Improving water use for dry season agriculture by marginal and tenant farmers in the Eastern Gangetic Plains

Prospects of protected cultivation in North Bengal for off-season vegetable production

Working Paper

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1. Introduction

Crop response to the environment is the ultimate decisive factor towards a quality harvest and hence simulation of an ideal microclimate is one of the essential prerequisites of modern horticulture coupled with judicious application of agro-inputs to get higher quantum of healthy product per unit area through an environment safely sustainable approach leading to manifold return. Protected cultivation refers to growing the crops inside an artificially constructed structure where environmental parameters are modified to be more favourable for crop growth, development and flowering. Besides favourable microclimate simulation, protected cultivation may also provide advantages including – year round cultivation, off-season cultivation, improvement in quality of produce (Kuswardhani *et, al*., 2014), increase in yield per unit area (Negi *et, al*., 2013), protection of crops from vagaries of climatic conditions like - heavy precipitation, chilling (Mishra *et, al*., 2010), scorching etc., judicious application of space and agro-inputs, reduced use of water, production of seedlings for off-season cultivation etc thereby realizing manifold return on investment (Singh and Sirohi, 2006).Almost every country in the world are producing greenhouse crops to get quality production at higher magnitude per unit of land area.The difference between the principle of protected cultivation of the temperate world and the tropical world is lying in the fact that protected houses in temperate region spend much money to step up the temperature but the tropical and sub-tropical region spend much money to lower down the temperature and that's why the technique differs region-wise. Upto the Second World War glass was the predominating cladding material but with the advent of polyethylene as cladding material, the technique spread from the developed world to the developing (Maitra and De, 2016). In India the concept has recently matured. Singh (2014) reported an area of 40,000ha under protected cultivation of horticultural crops in India. Spehia (2015) reported that out of 170000 ha of vegetable farming, an area of 223.18 ha was under greenhouse cultivation in Himachal Pradesh (a state in India).

This chapter shows that erecting small bamboo frame protected structures in homestead areas, crops can be protected from excessive precipitation, excessive solar radiation and excessive heat and cold. Management of those become very easy by the members of the farm family particularly the women folk. Effective water management strategies are major impetus under the DSI4MTF project funded by the Australian Centre for International Agricultural Research (ACIAR) which can be achieved accommodating drip irrigation system in the protected structures. Singh and Hasan (2011) recommended zero energy naturally ventilated greenhouses for high value vegetable cultivation which can be equipped with low-pressure drip irrigation system to make them energy efficient ecofriendly model. Perceiving the relative advantages of protected cultivation, two number of small bamboo made protected structures in each project site namely Dhalaguri and Uttar Chokowakheti have been established along with drip irrigation facility wherein cucumber, capsicum, coriander leaf, Spinach Beet and cauliflower have been practiced by the farmers and the relative advantages are summarized below.

2. The study area:

The villages namely Dhalaguri and Uttar Chokowakheti are situated at the Ambari Gram Panchayat, Block II of Cooch Behar district and Uttar Chokowakheti Gram Panchayat of

Alipurduar district respectively in the sub-Himalayan Terai region of West Bengal, India. The main characteristics of these two villages are heavy precipitation (2200-2500 mm) in rainy season coupled with a comparatively dry and prolonged winter. The demography dominates with low caste population and agriculture is the main source of livelihood in Dhalaguri whereas in Uttar Chokowakheti, forest related activities are running simultaneously with agriculture for livelihoods. The average farmers are mostly marginal with low operational size holding (0.8ha) and tenant working as agricultural labourer. Due to limited irrigation infrastructure in both the villages, cultivation of Rabi season crops in many of the land holdings in the preceding years were not done. A number of diesel pumpsets, solar pump, drip irrigation system had been provided by the project to promote the dry season agriculture in the two villages. Two numbers of small (48m^2 in dimension) bamboo-framed polyhouses in both the villages along with drip irrigation system were developed for protected cultivation of off-season vegetables. In the village Dhalaguri the protected structures and drip irrigation system were located at site -2 (Karjeepara) and in the village Chokowakheti the same were constructed at site -3 (Bholaghat).

