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Enhancing *Rabi* Brinjal Productivity and Profitability Through Drip Irrigation and Fertigation

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ABSTRACT

A field experiment was conducted in red sandy loam soils at College Farm, Professor Jayashankar Telangana State Agricultural University (PJTSAU), Telangana, India during the *rabi* seasons of 2018–19 and 2019–20. The objective of the experiment was to investigate the impact of drip irrigation regimes and fertigation levels on the yield and economic aspects of brinjal during *rabi* season. The treatments comprised of three levels of irrigation (I1: 0.8 Epan, I2: 1.0 Epan and I3: 1.2 Epan) as main plots and four fertigation levels [F_{60}: 60%; F_{80}: 80%; F_{100}: 100% and F_{120}: 120% of the recommended dose of N and K (150 kg N and 90 kg K_2O ha^{-1})] as subplots, with each treatment replicated thrice. The results indicated that scheduling drip irrigation at 1.0 Epan and fertigation with 100% RDNK resulted in highest fresh fruit yield (41.6 t ha^{-1}), water productivity (0.50 t m^{-3}), net returns (₹ 1,88,017 ha^{-1}) and benefit: cost (B:C) ratio (2.3) over rest of the treatments. However, this treatment demonstrated comparable yields with that of 120% RDNK applied under the same irrigation regime (1.0 Epan) (41.9 t ha^{-1}), as well as to treatments involving drip irrigation scheduled at 1.2 Epan with fertigation at either 100% (41.8 t ha^{-1}) or 120% (41.9 t ha^{-1}) RDNK. The yield improvement and water saving due to scheduling of drip irrigation at 1.0 Epan in combination with fertigation at 100% RDNK, was to the tune of 28% and 22%, respectively over $I_{0.8}F_{60}$ (0.8 Epan+60% RDNK) treatment.

KEYWORDS: Brinjal, drip fertigation, economics, water productivity

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1. INTRODUCTION

India, with its diverse agro-climatic conditions, supports a wide range of crop cultivation. In the fiscal year 2021, approximately 0.75 mha of agricultural land in the country is dedicated to vegetable cultivation. Among many vegetable crops grown in India, brinjal (*Solanum melongena* L.), is cultivated throughout the year in all the states except at higher altitudes (Dipak et al., 2023). It is grown twice or thrice in a year and fruit is available practically throughout the year. Globally, India is the second largest producer of brinjal, next to China. India's brinjal production reached 12.98 mt during 2021–22 (Anonymous, 2022).

The water and nutrients are the two vital inputs for enhancing vegetable production to meet ever increasing demand to meet the needs of growing population. Their proper management is crucial for enhancing crop productivity as they play a direct and interconnected impact on plant growth and yield. Excessive water can cause stress similar to that caused by drought (Hirabayashi et al., 2013) and causes hypoxia in plant roots (Voesenek and Bailey-Serres, 2015). Proper reduction in agricultural irrigation can benefit crops in terms of photosynthetic metabolism (Morales et al., 2020), especially through drip irrigation (Wang et al., 2020). This method is most efficient for water/fertilizer distribution as it allows precise timing, controlled distribution of water and application of nutrients in the crop root zone than traditional methods (Godara et al., 2013; Pandey et al., 2013). Further, drip irrigation is preferred over conventional methods because of it's high water application efficiency, reduction in conveyance, deep percolation and evaporation losses. Uniform application of water to the rootzone of the crop helps in maintaining optimum soil moisture with proper aeration. The root-soil interaction can increase the yield and quality of crops (Wang et al., 2020). Furthermore, it helps in saving labour, cost of production and increasing the productivity. Application of N and K containing fertilizers through drip ensures their efficient utilization and higher productivity (Anu and Habeeburrahman, 2015).

