



Standardization of fertigation scheduling in broccoli (*Brassica oleracea* var *italica*)

SAJAL DEBBARMA^{1*}, LALIT BHATT¹, P K SINGH¹, POONAM GAUTAM¹,
MANOJ RAGHAV¹, LAVLESH¹ and A K SINGH²

Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Uttarakhand 263 145, India

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ABSTRACT

Efficient use of water and fertilizer is extremely critical to sustain the agricultural production, in the context of declining per capita land and water availability, pollution and increasing cost of fertilizers. A field experiment was conducted at Vegetable Research Centre of G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India during the *rabi* 2016–17 and 2017–18 to study the effect of fertigation with levels and scheduling on growth, yield and economics of broccoli (*Brassica oleracea* var *italica*). The experiment was laid out in two factorial RBD with one additional treatment consisting of five fertigation levels and three fertigation scheduling along with one control (soil application of RDF with flooding) replicated thrice. The outcome of study revealed that fertigation of broccoli with water soluble fertilizer gave significantly higher plant growth, net return and benefit cost ratio as compared to the soil application of RDF with flooding (control). Fertigation treatments registered a significantly higher yield of 13.74 t/ha and it was higher by 15.96% over the conventional method of fertilization (11.85 t/ha).

Keywords: B:C ratio, Broccoli, Drip fertigation, Scheduling, Water-use efficiency

Broccoli (*Brassica oleracea* L. var. *italica*), which derives its name from the Latin word 'brachium' meaning arm/branch, belongs to the family Brassicaceae (Boswell 1949). It contains 2500 IU vitamin A, 103 mg calcium, 78 mg phosphorous, 382 mg potassium and 113 mg vitamin C in 100 g of edible part (Kohli *et al.* 2006). Consumption of broccoli in daily diet minimizes the incidence of various types of cancers in human beings. Broccoli is a crop of cool and moist climatic conditions and grows well during winter season in North India and during summer and rainy seasons in hills. It has high cultivation potential in *tarai* region of Uttarakhand.

Water demand for agriculture is expected to increase almost by 20% to meet 70% increase in food production needed to feed 9.6 billion people by 2050. Drip irrigation is one of the efficient methods of irrigation having about 90% water application efficiency. Efficient use of water and fertilizer is extremely critical to sustain the agricultural production, in the context of declining per capita land and water availability, pollution and increasing cost of fertilizers.

Drip fertigation allows application of nutrients exactly and uniformly only to the wetted root volume which remarkably increases the application efficiency of the fertilizer. Despite the widespread use of high frequency irrigation system and fertigation elsewhere in India not much information is available on different aspects of fertigation on crops, particularly in broccoli. Split fertilizer application enhances nutrient efficiency, promote optimum yield, and mitigate the losses. Most of the work on nutrient management has been carried out using conventional methods of NPK fertilizer application. The information on use of water-soluble fertilizers, which has recently been introduced in the country especially for fertigation, is scanty. A retrospective analysis of work done on the above-mentioned problems showed extremely limited information on vegetable crops, especially on broccoli. Hence, the present study entitled "Standardization of fertigation scheduling in broccoli (*Brassica oleracea* var *italica*)" was undertaken to study the effect of fertigation and scheduling on growth, yield and economics of broccoli.

MATERIALS AND METHODS

The study was undertaken at Vegetable Research Centre of G B Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India during *rabi* 2016-17 and 2017-18. Pantnagar is geographically situated at an altitude of 243.84 m above mean sea level with a latitude of 29⁰ N and longitude of 79.3⁰ E. The climate of Pantnagar is

Present address: ¹Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Uttarakhand; ²CPCT, IARI, New Delhi. *Corresponding author e-mail: twiprasasajal@gmail.com.

humid sub-tropical with maximum temperature ranging from 32–43°C in summer (May-June) and minimum temperature ranging from 0–9°C during winter (January). The physico-chemical properties of the surface soil were analysed before transplanting of seedlings. The soil had a pH value of 7.23, available N of 160.22 kg/ha, available P of 46.86 kg/ha and available K of 323.90 kg/ha. The field trial was laid out in two factorial RBD with one additional treatment replicated thrice. The first factor is the NPK fertigation levels denoted by F, whereas the second factor is the scheduling of NPK fertigation throughout the growth period denoted by S along with a treatment of soil application of RDF with surface irrigation (Control). Treatment details are as follows:

