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# IMPACT OF IRRIGATION REGIMES AND FERTIGATION SCHEDULING ON BRINJAL CROP

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**ABSTRACT**

Efficient management of water and fertilizers is crucial for sustainable agricultural production, especially in resource-limited environments. Brinjal (*Solanum melongena* L.), a widely cultivated vegetable in India, requires careful optimization of these inputs to maximize yield and resource use efficiency. This study evaluated the effects of various irrigation regimes and fertigation schedules on the yield and resource use efficiency of Brinjal over three cropping seasons (2018-2021) at the Research cum Demonstration Farm, Junagadh Agricultural University. The experiment involved the cultivation of the Brinjal variety GJLB-4 using a drip irrigation system, with nine treatment combinations of irrigation levels (0.6 ETc, 0.8 ETc, and 1.0 ETc) and fertigation levels (50%, 75% and 100% of the recommended dose of fertilizer). The study aimed to determine the optimal balance between water and fertilizer application for maximizing yield and resource efficiency. The results revealed that the combination of 0.8 ETc irrigation with 100% RDF produced the highest yield of 35,216 kg/ha and a water use efficiency (WUE) of 81.45 kg/ha.mm. In contrast, 0.6 ETc irrigation with 100% RDF combined achieved the highest WUE at 75.73 kg/ha.mm, demonstrating the potential of reduced water application to enhance efficiency. Fertilizer use efficiency (FUE) was highest in the 1.0 ETc irrigation with 50% RDF treatment, indicating that lower fertigation levels can still maintain high efficiency. This study underscores the importance of optimizing irrigation and fertigation strategies to improve both yield and resource use in Brinjal cultivation, offering valuable insights for sustainable agriculture practices in similar agro-climatic regions.

***Key words :*** Brinjal, Fertigation scheduling, Fertilizer use efficiency (FUE), Irrigation regimes, Water use efficiency (WUE).

## Introduction

India, with its diverse agro-climatic zones, supports extensive cultivation of a variety of crops, particularly vegetables. In the fiscal year 2021, nearly 0.75 million hectares of Indian agricultural land were dedicated to vegetable production. Among these, brinjal (*Solanum melongena* L.) is one of the most widely cultivated vegetables across the country, thrives across diverse agro-climatic zones, with the exception of high-altitude regions. (Dipak *et al.*, 2023). India ranks as the second-largest producer of brinjal globally, following China. This hardy crop, belonging to the Solanaceae family and related to tomato and potato, adapts well to various soils and climates, producing fruits in a range of colors from purple and green to white. Its versatility, nutritional value and cultural importance make brinjal a staple in Indian diets, with variations in fruit shape and size meeting diverse consumer preferences nationwide. Known as the "vegetable of the masses," brinjal is an essential component of Indian agriculture and cuisine. Major brinjal-producing states include Odisha, Bihar, Karnataka, Gujarat, West Bengal, Andhra Pradesh, Maharashtra and Uttar Pradesh (Anonymous, 2004).

Water and nutrients are essential inputs for enhancing vegetable production to meet the growing demand of an expanding population. Their efficient management is crucial, as both have a direct and interconnected impact on plant growth and yield. Over-watering, much like drought stress, can induce hypoxia in plant roots, limiting their function (Voesenek and Bailey-Serres, 2015) and stressing plant physiology (Hirabayashi *et al.*, 2013). Moderating agricultural irrigation, especially through drip systems, has shown to benefit crop photosynthesis and overall health (Morales *et al.*, 2020; Wang *et al.*, 2020). Drip irrigation allows for precise timing and controlled distribution of water and nutrients directly to the root zone, enhancing water and fertilizer use efficiency over conventional irrigation methods (Deshmukh *et al.*, 2016; Godara *et al.*, 2013; Pandey *et al.*, 2013). This technique minimizes conveyance losses, deep percolation, and evaporation while ensuring soil moisture balance and optimal root aeration, which together can improve crop yield and quality (Wang *et al.*, 2020; Kumar *et al.*, 2016). Additionally, drip irrigation reduces labor, production costs, and increases productivity by enabling efficient nutrient delivery, especially for nitrogen and potassium (Anu and Habeeburrahman, 2015).

