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Economic feasibility of tomato (*Solanum lycopersicum*) production under protected and unprotected environment

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ABSTRACT

Tomato (*Solanum lycopersicum* L.) is a high-value crop that is in high demand globally. The present study was carried out at G B Pant University of Agriculture and Technology (GBPUAT), Pantnagar, Uttarakhand during 2016–18 with the objective to explore the economic feasibility of tomato production under controlled and uncontrolled environments. The present study examines the costs and returns associated with the production of tomatoes in greenhouses and open fields, including the initial investment, operational costs, and revenue generated. The study found that greenhouse tomato production was more expensive, with a higher initial investment and operational costs, but generated higher yields and returns per unit area. On the other hand, open-field tomato production had lower initial investment and operational costs but had lower yields and returns per unit area. Overall, tomato production can be economically feasible under both controlled and uncontrolled environments, but the decision to use either method should be based on the specific conditions of each farm and the market demand for the product.

Keywords: Open environment, Polyhouse, Sensitive analysis, Tomato crop

Tomato (*Solanum lycopersicum* L.) is a major vegetable crop that has achieved tremendous popularity in the polyhouse over the last century (Boulard 2017). Tomatoes, besides being tasty, are useful for maintaining good health due to ample source of vitamin A and C. Cooked tomatoes and its products are the best source of lycopene, which is a powerful antioxidant and helps in preventing the development of cancer. Hence, the crop is gaining importance in developing and developed countries. Efforts are being made to develop the quantity and quality of produce by adapting controlled environment, as the yield and quality are poor in open climate due to low winter temperatures and frost attack.

Prevailing low temperature and frost injury during winter season are limiting factor for successful cultivation of tomato under the northern, north-eastern and North East Himalayan (NEH) agro-climatic regions. It is difficult to grow this vegetable under open conditions during November–February because of adverse effects of low temperature on overall morphological growth and fruit setting (Allen *et al.* 2007). Tomatoes require a high water potential for optimal vegetative and reproductive development. Not only do microclimate parameters affect the crop water requirement, but also it depends very much upon crop variety, season and the method of tomato cultivation.

Polyhouse cultivation using micro-irrigation is a steadily growing agricultural sector worldwide (Mahajan *et al.* 2006, Lohano and Mari 2015, Malhotra 2017). The utilization of polyhouses, mainly for cultivation of vegetables and ornamental, is undergoing transformation for modernization that allows yield improvement (Thompson *et al.* 2007). Polyhouses may range from low cost such as plastic polyhouses to more sophisticated polyhouses, for example, the glass and controlled polyhouses (Tiwari 2003). This type of modern agriculture has many advantages especially for reducing the climatic hazard. Both methods have their advantages and disadvantages, and farmers must choose the best method depending on various factors such as climate, location, cost, and market demand. In this article, we will explore the production of tomatoes under both greenhouse and open environment conditions, highlighting their benefits.

MATERIALS AND METHODS

The present study was carried out at the research farm of G B Pant University of Agriculture and Technology (GBPUAT), Pantnagar (29.0210°N, 79.4897° E and 243.83 m amsl), Uttarakhand during 2016–18 with the objective to explore the economic feasibility of tomato production under controlled and uncontrolled environments in a single-span polyhouse. The study area comes under climatic zone of western Himalayan region and is located in the Shivalik

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foothills of the Himalayas and represents the Tarai regions of Uttarakhand.