3. Protected structures:

Two numbers of polyhouses having dimensions of 12 m x 4 m (48m^2) had been established in each village (pict.-1 shows the preparatory stage at Uttar Chokowakheti) along with drip irrigation facility from an overhead tank. The polyhouses were made of bamboo poles fitted with nut and bolt. 200 micron thick UV stabilized polyethylene sheet was used as cladding material. Aluminium channels were fixed on bamboo poles for attaching the polyethylene sheet using metal made springs. Above the polyethylene sheet 50% agro-shade net was used as shading material (shown as green material in pict.-2). Four rows of drip irrigation laterals with 20 emitters per lateral were fitted to the main line which were operated through valves in each lateral. The drip irrigation system included overhead tank of 1000 litre, pumps and filter. The water lifting and distribution system were operated electrically.

Pict.–1: Polyhouse at Uttar Chokowakheti during preparatory stage

Pict.-2: Polyhouse with agro-shade net and drip irrigation facility at Dhalaguri

4. The cost of development of low cost protected structures by the farmers

Crops can be protected from excessive precipitation, solar radiation, heat and cold by preparing small bamboo made protected structures in homestead areas. Management of this kind of polyhouse becomes easier for the farmers. The material requirement for such a bamboo made protected structure of 5m (width) x 10m (length) x 3m (central height) is as follows –

a. *Bamboo (locally available) –*

Pole of 3m – 22 pieces

Pole of 5m – 14 pieces

Pieces of 2.75m length – 16 pieces

Pieces of 0.5m length – 8 pieces

*(one piece of Bamboo approximately runs 5.5m-6m)

Total requirement – 34 number of Bamboos (matured bamboo will be selected) but 10% extra will be required to avoid any shortfall. So, 4 number of additional bamboos will be required for this purpose. Another 2 number of Bamboos will be required to prepare splits and supports. Hence, a total of 40 number of bamboos will be required.

b. *UV stabilized polyethylene sheet of 200 micron thickness* –Total requirement is 162 m^2

c. *Nails, spring, channel, rope, ribbon, frame of door etc.*

d. *Agro-shade net (50%)* - 100 m^2 including 10% extra to be required

e. *Two hired labourers for two days*

f. *Miscellaneous*

Table – 1: Cost of development of the protected structure

Sl. No.	Item	Quantity	Rate	Amount (Rs.)
1	Bamboo	40 numbers	Rs. 80 /piece	Rs. 3200/-
2	UV-stabilized polyethylene sheet of 200 micron thickness	162m^2	Rs. 65/m^2	Rs, 10530/-
3	Nails Spring Channel Nylon Rope Ribbon Frame of Door	2Kg 100 pieces 100 m 1Kg 100m 1 piece	Rs.80/Kg Rs. 2.5/piece Rs. 3/m Rs.80/Kg Rs.2/m Rs.100/piece	Rs,160/- Rs.250/- Rs.300 Rs.80/- Rs.200/- Rs.100/-
4	50% Agro-shade Net	100m^2	Rs.20/m^2	Rs.2000/-
5	Wages	2 men for 2 days	Rs.250/person/day	Rs.1000/-
6	Miscallaneous cost	-	-	Rs.400/-
			Grand Total	**Rs.18220/-**

5. Interventions:

Discussion (Pict. - 3), formulation of design, construction of protected structures and drip irrigation were the part and parcel at the initial phase.

Pict.-3: Discussion regarding selection of crops

After erection of houses initially cucumber was grown by the farmers afterwards the cropping sequence was prepared as per discussion which is presented below.

Table - 2: Cropping sequences in the protected structures of the villages Dhalaguri and Uttar Chokowakheti

Month	Crops	Month	Crops
	Protected structure - 1		**Protected structure - 2**
Village Dhalaguri			
December, 2016 – June, 2017	Off-season Capsicum	December, 2016 – April, 2017	Cucumber
July, 2017 – November, 2017	Cauliflower	May, 2017 –August, 2017	Off-season Coriander leaf and off-season Spinach Beet
December, 2017 – May, 2018	Capsicum (both main season and off-season)	September, 2017 – November, 2017	Cauliflower
June, 2018 – September, 2018	Off-season Coriander Leaf	December, 2017 – June, 2018	Off-season Capsicum
September, 2018 – December, 2018	Cauliflower	June, 2018- August, 2018	Off season Spinach Beet
		September, 2018 – December, 2018	Cauliflower
Village Uttar Chokowakheti			
June, 2017 – September, 2017	Off-season Coriander leaf and off-season Spinach Beet	June, 2017 – September, 2017	Off-season Coriander leaf and off-season Spinach Beet
September, 2017 – November, 2017	Cauliflower	September, 2017 – November, 2017	Cauliflower
December, 2017 – June, 2018	Off-season Capsicum	December, 2017 – June, 2018	Off-season Capsicum

The protected cultivation in low cost bamboo-made polyhouse at the village Dhalaguri was started with Cucumber. Picture-4 to Picture-7 represent the different stages of crop growth and harvesting of produce.