Numerous studies have shown that drip irrigation, combined with fertigation, can save 8.8–53.3% of water, improve fertilizer use efficiency by 30.1–110.6%, and increase yields by 20.9–104.0% across various crops (Tiwari *et al.*, 2003; Singandhupe *et al.*, 2007; Hatami *et al.*, 2012; Iqbal *et al.*, 2014; Jha *et al.*, 2017; Praveen Rao and Ramulu, 2019). Drip irrigation has also demonstrated a water use efficiency (WUE) improvement of 68–77% over surface irrigation (Singandhupe *et al.*, 2003). India, with an estimated potential of 27 million hectares for drip irrigation, has expanded this system to 4.5 million hectares, positioning itself as a global leader in drip irrigation application (Narayanamoorthy, 2008; Praveen Rao and Ramulu, 2019). Moreover, fertigation has become a preferred fertilization method, reducing fertilizer needs by 30–50% without compromising yields (Hongal and Nooli, 2007; Aujla *et al.*, 2007; Rekha and Mahavishnan, 2008). Considering these advantages, a field study was conducted to explore ways to improve brinjal productivity and profitability through optimized irrigation and fertigation strategies.

## Materials and Methods

### Field Experimental details

The field experiment was conducted from 2018 to 2021 at the Research cum Demonstration Farm, Research Testing & Training Center, Junagadh Agricultural University, Junagadh. The trial utilized the brinjal variety GJLB-4, sown at a seed rate of 0.3–0.35 kg/ha with plant spacing of 90 × 60 cm. The recommended dose of fertilizer (RDF) applied was 100:37.5:37.5 (N:P:K).

A drip irrigation system was implemented, laterals spaced 0.90 m apart and with dripper distances as 0.60 m, with a discharge rate of 4 liters per hour under an operating pressure of 1-1.2 kg/cm². The experimental design followed the Large Plot Technique with three replications, testing nine treatment combinations across two factors. Factor I included three irrigation levels (I1: 0.6 ETc, I2: 0.8 ETc, and I3: 1.0 ETc), while Factor II consisted of three fertigation levels (F1: 50% RDF, F2: 75% RDF and F3: 100% RDF).

Fertigation was administered by applying 100% of phosphorous and 25% of N and K as a basal dose and remaining 75% of N and K were applied through drip irrigation in 7 equal splits after 25 days of transplanting at 12 days interval according to the treatments.

### Data collection

The data on ancillary traits were recorded on five tagged plants in the net plot area. A total of eight and seven pickings were taken. The parameters measured during the study included: No. of fruits per plant (Nos.), Average fruit weight per plant (g), Brinjal yield (kg/ha) Fertilizer Use Efficiency (kg/kg) and Water Use Efficiency (kg/ha.mm).

The fresh fruit yield from all the pickings was summed up to report the final fresh fruit yield. Treatment wise total cost was calculated considering the fixed cost (cost of drip irrigation and cost of cultivation) variable cost (cost of irrigation water applied and fertilizer cost), Interest on working capital @ 12%, Rental value of land, Managerial charge @ 10% . The Total Cost (` /ha), Gross returns (` /ha), Net returns (` /ha), B:C ratio and Water Profitability (` /mm of water used) were computed by the formulas furnished below.

Cost of Cultivation (` /ha) = Common cost (` /ha) + Treatment cost (` /ha) (1)

Total Cost(` /ha) = Cost of Cultivation (` /ha) + Interest on working capital @ 12% (` /ha)+ Rental value of land (`/ha) + Managerial charge @ 10% (`/ha) (2)

Gross returns (`/ha)= Fresh fruit yield (kg/ha) × Market price (`/kg) (3)

Net returns (`/ha) = Gross returns (`/ha)- Total Cost (`/ha) (4)

B:C ratio= Gross returns (`/ha)/ Total Cost (`/ha) (5)

Water Profitability (`/mm of water used) = Net returns (`/ha)/ Water applied (mm) (6)

Further, the standard error of means (SEm±) and least significant difference at 5% probability (p=0.05) were used to compare the treatments to evaluate the effects.