Many researchers have reported saving in water by 8.8 to 53.3% besides enhancing fertilizer use efficiency by 30.1 to 110.6% and yields by 20.9–104.0% due to drip irrigation and fertigation across various horticultural and agricultural 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). Further, drip irrigation improved the WUE by 68–77% over surface irrigation (Singandhupe et al., 2003). In India, the potential for the drip irrigation system is estimated to be 27 mha (Narayanamoorthy, 2008). But, the area under this method of irrigation has grown to 4.5 mha only during the last two decades, making India the largest drip irrigator in the World (Praveen Rao and Ramulu, 2019). It shows that there is still scope for extending this efficient irrigation technique. Further, fertigation has become a widely accepted practice for fertilizing agricultural and horticultural crops (Praveen Rao and Anitha, 2016). This approach helps to reduce the fertilizer requirements by 30–50% without compromising crop yield (Singandhupe et al., 2003; Hongal and Nooli, 2007; Aujla et al., 2007; Rekha and Mahavishnan, 2008). Thus, still there are umpteen no. of opportunities to promote drip fertigation in different crops. In view of the limited information available, a field trial was carried out with an objective to improve the productivity and profitability of *rabi* brinjal with reduced water consumption and minimizing fertilizer application.

2. MATERIALS AND METHODS

2.1. *Study site and year of experimentation*

The experiment was conducted during *rabi* 2018–19 (September–May) and 2019–20 (October–May) at college farm, College of Agriculture, Professor Jayashankar Telangana State Agricultural University (PJTSAU), Telangana, India situated at 17°19'24.75"N latitude, 78°24'33.82"E longitude and an altitude of 549 m above the mean sea level. The soil of the experimental area was red sandy loam.

2.2. *Details of treatments and agronomic operations*

The experiment was laid out with 12 treatment combinations replicated thrice, in a split plot design with three main plot treatments and four sub-plots. The main plots comprised of $I_{0.8}$: Surface drip irrigation at 0.8 Epan; $I_{1.0}$: Surface drip irrigation at 1.0 Epan; $I_{1.2}$: Surface drip irrigation at 1.2 Epan and four fertilizer levels F_{60}: 60% recommended dose (RD) of nitrogen and potassium (N and K); F_{80}: 80% RD of N and K; F_{100}: 100% RD of N and K and F_{120}: 120% RD of N and K as subplots. N was applied through urea, P_2O_5 through mono ammonium phosphate (MAP) and K_2O through sulphate of potash (SOP). The brinjal hybrid Kanakadurga was transplanted at a spacing of 40×60 cm^2 during September in 2018 and October in 2019.

Fertigation with 100% recommended dose of Nitrogen and Potassium (RDNK) (150 and 90 kg N and K_2O ha^{-1}) was applied @ 1.71, 1.80 and 0.64 kg N ha^{-1}day^{-1} and 1.03, 1.08 and 0.39 kg K_2O ha^{-1} day^{-1} during 10 to 45 DAT (days after transplanting), 45 to 70 DAT and 70 to 140 DAT, respectively.

The dosages for other levels were calculated accordingly and applied once in three days. N and K fertigation was applied in 33 splits as per the treatment, P was applied equally to all the treatments (Table 1). 80% of the entire P_2O_5 was applied in three splits @ 24 kg P_2O_5 ha^{-1} each at 10 to 45

Table 1: N and K fertigation schedule (150:90 kg ha^{-1}) in *rabi* brinjal

Crop duration	Days	Applied N			Applied K_2O		
		%	No. of splits	kg ha^{-1} day^{-1}	%	No. of splits	kg ha^{-1} day^{-1}
10–45 DAT	35	40	8	1.71	40	8	1.03
45–70 DAT	25	30	8	1.80	30	8	1.08
70–140 DAT	70	30	17	0.64	30	17	0.39

DAT and the remaining 20% of the P_2O_5 was applied @ 9 kg each at 45 and 70 DAT.

2.3. 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 starting from February second fortnight up to the May during 2018–19 and 2019–20, respectively. The fresh fruit yield from all the pickings was summed up to report the final fresh fruit yield. The cost of cultivation (COC), gross returns (GRs), net returns (NRs) and B:C ratio were computed by the formulas furnished below.

COC (₹ ha^{-1}): Input cost+labour cost

GRs (₹ ha^{-1}): Fresh fruit yield×Market price

NRs (₹ ha^{-1}): GRs-COC

B:C ratio: GRs/COC

Further, the standard error of means (SEm±) and least significant difference at 5% probability (p=0.05) were used to compare the treatments and draw valid conclusions as per the procedure by given Panse and Sukhatme (1985).

