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Doubling Farmer Income through Cultivating Headed Broccoli (*Brassica oleracea var. Itilica*) under Different Irrigation Regimes and Water Saving Techniques

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Doubling Farmer Income through application of precious irrigation and water saving techniques in vegetable crops may be possible under change in climatic and water scarcity conditions by proper inclusive adaptation of the results of present field experiment investigation. Significantly higher, net returns and benefit cost ratio Was observed in IR treatment $I_{1.00}$. Total cost of cultivation and benefit cost ratio were significantly higher in IR treatment $I_{0.75}$. The net returns and benefit cost ratio were

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significantly higher in WST treatment M_K and benefit cost ratio were in M_C. The treatment combination $I_{1.00}$ x M_K had given higher returns followed by followed by the treatment $I_{0.75}$ x M_{BP} among all the treatments. However, based on the IWM aspect to overcome the problem of irrigation water scarcity, adaptation and mitigation of changed climate as well as projected future climate change through precision farming, increasing leaf area, decreasing ambient temperature and economic profitability factor i.e. net returns from the cultivation of headed broccoli, the treatment combination $I_{0.75}$ x M_{BP} and $I_{0.50}$ x M_{BP} were observed significantly superior amongst all the treatments.

Keywords: Broccoli; IR; WST; economics; doubling farmer income; BCR.

1. INTRODUCTION

Agriculture is highly vulnerable to seasonal weather variability, to climatic variability and to climate change and the growth, development and yield of crops as well as animal and fishery are depending on the prevailing extreme weather events. The significant change and future projection in Indian climate observing alike pattern of the global climate change. Certainly, cumulative impact of global climate change, increasing trend of temperature and climatic extremes has seen at continental as well as at regional level. In India, increased vulnerability, both locally and regionally, causing reductions in agricultural yields (Bhatta and Aggrawal, 2015; FAO, 2017; Ray, et al. 2019); [1]. Across the Indian region, change in temperature was not found uniform and annual mean temperature both maximum and minimum temperatures showed warming trends of 0.51, 0.72 and 0.27°C per 100 year respectively during the period 1901-2007 (Ray et al., 2019); [1,2]. The minor distraction of earth water cycle or Earth atmosphere are affecting largely on ecosystem and which are utterly disrupt biodiversity/natural world on Earth; ultimately, which are affecting badly on food chain. Armstrong, [3] noted akin statement, across the globe, 44 countries are projected to either extremely high or high water stress level (ratio of water withdrawals to water supply) in 2040 and India is one of them, having a high water stress level country.

Due to increasing global population (10 billian) and Indian (1.67 billian); food grain production need to be increased by 70% by 2050 compared to today for feed to the increase in population (world bank, 2022) and fresh vegetable production needs to be increased in the upcoming years to ensure a healthy diet for everybody (Krishna Bahadur et al., 2018). But now a days decrease in fresh water availability (a major input towards crop production) makes the problem even more challenging. Due to rapid urbanization and industrialization fresh water share to agricultural sector is decreasing day by day, and it's demand in India will be increased by 25% and 40%, the share of irrigation for fresh water will declined to 77.76% and 69.25% respectively by the year 2025 and 2050 [4], (world bank, 2022). Similarly, it was projected that gross per capita water availibilty in India will decline from 1820 m3/yr in 2001 to as low as 1140 m3/yr in 2050 (Ray et al., 2019). Thus, more food need to be produced with less available water resources.

Brocooli is nutritionally very high valuable crop because of its properties of law fat, low in calories with rich energy, high protein, vitameans (B2,C,K) riboflavin, thiamine, niacin and minerals (Iron, magnesium), anti-carcinogenic properties resulting from glucosinolate synthesization in broccoli florets (Erken et al., 2013; Baidya et al., 2017). Recently broccoli is gaining popularity in big cities/metropolitain cities, among rich peoples, but not in sub urban and rural areas due to lack of awareness regarding nutrative value, consumption, recipe and taste etc. Commercial cultivation is still of broccoli on infancy stage because of lack of poor awareness in farming community and non avalibality of cultivation package of practice [5], (Baidya et al., 2017). Recently in India seen that expansion of the area consecrated to broccoli in Maharashtra, West Bengal and Zarkhand states to meet the increased demand of big city markets (Jaybhaye, 2019). Therefore, the Indian farmers have a huge scope, to cultivate brocooli well manner and marketing well to achieving target of 'Doubling Farmer Income' through 'Per Drop More Crop' technology mission by maximizing the productivity of crops and the income of farmers by use of precise water management [6-9].

