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Standardization of fertigation schedules on plant growth and yield of broccoli

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Abstract
Broccoli (*Brassica oleracea* var. *italica* L.), is an important cole crop with high nutritional value gaining popularity in metropolitan cities of Telangana state. Considering the inadequacy of information regarding the nutrient requirement of exotic vegetable broccoli through fertigation, the present study was aimed to standardize the appropriate fertigation schedule, thereby providing highly nutritive non-native vegetables to the farmers of our state. The experiment was conducted for two years (*Rabi* 2019-20 & 2020-21) which was laid out in randomized block design with five treatments *viz* (60% RDF, 80% RDF, 100% RDF, 120% RDF along with control) and four replications. Significant difference was observed among the treatments with respect to growth and yield parameters. The pooled data revealed that, among 5 treatments maximum yield per ha was recorded in T_4 -120% RDF (222.27 q/ha) which was on par with the treatments T_3 -100% (214.68 q/ha) & T_2 -80% (210.03 q/ha). However, the highest B:C ratio (1:4.70) was observed in treatment T_2 -80% RDF (160-100-100 NPK kg/ha) through drip irrigation by using fertilizers like Urea (276 kg/ha), 75% P applied as basal through SSP (468 kg/ha), water soluble fertilizers 12-61-0 - MAP (41 kg/ha) & 13-0-46 –KNO_3 (225 kg/ha) in 17 splits at 5 days interval. Among the treatments studied, T_2 -80% RDF gave a similar yields as 100% RDF and 120% RDF and highest B:C ratio of 1:4.70 with 20% fertilizer saving without affecting growth and yield parameters.

Keywords: Broccoli, standardization, fertigation, growth, curd yield, B:C ratio

Introduction
Broccoli (*Brassica oleracea* var. *italica* L.; 2n=x=18), is an important vegetable among the cole crop belongs to the family *Brassicaceae* or *crucifereae* and originated from the Mediterranean region. Sprouting broccoli with a kind of terminal head consisting of green buds and thick fleshy flower stalks morphologically resembles the cauliflower except secondary heads, which develop in the axil of leaves and may contribute up to 50 percent of the total yield. Broccoli is known as the "Crown of jewel nutrition" as it is a rich source of many minerals, vitamins such as vitamin A and C, carotenoids, fiber, calcium and folic acid besides its antioxidant and anti-carcinogenic properties. It also contains a few important phyto-chemicals, sulphoraphane, beta-carotene, indole-3-carbinol, glucosinolates which help to fight against many cancers (Aires *et al.* 2006) [1]. Nowadays, more attention to broccoli is due to its multifarious use and great nutritional value. (Talalay & Fahey, 2001; Rangkadilok *et al.* 2002 & Rangkadilok *et al.* 2004) [23, 12, 13].

Fertigation provides a variety of benefits to the users like high crop productivity, quality, resource use efficiency, environmental safety, flexibility in field operations, effective weed management and successful crop cultivation in fields with undulating topography. Regular and unbalanced use of chemical fertilizers leads in the end to a decrease in the base saturation and to acidification of soil (Roe, 1998) [11]. Hence, judicious use of fertilizers needs to be addressed. Fertigation facilitates the enhanced mobility, availability and uptake of applied nutrients because of higher soil moisture content (Silber, 2008) [18] and more frequent application of fertilizers, corresponding to quantitative and timely demand by the crops (Srivastava, 2005) [22]. Therefore, fertigation can potentially reduce the transport of nutrients away from the root zone. This remarkably increases fertilizer- and water-use efficiency, which reduces production costs (Bar-Yosef, 1999; Solaimalai *et al.* 2005) [2, 21]. In this context, fertigation, where water-soluble solid fertilizers or liquid fertilizers are applied through a drip irrigation system, can be a logical approach. These fertilizers are very expensive in India, as they are imported and not subsidized. Conventional, inexpensive fertilizers that are water soluble can also be tried in fertigation. Previous studies have reported significant fertilizer

savings of 20-60% along with 8-41% increases in yields of horticultural and vegetable crops as a result of fertigation (Jucilene *et al*. 2009; Singh *et al*. 2010) [4, 20].