3. RESULTS AND DISCUSSION

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

Among many yield attributing characters, only the average number of fruits per plant and average weight of fruits per plant were significantly influenced by irrigation and fertigation levels (Table 2). The average number of fruits per plant increased significantly with increase in the irrigation regime from 0.8 to 1.2 Epan with highest value recorded at 1.2 Epan (66.50). Further, the average weight of the fruits per plant was found to be maximum in the treatment where irrigation was scheduled at 1.2 Epan (4.39 kg $plant^{-1}$) and was on par with 1.0 Epan (4.32 kg $plant^{-1}$). 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 $plant^{-1}$, average fruit weight and fruit diameter with drip irrigation in brinjal.

Table 2: No. of fruits $plant^{-1}$, average weight of fruits $plant^{-1}$ and fruit yield as influenced by different irrigation regimes and fertigation levels

Treatments	No. of fruits $plant^{-1}$	Average weight of fruits $plant^{-1}$ (g)	Fruit yield (t ha^{-1})
Main treatments (Drip irrigation regimes)			
$I_{0.8}$ (0.8 Epan)	54.89	3.98	36.0
$I_{1.0}$ (1.0 Epan)	64.40	4.32	40.1
$I_{1.2}$ (1.2 Epan)	66.50	4.39	40.7
SEm±	0.27	0.03	0.17
CD (p=0.05)	1.04	0.13	0.67
Sub treatments (Fertigation levels)			
F_{60} (60% RDNK)	55.26	3.89	36.1
F_{80} (80% RDNK)	60.87	4.20	38.5
F_{100} (100% RDNK)	65.59	4.37	40.3
F_{120} (120% RDNK)	66.00	4.45	41.0
SEm±	0.27	0.07	0.30
CD (p=0.05)	0.82	0.20	0.90
Interaction	NS	NS	*S

S: Significant

These results are in agreement with the earlier findings of Jha et al. (2017), who observed increased number and weight of the tubers per plant with increasing irrigation water salinity under drip irrigation as compared to furrow irrigation.

Fertigation with 120% RDNK resulted in significantly higher number of fruits $plant^{-1}$ (66.00) and average weight of the fruits per plant (4.45 kg $plant^{-1}$) as compared to 60% and 80% RDNK (55.26 and 3.89 kg $plant^{-1}$; 60.87 and 4.20 kg $plant^{-1}$), but, it was on par with that of 100% RDNK (65.59 and 4.37 kg $plant^{-1}$) (Table 2). This could be attributed to the fact that application of nitrogen up to certain level helped in the synthesis of greater amount of carbohydrates and more efficient protein synthesis and then the same might be translocated into the developing fruits. The potassium up to certain level might have encouraged better utilization of assimilates through efficient transport to the developing fruits in brinjal. This dose 100% RDNK was presumed to be more effective in controlling these physiological parameters resulting in increased fruit characters.

Increasing the dose beyond this level did not show any significant increase in the yield attributing characters. Higher number of fruits, average fruit weight and fruit size in brinjal was reported by Seema et al. (2023) with every increment of the applied nitrogen.

The interaction between drip irrigation regimes and fertigation levels for average number of fruits plant^{-1} and average weight of fruits plant^{-1} was found to be non-significant. The other yield attributing characters like average weight of the fruit (62.5–74.1 g), average fruit length (15.0–17.7 cm) and diameter (18–25 mm) were not influenced by neither irrigation nor fertigation levels (Figure 1).