Thus, along with the irrigation methods and levels, application of water saving techniques (WST) is todays urgent need, which can help to minimize the scarcity of water problem of agriculture sector. WST can reduce the evaporation loss and encourage transpiration and there by enhance the effective utilization of root zone water towards crop production. It happens by creating a barrier between the soil surface and atmosphere [10,11]. Hence, environmental friendly, biodegradable and allied material is used in the present experiment for WST application, viz., hydrogel (M_H), potassium nitrate (KNO_3), black polyethylene, paddy straw mulch (M_{PS}) etc. Hydrogel has holding water during irrigation and relasing as when required to crop; KNO_3 used as a antitranspirant and osmoprotectents; black polyethylene and paddy straw used as a mulch treatment, and mulching minimizes evaporation loss and can influence root zone moisture distribution, which may enhance transpiration (Rust and Turral 3 capter /Rijsberman, 2006); Jaybhaye and Mukherjee, [12]. Under condition of chaning climate, current water scarcity and future water shortage required adaptation and implementation planning. The most common adaptations are on-farm water management, water storage, soil moisture conservation and irrigation responses are provide economic, institutional or ecological benefits and reduce vulnerability (high confidence). Large scale irrigation can also alter local to regional microclimate (high confidence) [2]. ‘Per Drop More Crop’ is new priorites research paradigm on water productivity, hence, in this thematic areas planed and designed present research experiment and worked out economics of broccoli crop under different irrigation regimes and water saving techniques which is described as below under different heads [13-15].

2. MATERIALS AND METHODS

The research experiment was carried out during 2016-17 and 2017-18 (during the period of November to January) in the ‘‘C’ Block Research Farm of Bidhan Chandra Krishi Vishwavidyalaya, Kalyani, West Bengal, (India). Its geocoordinates are: longitude 88^0 31^1 East, latitude 22^0 58^1 North and its altitude is 9.75 m above mean sea level.

An irrigation-based research experiment was carried out to evaluate the yield response of headed broccoli to four seasonal levels of given water that ranged from 25 to 100% of ET_C in a field. To schedule irrigation, daily ETc (AET) was calculated based on the product of daily ET_O (PET) times a crop coefficient. To calculate ET_O, the FAO-56 Penman–Monteith (FAO-56 PM) equation was used (Allen et al., 1998a). The agrometeorological observatory is located less than 500 m away from the experimental broccoli field (AICRP on Agrometeorology, Kalyani, B.C.K.V., Nadia) and from which climatic data was taken. Crop coefficient (Kc) values used for calculation of AET were: 0.7 during the rosette development (RSD) period; 1.05 during heading (HD) and 0.95 during the harvesting (HT) growth stage (Allen et al., 1998b; Lopez-Urrea et al., 2009). The 4 irrigation regimes (IR) main treatments distinct in this experiment were: (i) IW/CAET = 1.0 ($I_{1.0}$), (ii) IW/ CAET = 0.75 ($I_{0.75}$), (iii) IW/ CAET = 0.50 ($I_{0.50}$) and (iv) IW/ CAET = 0.25 ($I_{0.25}$) and 5 water saving techniques (WST) as sub treatments were: (i) no water saving techniques application (M_C – controlled), (ii) hydrogel (M_H) @ 50 kg/ha, (iii) potassium nitrate (KNO_3) (M_K) @1.5% (iv) black polyethylene mulch (M_{BP}) @ 30 µ thickness and (v) paddy straw mulch (M_{PS}) @ 5 t/ha applied in sub-plots. The depth of irrigation on each occasion was 25 mm. After attainment 25, 33.3, 50 and 100 mm cumulative actual evapotranspiration (CAET) value, irrigations were given to $I_{1.00}$, $I_{0.75}$, $I_{0.50}$ and $I_{0.25}$ treatment, respectively. Irrigation was applied initially to the plant by a water can for initial establishment, which accounts in total 4.0 mm to each plot, followed by direct irrigation to each plot through a discharge pipe, for each plot an amount of 219.0 litres of water were applied during irrigation every time. During both the experimental years, mulching was imposed at the time of transplanting, Pusa hydrogel was applied the next day after transplanting at the root zone (10 cm soil depth) of each plant by ring method under the experimentations (Mandal et al., 2015) and applied weekly foliar spray of potassium nitrate. While, special care has been taken to keep the plant population (40,000 plants ha^{-1}) during the growing season.