Experimental field design: The experimental site of an area 100 m^2 and 60 m^2 respectively were provided for polyhouse and open field crops during 2016–18. Area under polyhouse and open field were divided into 18 and 9 plots respectively of size 3 m × 1 m. The experiment was laid out in randomized block design having 6 treatments for polyhouse comprising drip irrigation on varied rates of evapotranspiration (ET_c) replenishment with and without linear low-density polyethylene (LLDPE) plastic mulch combinations. The treatments consist of T_1, 100% of ET_c with plastic mulch; T_2, 100% of ET_c without plastic mulch; T_3, 75% of ET_c with plastic mulch; T_4, 75% of ET_c without plastic mulch; T_5, 50% of ET_c with plastic mulch and; T_6, 50% of ET_c without plastic mulch and included 3 treatments for open environment namely T_7, 100% of ET_c without plastic mulch; T_8, 75% of ET_c without plastic mulch and; T_9, 50% of ET_c without plastic mulch replicated thrice. A gap of 0.5 m between each plot and 0.5 m path was left in center of the polyhouse for main line. The drip irrigation systems were installed with the mainline with a pressure rating up to 4 kg/cm^2. The drip tapes of diameter 20 mm having emission points at 20 cm spacing with flow rate of 1.1 litre/h were laid parallel between the two rows of crop. The rate of application of water at different level was maintained by operating the valve at the inlet of each lateral. The irrigation scheduling was done on the basis of crop evapotranspiration estimation using Class A Pan Evaporimeter data, installed in polyhouse and open field, respectively. Daily pan evaporation readings were recorded for the determination of crop evapotranspiration.

Estimation of crop evapotranspiration (ET_c): Crop evapotranspiration under standard conditions is defined as the evapotranspiration from disease free, well fertilized crops, grown in large fields, under optimum field conditions and achieving full production under the given climatic conditions. The crop evapotranspiration differs distinctly from the reference evapotranspiration (ET_0) as the ground cover, canopy properties and aero dynamic resistance of the crop are different from the grass (Allen *et al.* 1994). The effects of characteristics that distinguish field crops from grass are integrated into the crop coefficient (K_c). In the crop coefficient approach, crop evapotranspiration was calculated by multiplying ET_0 by K_c. The daily irrigation water requirement for the vegetable crops was estimated as:

$$WR = ET_o \times K_c \times W_p \times A \quad (1)$$

where, WR, Crop water requirement (L/d); ET_o, Reference evapotranspiration (mm/day); K_c, Crop coefficient; W_p, Wetting fraction (taken as 0.90 for close-growing crops) and; A, Plant area, m [i.e. spacing between rows, m (×) spacing between plants, m]. The crop coefficients, K_c, were used based on the FAO-56 curve methods. The crop coefficient, values varies with the type of crop, its growing stage, growing season and the prevailing weather conditions. The shape of the curve represents the changes in the vegetation and ground cover during plant development and maturation that affect the ET_c/ET_0 ratio. The valve of K_c taken from FAO Irrigation and Drainage Paper No. 56 for the crop.

Drip irrigation scheduling of tomato crop: The volume of water applied using drip irrigation system was estimated with the following relationship as given in INCID (1994):

$$V = \sum (E_p \times K_C \times K_p \times S_p \times S_r \times WP - ER) \quad (2)$$

where, V, Total amount of water applied (litre/day/plant); E_p, Pan Evaporation (mm); K_c, Crop coefficient; K_p, Pan coefficient; S_p, Plant to plant spacing (m); S_r, Row-to-row spacing (m); WP, Percentage wetted area (90%) and; ER, Effective rainfall (mm). The effective rainfall (ER) was calculated on monthly basis based on USDA, S.C.S method (United States Department of Agriculture, Soil Conservation Service) as:

$$ER = Pt\left[\frac{125 - 0.2 \times Pt}{125}\right] \text{ for } P_t < 250 \text{ mm} \quad (3)$$

$$ER = 125 + 0.1 \times Pt \text{ for } P_t > 250 \text{ mm} \quad (4)$$

where, ER, Effective rainfall (mm) and; P_t, Total rainfall (mm).

In this study calculation of crop coefficient, K_c, for different growth stages of tomato were considered based on the published report and local studies carried out in India. The crop coefficient K_c values are varying with the type of crop, its growing stage, growing season and prevailing weather conditions. The crop coefficient value for initial stage $K_{c\ init}$ was taken as 0.6, for mid stage was taken as 1.15 and for end stage it was taken as $K_{c\ end}$ as 0.80 for open environment. Inside polyhouse, the crop coefficient value for initial stage $K_{c\ init}$ was taken as 0.6, for mid stage was taken as 1.40 and for end stage it was taken as $K_{c\ end}$ as 1.0.