The fruit yield of brinjal showed a significant increase with an increase in the level of applied water up to 1.0 Epan, indicating that optimal water supply enhances fruit production (40.1 t ha^{-1}). However, when the water level was further increased beyond 1.0 Epan (1.2 Epan), there was no significant increase in the fruit yield (40.7 t ha^{-1}) and was statistically at par with that of 1.0 Epan, but, significantly higher than other treatments tested in the study (0.8 Epan). Scheduling drip irrigation @ 1.0 Epan resulted in 28% higher fruit yield of brinjal and saving of 22% irrigation water over 0.8 Epan treatment. Drip fertigation resulted in significantly higher yields of 37–49% in brinjal compared to both flood irrigation (Goswami et al., 2006) and furrow irrigation (Aujla et al., 2007). Similarly, Chauhan et al. (2013) reported drip irrigation at 1.0 ETc as the optimum irrigation schedule for brinjal with 30.95% higher fruit yield saving 24.62% irrigation water over conventional surface irrigation. The lower yields in the 0.8 Epan treatment may be attributed to reduced nutrient uptake by the plants under low moisture conditions, despite the application of a high amount of fertilizer. These results are in accordance with Kumar et al. (2010), who reported lowest yield of brinjal at 50% PE though the applied fertilizer was high. The drip irrigation at optimum level helps to maintain favorable moisture regimes, which increases the availability of water in the soil and the crop utilizes the water very effectively for the growth and development (Singh et al., 2023).

Significant variation was observed in the fresh fruit yield of brinjal among different fertigation treatments (Table 2). Fertigation at 100% recommended dose of N and K fertilizer (RDNK) recorded significantly higher fruit yield of brinjal (40.3 t ha^{-1}) compared to 60% and 80% RDNK (36.1 t ha^{-1} and 38.5 t ha^{-1}) and was on par with 120% RDNK (41.0 t ha^{-1}) during the two years of experimentation and on pooled basis also (Figure 2). The increase in the fruit yield was mainly due to increase in the number of fruits plant^{-1}, average fruit weight, and fruit size.

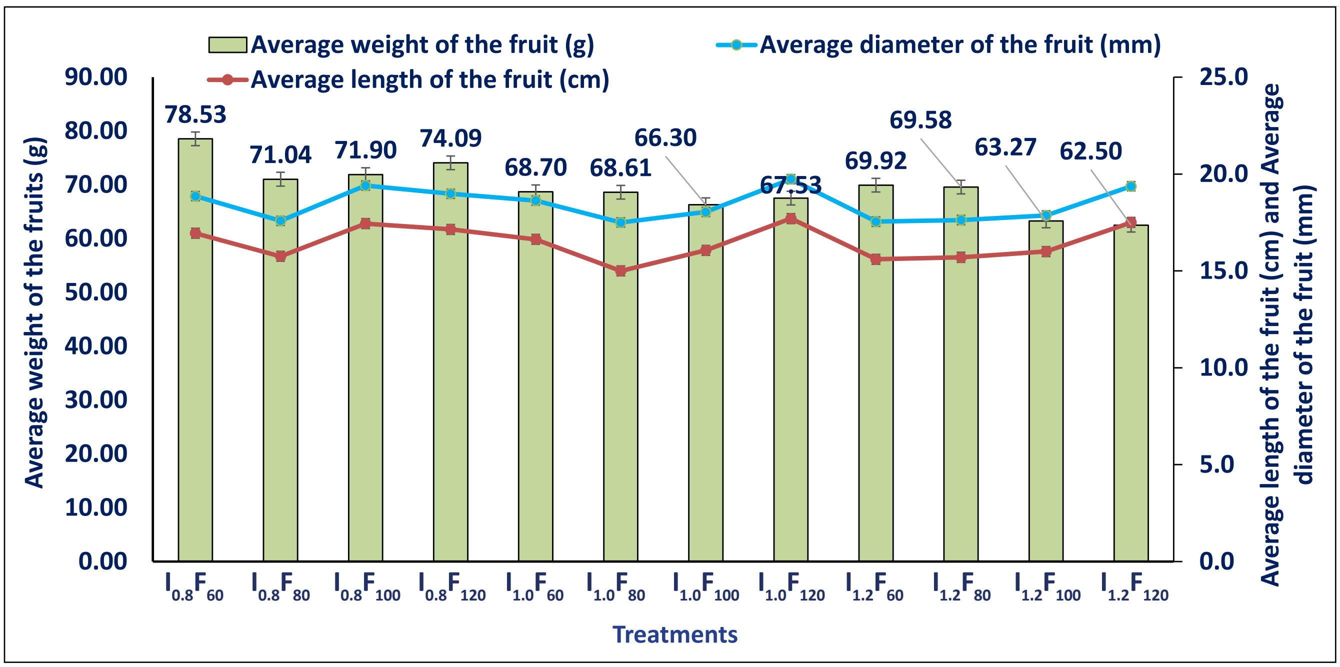

Figure 1: Yield attributes of *rabi* brinjal as influenced by irrigation regimes and fertigation levels

