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WATER PRODUCTIVITY AND ECONOMIC RETURN OF BOTTLE GOURD AT DIFFERENT IRRIGATION AND FERTIGATION DOSES

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Abstract

Bottle gourd needs frequent watering with fertilization to get a potential yield. The experiment was conducted in the Irrigation and Water Management Division, Bangladesh Agricultural Research Institute (BARI), Gazipur, during the *Rabi* season (2017–2020) to determine fruit yield, water productivity, and net return. There were five irrigation treatments such as ring basin irrigation at 7 days interval (T_1) with recommended fertilizer, drip-fertigation at an alternate day with 0, 20, 35, and 50% (T_2-T_5) less nitrogen (N) potassium (K) than the recommended doses. T_4 gave the significantly highest fruit yield (39.30 t ha^{-1}). Drip-fertigation system saved 50% of seasonal water than the ring basin method. Treatment T_4 gave the highest water productivity (17 kg m^{-3}) and benefit-cost ratio (BCR) (3.16). Therefore, it can be concluded that bottle gourd can be irrigated every alternate day through a drip-fertigation system using 35% less NK than the recommended doses to get a higher yield, water productivity, and net return.

Keywords: Drip fertigation, Yield, Water productivity, Net return, BCR.

Introduction

Global vegetable production has increased from 646 million tons in 2000 to 1.13 billion tons in 2019 (FAO, 2021). Among them, Bangladesh ranked third (16 million tons/annum), while China and India ranked first and second (Islam, 2021).

One of the prospective vegetable crops is bottle gourd (*Lagenaria siceraria* L.), which belongs to the Cucurbitaceae family. It is a very popular vegetable in Bangladesh and is widely cultivated throughout the country mostly during the winter season. Its production is highly profitable and yield per hectare of land is highly dependent on the proper use of fertilizer and pesticides (Akter 2014; Hasan *et al.*, 2014; 2017). Its production has increased from 1.5% (2013-14) to 1.7% (2020-21) of yearly total vegetable production (BBS, 2021).

Crop cultivar, soil, and local climate are important characteristics that regulate the fruit yield and water requirement of the crop. For high-yielding varieties, it is suggested to irrigate at 5 to 6-day intervals depending on soil, location, and temperature to produce a better fruit yield in terms of quality and quantity (Bosh *et al.*, 1980). Another study in Hathazari, Chattogram, Bangladesh on BARI Lau-4

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gave higher fruit yield, water productivity, and economic return by irrigating 3-day intervals using the ring basin irrigation method (Haque and Faisal, 2021). Another study in Rampur, Chitwan, Nepal on bottle gourd with different varieties gave the significantly highest number of nodes plant^{-1} using daily irrigation with 75% of Pan Evaporation. This highest number of nodes plant^{-1} creates the possibility of higher brunch and consequently, higher bearing of fruit (Adhikari *et al.*, 2008).

Along with irrigation and proper use of fertilizer is also necessary for maintaining plant growth and fruit yield (Ananda Murthy *et al.*, 2020; Kumar *et al.*, 2022; Meena and Bhati, 2017; Tan *et al.*, 2009). A field study in Akola, India gave the significantly highest yield of bottle gourd (27 t ha^{-1}) using drip fertigation with 200:100:100 kg NPK ha^{-1} at 7-day intervals (Kumar *et al.*, 2022). However, a study on the effect of irrigation and fertilizer on bottle gourd in Bangladesh is not found.

