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Effect of fertigation levels and schedules on economics of broccoli (*Brassica oleracea* var. *italica*) cultivation

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Abstract
A field experiment was carried out in Vidarbha region of Maharashtra (India) to study the economic analysis of broccoli cultivation under fertigation levels and schedules at the Instructional Farm, Department of Vegetable Science, Dr. PDKV, Akola, Maharashtra, India during the winter season 2021-2022 to found out the effect of fertigation levels and schedules on the economic analysis of broccoli (*Brassica oleracea var italica*). The experiment layout was split plot design which consists of three fertigation levels (75, 100 and 125% RDF) with one control (100% RDF) through conventional method and three fertigation scheduling (S_1, S_2 and S_3) with three replication. The results of the experiment revealed that, highest cost of cultivation (135355 Rs.) of broccoli recorded under application of 125% RDF with fertigation schedule S_2 (15% NPK at transplanting to plant establishment, 1-10 DAT), 50% NPK at curd initiation stage,11-35 DAT and 35% NPK at curd development stage,36-60 DAT). At the same time, the net return and B:C ratio also were higher by (336444 Rs.) and (3.49). The economic analysis stated that the yield and income of farmers can be increased with help of fertigation technology in case of broccoli cultivation.

Keywords: Broccoli, fertigation, schedules, economics

Introduction
Broccoli is a wonderful vegetable. It is packed with nutrients and vitamins and is sometimes even called a superfood. A major portion of broccoli consumption is only in the metros. When it comes to rural India, it is seldom consumed. Consumers do not purchase broccoli as they either do not know how to cook or consume it and find it unappealing if they try it. Broccoli is acknowledged as the "Crown of Jewel Nutrition" as it is fairly rich in vitamin A, vitamin C and minerals. Broccoli is important cole crop. It is highly nutritious cole crop in Brassicaceae family and contains vitamin A (623 IU), vitamin C (89.2 mg), vitamin B1, vitamin B2, vitamin B3, and minerals like calcium, phosphorus, potash and iron. Eating great amount of broccoli may also have desired benefits, since broccoli is also a rich source of many vitamins and minerals such as vitamin A and C, carotenoides, fiber, calcium and folic acid**.** Eating of broccoli in daily diet minimizes the incidence of various types of cancers in human beings. In India, broccoli mainly famous in Himachal Pradesh, UK and Jammu & Kashmir and Northern plains.
The broccoli is heavy feeder crop and will do well with a dose of fertilizer every couple of weeks. Broccoli demands sufficient supply of soil moisture to produce maximum yields of good quality. Past research have proved that drip fertigation is the most acceptable method of irrigation for vegetables, and it is possible to increase water use efficiency by well scheduled irrigation programs e.g., broccoli. Due to water scarcity, the available water resources should be very effectively utilized through water saving irrigation technologies. Fertigation accelerates a variety of advantages to the users like higher 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 unstable use of chemical fertilizers illustrate in the end to a decrease in the base saturation and to acidification of soil. Hence, prudent use of fertilizers needs to be addressed. Fertigation accelerates the mobility, availability and uptake of applied nutrients because of higher soil moisture content (Silber, 2008) [18] and more periodic supply of fertilizers, corresponding to quantitative and timely

demand by the crops. Fertigation scheduling is a critical management input to assure optimum soil nutrients status for proper plant growth and development as well as for optimum yield and economic benefits.

Thus, it is required to develop fertigation scheduling schemes under domestic climatic conditions to utilize infrequent water resources comprehensively and adequately. Convenient fertigation scheduling is to increase fertilizer capability by applying the equal amount of fertilizer required to flood the soil nutrients to desire level, saves nutrients resources and energy. Thus it is essential to improve fertigation scheduling techniques under established climatic surroundings in order to use of scare nutrients resources adequately for broccoli production.

Methodology

The experiments were carried out at vegetable research unit, Dr. PDKV, Akola, Maharashtra, and Agriculture Training School, Buldhana during winter Season of 2021-22. The climate of Akola is semi-arid and is characterized by three distinct seasons *viz*., hot and dry summer from March to May, warm and rainy monsoon from June to October and mild winter from November to February and Buldhana district lie between 19°51 to 21°17 North latitudes and 76°38 to 76°40 east longitudes. It is surrounded by Satpuda mountain ranges. The climate of the district is hot and humid. In some parts of the districts *i.e* khamgaon, Jalgaon (Jamod) and Shegaon area the climate is very hot in summer, which reaches to 42 °C in the month of May and is much cold in winter during the month of December which come down to 8 °C to 10 °C. Buldhana district falls in the rainfall zone between 700-800 mm per annum.