The increased yields in higher fertigation treatments can be attributed to the frequent and precise application of nutrients through the drip system, leading to improved nutrient uptake by the plants. The elevated levels of N and K provided in the higher fertigation treatments might have facilitated the translocation of sufficient food materials for fruit development and increased fruit yield. These results coincide with that obtained by Aujla et al. (2007) who found that fruit yield of eggplant had a positive response to the increase of nitrogen fertilizer under different irrigation levels. Besides, regular availability of nutrients to the plants at three-day interval, might have prevented the leaching of applied fertilizers and ensured that the plants received

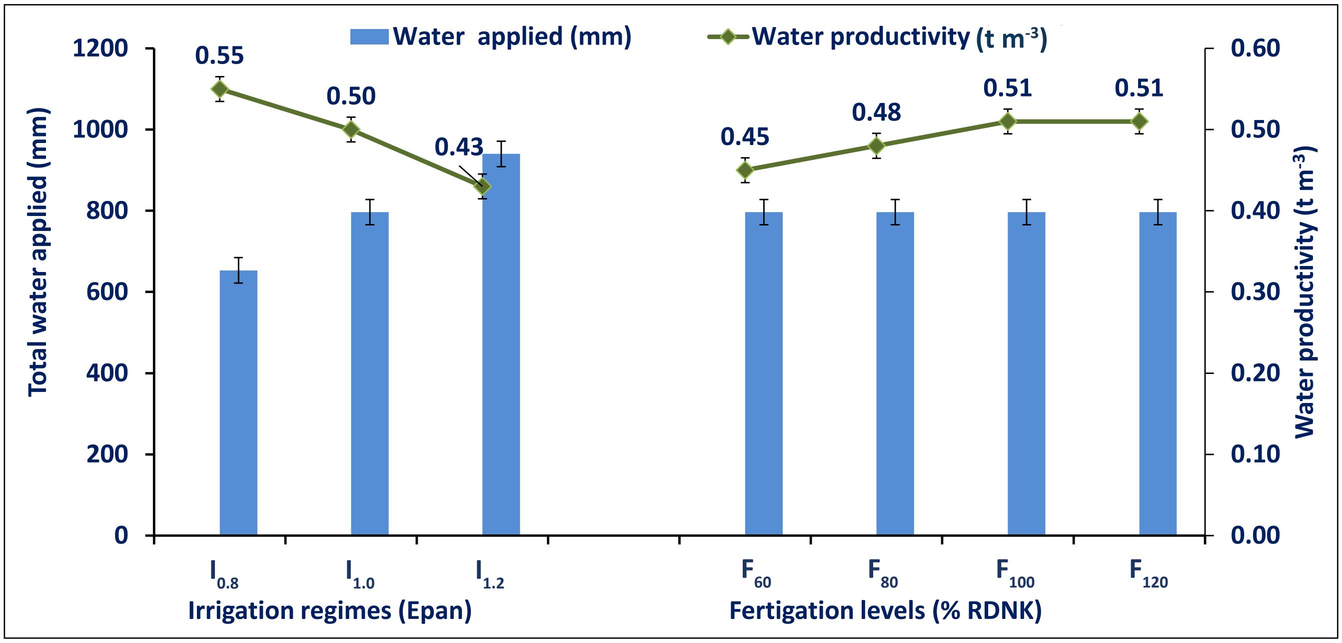

Figure 2: Water applied and water productivity as influenced by drip irrigation and fertigation levels on *rabi* brinjal

a required amount of nutrients (Chauhan et al., 2013). Fertigation helps with better root development of the crop, which leads to the absorption of more water and nutrients from the soil as compared to other methods (Singh et al., 2023).