Drip fertigation is a modern technique and is widely used in many developed countries for horticultural crops. The concept of drip fertigation is to create a continuous method strip along the lines of the plants. It increases the irrigation water and fertilizer use efficiency to a considerable extent and is recommended for high-value horticultural crops. This technology saves both water and fertilizer and gives a higher fruit yield than any other method (Bar-Yosef, 2020; Bresler, 1977; Dasberg and Or, 1999). Several studies have been reported on drip-fertigation method is a more water-saving irrigation method for increasing fruit yield, water productivity, and irrigation water productivity of bottle gourd. (El-Seifi *et al.*, 2015; Mubarak and Janat, 2021; Suresh and Kumar, 2007; Tan *et al.*, 2009). However, information regarding drip-fertigation of bottle gourd in the context of Loamy soil in Bangladesh (AEZ 28) is not known. Hence, the present study was undertaken to determine the performance of bottle gourd under drip-fertigation systems at different irrigation intervals and fertigation doses. Therefore, the objective was to determine fruit yield, water productivity (or water use efficiency), and net return of bottle gourd for the drip-fertigation system.

Materials and Methods

The experiment was conducted on bottle gourd (var. BARI Lau-3) during three consecutive *Rabi* seasons from 2017 to 2020 in the experimental field of Irrigation and Water Management Division, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur. In 2018–19, the plants were damaged after two harvests due to heavy rainfall and wind speed. The soil was silty clay loam with an average bulk density of 1.50 g cc^{-1} and a field capacity of 28 % (by dry weight basis). Cumulative evaporation and rainfall during the study period were 414.60 mm and 179.00 mm (2017–18 in Figure 1a), and 627.50 mm and 123.00 mm (2019–20 in Figure 1c). The mean evaporation during the day was 2.76 mm and 3.69 mm (Figures 1a and c). The temperature during the day and night varied from 17.20–35.60°C and 5.50–30.00°C (2017–18 in Figure 1b), and 15.30–37.00°C and 9.00–24.60°C (2019–20 in Figure 1d), respectively.