A) Fertigation levels (NPK) : 5

F₁, 120% of RDF; F₂, 100% of RDF; F₃, 80% of RDF; F₄, 60% of RDF; F₅, 40% of RDF;

B) Scheduling of NPK fertigation throughout the growth period : 3

Crop growth stage	No. of splits	Total nutrients supplied		
		N	P ₂ O ₅	K ₂ O
S₁				
5-20 DAT	4	25 % of fertigation levels	15 % of fertigation levels	20 % of fertigation levels
21-36 DAT	4	40 % of fertigation levels	15 % of fertigation levels	25 % of fertigation levels
37-52 DAT	4	20 % of fertigation levels	50 % of fertigation levels	40 % of fertigation levels
53-68 DAT	4	15 % of fertigation levels	20 % of fertigation levels	15 % of fertigation levels
S₂				
5-20 DAT	4	25 % of fertigation levels	25 % of fertigation levels	25 % of fertigation levels
21-36 DAT	4	25 % of fertigation levels	25 % of fertigation levels	25 % of fertigation levels
37-52 DAT	4	25 % of fertigation levels	25 % of fertigation levels	25 % of fertigation levels
53-68 DAT	4	25 % of fertigation levels	25 % of fertigation levels	25 % of fertigation levels
S₃				
5-20 DAT	4	20 % of fertigation levels	20 % of fertigation levels	20 % of fertigation levels
21-36 DAT	4	40 % of fertigation levels	30 % of fertigation levels	20 % of fertigation levels

Crop growth stage	No. of splits	Total nutrients supplied		
		N	P ₂ O ₅	K ₂ O
37-52 DAT	4	30 % of fertigation levels	30 % of fertigation levels	30 % of fertigation levels
53-68 DAT	4	10 % of fertigation levels	20 % of fertigation levels	30 % of fertigation levels

The seeds were sown in well prepared nursery and four weeks old seedlings cv *Paraiso* were transplanted in second week of October. The RDF was kept as 150:60:60 kg of NPK per ha in all the treatments. Fertigation was done through venturi starting 5 DAT and the fertilizer doses were changed after every 15 days interval as per the scheduling. The water-soluble fertilizer, i.e. WSF-18:18:18 was used for fertigation. To meet the NPK requirement of different treatments, WSF was supplemented with urea, SSP and MOP. In case of conventional method of fertilization, the entire dose of P and K and half dose of N was applied as basal. The remaining dose of nitrogen was applied in two splits at 15 and 45 DAT. Observations were recorded for various plant growth parameters, maturity parameters, yield attributing parameters using standard methods. To get gross return/ha, the head yield (t/ha) obtained in each treatment was multiplied with prevailing local mandi rates. Net return in each treatment was calculated by subtraction of cost of cultivation from the gross return. Benefit-Cost ratio was computed in each treatment with division of gross return by cost of cultivation. The data of both the years were statistically analysed applying the two-stage method of control vs rest analysis suggested by Rangaswamy (2015).

RESULTS AND DISCUSSION

Growth attributes: Two years pooled data (Table 1) indicate that growth parameters were significantly influenced by various fertigation levels and scheduling. Amongst the various fertigation levels studied, significantly higher plant height (93.24 cm) and number of leaves per plant (44.58) was recorded under treatment F₁ (fertigation at 120% of RDF) followed by F₂, whereas significantly minimum plant height of 72.60 cm and leaf number of 28.91 was recorded under F₅ (fertigation at 40% of RDF). There was significant effect of scheduling on plant height and leaf number. Maximum plant height (86.00 cm) and leaf number (37.98) was recorded under scheduling S₁ which was statistically *at par* with S₃. Significant difference in plant height and leaf number between the control and fertigation treatments was also observed. Control treatment registered significantly lower height of 78.85 cm and leaf number of 30.43 as compared to 84.50 cm and 36.00 under fertigation treatments.