The design of field experiment was a split plot design with three replicated plots per treatment and each plot was comprised of a raised bed (100 cm) and furrow (30 cm) system. In each ridge, two rows of broccoli crop were transplanted. In the case of mulch a strip of 15 cm wide area at the middle part of the furrow remains uncovered for easy entry of irrigation and rainfall water respectively. Irrigation was applied in the furrows and water seeped into the root zone of the crop in a raised bed. Each plot size was 2.5 m x 3.5 m (8.75 m^2) surrounded by 1.5 m wide buffer strip to control lateral seepage of water in-between connecting plots. The rotary power tiller with 100 mm tillage depth was used for land preparation and by two cross-wise passes land was prepared, followed by surface levelling was made with a wooden leveler. Twenty-five day old seedlings of broccoli (Cv. Centauro) were transplanted at 50 cm x 50 cm spacing on 9^{th} and 6^{th} November of 2016-17 and 2017-18 respectively. There were 4 plants m^{-2}, which is followed by the broccoli growers of the region. The fertilizers were given to the experimental plots through soil application before transplanting, during land preparation; prior to application of farm yard manure (@ 15.0 t ha^{-1}) it was properly mixed with the soil. Fertilizers were applied @ 180 kg N trough urea, 80 kg P_2O_5 through SSP and 80.0 kg K_2O through MOP per hectare according to Thapa and Rai (2012); Tamang et al. (2017). Complete doses of phosphate and potassium were given as basal; whereas, nitrogen was given in three splits, 50 % as basal and 25 % at 30 DAT + 25 % at 50 DAT. Boron as a micronutrient @ 15.0 g/lit in the form of borax (20 %) was applied as a foliar spray on the plant at 30 and 50 DAT.

Broccoli was manual harvested four times, on 10,13,16 and 19 January 2017; 15,17,20 and 23 January 2018 plants with fully matured net head were harvested starting from 63 and 66 days after transplanting during the year 2017 and 2018 respectively. Most of the treatments reach marketable maturity 72-78 days after transplanting. A total of 4 harvestings at 2-3 day intervals were carried out. From each harvest and each treatment, the well-shaped net heads (head with 2-3 jacket leaf) which were green in color and appeared marketable (head with a portion of 5-10 cm of the main stem) were harvested and weighed (g $plant^{-1}$). The cumulated marketable net head fresh weight i.e, net head yield (NHY) was calculated and represented as t ha^{-1}.

Entire collected data was taken for analysis of statistical differences among irrigation regims and WST, and their interaction on net head yield was tested by using SAS (ver. 9.3, SAS, Inc., Cary, NC) computer package program. The mean values were evaluated and analysis of variance was performed by the ‘F’ (variance ratio) test. The means were compared using the critical difference (CD) test at 5% significance level.

Economic analysis in order to evaluate the most profitable treatment, economic analysis of treatments combination (Table-3) was worked out in terms of net returns and benefit cost ratio (BCR). Economic evaluation of different treatment combinations was done through partial budgeting as suggested by Perrins et al. (1979); Dhotra et al. [16]. Net return were calculatedby deducing the total cost of cultivation from the gross return. Gross return and variable cost (total cost of cultivation) were calculated considering the rates of harvested fresh net head brocooli of Rs. 20000 per ton (2016-17) and Rs. 25000 per ton (2017-18). While, benefit cost ratio (BCR) was calculated using the following formula:

$$\mathrm{BCR} = \frac{\text{Gross Return}}{\text{Total variable cost}}$$

3. RESULTS AND DISCUSSION

The market survey of price for brocooli purchase was made physically by visiting to vegetable market, vegetable sellers, a roadside vegetable vendor, and visit to super market/super bazar (viz., Big Bazaar, More and D Mart) of Kalyani (West Bengal) and near by towns of Kalyani (viz., Kanchrapara and Jaguli of Nadia 24 Pargana district, Kolkatta), as well as visit to Pune and Ahmamaddnagar cities (Mahrashtra). And it also done by digital market as well as by e-commerce through online stores (viz., Amazon and Flipcart etc.). While, in addition to this, adaptation for consumption survey was done in Kalyani and near to Kalyani towns from differ socieconmic families. In the local vegetable market, vegetable sellers and a roadside vegetable vendor average price observed Rs. 15-60 per kg and Rs. 100-200 per kg in big cities as well as in online stores, digital market (data is not preented). It was also found very poor awareness in sub-regional town and rural area regarding daily use, recipe, taste, nutritional values, keeping quality and non willing to change in consumption instead of cauliflower. And ultimately it affected on market rate, due to which local (rural places) price was found lower than urban places (Baidya et al., 2017).