## Results and Discussion

### Effect of drip irrigation and fertigation levels on the yield attributes and yield of brinjal

The number of fruits per plant and Brinjal yield were significantly influenced by irrigation and fertigation levels while average weight of fruits per plant was found non-significant (Table 1). The number of fruits per plant increased significantly with increase in the irrigation levels from 0.6 to 0.8 $Et_c$ with highest value recorded at 0.8 $Et_c$ (20) and it was at par with 1.0 $Et_c$. Further, the average weight of the fruits per plant was found to be maximum in the treatment where irrigation was scheduled at 0.8 $Et_c$ (84.46 g). The yield attributing characters increased with the increasing level of irrigation as water applied was sufficient to meet the metabolic activities like cell-division, reproductive growth and translocation of photosynthates. Earlier, Seema *et al.* (2023) reported increased number of fruits per plant, average fruit weight and fruit diameter with drip irrigation in brinjal.

The application of fertigation with 100% RDF resulted in a significantly higher fruit count per plant (19) and an increased average fruit weight (86.40 g) compared to treatments with 50% and 75% RDF (Table 1). This enhanced response may be attributed to the adequate supply of nitrogen, which likely promoted substantial carbohydrate synthesis and more efficient protein formation, both of which are critical for fruit development. Additionally, potassium application at this level appeared to support effective transport and utilization of assimilates within the developing fruits of brinjal. Thus, the 100% RDF application was considered the most effective in influencing physiological parameters that contribute to yield enhancement.

The interaction between irrigation and fertigation levels was non-significant for the number of fruits per plant; however, it was significant for average fruit weight (Fig. 1). Brinjal yield exhibited a substantial increase with irrigation levels up to 0.8 ETc, achieving a yield of 35,216 kg/ha. Further increments in irrigation beyond 0.8 ETc (1.0 ETc) did not produce a statistically significant yield increase, as yields were comparable to those recorded at 0.8 ETc (Table 2). Drip fertigation demonstrated a marked yield improvement of 37–49% compared to conventional flood irrigation (Goswami *et al.*, 2006) and furrow irrigation methods (Aujla *et al.*, 2007). The lower yield observed under the 0.6 ETc irrigation treatment may be attributed to reduced nutrient uptake under suboptimal soil moisture conditions, despite high fertilizer inputs. These results are consistent with findings by Kumar *et al.* (2010), who reported minimal yields at 50% PE even with substantial fertilization. Drip irrigation at optimal levels helps maintain favorable soil moisture conditions, enhancing water availability and enabling the crop to utilize water more effectively for growth and development (Singh *et al.*, 2023).

**Table 1 :** Yield and Yield attributes as influenced by different irrigation regimes and fertigation levels.

| Treatments | No. of fruit per plant (nos) | Average weight of fruits per plant (g) | Brinjal yield (kg/ha) |
|---|---|---|---|
| **A. First Factor –Irrigation Regimes** | | | |
| I1 | 15 | 83.30 | 23218 |
| I2 | 20 | 86.27 | 31552 |
| I3 | 20 | 84.38 | 30711 |
| S.Em. ± | **0.31** | **1.95** | **543.9** |
| C.D. at 5% | **0.89** | **NS** | **1548.3** |
| **B. Second Factor – Fertigation Level** | | | |
| F1 | 17 | 83.09 | 26059 |
| F2 | 18 | 84.46 | 28852 |
| F3 | 19 | 86.40 | 30570 |
| **S.Em. ±** | **0.31** | **1.95** | **543.9** |
| **C.D. at 5%** | **0.89** | **NS** | **1548.3** |
| **Interaction Effect (I X F)** | | | |
| S.Em. ± | **1.06** | **0.53** | **1539.2** |
| C.D. at 5% | **3.03** | **NS** | **4380.9** |
| **C.V. (%)** | **9.05** | **12.02** | **9.92** |

**Table 2 :** Fruit yield (kg/ha) as influenced by drip irrigation and fertigation levels on brinjal.

| Treatments | Fruit yield (kg/ha) | | |
|---|---|---|---|
| | **F1** | **F2** | **F3** |
| **I1** | 21685 | 23414 | 24555 |
| **I2** | 27199 | 32241 | 35216 |
| **I3** | 29292 | 30901 | 31939 |
| **S.Em. ±** | **1539.2** | | |
| **C.D. at 5%** | **4380.9** | | |
| **C.V. (%)** | **9.92** | | |