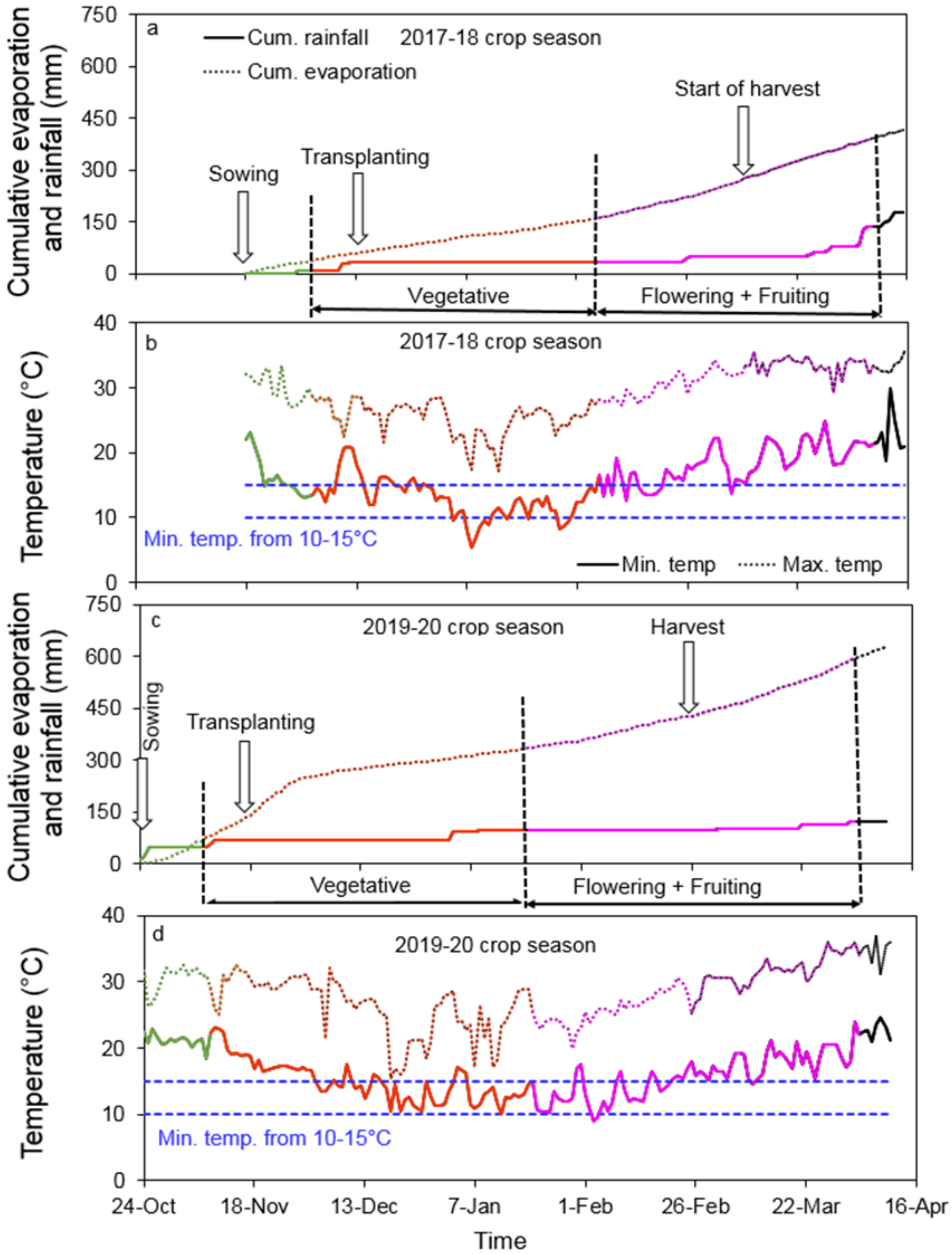

Fig. 1. Weather parameters of cumulative evaporation and rainfall (a, c), and minimum and maximum temperature (b, d) during the 2017–18 and 2019–20 crop seasons. The downward arrows in a and c present the time of sowing, transplanting, and the start of fruit harvest. The vegetative stage is highlighted in red, while the flowering and fruiting stages are highlighted in purple colour.

The experiment was laid out in a randomized complete block design with five treatments and three replications. The treatments were: T_1 = Ring basin irrigation at 7-day intervals with recommended fertilizer doses (RFD) (control) , T_2 = Drip-fertigation at an alternate day with 0% less NK than RFD (or 150:150 kg NK ha^{-1}), T_3 = Drip-fertigation at an alternate day with 20% less NK than RFD (or 120:120 kg NK ha^{-1}), T_4 = Drip-fertigation at an alternate day with 35% less NK than RFD (or 98:98 kg NK ha^{-1}) and T_5 = Drip-fertigation at an alternate day with 50% less NK than RFD (or 75:75 kg NK ha^{-1}).

The seeds of the bottle gourd were sown on 18 November 2017 and 24 October 2019 to produce seedlings. The seedlings were transplanted in the experimental plots on 13 December 2017 and 16 November 2019. The unit plot size was 4 m × 4 m with a 1.5 m buffer. The N and K in the form of urea and muriate of potash (MP) were applied with irrigation water as per the design of the treatments. The total phosphorus (P) in the form of triple super phosphate (TSP), gypsum, borax, zinc (Zn), and magnesium was applied as a basal dose in the pit. Cow dung was applied at the rate of 10 kg pit^{-1}. A total fertilizer of 150, 175, 150, 100, 12, 10, and 40 kg ha^{-1} urea, TSP, MP, gypsum, zinc, boric acid, and magnesium sulphate was used (BARI Agricultural Technology Handbook, 2020). However, irrigation was applied based on the treatments. The intercultural operations, insecticides and pesticides were applied as and when necessary. Fruits were harvested from 11 March to 16 April 2018 in 2017–18 crop season and from 25 February to 10 April 2020 in 2019–20 crop season.