Pict.-4: Cucumber in polyhouse at Dhalaguri village

Pict.-5: Full grown cucumber plants in the polyhouse

Pict.-6: Scientists visiting the protected structures

Pict.-7: Harvesting of cucumber

6. Activities:

Accordingly the following crops were cultivated in the polyhouses. The cultivars and time of plantings are presented below.

Table – 3: The cultivars and time of planting of different crops along with seed requirement and seed cost for the protected structures of the villages Dhalaguri and Uttar Chokowakheti in 2017.

Sl. No.	Crop	Botanical name	Family	Unit Size	Variety	Date of Planting	Seed Required (g)	Cost of Seed (Rs.)
1.	Cucumber	*Cucumis sativus*	Cucurbitaceae	24m^2	Malini	28.12.2016	10g	Rs. 220/-
2.	Capsicum	*Capsicum annuum* var. *grossum*	Solanaceae	48m^2	Mekong F1	20.12.2016	5g	Rs. 400/-
3.	Coriander leaf	*Coriandrum sativum*	Umbelliferae	24m^2	Local	27.05.2017	500g	Rs. 150/-
4.	Spinach Beet	*Beta vulgaris* var. *bengalensis*	Chenopodiaceae	24m^2	Local	28.05.2017	500g	Rs. 240/-
5.	Cauliflower	*Brassica oleracea* var. *botrytis*	Cruciferae	48m^2	Dawn – 175 – for Dhalaguri	13.09.2017	5g	Rs. 200/-

					SV4051AC – for Uttar Chokowakheti			

The critical inputs were collected and supplied. The participant farmers have been trained on management of protected structures and drip irrigation system (Pict. – 8 depicts the training on drip irrigation, Pict. – 9 depicts the time period requirement for tank filling, Pict.-10 shows the determination of discharge ability of emitters and Pict.-11 shows the training on microclimate management), raising of seedling (Pict. – 12 & 13 represent imparting training on seedling raising of horticulture crops) and land and crop management practices (Pict. -14, 15 & 16 represent imparting training on transplanting in protected structures, Pict. – 17 &18 denote human resource development regarding protected cultivation of Capsicum) simultaneously. Frequent visit for monitoring the crop cultivation practices by the farmers was also a vital part in this programme (Pict. – 19 shows the visit of scientists to the Capsicum house).

Pict.-8: Hands on experience on drip management

Pict.-9: Data collection regarding tank filling

Pict.-10: Data collection on discharge ability of emitters

Pict.-11: Training on microclimate management

Pict.-12: Training on raising of seedling

Pict.-13: Training on raising of cauliflower seedling

Pict.-14: Training on Cauliflower transplanting

Pict.-15: Transplanting of capsicum at Uttar Chokowakheti

Pict.-16: Transplanting of cauliflower at Uttar Chokowakheti

Pict.-17: Training on Capsicum management

	
Pict.-18: Training technique in Capsicum	*Pict.-19: Scientists visiting the Capsicum house*

As per the formulated programme the first ever protected cultivation of five crops in both the villages were started. The relevant information regarding crop cultivation is stated below.

Table – 4: Irrigation and nutrient requirement in protected cultivation of vegetables in the villages Dhalaguri and Uttar Chokowakheti in 2017

Sl. No.	Crop	Manures and fertilizer application	Cost of manures and fertilizers	Water requirement in open field	Water application through drip irrigation	Cost of water application
1.	Cucumber	10.5 Kg vermicompost Urea – 0.70 Kg, SSP - 1.40 Kg, MOP – 0.35 Kg	Rs. 62.16/-	20 hectare centimetre	686.40 lit	Rs. 8.24/-
2.	Capsicum	60 Kg vermicompost Urea – 5 Kg SSP – 20Kg MOP – 3 Kg 19:19:19 – 100g	Rs. 486.20/-	25-40 hectare centimetre	1830.2 lit	Rs. 21.96/-
3.	Coriander leaf	24 Kg vermicompost	Rs. 96/-	5-10 hectare centimetre	232.0 lit	Rs. 2.78/-
4.	Spinach Beet	24 Kg vermicompost	Rs. 96/-	5-10 hectare centimetre	225.6 lit	Rs. 2.71/-
5.	Cauliflower	8.50 Kg vermicompost	Rs. 34/-	15-30 hectare centimetre	--	NIL

The profitability of the ventures is also determined which are presented in table – 5.

