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Response of Broccoli (*Brassica oleracia* L.) to Different Irrigation Regimes

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Abstract

The study was conducted at the experimental field of Horticulture Research Centre, BARI, Gazipur during Rabi seasons in three years (2012 to 2015) to investigate the response of broccoli (cv. Premium crop) under different irrigation regimes. The experiment was conducted in RCBD with five replications. There were four treatments: I_1=Irrigation up to FC at 5 days interval after plant establishment (PE), I_2= Irrigation up to FC at 10 days interval after PE, I_3 = Irrigation up to FC at 15 days interval after PE and I_4= Irrigation up to FC at 20 days interval after PE. A significant response of broccoli to different irrigation levels was observed. Among the different treatments, I_2 (irrigation at 10 days interval) was significantly better yielding (19.98 t/ha, 20.63 t/ha and 16.24 t/ha in 1st, 2nd and 3rd year, respectively). The lowest yields were observed from the treatment I_4 each in all 3 years. The highest seasonal water (382.30 mm, 296.58 mm and 305.00 mm in 1st, 2nd and 3rd year) were used in treatment I_1 and the lowest (204.60 mm, 185.66 mm and 179.77mm in the 1st, 2nd and 3rd year) were used in treatment $I_{4,}$ I_3 and I_3, respectively. The results suggest that irrigation at 10 days interval (I_2) might be optimum irrigation schedule for broccoli production on the basis of gross return. But in respect of economic profitability, the highest marginal rate of return is obtained from treatment I_3.

Keywords: Broccoli, irrigation regime, water productivity, economic profitability

1. Introduction

Broccoli (*Brassica oleracia* L.) belonging to the family of Cruciferae is a delicious and one of the most vitamin rich winter vegetables. It is a member of cole crops, which is recently cultivated in Bangladesh and closely related to cauliflower and cabbage. It is fairly rich in carotene and ascorbic acid and contains appreciable quantities of thiamin, riboflavin, niacin and iron (Thompson and Kelly, 1985). There is a good scope for its large scale cultivation in Bangladesh for increasing vegetable diversification and to meet vegetable demand of the country's people. However, the yield of broccoli in Bangladesh is low compared to that of other countries.

The crop is grown in Bangladesh during winter when there is low precipitation and high evapotranspiration. Crop cultivation during this dry period usually requires irrigation. Broccoli being a shallow rooted crop requires frequent irrigation to keep the plant vigorous. Studies of various workers indicated that frequent irrigation gave the higher yields of curd (Islam *et al*., 1996; Gomes *et al*., 2000). Non-judicious irrigation not only reduces the efficiency of fertilizer and water use but also reduces the yield of Cole crop (Rahman *et al.*, 1988).

Water deficits in any growth stage will decrease optimum growth and head quality of broccoli. The amount of water within the plant is small compared with the amount of water transpirated, and as a consequence, water uptake from the soil via the roots is very high. The extraction of water by roots and evaporation losses progressively reduce the moisture content of the soil to less than field capacity. If not replenished, soil water levels may ultimately reach the wilting point for plant growth. Broccoli growers are likely to over-apply water to achieve a desired yield, which results water loss from the system (Pasakdee *et al*., 2006). Improper irrigation management not only wastes available water resources, but also causes nutrient losses by leaching, runoff, and denitrification of N in both organic and conventional farming. Irrigation scheduling is a critical management input to ensure optimum soil moisture status for proper plant growth and development as well as for optimum yield, water use efficiency and economic benefits (Himanshu, *et al*., 2013).

To quantify the exact amount of water required by a plant, it is necessary to consider two major parameters (Hanson *et al*., 1999): the amount of water required by the crop and also the rates of precipitation and evapotranspiration need to be considered to improve the accuracy of the estimation of the amount of water applied during the growing season. The optimum use of irrigation can be characterized as the rooting area, and at the same time, avoiding the leaching of nutrients into deeper soil layers (Kruger *et al*., 1999). Therefore, predicting the water content in the root zone can be a means of helping the farmer decide when, and how much to irrigate. The aim of irrigation management is to control soil water for optimal crop yield and quality while conserving water. Therefore, the study was undertaken to investigate the response of broccoli to different irrigation regimes and to predict an effective irrigation schedule for broccoli production.

2. Materials and Methods

The study was conducted at the experimental field of Horticulture Research Centre, BARI, and Gazipur during Rabi season of 2012-13, 2013-14 and 2014-15. The experiment was laid out in randomized complete block design (RCBD) with five replications. Four treatments were considered as: I_1=Irrigation up to FC at 5 days interval after plant establishment (PE), I_2= Irrigation up to FC at 10 days interval after PE, I_3 = Irrigation up to FC at 15 days interval after PE andI_4= Irrigation up to FC at 20 days interval after PE.