The actual costs were worked out for control treatments (Table 2a and 2b) which include production cost (nursery preparation, seed, field preparation, labour charges, fertilizer, insecticide/ pesticide, irrigation vharges, miscellaneous etc.) and marketing cost. The actual costs of all other IR and WST treatments which includes control treatments cost plus application of WST treatments material and labour chargs (Table 2a and 2b). Gross returns of all the treatments were varied from Rs. 364725 in $I_{0.75}$ x M_{BP} (IW/ CAET = 0.75 + black polyethylene mulch) treatment to Rs. 181350 in $I_{0.25}$ x M_C treatment (IW/ CAET =

0.25 + no water saving techniques application) treatment (Table 3). Which is also reported by others in cabbage [17], cauliflower [18] and Saha et al., [19]. The total cost of cultivation was ranged Rs. 163545 to Rs. 100362 including marketing cost but in B:C ratio we were include without marketing cost. Our experiment results revealed that total cost of cultivation per hectare was observed to be highest (Rs. 163545) in $I_{1.00}$ x M_H (IW/ CAET = 1.00 + hydrogel) treatment, whereas it was found to be lowest (Rs 100362) in $I_{0.25}$ x M_C. Cost and return analysis of broccoli cultivation produced in different treatments of IR and WST (Table 3) shown that net returns were highest (Rs. 251236) in treatment $I_{1.00}$ x M_K (IW/ CAET = 1.00 + potassium nitrate-KNO_3) and it was found on par (Rs. 231775) with $I_{0.75}$ x M_{BP}, whereas, it was found to be lowest (Rs. 25759) in treatment $I_{0.25}$ x M_H (IW/ CAET = 0.25 + hydrogel).

Though the highest net head yield was recorded under $I_{0.75}$ x M_{BP} treatment (16.21 t ha^{-1}) (Table 1), the highest net returns was observed under $I_{1.00}$ x M_K treatment and it was more by 8%. It is because of yield under $I_{1.00}$ x M_K (15.99 t ha^{-1}) was found on par and low total cost of cultivation (18%) as well as minor difference in gross return (1.4%) in between these two treatments. Although the total cost of cultivation and gross return was recorded lowest under $I_{0.25}$ x M_C treatment, the lowest net return was noted under $I_{0.25}$ x M_H treatment, it is because of negligibale difference in net head yield and in gross return (3%), more difference in total cost of cultivation (60%) within $I_{0.25}$ x M_H and $I_{0.25}$ x M_C treatment were recorded.

On similar line benefit cost ratio (BCR) was recorded and it ranged from 1.16 in $I_{0.25}$ x M_H to 3.31 in $I_{1.00}$ x M_K. Non-significant and minor differences (4.7 %) in between highest value (3.31) of $I_{1.00}$ x M_K and 3.16 of $I_{1.00}$ x M_C (IW/ CAET = 1.00 + no water saving techniques application) treatments were recorded. It is because of the reasons stated above under net return and gross return.

Similar results were obtained by [20] who found that application of 30 ppm GA3 gave highest net realization (Rs 167164). Results are also in consonance with the findings of Verma [21] who recorded the highest net realization (Rs 23460 per hectare) with a cost benefit ratio of 1: 7.53 as compared to control.

Table 1a. Effect of different irrigation regimes and on net head fresh yield (t ha^{-1}) of broccoli during 2016-17 and 2017-18

Irrigation Regimes	2016-17	2017-18	Pooled	Water Saving Techniques	2016-17	2017-18	Pooled
$I_{1.00}$	17.19	13.15	15.17	M_C	13.06	10.08	11.57
$I_{0.75}$	16.58	12.02	14.30	M_H	14.11	10.56	12.34
$I_{0.50}$	14.45	9.99	12.22	M_K	14.14	11.74	12.94
$I_{0.25}$	11.91	7.74	9.82	M_{BP}	18.49	12.40	15.45
SE (m) $\pm$	0.45	0.21	0.43	M_{PS}	15.35	8.85	12.10
CD (P=0.05)	1.56	0.74	1.33	SE (m) $\pm$	0.57	0.23	0.54
				CD (P=0.05)	1.66	0.66	1.51

M_C: no water saving techniques (Control); M_H: hydrogel application; M_K: KNO_3 application; M_{BP}: black polyethylene mulch; M_{PS}: paddy straw mulch

Table 1b. Interaction effect of different irrigation regimes and water saving techniques on net head yield (t ha^{-1}) of broccoli during 2017and 2017-18