Table - 5: The comparative cost of production, selling price, net return and B:C Ratio of protected cultivation of vegetables in the villages Dhalaguri and Uttar Chokowakheti in 2017

Sl. No.	Crop	Cost of production	Yield	Selling price	Net return	B:C Ratio (Total return/ Total Cost)
1.	Cucumber	Rs. 296.90 (including crop protection)	40 Kg	Rs. 480/-	Rs. 183.10 (3 months)	1.62
2.	Capsicum	Rs. 908.16/- (excluding cost of vermicompost)	100 Kg	Rs. 5600/-	Rs. 4691.84 (6 months)	6.17

3.	Coriander leaf	Rs. 248.78 /-	7200 plants (9.6 Kg)	Rs. 2880/-	Rs. 2631.22 (2.5 months)	10.58
4.	Spinach Beet	Rs. 338.71/-	66 Kg	Rs. 2310/-	Rs. 1971.29 (2.5 months)	6.82
5.	Cauliflower	Rs. 314.00/- (including nursery raising)	68 Kg	Rs. 2040/-	Rs. 1726.00 (2.5 months)	6.50

Pict.-20: Spinach Beet grown in Polyhouse

Pict.-21: Coriander leaf grown in polyhouse

7. Repetition of the crops in 2018:

After analysis of the results in the first year the crops mainly the Capsicum and off season Coriander Leaf and Spinach Beet were tried for the second time in Dhalaguri. The comparative results are presented below (Table - 6).

Table – 6: The cultivars and time of planting of different crops in the protected structures of the village Dhalaguri in 2018

Sl. No.	Crop	Botanical name	Family	Unit Size	Variety	Date of Planting	Seed Required	Cost of Seed
1.	Capsicum	*Capsicum annuum* var. *grossum*	Solanaceae	96m^2	Mekong F1	24.01.2018	10g	Rs. 350/-
2.	Coriander leaf	*Coriandrum sativum*	Umbelliferae	48m^2	Local	14.06.2018	500g	Rs. 200/-
3.	Spinach Beet	*Beta vulgaris* var. *bengalensis*	Chenopodiaceae	30m^2	Local	13.06.2018	1.00Kg	Rs. 150/-

The data on nutrient application and water management of vegetable crops under protected condition are also summarized here.

Table – 7: Irrigation and nutrient requirement in protected cultivation of vegetables in the village Dhalaguri in 2018

Sl. No.	Crop	Manures and fertilizer application	Cost of manures and fertilizers	Water requirement in open field	Water application through drip irrigation	Cost of water application
1.	Capsicum	55 Kg vermicompost Urea – 6 Kg 10:26:26 – 15Kg	Rs. 860/-	25-40 hectare centimetre	175 lit	Rs. 2.10/-

2.	Coriander leaf	NIL	NIL	5-10 hectare centimetre	300 lit	Rs. 3.60/-
3.	Spinach Beet	Nil	NIL	5-10 hectare centimetre	NIL (Residual)	NIL

The comparative economics and cost:benefit ratio of the cultivated three crops namely Capsicum, Coriander Leaf and Spinach Beet are also tabulated here -

Table - 8: The comparative cost of production, selling price, net return and B:C Ratio of protected cultivation of vegetables in the villageDhalaguriin 2018

Sl. No.	Crop	Cost of production	Yield	Selling price	Net return	B:C Ratio (Total return/ Total Cost)
1.	Capsicum	Rs. 1397.10/- (including cost of vermicompost)	112 Kg	Rs. 5510/-	Rs. 4112.90 (5 months)	3.94
2.	Coriander leaf	Rs. 233.60 /-	6 Kg	Rs. 3000/-	Rs. 2766.40 (2.5 months)	12.84
3.	Spinach Beet	Rs. 180/-	35 Kg	Rs. 1400/-	Rs. 1220.00 (2.5 months)	7.78

8. Saving of water through protected cultivation in low cost polyhouses with drip irrigation system:

The actual use of water during crop cultivation in low cost polyhouses in 2017 and in 2018 are compared to open field cultivation and presented below.