The initial soil sample of the experimental plot was collected and analysis was done and the analytical results are shown in Table 1. The soil of the field was loamy having a bulk density of 1.40 gm/cc, water content at wilting point (WP) and field capacity (FC) were 14% and 28%, respectively. The unit plot size and spacing were 3.6 m × 2.4 m and 0.6 m × 0.4 m, respectively. Thirty days old healthy broccoli (cv. Premium crop) seedlings were transplanted in the experimental plot on 17 November 2012 and on 20 November 2013 and the crop was first harvested on 17 January, 2013 and on 10 January 2014. In 3rd year seedlings were transplanted in the experimental plot on 20 November 2014 and harvesting was completed within 18th February 2015.

Fertilizers were applied at the rate of 150, 50, 80, 30, 5, 2 and 1 kg/ha N, P, K, S, Zn, B and Mo, respectively as the form of urea, TSP, MoP, gypsum, ZnO, boric acid and sodium molybdate, respectively. The entire amount of cow dung (5 t/ha), half MoP and total amount of other fertilizers except urea were applied as basal and were incorporated into the soil during final land preparation. Urea was applied as top dressing in three equal installments at 15, 30 and 45 DAT, respectively. Rest half of MoP was applied at 30 days after transplanting (DAT). Plants were established at 20 days and a common irrigation was applied till plant establishment. Intercultural operations such as weeding, earthing up were done as and when required. Data on plant height, no. of leaves per plant, head diameter and marketable yield (terminal head + lateral head) and yield contributing parameters were recorded. The data were analyzed using MSTAT-C program and the treatment means were separated by DMRT at 5% level of probability.

Initial soil moisture was measured using gravimetric method. Soil moisture prior to irrigation according to treatment and at the time of harvest was determined by the same method. Irrigation water was applied to bring the soil moisture up to field capacity considering the effective root zone depth. Irrigation treatments began after the plants establishment. Check basin method of irrigation was applied to each plot using hose pipe by calculating discharge.

Irrigation water was calculated using the following equation (Michael, 1978):

$$d = \frac{FC - MCi}{100} \times As \times D$$

Where,

d= Depth of irrigation (cm)

FC= Field capacity of the soil (%)

MC_i= Moisture content of the soil at the time of irrigation (%)

A_s= Apparent specific gravity of the soil (g/cc)

D= Depth of effective root zone (cm)

Seasonal water requirement was calculated using water balance equation as below:

Seasonal water requirement (mm) = Total irrigation applied (mm) + effective rainfall (mm) from rainfall data + Soil water contribution (mm) from soil moisture analysis (Appendix 1, 2 and 3).

3. Results and Discussion

3.1. Effect of irrigation

Data on yield and yield contributing characters were summarized in Tables 2a and 2b. The results indicate that different levels of irrigation water had significant effect on plant height, no. of lateral heads per plant and head length except no. of leaves per plant in the first year (Table 2a). But in the second year, plant height, no. leaves per plant, days to 50% head initiation and no. of lateral heads per plant except days to first head initiation and head length showed significant effect (Table 2a and 2b). Similarly, in 3rd year, plant height, days to 50% head initiation, no. of lateral heads per plant and head length except no. of leaves per plant and lateral head per plant were significantly affected by the treatment (Table 2a and 2b). Maximum head diameter 17.16 cm, 16.18 cm and 15.60 cm was recorded in treatment I_2 for 1st, 2nd and 3rd year, respectively (Table 2b). The highest unit head weights (353.7, 358.2 and 389.80 g in 1st, 2nd and 3rd year, respectively) were found in treatment I_2 in each year (Table 2b).

Similarly, the highest yield (19.98 t/ha) was obtained from treatment I_2 followed by treatment I_3 (17.56 t/ha) and lowest yield (14.28 t/ha) was obtained in treatment I_4 in the first year (Table 2b). Whereas in the second year, the highest yield (20.63 t/ha) was observed in the treatment I_2 followed by treatment I_1 (19.05 t/ha) and the lowest yield (15.49 t/ha) was observed (Table 2b) in the treatment I_4 (irrigation at 20 days interval). In the 3rd year, the highest yield (16.24 t/ha) was observed in the treatment I_2 followed by treatment I_1 (15.73 t/ha) and the lowest yield (14.80 t/ha) was observed (Table 2b) in the treatment I_4 (irrigation at 20 days interval). So, it was observed that treatment I_2 gave the higher results and I_4 gave the lower performance in each of the 3 years. This finding is in agreement with Gomes *et al*. (2000) who reported that the highest curd yield of broccoli was observed from 12 days interval irrigation.

3.2. Water use and water productivity

Total water used, based on water requirement, and water productivity, based on yield (kg/ha) per unit water applied, is presented in Table 3. Total water use varied with the variation of the amount of irrigation water applied to the plots. The amount of irrigation water applied was increased with the increased irrigation frequency.