Economic feasibility analysis of tomato production under polyhouse: In this study benefit cost ratio (B:C ratio) and net seasonal income (NSI) were determined to assess the economic feasibility of the crop using drip irrigation as suggested by Tiwari *et al.* (1998). Depreciation, prevailing rate of interest and repair and maintenance cost of the system were considered to calculate the seasonal system cost of drip irrigation system. The fixed cost of drip irrigation system was determined to be ₹1,10,000/ha. The useful life of drip system was considered to be 7 years. The initial cost of polyhouse includes the cost of all components of polyhouse including the structural, cladding material etc. The life of the polyhouse was taken as 24 years. The system cost was evaluated by appropriating the fixed cost of system over life period of drip irrigation set. The rate of interest was taken as 13.5%, the prevailing interest rate for agricultural loan. Cost of repairs and maintenance of set is @2% of initial cost of the drip irrigation set per year. Expenses incurred on ploughing, preparation of land, seeds, fertilizers, weeding, plant protection measures, harvesting, threshing, irrigation water, and labour were considered to calculate the cost of production of tomato. In this study, the variable selling prices were considered to evaluate the net seasonal income (NSI) and benefit cost (B:C) ratio.

RESULTS AND DISCUSSION

Effect of different level of irrigation on yield and water productivity of tomato crop under polyhouse and open environment: The water use efficiency and amount of water used to produce unit quantity of tomato was also analyzed and compared with control. In polyhouse, the average yield per plant in treatments T_1, T_2, T_3, T_4, T_5 and T_6 were 4.78, 5.14, 5.01, 4.56, 3.92 and 3.52 kg/plant, respectively whereas for open environment the average yield per plant in treatments T_7, T_8 and T_9 were 2.54, 2.04 and 1.64 kg/plant, which is very less than that of control (T_2). The effect of various treatments on average yield per plant was found to be significant (Table 1). The yield was found maximum in control followed by treatment T_3. The maximum production observed was 18.97 kg/m^2 in treatment T_2 while minimum was 6.12 kg/m^2 in treatment T_9 (Table 1). The water productivity is the amount of water applied to produce 1 kg of tomato, which was maximum (20.47 litre/kg) for T_7 (100% of ET_c) in open environment.

Economic feasibility of tomato production under naturally ventilated polyhouse: The economic analysis for the production has been worked under different level of irrigation and mulching treatments under polyhouse. The life period of the polyhouse was taken as 24 years. The initial

Table 1 Economics analysis of tomato crop under different irrigation treatments under naturally ventilated polyhouse