Present study was set out in split plot design. There were 4 different fertigation levels F_1- 100% RDF (Conventional method), F_2- 75% RDF, F_3- 100% RDF and F_4-125% RDF through fertigation method) with three schedules S_1, S_2 and S_3.

Factor A: Fertigation levels: (Main Plot factor)

1. F_1: 100% RDF (100: 50: 50 NPK Kg ha^{-1}) – through soil application
2. F_2: 75% RDF (75: 37: 37 NPK Kg ha^{-1})- through fertigation
3. F_3: 100% RDF (100: 50: 50 NPK Kg h^{-1})- through fertigation
4. F_4: 125% RDF (125: 62.5: 62.5NPK Kg ha^{-1})- through fertigation

Factor B: Fertigation Schedules: 03 (Sub plot factor) – 12 splits at 5 days interval

Fertigation Schedules

Sr. No.	Fertigation Schedules	Transplanting to plant establishment (1-10 DAT)	Curd initiation stage (11-35 DAT)	Curd development stage (36-60 DAT)
1	Schedule-1	10%NPK	40%NPK	50%NPK
2	Schedule-2	15%NPK	50%NPK	35%NPK
3	Schedule-3	20%NPK	45%NPK	35%NPK

Generally 30 days old seedlings of broccoli variety Palam samridhi were transplanted in second fortnight of October in the plot size 450 m^2 in the trial period. Replanting of seedlings were done in the early morning. Frequent watering was applied just after the replanting and the gap filling was done seven days after replanting.

Statistical Analysis: The data was assembled from the studied field was statistically examined by ANOVA for split plot design. Critical difference was figured out at five per cent probability level when the treatment differences were discovered significant and the values were well suited. The treatment differences that were not significant were denoted by N.S.

Results and Discussion

Yield parameters

Table 1: Effect of fertigation levels and schedules on curd yield (g) per plant and curd yield (q) per hectare of broccoli

Treatments	2021-22				2021-22				Pooled			
Curd yield (g) per plant												
Fertigation levels	**S_1**	**S_2**	**S_3**	**Mean**	**S_1**	**S_2**	**S_3**	**Mean**	**S_1**	**S_2**	**S_3**	**Mean**
F_1	397.85	416.77	397.72	404.11	393.01	413.08	395.04	400.38	395.43	414.92	396.38	402.25
F_2	410.86	430.71	420.47	420.68	408.84	426.64	417.10	417.53	409.85	428.67	418.78	419.10
F_3	437.17	442.15	435.99	438.43	432.63	441.94	434.59	436.38	434.90	442.05	435.29	437.41
F_4	436.50	447.11	438.66	440.75	434.19	445.79	435.39	438.45	435.34	443.45	437.03	438.60
Mean	420.59	434.18	423.26		417.17	431.86	420.53		418.88	432.27	421.87	
F-test	Sig	Sig	Sig		Sig	Sig	Sig		Sig	Sig	Sig	
SE(m)±	2.80	2.55	5.01		1.49	2.23	3.93		1.33	2.15	3.75	
CD at 5%	8.45	7.67	15.08		4.48	6.69	11.79		3.99	6.45	11.25	
Curd yield (q) per hectare												
Fertigation levels	**S_1**	**S_2**	**S_3**	**Mean**	**S_1**	**S_2**	**S_3**	**Mean**	**S_1**	**S_2**	**S_3**	**Mean**
F_1	110.47	115.77	110.51	112.25	105.17	114.74	109.73	109.88	108.45	113.25	109.10	110.26
F_2	116.79	119.64	114.13	116.85	113.56	118.51	115.86	115.98	113.85	119.07	116.32	116.41
F_3	121.11	122.85	121.43	121.79	120.17	122.94	116.72	119.94	120.80	122.93	120.91	119.35
F_4	121.81	124.19	121.15	122.41	117.60	123.82	120.76	120.72	122.39	124.01	121.79	121.57
Mean	116.56	120.61	116.83		114.87	119.50	117.27		116.50	119.93	117.53	
F-test	Sig	Sig	Sig		Sig	Sig	Sig		Sig	Sig	Sig	
SE(m)±	0.77	0.70	1.39		0.41	0.61	1.09		0.37	0.59	1.04	
CD at 5%	2.34	2.10	4.17		1.23	1.83	3.27		1.12	1.79	3.12	