Table 1. Chemical properties of the initial soil of the experimental field at Joydebpur, Gazipur

Location	pH	OM	Ca	Mg	K	Total N %	P	S	B	Cu	Fe	Mn	Zn
			meq/100g				µg/g						
Joydebpur	6.5	0.90	5.5	1.7	0.18	0.08	10	12	0.1	1	43	4.2	1.0
Critical level	-	-	2.0	0.5	0.12	-	7	10	0.2	0.2	4	1.0	0.6

Table 2a. Effect of different irrigation levels on the yield and yield contributing characters of broccoli during 2012-13

Treat-ment	Plant height (cm)			Leaves per plant (no.)			Lateral heads per plant (no.)			Days to 50 % HI	
	2012-13	2013-14	2014-15	2012-13	2013-14	2014-15	2012-13	2013-14	2014-15	2013-14	2014-15
I_1	69.40ab	77.34a	70.60a	12.96	11.60a	13.44	6.15b	6.92ab	6.67	48.20b	45.4b
I_2	73.06a	73.36ab	69.72a	13.32	11.22b	13.08	7.55a	7.24a	5.33	49.00ab	46.0ab
I_3	69.88ab	71.78b	69.60a	13.12	11.08b	12.88	6.45b	6.38b	5.10	49.20ab	46.0ab
I_4	66.94b	72.90b	67.12b	12.64	10.56c	13.00	4.95c	6.12b	5.00	49.40a	47.4a
CV (%)	5.48	4.11	1.62	6.07	2.36	4.48ns	7.29	8.55	7.33ns	1.46	2.23

Means having same or without letter(s) do not differ significantly at 5% level of probability

Table 2b. Effect of different irrigation levels on the head yield of broccoli during from 2012-13 to 2014-15

Treat-ment	2012-13				2013-14				2014-15			
	Head length (cm)	Head dia. (cm)	Unit head weight (g)	Yield (t/ha)	Head length (cm)	Head dia. (cm)	Unit head weight (g)	Yield (t/ha)	Head length (cm)	Head Dia. (cm)	Unit head wt, (g/pl)	Head yield (t/ha)
I_1	14.06ab	16.12b	302.7b	16.44b	14.26	15.40ab	337.1a	19.05a	12.84c	14.84ab	377.40a	15.73a
I_2	14.78a	17.16a	353.7a	19.98a	14.22	16.18a	358.2a	20.63a	13.96ab	15.60a	389.80a	16.24a
I_3	14.30ab	16.52b	312.6b	17.56b	13.54	14.66ab	300.1b	17.20b	14.52a	14.84ab	375.20ab	15.63ab
I_4	13.16b	14.44c	259.4c	14.28c	13.50	14.00b	272.3c	15.49c	13.56bc	14.20b	355.20b	14.80b
CV (%)	5.90	7.93	9.59	8.34	7.99	7.36	5.21	6.87	4.59	4.02	4.05	4.05

Means having same or without letter(s) do not differ significantly at 5% level of probability

Table 3. Effect of different irrigation levels on the water use and water productivity of broccoli during 2012-13 to 2014-15

Treat-ment	2012-13			2013-14			2014-15		
	Total water used (mm)	Yield (kg/ha)	Water productivity (kg/m^3)	Total water used (mm)	Yield (kg/ha)	Water productivity (kg/m^3)	Total water used (mm)	Yield (kg/ha)	Water productivity (kg/m^3)
I_1	382.30	16440	4.30	296.58	19050	6.42	305.00	15725	5.16
I_2	242.78	19980	8.23	218.26	20630	9.45	200.23	16241	8.11
I_3	217.82	17560	8.06	185.66	17200	9.26	189.77	15633	8.24
I_4	204.60	14280	6.98	190.16	15490	8.15	185.22	14800	7.99

Table 4. Partial budget and dominance analysis for different treatments of broccoli for the year of 2012-14 and 2014-15

Treat-ment	Gross return (Tk./ha)		Total variable cost (Tk./ha)		Gross margin (Tk./ha)		Remarks	
	2012-14	2014-15	2012-14	2014-15	2012-14	2014-15	2012-14	2014-15
I_4	297700	296000	104485	106575	193215	189425	CU	CU
I_3	347600	312660	104616	106708	242984	205952	CU	CU
I_2	406100	324820	105479	107589	300621	217231	CU	CU
I_1	354900	314500	108747	110921	246153	203579	CD	CD

CU= Cost undominated; CD= Cost dominated

Table 5. Marginal analysis of un-dominated irrigation treatments of broccoli for the year of 2012-14 and 2014-15