In this experiment, irrigation was applied using two irrigation methods (ring basin method as a control and drip-fertigation method as an efficient and smart irrigation method). For the ring basin method, the amount of irrigation water was calculated based on soil moisture deficit up to field capacity and applied using a hose pipe based on time to reach the volume. Soil moisture was determined before each irrigation by gravimetric method. The same formula was used for irrigating other winter crops in the same study area (Mila *et al.*, 2015; 2017). For the drip-fertigation system, irrigation was applied every alternate day meeting the demand for crop evapotranspiration. The average dripper discharge was 3.8 litres hr^{-1}. Common irrigation of a total of 12 mm and 5 mm was applied from sowing to plant establishment for the 2017–18 and 2019–20 crop seasons. The irrigation treatments were started 7 days after transplanting. Drip irrigation time was varied from 25 minutes (initial stage) to 60 minutes (flowering + fruiting stages), depending on crop evapotranspiration (ET). The initial stage included the vegetative stage spanned from 3 Dec (or 15 days after transplanting) –5 Feb (or 79 DAT) in 2017–18 and 8 Nov (or 15 DAT)–19 Jan (or 87 DAT) in 2019–20 and flowering and fruiting stages after the end of vegetative to 7 days before the last harvest is shown in Figures 1a and c.

Drip-fertigation system

Four tanks were installed for four fertigation treatments (T_2–T_5) and placed at a height of 1 m from the ground surface supported by either a bamboo structure or iron frame on one side of the treatments. The tank had a capacity of 215 litres. A water tap was attached to one side of the bottom part of each tank to which the fertigation system was connected. The drippers were set according to the plant spacing in the treatments. Each plant received an emitter through which, water was applied to the plant in drips.

Water productivity and irrigation water productivity

Water productivity (WP) and irrigation water productivity (IWP) were calculated using the following formula:

WP (kg/m^3) = Fruit yield (t ha^{-1}) × 100/seasonal water use (mm) (1)

IWP (kg/m^3) = Fruit yield (t ha^{-1}) × 100/Irrigation water use (mm) (2)

Where, seasonal water use is the water used by irrigation, effective rainfall, and soil water change (Mila, 2021).

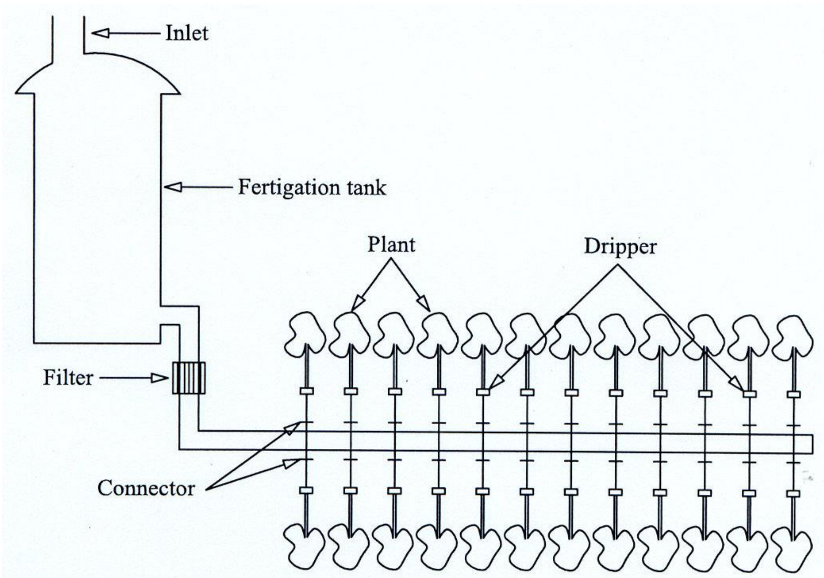

Fig. 2. Schematic diagram of the drip-fertigation system.

After harvest, the data on yield attributes of fruit length, fruit diameter, number of fruits $plant^{-1}$, unit fruit weight, and weight of fruit $plot^{-1}$ were recorded. Finally, fruit yield (t ha^{-1}) was calculated from the weight of the fruit $plot^{-1}$.