More vegetative growth of broccoli with increasing the fertigation levels which may be because of the application of increasing levels of fertigation attributed to better nutritional environment in the root zone as well as in the plant system

Table 1 Effect of fertigation levels and scheduling on growth, maturity, yield and yield attributing parameters in broccoli (pooled data of 2 years)

Treatment	Plant height (cm)	Leaf number	Days taken to head initiation	Days taken to 50 % head maturity	Net head weight (g)	Yield (t/ha)
<i>Fertigation levels</i>						
F ₁	93.24	44.58	49.65	64.10	450.45	15.01
F ₂	88.44	40.08	50.81	65.66	455.98	15.20
F ₃	88.26	36.02	52.10	67.25	416.47	13.88
F ₄	79.91	30.42	53.38	69.01	388.79	12.96
F ₅	72.60	28.91	54.32	70.54	350.04	11.67
SEm ±	0.48	0.49	0.23	0.31	2.18	0.07
CD (5%)	1.40	1.43	0.66	0.89	6.30	0.21
<i>Scheduling</i>						
S ₁	86.00	37.98	51.97	67.34	414.93	13.83
S ₂	82.32	32.78	52.15	67.26	407.34	13.58
S ₃	85.15	37.25	52.04	67.34	414.75	13.82
SEm ±	0.48	0.49	0.23	0.31	2.18	0.07
CD (5%)	1.08	1.11	NS	NS	4.88	0.16
<i>Control vs Rest</i>						
Control	78.85	30.43	53.50	70.00	355.56	11.85
Rest	84.50	36.00	52.05	0.39	412.34	13.74
SEm ±	0.61	0.63	0.29	0.39	2.76	0.09
CD (5%)	1.77	1.81	0.84	1.13	7.97	0.27
<i>Interaction (F×S)</i>						
SEm ±	0.48	0.49	0.23	0.31	2.18	0.07
CD (5%)	NS	NS	NS	NS	NS	NS

(Singh *et al.* 2004) resulting in higher nutrient uptake by plant promoting better growth and development. Kumar and Sahu (2013) also reported similar results in cabbage. Higher vegetative growth of broccoli under S₁ as compared to S₂ and S₃ could be attributed to the relatively higher amount of nitrogen applied at the vegetative stage of crop (21-36 DAT) which leads to better photosynthesis and express in terms of higher vegetative growth. Trani and Raij (1997) also reported that nitrogen requirement in broccoli was higher during the vegetative stage of crop therefore, nitrogen fertilization is extremely important in this stage for proper vegetative growth of plant.

Maturity parameters: Among the fertigation levels, minimum number days taken to head initiation (49.65) and days taken for 50% head maturity (64.10 days) was recorded under F₁ and maximum days was observed under treatment F₅. The difference in days taken to head initiation between the control and rest of the fertigation treatments was found significant. The days taken to head initiation and 50% head maturity under control were 53.50 days and 70 days as compared to 52.05 and 67.31 days under fertigation treatments.

Better vegetative growth at higher dose of NPK was attributed due to better nutrient availability which favours the early curd initiation. The early maturity of head under high fertigation level might be attributed to the better and more

uptake of nutrients by plant promoting higher vegetative growth corresponding early head development which leads to early maturity of head. It was also observed by Shree *et al.* (2014) in his study on cauliflower that higher fertility level favoured the early maturity time. These results could also be supported with the results of Meena (2017) in cauliflower.

Yield and yield attributes: As evident from data (Table 1) individual head weight, yield of broccoli was significantly influenced by fertigation levels and scheduling. Significantly higher head weight (455.98 g) was recorded in treatment F₂ and it was statistically at par with F₁. Pooled data of both the years indicate that the yield obtained with 100% of RDF (15.20 t/ha) and 120% of RDF (15.01 t/ha) applied through drip were statistically *at par*, but significantly better over 80% (13.88 t/ha), 60% (12.96 t/ha) and 40 % (11.67 t/ha) of RDF. Scheduling also had significant impact on head weight and yield of broccoli. Maximum net head weight (414.93 g) and yield (13.83 t/ha) was recorded in scheduling S₁ followed by S₃. Pooled data revealed that fertigation treatments registered a significantly higher yield of 13.74 t/ha and it was higher by 15.96% over the control plots (11.85 t/ha).

Increase in head weight and yield of broccoli under fertigation might be attributed to the maintenance of favourable soil water regime in the root zone, which in turn helped the plants to utilize water and nutrients

more efficiently from the wetted area (Singh *et al.* 2002). Application of 120% of RDF through fertigation resulted in lower yield than 100 % RDF which might be due to the excessive dry matter production due to higher dose of N and K which lead to luxury consumption of K and higher accumulation of N in the leaves. This result was in agreement with the result obtained by Vasu and Reddy (2013) in cabbage. Heavier head and yield observed under scheduling S₁ and S₃ might be attributed to the optimum supply of phosphorus and potassium at the head initiation stage required for the growth and development of head. Filho *et al.* (2017) reported the higher demand of phosphorus and potassium of broccoli is in the reproductive stage between 35 to 55 DAT. Present findings are also supported by Castoldi *et al.* (2009).