IR x WS	Net head yield (t ha^{-1})		
	2016-17	2017-18	Pooled
$I_{1.00}$ x M_C	16.50	12.30	14.40
$I_{1.00}$ x M_H	18.21	12.71	15.46
$I_{1.00}$ x M_K	16.70	15.27	15.99
$I_{1.00}$ x M_{BP}	17.58	14.25	15.91
$I_{1.00}$ x M_{PS}	16.97	11.25	14.11
$I_{0.75}$ x M_C	15.58	12.08	13.83
$I_{0.75}$ x M_H	16.43	11.82	14.12
$I_{0.75}$ x M_K	15.95	13.44	14.70
$I_{0.75}$ x M_{BP}	18.67	13.75	16.21
$I_{0.75}$ x M_{PS}	16.26	9.03	12.64
$I_{0.50}$ x M_C	11.33	8.70	10.01
$I_{0.50}$ x M_H	13.67	9.25	11.46
$I_{0.50}$ x M_K	12.75	11.29	12.02
$I_{0.50}$ x M_{BP}	20.05	12.22	16.14
$I_{0.50}$ x M_{PS}	14.43	8.50	11.46
$I_{0.25}$ x M_C	8.84	7.27	8.06
$I_{0.25}$ x M_H	8.14	8.48	8.31
$I_{0.25}$ x M_K	11.17	6.92	9.04
$I_{0.25}$ x M_{BP}	17.66	9.40	13.53
$I_{0.25}$ x M_{PS}	13.73	6.62	10.17
SE (m) $\pm$	1.15	0.46	1.07
CD (P=0.05)	3.31	NS	NS
SE (m) $\pm$	1.12	0.46	1.05
CD (P=0.05)	3.34	NS	NS
GM	15.03	10.73	12.88
CV (%)	13.25	7.41	11.77

M_{C-} ; no water saving techniques (Control); M_H - : hydrogel application; M_{K-} : KNO_3 application; $M_{BP-:}$ black polyethylene mulch; M_{PS-} :paddy straw mulch

Table 2a. Cost of cultivation of broccoli under different treatment (2016 – 17)

Sr. No.	Operation			Cost (Rs.)		Mean			Cost (Rs.)					Cost (Rs.)			Mean
A.	Production cost	$I_{1.00}$	$I_{0.75}$	$I_{0.50}$	$I_{0.25}$		$I_{1.00}$	$I_{0.75}$	$I_{0.50}$	$I_{0.25}$	Mean	M_C	M_H	M_K	M_{BP}	M_{PS}	
I	Labor for nursery management:																
	Nursery bed preparation for 1 hectare land, seed treatment, watering, plant protection measures etc.	6 bed	6	6	6	6	1710	1710	1710	1710	1710	1710	1710	1710	1710	1710	1710
II	Higher labor for preparatory tillage, transplanting, intercultural operations and allied activities:																
i)	Field preparation by tractor	2 times					9750	9750	9750	9750	9750	9750	9750	9750	9750	9750	9750
ii)	Hired labour for :																
A)	preparatory tillage (ridges making and layout) FYM/ Fertilizer application	20					5700	5700	5700	5700	5700	5700	5700	5700	5700	5700	5700
B)	Transplanting	18					5130	5130	5130	5130	5130	5130	5130	5130	5130	5130	5130
C)	Hoeing and weeding	40					11400	11400	11400	11400	11400	11400	11400	11400	11400	11400	11400
D)	Fertilizer application, boron spray	5					7125	7125	7125	7125	7125	7125	7125	7125	7125	7125	7125
E)	Plant protection measures	25					1425	1425	1425	1425	1425	1425	1425	1425	1425	1425	1425
F)	Irrigation:																
a)	For pre-transplanting	2					570	570	570	570	570	570	570	570	570	570	570
b)	After transplanting for standings in field (2-3 days interval watering by can)	9					2565	2565	2565	2565	2565	2565	2565	2565	2565	2565	2565
c)	For throughout crop going period (Through flood irrigation method)	12	8	6	4	30	3420	2280	1710	1140	2137.5	8550	8550	8550	8550	8550	8550
G)	For treatment application used labour																