Significant differences were observed in fresh fruit yield of brinjal across various fertigation treatments (Table 2). Fertigation at 100% of the recommended dose of N and K fertilizers (RDF) consistently achieved significantly higher fruit yields compared to 75% and 50% RDF, both

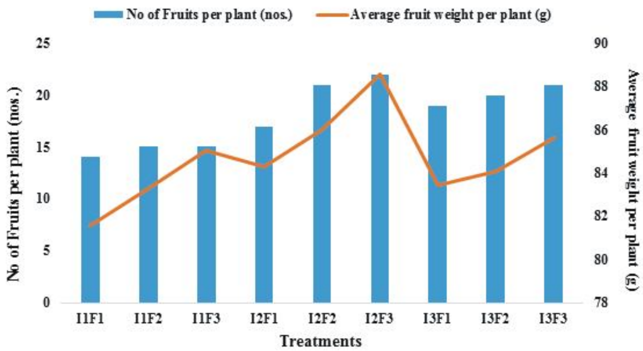


**Fig. 1 :** Yield attributes of brinjal as influenced irrigation levels and fertigation levels.

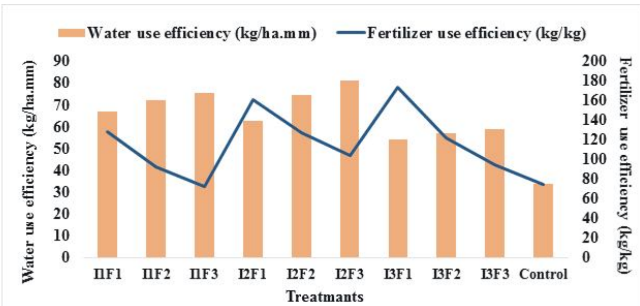


**Fig. 2 :** Water use efficiency and fertilizer use efficiency as influenced irrigation levels and fertigation levels on Brinjal.

annually and on a pooled basis over the three-year study period (Table 2). This increase in yield was primarily due to a higher number of fruits per plant and an increase in average fruit weight.

The enhanced yields under higher fertigation treatments can be attributed to the precise and frequent application of nutrients through the drip system, which improved nutrient uptake efficiency in the plants. The elevated N and K levels in the 100% RDF treatments likely facilitated the adequate translocation of nutrients essential for fruit development, thereby contributing to the yield increase. These results are consistent with those reported by Aujla *et al.* (2007), who observed a positive response of eggplant fruit yield to increased nitrogen levels under various irrigation regimes. Moreover, the regular nutrient supply at three-day intervals likely minimized nutrient leaching, ensuring that plants received the necessary nutrients continuously (Chauhan *et al.*, 2013). Fertigation also supports enhanced root development, allowing plants to absorb more water and nutrients compared to conventional application methods (Singh *et al.*, 2023).

The findings of this study align with research by Kumari and Kaushal (2014), who reported that drip fertigation not only increased yield and water use efficiency but also saved 25% of fertilizer and 40% of water inputs.

## Interaction effect of drip fertigation and irrigation levels on fruit yield

The interaction between fertigation and irrigation levels was statistically significant, with the highest fruit yield (35,216 kg/ha) observed in the treatment where 100% RDF fertigation was combined with a drip irrigation level of 0.8 ETc (Table 3). As the fertigation level increased, there was a corresponding increase in the number of fruits per plant and average fruit weight. Future studies could further optimize fertigation schedules according to specific crop growth stages, potentially lowering fertilizer application rates and enhancing profitability for farmers (Singh *et al.*, 2023).

## Effect of drip fertigation and irrigation levels on water and fertilizer use efficiency

Water use increased as irrigation levels rose (Fig. 2). The highest water use efficiency (WUE) of 81.45 kg/ha.mm was achieved with 100% RDF at an irrigation level of 0.8 ETc, while the lowest WUE (54.20 kg/ha.mm) occurred at 50% RDF with an irrigation level of 1.0 ETc. Higher WUE was consistently observed with 100% RDF compared to lower fertigation levels. This may be attributed to the consistent availability of moisture and nutrients provided by the drip system throughout the growth stages, enhancing nutrient uptake and overall brinjal yield. These findings are supported by similar results from Seema *et al.* (2022) and Ji *et al.* (2022).