S. No.	Cost economics	Treatment					
	Particulars	T_1	T_2	T_3	T_4	T_5	T_6
1. (i)	Fixed cost of polyhouse	70200	70200	70200	70200	70200	70200
a	Life (years)	24	24	24	24	24	24
b	Depreciation @10%	2632.5	2632.5	2632.5	2632.5	2632.5	2632.5
c	Interest @13.5%	9477	9477	9477	9477	9477	9477
(ii)	Fixed cost of Shade net	21840	21840	21840	21840	21840	21840
d	Life (years)	4	4	4	4	4	4
e	Depreciation @10%	4914	4914	4914	4914	4914	4914
f	Interest @13.5%	2948.4	2948.4	2948.4	2948.4	2948.4	2948.4
g	Total (b+c+e+f)	19971.9	19971.9	19971.9	19971.9	19971.9	19971.9
h	Total cost for 6 months	9985.95	9985.95	9985.95	9985.95	9985.95	9985.95
2.	Fixed cost of drip irrigation	5491.2	5491.2	5491.2	5491.2	5491.2	5491.2
a'	Life (years)	7	7	7	7	7	7
b'	Depreciation @10%	706	706	706	706	706	706
c'	Interest @10%	549.12	549.12	549.12	549.12	549.12	549.12
d'	Total (b'+c')	1255.12	1255.12	1255.12	1255.12	1255.12	1255.12
e'	Total cost for 6 months	627.56	627.56	627.56	627.56	627.56	627.56
3.	Cost of mulch (□/78m^2)	195		195		195	
4.	Cost of cultivation (□/78m^2)	4979.52	4979.52	4979.52	4979.52	4979.52	4979.52
5.	Total cost for 6 months (h+e'+3+4)	15788.03	15593.03	15788.03	15593.03	15788.03	15593.03
6.	Yield (kg/78m^2)	1375.92	1479.66	1443	1312.74	1128.66	1013.22
7.	Selling price (□/kg)	10	10	10	10	10	10
8.	Total net seasonal income for 6 months	13759.2	14796.6	14430	13127.4	11286.6	10132.2
9.	B:C ratio (No. 8/ No. 5)	0.87	0.94	0.91	0.84	0.71	0.64
10.	Selling price (□/kg)	15	15	15	15	15	15
11.	Total net seasonal income for 6 months	20638.8	22194.9	21645	19691.1	16929.9	15198.3
12.	B:C ratio (No. 11/ No. 5)	1.30	1.42	1.37	1.26	1.07	0.97
13.	Selling price (□/kg)	20	20	20	20	20	20
14.	Total net seasonal income for 6 months	27518.4	29593.2	28860	26254.8	22573.2	20264.4
15.	B:C ratio (No. 14/ No. 5)	1.74	1.89	1.82	1.68	1.42	1.29
16.	Selling price (□/kg)	25	25	25	25	25	25
17.	Total net seasonal income for 6 months	34398	36991.5	36075	32818.5	28216.5	25330.5
18.	B:C ratio (No. 17/ No. 5)	2.17	2.37	2.28	2.10	1.78	1.62

Treatment details are given under Materials and Methods.

cost of polyhouse includes the cost of all components of polyhouse including structural material, cladding materials, shade net, pumping unit, filter and distribution networks of irrigation system. The depreciation cost was assumed to be 10% of the total cost whereas the rate of interest was taken as 13.5%.

The cost of cultivation of tomato includes expenses incurred on preparation of land, seed, nursery management, mulching, vermin-compost, soil solarisation, cost of fertilizers, manures and their application, weeding, plant protection measures, cost of irrigation water and picking of fruits. During the growing period, the market price of tomato varied ₹10–25, that was used to evaluate the benefit cost (B:C) ratio and net seasonal income (NSI). At selling price of ₹10, the B:C ratio ranged from 0.64–0.94 which were not profitable (Table 1 and Fig 1). When selling price was ₹15, the B:C ratio ranged from 0.97–1.42. The highest B:C ratio was found for treatment T_2 with value of 1.42 followed by treatment T_3 and lowest for treatment T_6 with a value of 0.97. When selling price was ₹25, the B:C ratio ranged from 1.62–2.37. The highest B:C ratio was found for treatment T_2 with value of 2.37 followed by treatment T_3 with value of 2.28 and lowest for treatment T_6 with a value of 1.62. The net seasonal income was found to be highest for treatment T_2, followed by treatment T_3 and lowest for treatment T_6 at different selling price.