The data stated that fertigation levels significantly influenced on curd yield plant^{-1} (g) and curd yield plant^{-1} (q) (Table 1) of broccoli. The data clearly stated that, the maximum curd yield plant^{-1} (g) of broccoli was found (438.60 g, 121.57 g) in the fertigation level F_4 (125% of RDF) and similarly the minimum curd per plant^{-1} (g) and curd yield ha^{-1}(q), (402.25 g, 110.26 g) was found in the F_1 (100% RDF- through soil application). The higher yield obtained due to better water and nutrients uptake and also with excellent soil-water and air relationship with higher oxygen concentration in the root zone. It possibly due to the optimum moisture conditions in the entire root zone of the crop which reflected in better physiological activities of plants leading into augmented dry matter accumulation. The results were similar agreement by Patil and Gadge (2016) [13] in cucumber, Amala and Syriac (2016) [2] in tomato, Bhoutekar *et al.* (2017) [5] in cauliflower and Baby *et al.* (2022) [4] in onion.

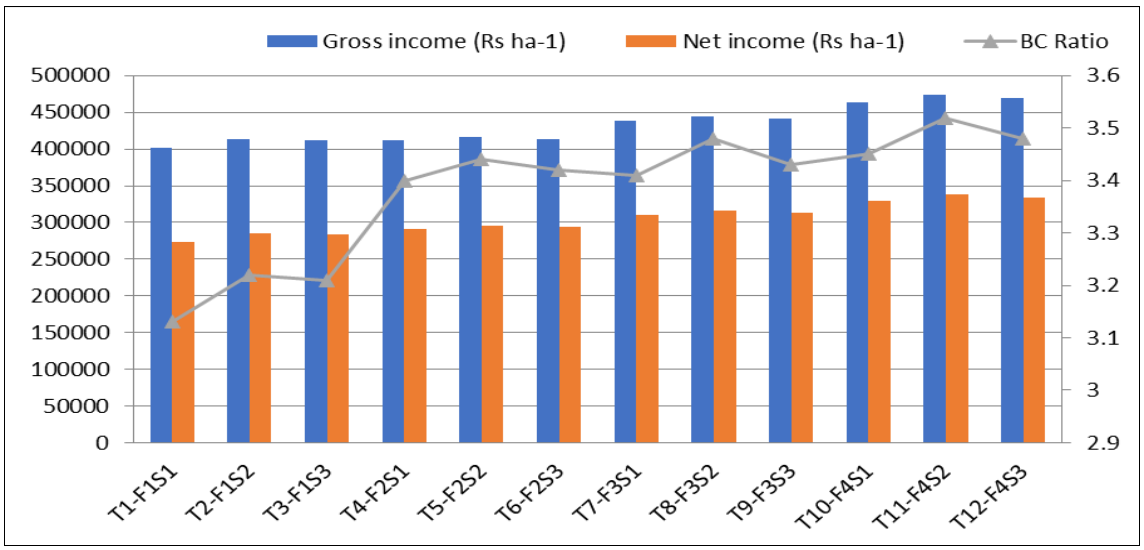
The data indicated that fertigation schedules significantly influenced the curd yield plant^{-1} (g) and curd yield plant^{-1} (q). The data clearly stated that, the fertigation schedule (S_2) recorded maximum curd yield plant^{-1} (g) and curd yield ha^{-1} (q) of broccoli which is (432.27 g, 119.93 q) and similarly fertigation schedule (S_1) recorded the minimum curd yield plant^{-1} (418.88 g, 116.50 q). The higher yield obtained possibly due to better proportion of air- soil-water which was maintained throughout the life periods crop in drip fertigation. Throughout the growth stage of crop water soluble fertilizers provides readily available nutrients to crop which, produces optimum yield. The results were similar agreement with Hari and Devi (2016) [7] in bittergourd, Nikzad *et al.* (2020) [12] in cabbage and Kshirsagar *et al.* (2021) [10] in bittergourd.