Considering the inadequacy of information on nutrient requirement of broccoli through fertigation and expecting a good demand for this exotic high- value minor vegetable, crop specific fertigation schedule is to be developed. Keeping in view the above facts in mind, an experiment entitled "Standardization of fertigation schedules on plant growth and yield of broccoli (*Brassica oleracea* var. *italica*)" was taken up.

Materials and Methods

The present experiment were conducted to study the influence of different fertigation levels on growth and yield of broccoli during (*Rabi* 2019-20 & 2020-21) in randomized block design with five treatments *viz*.T_1 -60% RDF(120-75-75 NPK kg ha-1), T_2 -80% (180-100-100 NPK kg ha-1) RDF, T_3 -100% RDF (200:125:125 NPK kg ha-1), T_4 -120% RDF (240-150-150 NPK kg ha-1) & T_5 –control (without fertilisers) and four replications at Vegetable Research Station, Agricultural Research Institute, Rajendranagar, Hyderabad, Telangana, India. Fertigation was scheduled at 5 days interval in 17 spilts using water soluble fertilisers Urea (276 kg/ha), 12-61-0 - MAP (41 kg/ha) & 13-0-46 –KNO_3 (225 kg/ha) through drip irrigation. 75% P applied as basal through SSP (468 kg/ha) and remaining 25% by using above water soluble fertilizers. Healthy seedlings were sown in the nursery beds of vegetable research station farm, Rajendranagar. 30 days old healthy seedlings with uniform growth were selected and transplanting in well prepared open field on raised beds at 45 cm ×30 cm spacing.

Periodical observations were recorded on growth and yield parameters. Five plants were randomly selected and tagged at vegetative stage from each treatment to record the data on the following attributes. The observations were recorded on plant height (cm), number of leaves per plant, plant spread at Harvest (cm) –E-W & N-S, curd length (cm), curd diameter (cm), primary curd weight (g), lateral curd weight (g), Total curd weight (g), yield (q/ha) and B:C ratio. Least significant difference at 5% level was used for finding the significant differences among the treatment means. Data on growth and yield components were collected using standard procedures and were analyzed statistically by online Statistical Analysis Tool given by Sheoran O.P *et al*, 2020 [16]. The Benefit: Cost (B:C) ratio was calculated by dividing the net returns by the cost of cultivation.

Fig 1: General view of experimental field

Fig 2: Broccoli curds at 80% RDF

Results and Discussion

The pooled data for two years (2019-20 & 2020-21) presented in Table 1 clearly show that there was significant difference in vegetative growth parameters *viz*, plant height, number of leaves per plant and plant spread at harvest with different fertigation levels.

a) Growth Parameters

Among the different treatments imposed on broccoli, T_3-100% RDF recorded highest plant height (55.27 cm) which was statistically on par with treatments T_4 -120% RDF & T_2 -80% RDF (54.41 cm and 52.50 cm respectively). Whereas, minimum plant height (49.25 cm) was recorded in Treatment T_5- No application of fertilizers.

Maximum number of leaves (24.51 plant^{-1}) was recorded in the treatment T_3 -100% RDF followed by the treatment T_4 -120% RDF with 22.57 leaves per plant and lowest were found in T_5- Control (17.50 plant^{-1}).

Similarly, plant spread was influenced significantly due to different fertigation levels at harvest. The plant spread in both East- West and North-South directions was found maximum in 100% RDF (50 cm & 49.86 cm respectively) and at par with T_2 -80% RDF (49.03 cm & 47.49 cm respectively). The minimum plant spread was noticed in T_5- Control. (44.11 cm & 44.50 cm respectively).

Table 1: Growth parameters of broccoli as influenced by fertigation.