a)	MC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
b)	MH	3	3	3	3	3	855	855	855	855	855		855				855
c)	MK	10	10	10	10	10	2850	2850	2850	2850	2850			2850			2850
d)	MBP	5	5	5	5	5	1425	1425	1425	1425	1425				1425		1425
e)	MPS	6	6	6	6	6	1710	1710	1710	1710	1710					1710	1710
H)	Harvesting (3 harvest taken)	20										5700	5700	5700	5700	5700	5700
I)	Irrigation charges :3 HP electric pump; 0.5 unit; 1 unit @ Rs. 4.0																
a)	Pre transplanting	0										0	0	0	0	0	0
b)	Throughout crop going period:	18 unit	12	9	6	18	72	48	36	24	45	180	180	180	180	180	180
J)	Material:(Agricultural inputs)																
i)	Nursery Management agricultural inputs:																
A)	Verme compost	6 kg					240	240	240	240	240	240	240	240	240	240	240
B)	Seed	400 gm					1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600
C)	Fungicide for seed treatment (Ridomil/Mancozeb)						300	300	300	300	300	300	300	300	300	300	300
D)	Plastic tunnel (made from Bamboo structure) for protection of seedlings from aberrant weather (viz., fog, unseasonal rain, hailstorm, heavy winds, high temperature etc .	6 No's.					900	900	900	900	900	900	900	900	900	900	900
ii)	Throughout experiment agricultural inputs:																
A)	Treatment application inputs:																
a)	MC	0	0	0	0	0	0	0	0	0	0	0					0
b)	MH	60000					60000	60000	60000	60000	60000		60000				60000
c)	MK	3000					3000	3000	3000	3000	3000			3000			3000
d)	MBP	30000					30000	30000	30000	30000	30000				30000		30000
e)	MPS	20000					20000	20000	20000	20000	20000					20000	20000
B)	Plant protection: At the time of Transplanting (Fungicide for seedling treatment) and for drenching (Ridomil/ Mancozeb 75 % Wp etc.) and Insecticides (Dursban/Chloropiriphos etc.)	1410					1410	1410	1410	1410	1410	1410	1410	1410	1410	1410	1410
C)	Fertilizer:	20 t					20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000
D)	Organic (FYM) @20 t/ha																
E)	Chemical (N 180 kg through urea; P 80 kg through SSP; K-60 kg through Potassium 50 %& Chloride 16 %) per hector						6525	6525	6525	6525	6525	6525	6525	6525	6525	6525	6525
F)	Boron (Micronutrient foliar spray)	3 time					2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500
I)	Miscellaneous expenditure						5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000
	Total Cost (A.)						207182	206018	205436	204854	205873	98280	159135	104130	129705	119990	122248
B.																	
i)	Transport cost						5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000
ii)	Packing Cartoon bag						2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
	Total Cost (B.)						7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000
	Total cost (A. + B.)						214182	213018	212436	211854	212872.5	105280	166135	111130	136705	126990	129248