3.1 Economics

The data recorded on effect of fertigation levels and schedules on economics of broccoli presented in Table 2. The highest benefit cost ratio (3.52, 3.47) was recorded by the treatment F_4S_2 (125% RDF through fertigation with schedule S_2 – 15% NPK at (Transplanting to plant establishment, 1-10 DAT), 50% NPK at (Curd initiation stage, 11-36 DAT) and 35% NPK at (Curd development stage, 36-60 DAT) which was followed by F_4S_3 (3.48, 3.42). The lowest benefit cost ratio (3.13, 3.10) was recorded by the treatment F_1S_1 (100% RDF through fertigation with schedule S_1 - 10% NPK at (Transplanting to plant establishment, 1-10 DAT),45% NPK at (Curd initiation stage,11-36 DAT and 40% at (Curd development stage, 36 to 60 DAT). The pooled data indicated that, in the middle of the different fertigation levels and schedules, F_4S_2 -125% of RDF with schedule S_2 -15% NPK at (Transplanting to plant establishment, 1-10 DAT), 50% NPK at (Curd initiation stage, 11-36 DAT) and 35% NPK at (Curd development stage, 36-60 DAT) recorded the highest cost of cultivation (135355 Rs.). and it gradually reduced under conventional method of fertilization along with surface irrigation (128182 Rs.) where fertigation is provided with F_1S_1- 100% of RDF with S_1-10% NPK at (Transplanting to plant establishment, 1-10 DAT),45% NPK at (Curd initiation stage,11-36 DAT and 40% at (Curd development stage, 36 to 60 DAT).

Table 2: Effect of different fertigation levels and fertigation schedules on BC ratio of broccoli

	First Location				Second Location				Pooled			
Treatments	**Cost of cultivation (Rs ha-1)**	**Gross income (Rs ha-1)**	**Net income (Rs ha-1)**	**BC Ratio**	**Cost of cultivation (Rs ha-1)**	**Gross income (Rs ha-1)**	**Net income (Rs ha-1)**	**BC Ratio**	**Cost of cultivation (Rs ha-1)**	**Gross income (Rs ha-1)**	**Net income (Rs ha-1)**	**BC Ratio**
T_1-F_1S_1	128185	401800	273614	3.13	128179	398650	270470	3.10	128182	400225	272042	3.12
T_2-F_1S_2	128186	413350	285163	3.22	128184	410200	282015	3.20	128185	411775	283589	3.21
T_3-F_1S_3	128185	411950	283764	3.21	128179	405300	277120	3.16	128182	408625	280442	3.19
T_4-F_2S_1	120732	411600	290867	3.40	120729	409850	289120	3.39	120730	410725	289993	3.39
T_5-F_2S_2	120737	416500	295762	3.44	120735	413350	292614	3.42	120736	414925	294188	3.43
T_6-F_2S_3	120735	414050	293314	3.42	120740	411600	290859	3.40	120737	412825	292086	3.41
T_7-F_3S_1	128311	438200	309888	3.41	128304	437500	309195	3.40	128307	437850	309541	3.41
T_8-F_3S_2	128319	443800	315480	3.48	128318	444150	315831	3.46	128318	443975	315655	3.47
T_9-F_3S_3	128318	441000	312681	3.43	128316	438550	310233	3.42	128317	439775	311457	3.42
T_{10}-F_4S_1	135351	464100	328748	3.45	135350	461650	326299	3.41	135350	462875	327523	3.43
T_{11}-F_4S_2	135357	473900	338542	3.52	135353	469700	334346	3.47	135355	471800	336444	3.49
T_{12}-F_4S_3	135355	469000	333644	3.48	135351	462000	326648	3.42	135353	465500	330146	3.45



