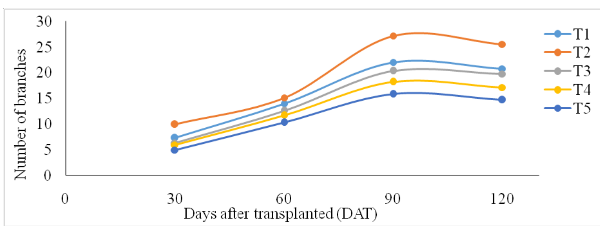

Fig. 3. Number of branches per plant as influenced by drip irrigation and irrigation scheduling

Yield character

The amount of water through the drip irrigation system and irrigation scheduling were found to have a significant effect on the number of fruits per plant at T2 (95.2) in terms followed by T1 (91.2), T3 (83.1), and T4 (74.6). The lowest number of fruits per plant was found in Treatment T5 (71.5) (traditional irrigation i.e., called control). The researchers believe that the higher number of fruits in the drip irrigation treatments is due to the more frequent and precise application of nutrients to the effective root zone of the plants. This makes the nutrients more readily available to the plants, which leads to increased growth and fruiting.

The different irrigation water frequencies of irrigation had a significant impact on brinjal yield as graphically represented in Fig. 4. The highest yield of brinjal was obtained in T2 (635.14 q/ha) when the plants were irrigated for 2 hours every two days, and the lowest yield of brinjal was found in T5 (479.06 q/ha) when the plants were irrigated for flood irrigation. The yields of brinjal were recorded in other treatments such as T1 (626.61 q/ha), T3 (573.26 q/ha) and T4 (504.09 q/ha), respectively. Thestatistical difference through the irrigation scheduling such as (2 hrs in two days intervals) in drip irrigation. It is also important to consider other factors that can affect total yield, such as variety, climate, and other agronomic practices.

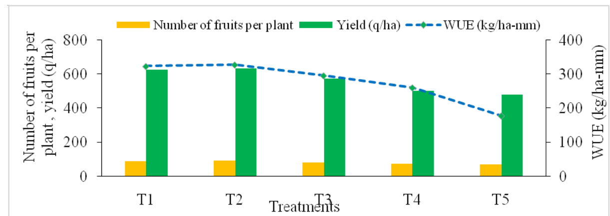

Fig. 4. Yield, number of fruits per plant and WUE of brinjal as influenced by drip irrigation and irrigation scheduling

Water use efficiency(WUE)

Graphically representation of WUE in Fig. 4 showsthe highest water use efficiency (WUE) was recordedin T2 at 327.29 kg/ha-mm through drip irrigation, while the lowest WUE in T5 was 169.88 kg/ha-mm through flood irrigation method. The values of WUE were found in treatments T1 (3.22.90 kg/ha-mm), T3 (295.41 kg/ha-mm) and T4 (259.76 kg/ha-mm), respectively. Because drip irrigation delivers water directly to the root zone of the plants, minimizing water losses through percolation, runoff, seepage, and soil evaporation.

Economic Analysis

The highest net return at was obtained in treatment (T2)163306 Rs/ha, while compared lowest net return at (T5) 101624Rs/ha and the maximum grass return were recorded at T2 (254056 Rs/ha) in terms of followed by T1 (250644 Rs/ha), T3 (229304 Rs/ha), T4 (201636 Rs/ha) and T5 (191624 Rs/ha), respectively expressed in Table 1. The benefit-cost ratio (BCR) values indicated that the drip irrigation system in T2 had the highest BCR of 2.80, followed by T1 (2.76), T3 (2.53), T4 (2.22), and T5 (2.13), respectively. This means that the drip irrigation system in T1, T2, T3 and T4 generated the highest benefits for every rupee invested compared to T5. Overall, the study found that drip irrigation is a more efficient and profitable way to irrigate brinjal crops than furrow irrigation. It results in higher yields,

Table 1. Economics of brinjal crop as influenced by irrigation scheduling and drip irrigation levels

Treatments	Crop yield (q/ha)	Gross return (Rs/ha)	Total cost (Rs/ha)	Net return (Rs/ha)	BCR
T1	626.61	250644	90750	159894	2.76
T2	635.14	254056	90750	163306	2.80
T3	573.26	229304	90750	138554	2.53
T4	504.09	201636	90750	110886	2.22
T5	479.06	191624	90000	101624	2.13

lower water consumption, and higher net returns (Olamide *et al.*, 2018).

Conclusion

The results indicated that the most favourable outcomes in terms of plant height, growth, yield, water use efficiency (WUE), benefit-cost ratio (B:C ratio), and economic returns were achieved with the T2 treatment, involving 2 hours of irrigation every two days. This demonstrates the effectiveness of drip irrigation, especially the T2 schedule, in optimizing eggplant production. Furthermore, the study highlighted the substantial differences in water use efficiency between drip irrigation (highest in T2 at 327.29 kg/ha-mm) and flood irrigation (lowest in T5 at 169.88 kg/ha-mm). This emphasizes the importance of adopting efficient irrigation techniques like drip irrigation for maximizing crop yield per unit of water utilized.Economically, T2 also indicated to be the most profitable, generating a maximum net return of 243,225 Rs/ha and the lowest net return was estimated at (T5) 176,930 Rs/ha, further highlighting the economic advantages of employing drip irrigation methods. Overall, the study underscores the significance of adopting modern irrigation technologies, particularly drip irrigation, to enhance agricultural productivity, conserve water resources, and improve the economic viability of vegetable crop cultivation, as evidenced by the superior results obtained in the treatment (T2).

Conflict of Interest: None

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