Economic feasibility of tomato production under open environment: The economic analysis for the production has been worked under different level of irrigation and mulching treatments under polyhouse. The seasonal cost of drip irrigation system included depreciation, prevailing bank interest and repair, and maintenance of the system. The fixed cost of drip irrigation system was determined to be ₹110000/ha. The useful life of drip irrigation was considered to be 10 years. The system cost was evaluated by distributing the fixed cost of the system over life of drip irrigation system. The rate of interest was taken as 5%, the prevailing interest rate for agricultural loan. The annual repair and maintenance of the system was taken as @2% of initial cost of drip irrigation system for the calculation. The cost of cultivation of tomato included expenses incurred on preparation of land, seed, nursery management, vermi-compost, ploughing, fertilizers, manures and their application, weeding, plant protection measures, irrigation water and picking of fruits. During the growing period, the market price of tomato varied ₹5–20, that was used to evaluate the benefit-cost (B:C) ratio and net seasonal income (NSI). At selling price of ₹5, the B:C ratio ranged from 0.52 to -0.27 which were not profitable (Table 2 and Fig 2). When selling price was ₹10, the B:C ratio ranged from -0.05 to 0.449. The highest B:C ratio was found for treatment T_7 with value of 0.449 followed by treatment T_8 and lowest for treatment T_9 with a value of -0.05. When selling price was ₹20, the B:C ratio ranged from 0.89–1.89. The highest B:C ratio was found for treatment T_7 with value of 1.89 followed by treatment T_8 with value of 1.33 and lowest for treatment T_9 with a value of 0.89. The net seasonal income was found to be highest for treatment T_7, followed by treatment T_8 and lowest for treatment T_9 at different selling price.

Sensitivity analysis: The market price of tomato was variable with respect to seasonal availability therefore further economic analysis was worked out to study the variable market price of tomato B:C ratio and net seasonal income (Rana *et al.* 1998). The relationship can be given by the straight line equation:

$$Y = aX + b \tag{1}$$

Where, Y= B:C ratio or net seasonal income (₹); X, market price (₹/kg); a and b are intercept and slope constants.

The values of a and b for the various treatments under polyhouse and open environment are given in Table 3. The constant indicate the change in the value of B:C ratio or net seasonal income per unit change in market price. From Fig 1 and Fig 2, it is possible to determine the value of the market price at which B:C ratio is unity and net seasonal income is zero, which is minimum support price necessary to get back the investment without any loss.

The production of tomato crop under polyhouse may be achieved to the level of 18.97 kg/m^2 at 100% level of water use (100% of ET_c without mulch) with the water productivity of 7.39 litre/kg. Whereas, the production of tomato crop in open environment may be achieved to the level of 9.38 kg/m^2 at 100% level of water

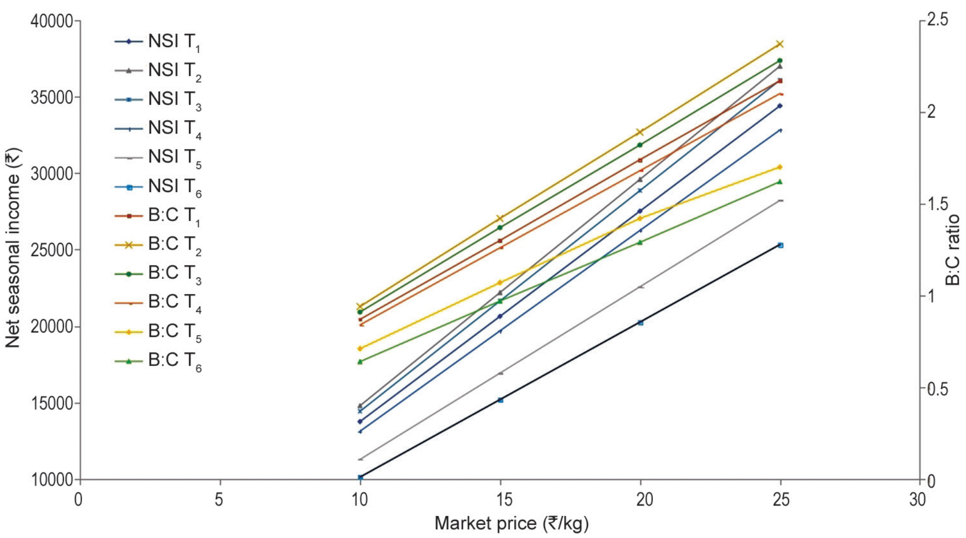

Fig 1 Effect of market price on B:C ratio and net seasonal income on production of tomato under naturally ventilated polyhouse.
Treatments details are given under Materials and Methods.