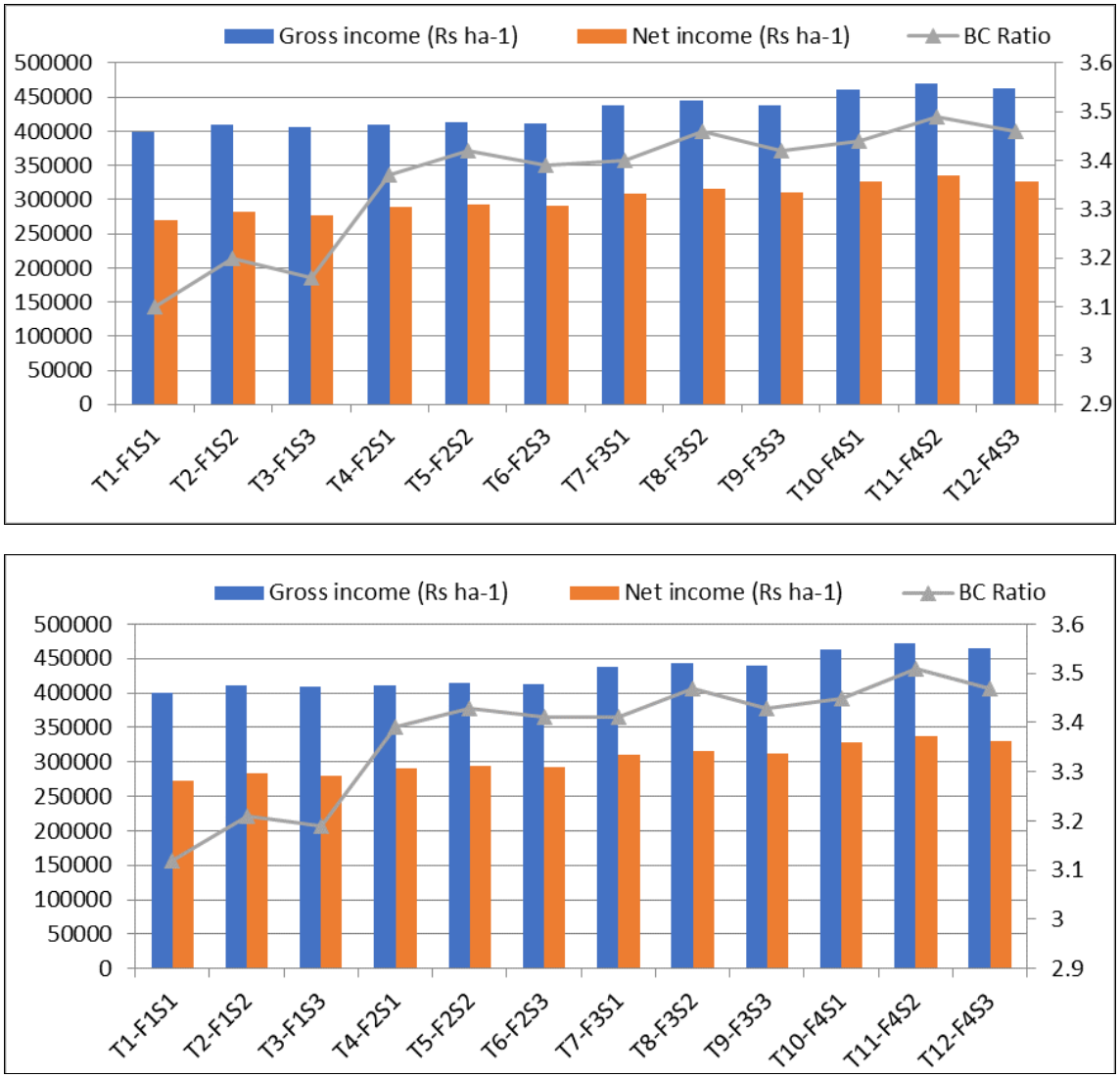


Fig 1: Effect of different fertigation levels and fertigation schedules on BC ratio of broccoli

As a result of this, the extra disbursement of water soluble fertilizers was well recompensed through higher supplementary income maximum net return in broccoli could be guaranteed by enhancing the productiveness by accommodating proven management practices. The present experiment showed that, application of 125% RDF with schedule S_2 secured the highest net income (Fig 1). This helped in the production of higher yield per hectare with maximum cost benefit cost ratio. The similar results were in agreement with the findings by Savitha *et al.* (2010) [17] in onion, Rajaraman and Pugalendhi (2013) [15] in cabbage, Prabhakar *et al.* (2013) [14] in watermelon, Vasu and Reddy (2013) [20] in cabbage, Joshi *et al.* (2015) [8] in okra, Hari and Devi (2016) [7] in bittergourd, Assinpol *et al.* (2017) [3] in brinjal, Agrawal *et al.* (2018) [1] in tomato, Birdar *et al.* (2018) [6] in broccoli, Kale *et al.* (2019) [9] in onion and Murthy *et al.* (2020) [11] in ridge gourd, Verma *et al.* (2020) [21] in cauliflower, Singh *et al* (2022) [19] in cucumber, Rawat *et al.* (2023) [16] in tomato.

Conclusion

This investigation has stated that higher fertigation level enhanced the yield of broccoli over conventional method of fertilization. As far as economics is concerned fertigation 125% of RDF through schedule S_2 15% NPK at (Transplanting to plant establishment, 1-10 DAT), 50% NPK at (Curd initiation stage, 11-36 DAT) and 35% NPK at (Curd development stage, 36-60 DAT) is recommended for maximization of yield and B:C ratio of broccoli at both the location the best with respect to net return (336444 Rs.) and B:C ratio (3.49).

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