The findings of this study are align with the research conducted by Rajalingam et al. (2022), who reported that fertigation with a combination of 150:100:150 kg $NP_2O_5K_2O$ ha^{-1} resulted in the highest yield of 37.11 t ha^{-1}. Similarly, in another study by Patidar et al. (2022) it was observed that drip fertigation at 150% recommended dose of fertilizer (RDF) recorded the significantly highest yield of 55.71 t ha^{-1}, which was on par with drip fertigation at 125% RDF (55.49 t ha^{-1}). Kumari and Kaushal (2014) reported that drip fertigation increased the yield and water use efficiency besides saving 25% fertilizer and 40% water.

3.2. Interaction effect of drip fertigation and irrigation levels on fruit yield

The interaction between fertigation and irrigation levels was found to be significant. The highest fresh fruit yield (41.6 t ha^{-1}) was recorded in the treatment where fertigation with 100% RDNK (150, 90 kg N and K_2O ha^{-1}) in combination with drip irrigation at 1.0 Epan than other combinations barring 1.0 Epan irrigation level scheduled along with fertigation at 120% RDNK (41.9 t ha^{-1}) (Table 3). Seema et al. (2023) reported that saline water and RDN applied through drip improved the eggplant yield by 22%.

Further, this treatment also showed comparable results to that of 1.2 Epan+100% RDNK (41.8 t ha^{-1}) or 120% RDNK (41.7 t ha^{-1}). As the fertigation level increased, so did the production of fruits plant^{-1} where drip fertigation at 150% RDF produced significantly more fruit plant^{-1} and fruit weight than other treatments according to Kumar et al. (2010). The fertigation schedule may be optimized according to the crop growth stages in future studies as it may lead to lower application of fertilizers resulting in more profit for the farmers (Singh et al., 2023).

3.3. Effect of drip fertigation and irrigation levels on water applied and water productivity

Water use increased with increase in the level of irrigation schedule (Figure 2). However, water productivity (WP) followed reverse trend. Highest water productivity of 0.55 t m^{-3} was recorded under 0.8 Epan, followed by 0.50 t m^{-3} under 1.0 Epan treatment and the lowest (0.43 t m^{-3}) was recorded in 1.2 Epan treatment. Higher water productivity of 0.51 t m^{-3} was recorded with either application of 100% or 120% RDNK than at lower fertigation levels. This might be due to more availability of moisture and nutrients throughout the growth stages in trickle system contributing to better uptake of nutrients and yield of brinjal. Chauhan et al. (2013) reported drip irrigation at 1.0 Epan was found to be the optimum for brinjal with 30.9% higher fruit yield and saved 29.6% irrigation water over conventional surface irrigation. Similar results were reported by Seema et al. (2022); Ji et al. (2022). Betageri and Kottiswaran (2019) reported higher yields of 83.3 t ha^{-1} under 80% ET_0 level and 100% RDF in addition saving 16.17% of water with mulch compared to without mulch condition in sandy clay loam soils of Coimbatore. In another study, drip fertigation at 150% RDF had the highest water usage efficiency followed by 125% RDF which could be due to higher

Table 3: Fruit yield (t ha^{-1}) as influenced by drip irrigation and fertigation levels on *rabi* brinjal

Irrigation levels vs Fertigation levels	F_{60} (60% RDNK)	F_{80} (80% RDNK)	F_{100} (100% RDNK)	F_{120} (120% RDNK)
$I_{0.8}$ (0.8 Epan)	32.5	34.7	37.5	39.3
$I_{1.0}$ (1.0 Epan)	37.5	39.5	41.6	41.9
$I_{1.2}$ (1.2 Epan)	38.3	41.2	41.8	41.7
		SEm±	CD (p= 0.05)	
Main treatments		0.17	0.67	
Sub treatments		0.30	0.90	
Interaction of subplot at same level of main treatments		0.52	1.55	
Interaction of main plot at same level of sub treatments		0.48	1.50	

yields in that treatment (Kumar et al., 2010). Saroch et al. (2016) concluded that for saving irrigation water (47.96%) and increasing WUE (88.34%), surface irrigation and fertilization with 100% of recommended NPK of brinjal crop should be replaced with drip irrigation and fertigation with 75% of recommended NPK. According to Kumar et al. (2010) highest water use efficiency of 111.5 kg ha^{-1} mm^{-1} and N, K use efficiency was recorded in drip irrigation at 75% of PE with fertigation of 75% of recommended N and K.