Economic analysis was done for the five irrigation treatments using a drip-fertigation and ring basin irrigation systems (with a 7-day interval). Among the drip-fertigation treatments, the fixed cost was the same but the variable cost varied due to the variation in the amount of fertilizer (especially NK), irrigation, and labour. The items included in calculating the fixed cost for the drip-fertigation system were the fertigation tank, GI fittings with a supporting platform, PVC pipe, and micro tube (Table 3a). The expected life for the drip-fertigation system was considered to be 4 years. The fixed cost per year was calculated by dividing the total fixed cost for the installation of the system by the expected life of the system. However, no installation cost was required for the ring basin irrigation method. The variable cost for both methods included the cost of seedlings, pit making, fertilizer, trial, irrigation, and labour (Table 3b). The current market price was used for calculating the variable costs. The total cost year^{-1} was calculated by the summation of the total fixed cost and the total variable cost year^{-1} (Table 3c). Net return was calculated by subtracting total cost from gross return year^{-1} (Table 3c). Finally, the benefit-cost ratio year^{-1} was calculated by the ratio of gross return and net return year^{-1} (Table 3c). Data on fruit yield and yield attributes were analysed by using R software (R Core Team, 2013). The correlation and regression analysis between fruit yield and yield attributes or water productivity or irrigation water productivity was done using Jamovi and Excel software.

Results and Discussion

Effect of ring basin and drip-fertigation irrigation method on fruit yield and yield attributes

The effect of drip-fertigation on fruit yield and yield attributes of bottle gourd for 2017–18 and 2019–20 are shown in Table 1. In both the years, fruits plot^{-1}, fruits plant^{-1}, the weight of fruit plot^{-1}, and yield were significant, while in the 2nd-year unit weight and diameter of fruit were significant. The maximum t yields of 37.2 and 41.4 t ha^{-1} were obtained from treatment T_4 followed by treatment T_5 (33.0 and 36.4 t ha^{-1}) By contrast, the significantly lowest yields of 25.0 and 24.3 t ha^{-1} were found by applying irrigation in the ring basin method at 7-day intervals with recommended fertilizer doses (control in Table 1). However, the highest yield treatment was 21–29% lower than that of the potential yield of this variety.

A study on bottle gourd produced a yield of 27 t ha^{-1} using 200:100:100 kg NPK ha^{-1} at 7-day intervals through drip fertigation (Kumar *et al.*, 2022). Another study on bottle gourd gave a higher yield of 36.2 t ha^{-1} using irrigation at 4-6 days intervals with 110:70 kg NP ha^{-1} (Meena and Bhati, 2017). However, this study obtained the highest yield in irrigating on every alternate day with 35% less NK than recommended (98:98 kg NK ha^{-1}). The reason might be frequent watering based on crop evapotranspiration with 35% less NK can make a better solution for plant water uptake and consequently higher yield. On the other hand, the use of NK with 20 or 50% less amount might create a solution of lower or higher density that makes plants a situation of fertilizer deficient condition in a way of uptaking less fertilizer (for low density) or no fertilizer (for high density). Therefore, in the future, it would be important to determine the scientific reason behind this yield increase with the use of 35% less amount of NK fertilizer.

Table 1. Fruit yield and yield attributes of bottle gourd used in ring basin and drip fertigation methods at different frequencies during 2017–18 and 2019–20.

Treatment	Fruit length (cm)	Diameter of fruit (cm)	Fruits plot^{-1} (no.)	Fruits plant^{-1} (no.)	Unit weight of fruit (kg)	Weight of fruits plot^{-1} (kg)	Fruit yield (t ha^{-1})
2017-18 crop season							
T_1	32.79	9.86	23.00	5.75	1.74	39.95	24.97
T_2	32.55	10.26	30.67	7.67	1.57	47.97	29.83
T_3	32.16	9.74	26.67	6.67	1.79	47.86	29.91
T_4	32.73	10.87	33.33	8.33	1.76	59.52	37.20
T_5	33.52	10.17	30.00	7.5	1.76	52.84	33.02
CV (%)	2.43	8.12	8.72	8.72	5.66	10.33	10.30
LSD$_{(0.05)}$	NS	NS	4.72	1.18	NS	9.65	6.00
2019-20 crop season							
T_1	32.77	9.86	25.66	6.41	1.74	38.80	24.25
T_2	32.34	10.32	31.66	7.91	1.58	52.74	32.96
T_3	32.40	9.75	29.33	7.33	1.70	52.91	33.07
T_4	33.00	10.52	37	9.25	1.87	66.22	41.39
T_5	33.34	10.25	33.4	8.33	1.74	58.30	36.44
CV (%)	2.95	3.15	10.78	10.7	4.63	5.50	5.54
LSD $_{(0.05)}$	NS	0.26	2.76	0.68	0.06	5.10	1.52