	Plant Height (cm)			No. of leaves			Plant spread at Harvest (E-W) (cm)			Plant spread at Harvest (N-S) (cm)		
Fertigation	**2019-20**	**2020-21**	**Mean**	**2019-20**	**2020-21**	**Mean**	**2019-20**	**2020-21**	**Mean**	**2019-20**	**2020-21**	**Mean**
T_1- 60%	49.80	50.07	49.94	18.66	19.41	19.03	45.45	44.75	45.10	46.35	47.85	47.10
T_2-80%	53.92	51.09	52.50	21.05	20.80	20.92	48.90	49.15	49.03	47.05	47.93	47.49
T_3-100%	55.02	55.52	55.27	23.90	25.13	24.51	49.75	50.25	50.00	50.50	49.21	49.86
T_4-120%	53.66	55.16	54.41	23.07	22.07	22.57	46.20	47.20	46.70	46.40	46.65	46.53
T_5-control	48.32	50.17	49.25	17.00	18.00	17.50	44.95	43.28	44.11	45.25	43.75	44.50
CD at 5%			3.73			1.90			2.14			2.67
C.V.%			2.50			3.18			1.60			1.99

An increase in vegetative growth parameters at optimum fertigation levels might be due to maximum uptake of nutrients which may be due to better availability of sufficient quantity of major nutrients. The enhanced plant growth might be due to the fact that nitrogen with synthesized carbohydrates was metabolised into amino acids and proteins which allowed the plants to grow faster. As nitrogen is one of the major plant nutrient required for the growth consequently its uptake increases the cell number and size leading to better growth and development of plant organs. The results are in conformity with Sanchita *et al.,* (2004) [14], Singh *et al.,* (2006) [19], Shinde *et al.,* (2006) [17], Tanpure *et al.,* (2007) [24], and Mohammadullah Nikzad *et al.,* (2020) [8]. Overall, the higher doses of NPK fertilizers resulted in higher values of all the growth parameters. The results are in line with those reported by Parameshwara (2003) [10], Hegazi and AL Sodon (2001) [3] and Vasu and Reddy (2013) [25].

b) Yield Parameters

The data presented in table 2 depicts that the results pertaining to yield attributing characters (Terminal curd length, Terminal curd width, Terminal curd weight and Lateral curd weight) as influenced by different fertigation levels; Fertigation of 100% RDF registered significantly higher terminal curd length (13.34 cm), terminal curd width (18.24 cm) and lateral curd width (12.04 cm) followed by the treatment 80% RDF (11.89 cm, 17.15 cm & 11.75 cm respectively) and 120% RDF (11.63 cm, 16.61 cm & 11.44 cm respectively) while the minimum values were recorded in the treatment with no application of fertilizers (10.62, 10.66 & 9.86 cm respectively).

The higher values for length and diameter of curd with these levels might be due to higher uptake of nutrients and translocation of source (leaf) to sink (curd). These results are in conformity with the findings of Sharma *et al.,* (2004) [15], Shinde *et al.,* (2006) [17] and Tanpure *et al.,* (2007) [24].

The total curd weight (terminal and lateral curds) is an important parameter which ultimately decides the yield of crop (Table 2). Fertigation levels with 100% RDF, 120% RDF & 80% RDF registered highest curd weight (384 g, 366 g & 359 g respectively) which are found on par. Whereas minimum curd weight (265 g) was observed in no application of fertilisers. An increase in curd weight might be due to increased nutrient availability in the root zone leads greater absorption of nutrients by plants which caused more curd weight. An optimum nutrition levels might have provided better translocation of minerals and increased accumulation of photosynthates in plants thus increased curd weight. The findings of this investigation were in close conformity with those of Mohapatra *et al.,* (2013) [9], Kumar and Sahu (2013) [5], Verma *et al.,* (2014) [26], Kumari *et al.,* (2015) [6] and Mankar *et al.,* (2015) [7].

Table 2: Yield attributing characters of broccoli as influenced by fertigation.