3.4. Effect of drip fertigation and irrigation levels on economics of rabi brinjal

The net returns and B:C ratio are the most important parameters to determine the cost-effectiveness of any recommendation. Significantly higher net returns were reported for drip irrigation at 1.2 Epan in combination with fertigation of 80% RDNK (₹ 1,90,565) which was on par with application of 100% RDNK either with drip irrigation scheduled at 1.0 or 1.2 Epan (₹ 1,88,017 and ₹1,89,525) (Table 4).

Least cost of cultivation was reported in $I_{0.8}F_{60}$, $I_{1.0}F_{60}$ and $I_{1.2}F_{60}$ (₹ 1,32,800 ha^{-1}) while $I_{0.8}F_{120}$, $I_{1.0}F_{120}$ treatments required highest cost of cultivation compared to other treatments (₹ 1,50,800 ha^{-1}). Sandal and Kapoor (2015) observed that fertigation leads to saving of fertilizer by 25–40%, increased returns and reduced leaching of the nutrients. The highest B:C cost ratio was recorded with $I_{1.2}F_{80}$treatment (2.37) and is comparable to $I_{1.2}F_{60}$, $I_{1.2}F_{80}$ and $I_{1.2}F_{120}$ treatments (2.30, 2.31 and 2.31). The higher B:C ratio was due to higher yields with a lower cost of cultivation in comparison to other irrigation regimes and fertigation levels because the B:C ratio not only depends upon the total yield of crop, but it also depends upon the cost of inputs used during the growing period of that crop. Surface drip irrigation at 1.2 Epan and fertigation with 80% RDNK recorded significantly higher B:C ratio (2.37) over 0.8 Epan and fertigation with 60% RDNK (1.96) which recorded the least value. These results are in conformity with Singh et al. (2023) who reported higher benefit cost ratio of 3.75 in the treatment which received 100% RDF through fertigation in tomato grown under greenhouse conditions.

Table 4: Effect of drip irrigation and fertigation levels on the economics of *rabi* brinjal

Treatments	Gross returns (₹ ha^{-1})	Cost of cultivation (₹ ha^{-1})	Net returns (₹ ha^{-1})	B:C ratio
$I_{0.8}F_{60}$	259643	132800	126843	1.96
$I_{0.8}F_{80}$	277937	138800	139137	2.00
$I_{0.8}F_{100}$	299663	144800	154863	2.07
$I_{0.8}F_{120}$	314563	150800	163763	2.09
$I_{1.0}F_{60}$	300040	132800	167240	2.26
$I_{1.0}F_{80}$	316123	138800	177323	2.28
$I_{1.0}F_{100}$	332817	144800	188017	2.30
$I_{1.0}F_{120}$	335198	150800	184398	2.22
$I_{1.2}F_{60}$	306071	132800	173271	2.31
$I_{1.2}F_{80}$	329365	138800	190565	2.37
$I_{1.2}F_{100}$	334325	144800	189525	2.31
$I_{1.2}F_{120}$	333651	150800	182851	2.21
SEm±	3871	-	3871	0.03
CD (p=0.05)	11967	-	11967	0.08

Sale price of Brinjal: ₹ 8000 t^{-1}; 1US$=₹ 69.7688 and 75.711 for the year 2018–19 and 2019–20, respectively

4. CONCLUSION

The study clearly demonstrated that the fertigation with 100% recommended dose of nitrogen and potassium (150, 90 kg N and K_2O ha^{-1}) along with surface drip irrigation at 1.0 Epan was found highly suitable for water scare situations. This treatment resulted in significant increase in fresh fruit yield by 28% (41.6 t ha^{-1}), while conserving water by 22% compared to other treatments besides higher water productivity (0.50 t m^{-3}) and B:C ratio (2.31). Further, in water rich areas, drip irrigation scheduling at 1.2 Epan coupled with fertigation @ 80% of the recommended dose of nitrogen and potassium (120, 72 kg N and K_2O ha^{-1}) was proved profitable with higher B:C ratio (2.37).

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