Table 2b. COST of cultivation of broccoli under different irrigation regimes and water saving techniques (2017-18)

Sr. No.	Operation	Cost (Rs.)				Mean	Cost (Rs.)					Cost (Rs.)					Mean
A.	Production cost	$I_{1.0}$	$I_{0.75}$	$I_{0.50}$	$I_{0.25}$		$I_{1.0}$	$I_{0.75}$	$I_{0.50}$	$I_{0.25}$	Mean	M_C	M_H	M_K	M_{BP}	M_{PS}	
I	Labor for nursery management:																
	Nursery bed preparation for 1 hectare land, seed treatment, watering, plant protection measures etc.	6 bed	6	6	6	6	1710	1710	1710	1710	1710	1710	1710	1710	1710	1710	1710
II	Higher labor for preparatory tillage, transplanting, intercultural operations and allied activities:																
i)	Field preparation by tractor	2 times					9750	9750	9750	9750	9750	9750	9750	9750	9750	9750	9750
ii)	Hired labour for :																
A)	preparatory tillage (ridges making and layout) FYM/ Fertilizer application	20					5700	5700	5700	5700	5700	5700	5700	5700	5700	5700	5700
B)	Transplanting	21					5985	5985	5985	5985	5985	5985	5985	5985	5985	5985	5985
C)	Hoeing and weeding	45					12825	12825	12825	12825	12825	12825	12825	12825	12825	12825	12825
D)	Fertilizer application, boron spray	5					8550	8550	8550	8550	8550	8550	8550	8550	8550	8550	8550
E)	Plant protection measures	30					1425	1425	1425	1425	1425	1425	1425	1425	1425	1425	1425
F)	Irrigation:																
a)	For pre-transplanting	2					570	570	570	570	570	570	570	570	570	570	570
b)	After transplanting for standings in field (2-3 days interval watering by can)	9					2565	2565	2565	2565	2565	2565	2565	2565	2565	2565	2565
c)	For throughout crop going period (Through flood irrigation method)	12	8	6	4	30	3420	2280	1710	1140	2137.5	8550	8550	8550	8550	8550	8550
G)	For treatment application used labour																
a)	M_C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
b)	M_H	3	3	3	3	3	855	855	855	855	855		855				855
c)	M_K	10	10	10	10	10	2850	2850	2850	2850	2850			2850			2850
d)	M_{BP}	5	5	5	5	5	1425	1425	1425	1425	1425				1425		1425
e)	M_{PS}	6	6	6	6	6	1710	1710	1710	1710	1710					1710	1710
H)	Harvesting (3 harvest taken)	20										5700	5700	5700	5700	5700	5700
I)	Irrigation charges :3 HP electric pump; 0.5 unit; 1 unit @ Rs. 4.0																
a)	Pre transplanting	0										0	0	0	0	0	0
b)	Throughout crop going period:	18 unit	12	9	6	18	72	48	36	24	45	180	180	180	180	180	180
J)	Material:(Agricultural inputs)																
i)	Nursery Management agricultural inputs:																
A)	Verme compost	6 kg					240	240	240	240	240	240	240	240	240	240	240
B)	Seed	400gm					1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600
C)	Fungicide for seed treatment (Ridomil/Mancozeb)		300					300	300	300	300	300	300	300	300	300	300
D)	Plastic tunnel (made from Bamboo structure) for protection of seedlings from aberrant weather (viz., fog, unseasonal rain, hailstorm, heavy winds, high temperature etc .	6 No's.					900	900	900	900	900	900	900	900	900	900	900
ii)	Throughout experiment agricultural inputs:																
A)	Treatment application inputs:																
a)	M_C	0	0	0	0	0	0	0	0	0	0	0					0
b)	M_H	60000					60000	60000	60000	60000	60000		60000				60000
c)	M_K	3000					3000	3000	3000	3000	3000			3000			3000
d)	M_{BP}	30000					30000	30000	30000	30000	30000				30000		30000
e)	M_{PS}	20000					20000	20000	20000	20000	20000					20000	20000
B)	Plant protection: At the time of Transplanting (Fungicide for seedling treatment) and for drenching (Ridomil/ Mancozeb 75 % Wp etc.) and Insecticides (Dursban/Chloropiriphos etc.)	3000					3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
C)	Fertilizer:	20 t					20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000
D)	Organic (FYM) @20 t/ha																
E)	Chemical (N 180 kg through urea; P 80 kg through SSP; K-60 kg through Potassiam 50 %& Chloride 16 %) per hector		6525					6525	6525	6525	6525	6525	6525	6525	6525	6525	6525
F)	Boron (Micronutrient foliar spray)	3 time					2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500
I)	Miscellaneous expenditure			5000				5000	5000	5000	5000	5000	5000	5000	5000	5000	5000
	Total Cost (A.)						**212477**	**211313**	**210731**	**210149**	**211167.5**	**103575**	**164430**	**109425**	**135000**	**125285**	**127543**
B.																	
i)	Transport cost						5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000
ii)	Packing Cartoon bag						2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
	Total Cost (B.)						**7000**	**7000**	**7000**	**7000**	**7000**	**7000**	**7000**	**7000**	**7000**	**7000**	**7000**
	Total cost (A. + B.)						**219477**	**218313**	**217731**	**217149**	**218167.5**	**110575**	**171430**	**116425**	**142000**	**132285**	**134543**

Table 3. Economics of broccoli as influenced by different irrigation regimes and water saving Techniques