	Terminal curd length (cm)			Terminal curd girth (cm)			Lateral Curd girth (cm)			Primary Curd weight (kg)			Lateral Curd weight (kg)		
Fertigation	**2019-20**	**2020-21**	**Mean**	**2019-20**	**2020-21**	**Mean**	**2019-20**	**2020-21**	**Mean**	**2019-20**	**2020-21**	**Mean**	**2019-20**	**2020-21**	**Mean**
T_1- 60%	10.74	11.09	10.91	12.85	12.15	12.50	10.70	10.96	10.83	0.24	0.09	0.17	0.09	0.08	0.08
T_2-80%	11.59	12.19	11.89	16.65	17.65	17.15	11.60	11.89	11.75	0.27	0.10	0.19	0.10	0.09	0.10
T_3-100%	12.95	13.72	13.34	17.81	18.67	18.24	11.82	12.27	12.04	0.30	0.11	0.21	0.11	0.10	0.10
T_4-120%	11.26	12.00	11.63	16.42	16.80	16.61	11.32	11.57	11.44	0.27	0.09	0.18	0.09	0.10	0.10
T_5-control	10.47	10.77	10.62	10.38	10.94	10.66	9.79	9.94	9.86	0.19	0.08	0.13	0.08	0.07	0.07
CD at 5%			0.42			1.35			0.22			0.06			0.02
C.V.%			1.31			3.16			0.69			12.60			7.42

c) Yield & Cost Economics

Similar trend was noticed with respect to yield component (Table 3). Significantly highest curd yield was observed under treatment T_3 100% RDF (27.68 kg plot^{-1} and 238.31 q/ha^{-1}), which was found on a par with treatments T_4 -120% RDF (26.32kg plot^{-1} and 226.61 q/ha^{-1}) and T_2- 80% RDF (25.88 kg plot^{-1} and 222.81 q/ha^{-1}). However, T_5-no application of fertilizers resulted in poor yield performance (19.08 kg plot^{-1} and 164.30 q/ha^{-1}) Yield is a complex character which involves the interaction of several intrinsic and external factors. It largely depends upon the production and mobilization of carbohydrates, uptake of water and nutrients from the soil, in addition to several environmental factors to which plants are exposed during the growing period. Irrespective of higher dose of nutrients supplemented, plant may uptake only the required amounts of nutrients for their better growth and dry matter production and might not use out of its nutritional requirement. At higher fertigation level, crop might meet its nutritional requirement leads to luxurious growth resulted in more interception of light and more translocation of photosynthates from source (vegetative part) to sink (reproductive part) which enhanced the yield. These results are in agreement with those reported by Shinde *et al.,* (2006) [17]and Tanpure *et al.,* (2007)[24].

Economic analysis of broccoli (Table 3) showed that, although yield levels were higher under T_3- 100% RDF and T_4-120% RDF (238.31 q/ha & 226.61 q/ha respectively), profitability was significantly higher under T_2 - 80% RDF (180-100-100 NPK kg ha-1) scheduled at 5 days interval in 17 spilts with B:C ratio of 1: 4.70 on account of 20% less fertilizer application leading to lower cost of production and it is also not economical to the farmer to go beyond the recommended dose of fertilizers for sustainable production of broccoli under open field conditions in Telangana.

Table 3: Yield and economics of broccoli as influenced by fertigation

	Total Curd weight (kg)			Total plot yield (Kg)			Yield per Ha (q)			B:C ratio
Fertigation	**2019-20**	**2019-21**	**Mean**	**2019-20**	**2020-21**	**Mean**	**2019-20**	**2020-21**	**Mean**	
T_1- 60%	0.345	0.293	0.319	24.84	21.06	22.95	213.9	181.35	197.6	3.88
T_2-80%	0.380	0.339	0.359	27.36	24.39	25.88	235.6	210.03	222.8	4.70
T_3-100%	0.423	0.346	0.384	30.42	24.93	27.68	262.0	214.68	238.3	4.49
T_4-120%	0.373	0.359	0.366	26.82	25.81	26.32	231.0	222.27	226.6	3.70
T_5-control	0.278	0.253	0.265	19.98	18.18	19.08	172.1	156.55	164.3	2.24
CD at 5%			0.048			3.52			30.33	
C.V.%			4.98			5.06			5.06	

Conclusion

From the present investigation, it can be concluded that fertigation with 80% RDF (180-100-100 NPK kg ha-1) scheduled at 5 days interval in 17 spilts is economical for superior yields (21.81q/ha) with 20% fertilizer saving and highest B:C ratio of 1:4.70 for sustainable production of broccoli under open field conditions in Telangana.

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