Economics: Among the different fertigation levels the maximum cost of cultivation was observed in fertigation with 120% of RDF (₹76107.96) and it gradually reduced to ₹60258.29 where fertigation is provided with 40% of RDF (Table 2). Under conventional method of fertilization along with surface irrigation the cost of cultivation recorded was ₹ 69776.75. Out of the three-scheduling studied maximum cost of cultivation was recorded in S₂ (₹ 69228.33) and lowest was under scheduling S₁ (₹67550.46). Among the fertigation levels, highest gross return of ₹230870, net return of ₹158462.6, B : C ratio of 3.19 was observed in treatment F₂ (100 % of RDF). While, the lowest net return of ₹10508.25 and lowest B: C of 2.58 was observed in control treatment. Amongst the three scheduling higher gross return of ₹209154, net return of ₹141603.5 and B:C ratio of 3.09 was observed under S₁ and minimum gross return (₹ 205371), net return (₹ 136142.7) and B:C ratio (2.96) was observed under S₂.

The higher cost of cultivation at higher fertigation levels and scheduling S₁ was attributed to the extra expenditure of NPK-18:18:18, electricity, labour, harvesting and packaging of extra yield. The increase in the value of gross return, net return and B:C ratio at 100% of fertigation levels and scheduling S₁ could be attributed to higher yield under optimum nutrient supply. These results are in agreement with those of Vasu and Reddy (2013) in cabbage. Soil application of fertilizers and surface irrigation resulted in the lowest B:C ratio. Supportive results were obtained by Shinde *et al.* (2002) in brinjal.

This study has shown that fertigation treatments increased the yield of broccoli by 15.96% over conventional method of fertilization. As far as economics is concerned fertigation at 100% of RDF through scheduling S₁ was the best with respect to net return (₹ 160061.4) and B:C ratio (3.24). Based on the overall performance, it could be concluded that under *tarai* conditions of Uttarakhand, fertigation of broccoli at 120:60:60 kg N, P₂O₅ and K₂O per ha through scheduling S₁ (25, 15 and 20 % N, P₂O₅ and K₂O of RDF between 5-20 days after transplanting (DAT), respectively, 40, 15 and 25 % N, P₂O₅ and K₂O of RDF between 21-36 DAT, respectively, 20, 50 and 40 % N, P₂O₅ and K₂O of RDF between 37-52 DAT, respectively,

Table 2 Effect of fertigation levels and scheduling on economics of broccoli (pooled data of 2 years)

Fertigation levels	Cost of cultivation (₹ /ha)				Gross return (₹ /ha)				Net return (₹ ha)				B:C ratio			
	Scheduling				Scheduling				Scheduling				Scheduling			
	S ₁	S ₂	S ₃	Mean	S ₁	S ₂	S ₃	Mean	S ₁	S ₂	S ₃	Mean	S ₁	S ₂	S ₃	Mean
F ₁	74992.79	77568.99	75762.09	76107.96	229095	226995	228885	228325	154102.2	149426	153122.9	152217	3.05	2.93	3.02	3.00
F ₂	71478.56	73628.81	72114.81	72407.39	231540	229995	231075	230870	160061.4	156366.2	158960.2	158462.6	3.24	3.12	3.2	3.19
F ₃	67565.31	69267.71	68080.11	68304.38	210075	207735	210015	209275	142509.7	138467.3	141934.9	140970.6	3.11	3	3.08	3.06
F ₄	63801.52	64983.62	64171.17	64318.77	197505	190095	196500	194700	133703.5	125111.4	132328.8	130381.2	3.1	2.93	3.06	3.03
F ₅	59914.12	60692.52	60168.22	60258.29	177555	172035	177345	175645	117640.9	111342.5	117176.8	115386.7	2.96	2.83	2.95	2.91
Mean	67550.46	69228.33	68059.28	68106.02	209154	205371	208764	207647	141603.5	136142.7	140704.7	137817.0	3.09	2.96	3.06	3.00
Control				69776.75			180285					110508.25				2.58

15, 20 and 15 % N, P₂O₅ and K₂O of RDF between 53-68 DAT, respectively) is the best and most economical for cultivation of broccoli. Hence, the same is recommended for commercial cultivation.

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