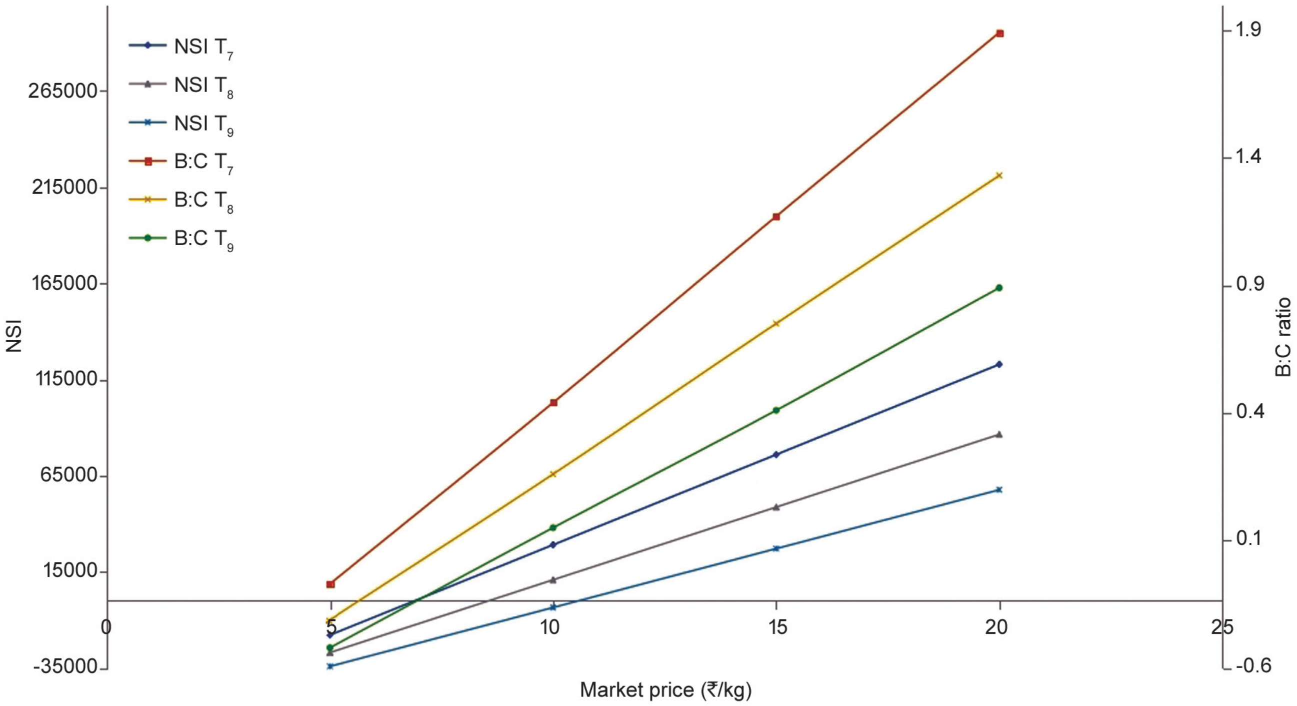

Fig 2 Effect of market price on B:C ratio and net seasonal income on production of tomato under open environment. Treatment details are given under Materials and Methods.