Treatment	Gross margin (Tk./ha)		Total variable cost (Tk./ha)		Marginal Variable Cost (Tk./ha)		Marginal Gross margin (Tk./ha)		Marginal rate of return (%)	
	2012-14	2014-15	2012-14	2014-15	2012-14	2014-15	2012-14	2014-15	2012-14	2014-15
I_4	193215	189425	104485	106575						
I_3	242984	205952	104616	106708	131	133	49769	16527	37992	12426
I_2	300621	217231	105479	107589	863	881	57637	11279	6679	1280

Appendix 1. Total water used by the broccoli during 2012-13

Treatment	No. of irrigation	Irrigation applied upto establishment (mm)	Total irrigation applied (mm)	Effective rainfall (mm)	Soil water contribution (mm)	Total water used (mm)
I_1	13	77	269	0	36.30	382.30
I_2	6	77	123	0	42.78	242.78
I_3	4	77	87	0	53.82	217.82
I_4	3	77	73	0	54.60	204.60

Appendix 2. Total water used by the broccoli during 2013-14

Treatment	No. of irrigation	Irrigation applied upto establishment (mm)	Total irrigation applied (mm)	Effective rainfall (mm)	Soil water contribution (mm)	Total water used (mm)
I_1	12	73	179	3	41.58	296.58
I_2	6	73	104	3	38.26	218.26
I_3	4	73	74	3	35.66	185.66
I_4	3	73	62	3	52.16	190.16

Appendix 3. Total water used by the broccoli during 2014-15

Treatment	No. of irrigation	Irrigation applied up to establishment (mm)	Total irrigation applied (mm)	Effective rainfall (mm)	Soil water contribution (mm)	Total water used (mm)
I_1	12	68	162	4	33.38	305.00
I_2	6	68	88	4	40.23	200.23
I_3	4	68	64	4	53.77	189.77
I_4	3	68	54	4	59.22	185.22

There was no rainfall in the 1st year but in the 2nd and 3rd year, the average rainfall occurred during the crop season was 3 and 4 mm and it was effective since it was much less than the soil moisture deficit (Data not shown). From the Table 3, it revealed that the highest water used (382.30 mm, 296.58 mm and 305.00 mm in the first, 2nd and 3rd year, respectively) in treatment I_1 (irrigation at 5 days interval) followed by treatment I_2 (irrigation at 10 days interval).

Gutezeit (2004) reported that applied water of broccoli ranged between 238–445 mm which is in agreement with this work. Imtiyaz *et al*. (2000) also reported that for two years and under drip irrigation method average of water use values varied from 150–375 mm in different treatments in Northwestern Botswana. The highest water productivity (8.23 kg/m^3) was obtained from treatment I_2 and the lowest (4.30 kg/m^3) was obtained from treatment I_1 in the 1st year. In 2nd year, the highest water productivity (9.45 kg/m^3) was obtained from treatment I_2 and the lowest (6.42 kg/m^3) was obtained from treatment I_1. But in the 3rd year, the highest water productivity (8.24 kg/m^3) was obtained from treatment I_3 and the lowest (5.16 kg/m^3) was obtained from treatment I_1. Therefore, from three years study, it can be concluded that the treatment I_2 performed much better than all other treatments. Similar results were observed in the findings of Ayas *et al*. (2011).

3.3. Economic comparison

Data pertaining to economic comparison are presented in Tables 4 and 5. From Table 5, it revealed that the highest marginal rate of return is obtained between the treatments I_3 and I_4 for the year 2012-14. If additional one hundred taka is invested on treatment I_3 instead of investing in treatment I_4, an additional amount of Tk. 37992 will be earned for every 100 taka additional investment. Similarly, investing in treatment I_2 instead of I_3 will give additional Tk.6679 for every 100 taka additional investment. In 2014-15, it also revealed that the highest marginal rate of return is obtained between the treatments I_3 and I_4 (Table 5). If additional one hundred taka is invested on treatment I_3 instead of investing in treatment I_4, an additional amount of Tk. 12426 will be earned for every 100 taka additional investment. Similarly, investing in treatment I_2 instead of I_3 will give additional Tk.1280 for every 100 taka additional investment. It is clear that irrigation at 15 days interval (I_3) showed more economic performance. So, irrigation at 15 days interval may be effective for those regions where scarcity of water exists and if water is not a limiting factor. But the highest yield and comparatively higher water productivity can be found by using 10 days interval (I_2) irrigation scheduling.

4. Conclusions

From 3 years results broccoli has a good response to irrigation. Irrigation at 10 days interval (I_2) gave the higher yield and higher water productivity in every year of its cultivation. But in respect of economic profitability, irrigation at 15 days interval gave the better results. Considering all irrigation treatments, irrigation at 10 days interval can be recommended for better broccoli production in Bangladesh.

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