Here, T_1 = Ring basin irrigation at 7 days interval with recommended fertilizer doses (RFD) (control); T_2, T_3, T_4, and T_5 = Drip-fertigation at an alternate day with 0%, 20%, 35% and 50% less NK than RFD.

Effect of ring basin and drip-fertigation irrigation method on water use, water productivity, and irrigation water productivity

Irrigation, water use, and water productivity of bottle gourd for ring basin and drip-fertigation irrigation method are shown in Table 2. Overall, the ring basin method used 482 mm and 448 mm of water over the season in 2017–18 and 2019–20, respectively. While, the drip-fertigation method used only 255 mm and 226 mm of water, respectively during same season. The drip-fertigation system saved 47 and 50% of seasonal water than that of the ring basin method. Previous studies on bottle gourd using drip irrigation at various frequencies and amounts or compared with other irrigation methods (Mubarak and Janat, 2021; Tan *et al.,* 2009). Another study in Nepal found that daily, 2-day, and 4-day irrigation intervals using drip fertigation with 75% and 50% of ET saved an average of 30% and 57% of water than that of 100% of ET (Tan *et al.*, 2009).

The effective rainfall during the growing season was 160 mm and 117 mm during 2017–18 and 2019–20, respectively. The maximum water productivity (WP) of 15 and 18 kg m^{-3} (or a mean of 17 kg m^{-3}) was recorded for treatment T_4 followed by T_5 and the lowest was estimated for treatment T_1. A similar result was found for irrigation water productivity (IWP). Compared with the ring basin method, treatment T_4 gave 3 and 5 times WP and IWP. A study on bottle gourd using 75 to 50% crop ET) gave an average of 1 to 2 times more IWP than that of 100% ET (Tan *et al.*, 2009).

Table 2. Water use and water productivity of bottle gourd in ring basin and drip-fertigation methods at different frequencies during 2017–18 and 2019–20.

Treatments	Irrigation applied (no.)	Water for plant establishment (mm)	Irrigation applied (mm)	Effective rainfall (mm)	Water use (mm)	Water productivity (kg m^{-3})	Irrigation water productivity (kg m^{-3})
2017–18 crop season							
T_1	12	12	310	160	482	5	8
T_2	22	12	83	160	255	12	36
T_3	22	12	83	160	255	12	36
T_4	22	12	83	160	255	15	45
T_5	22	12	83	160	255	13	40
2019–20 crop season							
T_1	11	5	326	117	448	5	7
T_2	28	5	104	117	226	15	32
T_3	28	5	104	117	226	15	32
T_4	28	5	104	117	226	18	40
T_5	28	5	104	117	226	16	35

Dripper discharge was 3.75 litres hr^{-1} for both years.

Here, T_1 = Ring basin irrigation at 7 days interval with recommended fertilizer doses (RFD) (control); T_2, T_3, T_4, and T_5 = Drip-fertigation at an alternate day with 0%, 20%, 35% and 50% less NK than RFD.