Fertilizer use efficiency (FUE) declined with increasing fertilizer doses. The highest FUE (173.54 kg/kg) was recorded with 50% RDF at an irrigation level of 1.0 ETc, while the lowest FUE (72.74 kg/kg) was observed with 100% RDF at 0.6 ETc. Although higher fertilizer doses tend to lower FUE, they generally support higher yield and water use efficiency. Similar findings were reported by Betageri and Kottiswaran (2019), who observed increased yields under 80% ET€ and 100% RDF, along with a 16.17% water savings using mulch in sandy clay loam soils in Coimbatore. Kumar *et al.* (2010) further indicated that drip fertigation at 150% RDF led to the highest water use efficiency, likely due to the increased yield achieved under this treatment.

## Effect of drip fertigation and irrigation levels on economics of brinjal

The net returns and benefit-cost (B:C) ratio are essential indicators for evaluating the economic feasibility of a recommendation. Drip irrigation at 0.8 ETc combined with 100% RDF fertigation yielded the highest net returns (` 1,82,955), closely followed by 100% RDF at 1.0 ETc (` 1,59,128) (Table 3).

**Table 3 :** Economics of brinjal cultivation.

| Treatments | Gross income (` /ha) | Total cost (` /ha) | Net return (` /ha) | BC Ratio (%) | Water Profitability (` /mm of water used) |
|---|---|---|---|---|---|
| $I_1F_1$ | 151796 | 52855 | 98941 | 1.87 | 305.13 |
| $I_1F_2$ | 163897 | 55727 | 108171 | 1.94 | 333.59 |
| $I_1F_3$ | 171886 | 58371 | 113515 | 1.94 | 350.07 |
| $I_2F_1$ | 190391 | 56056 | 134335 | 2.40 | 310.71 |
| $I_2F_2$ | 225686 | 60207 | 165479 | 2.75 | 382.75 |
| $I_2F_3$ | 246512 | 63558 | 182955 | 2.88 | 423.17 |
| $I_3F_1$ | 205043 | 59014 | 146028 | 2.47 | 270.21 |
| $I_3F_2$ | 216309 | 61839 | 154470 | 2.50 | 285.83 |
| $I_3F_3$ | 223572 | 64444 | 159128 | 2.47 | 294.44 |
| **Control** | 175711 | 52133 | 123578 | 2.37 | 165.88 |

**Note:** Average price of brinjal considered ` 7/kg.

The lowest total cultivation cost was observed in the I1F1 treatment, while I3F3 incurred the highest due to increased fertilizer and irrigation expenses. The maximum B:C ratio (2.88) was achieved with I2F3, similar to I2F2 (2.75). Additionally, the highest water profitability (` 423.17 per mm of water used) was noted with 100% RDF at 0.8 ETc. This higher B:C ratio resulted from increased yields paired with a relatively lower cultivation cost compared to other irrigation and fertigation treatments. These findings align with those of Singh *et al.* (2023), who reported a B:C ratio of 3.75 in tomato grown under greenhouse conditions using 100% RDF through fertigation.

## Conclusion

The findings of this study demonstrate that, for *rabi* season brinjal cultivation in the South Saurashtra Agro-climatic Zone, an integrated approach of applying a basal dose of 100% RDF for phosphorus ($P_2 O_5$) and 25% RDF for nitrogen (N) and potassium (K) at a ratio of 100:37.5:37.5 kg/ha, followed by the remaining 75% RDF of N and K through drip irrigation, is highly effective. This fertigation strategy, delivered in seven equal instalments starting 25 days post-transplanting at intervals of 12 days, significantly enhanced brinjal yield, net economic returns, and water use efficiency. Notably, it demonstrated a substantial water savings of up to 42% compared to traditional furrow irrigation. These results highlight the potential of this optimized drip fertigation schedule to improve resource use efficiency and profitability in brinjal cultivation, making it a viable water-saving and yield-enhancing approach for semi-arid regions like Saurashtra.

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