Sr. No.	IRXWS	Total cost of cultivation (Rs / ha)			Gross return (Rs/ ha)			Net return (Rs/ ha)			B: C Ratio		
		2016-17	2017-18	Average	2016-17	2017-18	Average	2016-17	2017-18	Average	2016-17	2017-18	Average
1	$I_{1.00}$ x M_C	100042	105337	102690	330000	307500	324000	229958	202163	221311	3.30	2.92	3.16
2	$I_{1.00}$ x M_H	160897	166192	163545	364200	317750	347850	203303	151558	184306	2.26	1.91	2.13
3	$I_{1.00}$ x M_K	105892	111187	108540	334000	381750	359775	228108	270563	251236	3.15	3.43	3.31
4	$I_{1.00}$ x M_{BP}	131467	136762	134115	351600	356250	357975	220133	219488	223861	2.67	2.60	2.67
5	$I_{1.00}$ x M_{PS}	121752	127047	124400	339400	281250	317475	217648	154203	193076	2.79	2.21	2.55
6	$I_{0.75}$ x M_C	98878	104173	101526	311600	302000	311175	212722	197827	209650	3.15	2.90	3.06
7	$I_{0.75}$ x M_H	159733	165028	162381	328600	295500	317700	168867	130472	155320	2.06	1.79	1.96
8	$I_{0.75}$ x M_K	104728	110023	107376	319000	336000	330750	214272	225977	223375	3.05	3.05	3.08
9	$I_{0.75}$ x M_{BP}	130303	135598	132951	373400	343750	364725	243097	208152	231775	2.87	2.54	2.74
10	$I_{0.75}$ x M_{PS}	120588	125883	123236	325200	225750	284400	204612	99867	161165	2.70	1.79	2.31
11	$I_{0.50}$ x M_C	98296	103591	100944	226600	217500	225225	128304	113909	124282	2.31	2.10	2.23
12	$I_{0.50}$ x M_H	159151	164446	161799	273400	231250	257850	114249	66804	96052	1.72	1.41	1.59
13	$I_{0.50}$ x M_K	104146	109441	106794	255000	282250	270450	150854	172809	163657	2.45	2.58	2.53
14	$I_{0.50}$ x M_{BP}	129721	135016	132369	401000	305500	363150	271279	170484	230782	3.09	2.26	2.74
15	$I_{0.50}$ x M_{PS}	120006	125301	122654	288600	212500	257850	168594	87199	135197	2.40	1.70	2.10
16	$I_{0.25}$ x M_C	97714	103009	100362	176800	181750	181350	79086	78741	80989	1.81	1.76	1.81
17	$I_{0.25}$ x M_H	158569	163864	161217	162800	212000	186975	4231	48136	25759	1.03	1.29	1.16
18	$I_{0.25}$ x M_K	103564	108859	106212	223400	173000	203400	119836	64141	97189	2.16	1.59	1.92
19	$I_{0.25}$ x M_{BP}	129139	134434	131787	353200	235000	304425	224061	100566	172639	2.74	1.75	2.31
20	$I_{0.25}$ x M_{PS}	119424	124719	122072	274600	165500	228825	155176	40781	106754	2.30	1.33	1.87
GM		122701	127996	125348	300600	268250	289800	177900	140255	164452	2.45	2.10	2.31

Table 4. Economics of broccoli as influenced by different irrigation regimes and water saving Techniques

Sr. No.	IRXWS	Total cost of cultivation (Rs / ha)			Gross return (Rs/ ha)			Net return (Rs/ ha)			B: C Ratio		
		2016-17	2017-18	Average	2016-17	2017-18	Average	2016-17	2017-18	Average	2016-17	2017-18	Average
1	$I_{1.00}$ x M_K	105892	111187	108540	334000	381750	359775	228108	270563	251236	3.15	3.43	3.31
2	$I_{0.75}$ x MBP	130303	135598	132951	373400	343750	364725	243097	208152	231775	2.87	2.54	2.74
3	$I_{0.50}$ x MBP	129721	135016	132369	401000	305500	363150	271279	170484	230782	3.09	2.26	2.74

4. CONCLUSION

The total cost of cultivation was ranged from Rs 163545 to Rs 100362 including marketing cost but in BCR we were include without marketing cost. The total cost of cultivation per hectare was observed to be 38% (Rs 163545) higher in $I_{1.00}$ x M_H treatment, compared to lowest treatment of $I_{0.25}$ x M_C (Rs 100362). Gross returns of all the treatments were varied from Rs 364725 in $I_{0.75}$ x M_{BP} treatment to Rs 181350 in $I_{0.25}$ x M_C treatment and difference between highest and lowest gross return recorded 50%. Net returns were recorded highest in treatment $I_{1.00}$ x M_K (Rs 251236) and it was found to be lowest by 90 % (Rs. 25759) in treatment $I_{0.25}$ x M_H. The BCR ranged from highest (3.31) in $I_{1.00}$ x M_H to lowest (1.16) in $I_{0.25}$ x M_H and difference within these treatments was observed 65%.

Based on the net returns and BCR study and obtained results may be concluded that application of irrigation regimes (IR) and water saving techniques (WST) $I_{1.00}$ x M_K treatment (IW/ CAET = 1.00 + potassium nitrate) was superior among all other treatments. Followed by application of IR and WST $I_{0.75}$ x MBP as well as $I_{0.75}$ x MBP treatment and $I_{1.00}$ x M_C was best among all other treatments. The application of irrigation regims $I_{0.25}$, and WST M_C and M_H treatment (i.e. $I_{0.25}$ x M_C and $I_{0.25}$ x M_H treatment) was poor among all other treatments.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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