Table 2 Economics analysis of tomato crop under different irrigation treatment in open environment

Cost economics	Treatment		
	T_7	T_8	T_9
Fixed cost (□/ha)	110000	110000	110000
Seasonal system cost (□/ha)			
Depreciation	9900	9900	9900
Interest	5500	5500	5500
Repair and maintenance	2200	2200	2200
Total (□/ha/year)	17600	17600	17600
Total cost for six months	8800	8800	8800
Seasonal cost of cultivation (□/ha)	55900	55900	55900
seasonal total cost (2e+3)	64700	64700	64700
Yield of produce (t/ha)	9.38	7.56	6.12
Selling Price	5	5	5
Income from produce	46900	37800	30600
Net seasonal income (□/ha)	-17800	-26900	-34100
B:C ratio (9/4)	-0.27	-0.41	-0.52
Selling Price	10	10	10
Income from produce	93800	75600	61200
Net seasonal income (□/ha)	29100	10900	-3500
B:C ratio (13/4)	0.44	0.16	-0.05
Selling Price	15	15	15
Income from produce	140700	113400	91800
Net seasonal income (□/ha)	76000	48700	27100
B:C ratio (13/4)	1.17	0.75	0.41
Selling Price	20	20	20
Income from produce	187600	151200	122400
Net seasonal income (□/ha)	122900	86500	57700
B:C ratio (13/4)	1.89	1.33	0.89

Treatment details are given under Materials and Methods.

use (100% of ET_c without mulch) with the water productivity of 20.14 litre/kg. Production of tomato under polyhouse was economically feasible at selling price from ₹15/kg. Whereas, production of tomato in open environment was

Table 3 Constant of linear regression for the effect of market price on B:C ratio and net seasonal income for tomato crop under polyhouse and open environment

Treatment	Regression constant	B:C ratio	NSI
T_1	a	0.086	1375.92
	b	0.001	3.60E-12
T_2	a	0.095	1479.65
	b	-0.011	0.08
T_3	a	0.0912	1443
	b	-0.001	7.27E-12
T_4	a	0.084	1312.74
	b	-2.22E-16	-1.09139E-11
T_5	a	0.0664	1128.66
	b	0.063	-3.63798E-12
T_6	a	0.0652	0
	b	-0.011	1013.22
T_7	a	0.284	18380
	b	-1	-64700
T_8	a	0.18492	11983.98
	b	-0.997	-64566.5
T_9	a	0.16856	10920
	b	-1.001	-64700

Treatment details are given under Materials and Methods.

economically feasible at minimum selling price of ₹20/kg.

REFERENCES

Allen R G, Smith M, Perrier A and Pereira L S. 1994. An update for the definition of reference evapotranspiration. *ICID bulletin* **43**(2): 1–34.

Allen R G, Masahiro T and Ricardo T. 2007. Satellite-based energy balance for mapping evapotranspiration with internalized calibration (METRIC) model. *Journal of Irrigation Drainage Engineering* **133**: 380–94.

Boulard T, Feuilloley P and Kittas C. 2017. Natural ventilation performance of six greenhouse and tunnel types. *Journal of Agricultural Engineering Research* **67**(4): 249–66.

Lohano H D and Mari F M. 2015. Status, growth and forecast of tomato and onion production in Pakistan. *Indus Journal of Biological Sciences* **2**(4): 497–502.

Mahajan G and Singh K G. 2006. Response of greenhouse tomato to irrigation and fertigation. *Agricultural water management* **84(**1–2): 202–06.

Malhotra S K. 2017. Horticultural crops and climate change: A review. *Indian Journal of Agricultural Sciences* **87**(1): 12–22.

Rana G and Katerji N. 2008. A measurement based sensitivity analysis of the Penman-Monteith actual evapotranspiration model for crops of different height and in contrasting water status. *Theoretical and Applied Climatology* **60(**1–4): 141–49.

Thompson R B, Gallardo M, Valdez L C and Fernández M D. 2007. Using plant water status to define threshold values for irrigation management of vegetable crops using soil moisture sensors. *Agricultural Water Management* **88**(1–3): 147–58.

Tiwari V, Tiwari K N and Singh B D. 1998. Shoot regeneration and somatic embryogenesis from different explants of Brahmi. *Plant Cell Reports* **17**: 538–43.

Tiwari G N. 2003. *Greenhouse Technology for Controlled Environment*, pp. 67–77. Narosa Publishing House, New Delhi.