Economic analysis between furrow and drip-fertigation method

Economic analysis for the drip-fertigation system over the traditional system for bottle gourd cultivation was done based on the mean of two years of data (2017-18 and 2019-20) in Table 3. The economic analysis reveals that the maximum benefit-cost ratio (BCR) 3.16 was obtained from treatment T_4 by applying 35% less NK than recommended doses through the drip-fertigation system followed by treatment T_5 (BCR 2.82) by applying 50% less NK than recommended doses through the drip-fertigation system. The lowest BCR of 1.92 was found by applying irrigation in a ring basin method at 7-day intervals with recommended fertilizer doses (control). The higher BCR in the drip fertigation method over ring basin methods was due to comparatively higher yield using less amount of irrigation and fertilizer which compensated with the higher cost incurred due to the installation cost, fertilizer, irrigation, and labour cost. Similarly, a higher return of

Taka 403137/ha was found in the drip-fertigation (T_4) system.. The findings agreed with the advantages of using the drip-fertigation method for growing high-value horticultural crops (Akanda *et al.,* 2004; Bar-Yosef, 2020; Biswas *et al.*, 2016; Bresler, 1977; Dasberg and Or, 1999). This is economic in terms of getting higher fruit yield, quality fruit, water savings, and judicious use of fertilizers but the initial installation cost was higher. However, this drip irrigation system can be used for more than one season if stored properly for the next season. Therefore, in the future, it needs further research on the improvement of this drip irrigation system for more functional and sustainable with minimum cost.

Table 3. Economic analysis for drip-fertigation over traditional system for bottle gourd cultivation .

(a). Fixed cost for two irrigation methods

Name of the items	Quantity	Rate (Tk.)	Cost (Tk./ha)	
			Ring basin	Drip-fertigation
Fertigation tank	40 nos.	1000	-	40000
GI fittings and supporting platform	-	-	-	10000
PVC pipe (0.0125 m diameter)	3000 m	4	-	12000
Micro-tube (0.32 m diameter)	7500 m	2.50	-	18750
Total fixed cost, Tk.				80750
Expected life of the system	4 years			
Total fixed cost year^{-1}				20188

b). Variable cost

Name of the items	Cost (Tk./ha)				
	T_1	T_2	T_3	T_4	T_5
Seedlings	1600	1600	1600	1600	1600
Pit making	2500	2500	2500	2500	2500
Fertilizer	19150	19150	16135	16000	14650
Trail	125000	125000	125000	125000	125000
Irrigation	20000	5000	5000	5000	5000
Labour	24000	16000	16000	16000	16000
Total variable cost (Tk.)	192250	192250	192250	166100	164750

(c). Net Return and benefit-cost ratio

Name of the items	Net return (Tk/ha.)				
	T_1	T_2	T_3	T_4	T_5
Average fruit yield ha^{-1} (ton)	24.61	31.40	31.49	39.30	34.73
Selling rate (Tk. ton^{-1})	15000	15000	15000	15000	15000
Gross return (Tk.)	369150	470925	472350	589425	520950
Total cost year^{-1} (Tk.)	192250	189438	187638	186288	184938
Net return year^{-1} (Tk. ha^{-1})	176900	281487	284712	403137	336012
Benefit-cost ratio		2.49	2.52	3.16	2.82

Here, T_1 = Ring basin irrigation at 7 days interval with recommended fertilizer doses (RFD) (control); T_2, T_3, T_4, and T_5 = Drip-fertigation at an alternate day with 0%, 20%, 35% and 50% less NK than RFD.

Conclusion

The highest fruit yield of bottle gourd 39.30 t ha^{-1} was obtained from treatment T_4 by applying 35% less NK than recommended doses through a drip-fertigation system followed by T_5 (34.73 t ha^{-1}) by applying 50% less NK than recommended doses through the same system. The ring basin and drip irrigation method required 241 mm and 465 mm of seasonal water. The drip fertigation system also saved 50% of seasonal water than that of the ring basin method. Treatment T_4 also gave 3, 6, and 2.5 times higher water productivity, irrigation water productivity, and net return than that of the ring basin method. Therefore, it can be concluded that the drip-fertigation system was more profitable than the ring basin irrigation system in cultivating bottle gourd.

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