Table - 9: Comparative use of water in protected cultivation of vegetables in 2017

Sl. No.	Name of the crop	Unit size	Water requirement in open field cultivation	Water to be required in open field cultivation	Water application in polyhouse through drip irrigation	Water applied as per requirement on percent basis	Water saving on percent basis
1.	Cucumber	$24m^2$	20 hectare centimetre	4800 lit.	686.4 lit	14.30%	85.70%
2.	Capsicum	$48m^2$	25-40 hectare centimetre	12000 lit – 19200 lit	1830.2 lit	15.25% - 9.53%	84.75%- 90.47%
3.	Coriander leaf	$24m^2$	5-10 hectare centimetre	1200lit – 2400lit	232.0 lit	19.33% - 9.67%	80.67% - 90.33%
4.	Spinach Beet	$24m^2$	5-10 hectare centimetre	1200 lit – 2400 lit	225.6 lit	18.80% - 9.40%	81.20% - 90.60%
5.	Cauliflower	$48m^2$	15-30 hectare centimetre	7200 lit – 14400 lit	0.0 lit	0.00%	100%

Table -10: Comparative use of water in protected cultivation of vegetables in 2018

Sl. No.	Name of the crop	Unit size	Water requirement in open field cultivation	Water to be required in open field cultivation	Water application in polyhouse through drip irrigation	Water applied as per requirement on percent basis	Water saving on percent basis
1.	Capsicum	$96m^2$	25-40 hectare centimetre	24000 lit – 38400 lit	175 lit	0.73% - 0.46%	99.27%- 99.54%
2.	Coriander leaf	$48m^2$	5-10 hectare centimetre	2400lit – 4800lit	300 lit	12.50% - 6.25%	87.50% - 93.75%
3.	Spinach Beet	$30m^2$	5-10 hectare centimetre	1500 lit – 3000 lit	0.00 lit	0.00%	100.00%

9. Salient Findings:

Among the five crops, Capsicum was the long duration one and the others were completed within 3 months. In case of Spinach Beet and Coriander leaf (Pict. – 20 & Pict. - 21) two successive crops were taken within two and half months. The cost of water application was least in Spinach Beet (Rs. 2.71/- in 2017 and nil in 2018) and was found maximum in Capsicum (around Rs. 22/-) in the first year and in Coriander Leaf in the second year (Rs. 3.60/-). Cauliflower was grown with the residual moisture of the preceding crops in the first year and it was found similar in Spinach Beet in the second year. No additional water was required for Cauliflower cultivation (Table - 4). Capsicum was found as the highest nutrient requiring crop both in terms of quantity and investment (Table – 4 and Table - 7). The cost of production was found least in Coriander leaf (Rs. 248.78/-) in 2017 and in Spinach Beet (Rs. 180/-) in 2018 and maximum in Capsicum (Rs. 908.16/- and Rs. 1397.10/- in 2017 and 2018 respectively). The maximum net return was realized from Capsicum (Rs. 4691.84/- and Rs. 4112.90/- in 2017 and 2018 respectively) and simultaneously (Table - 5) the minimum return was obtained from Cucumber (Rs. 183.10/-) within the two years. The minimum water saving as compared to open field cultivation was found 81.20% in Spinach Beet in 2017 (Table - 9). Total water saving under protected cultivation of cauliflower was noticed in 2017 (Table - 9) and in Spinach Beet in 2018 (Table - 10). The B:C ratio was found maximum in Coriander leaf (10.58 and 12.84 in 2017 and 2018 respectively) in short duration crops and in Capsicum (6.17 and 3.94) in long duration crops (Table – 5 and Table - 8) due to higher prices in the market as a result of low supply from conventional agriculture during off-season production which was also observed by Lal *et, al*. (2016) in Coriander Leaf. Agrawal *et, al*. (2003) reported the profitability of early Cauliflower under protected situation in Chhattisgarh region of India. Kaddi *et, al*. (2014) reported a lower B:C ratio in naturally ventilated polyhouse grown Cucumber than open field cultivation. Dhaliwal *et, al*. (2017) noticed an early as well as higher yield in polyhouse grown bell pepper.

10. Impact:

The cucumber production (Pict. – 4 to Pict. - 7) was non-remunerative due to the following fact that it was the first crop in the protected structures and farmers had little experience with the agronomy of the crop. Soon after this they made themselves acquainted with the technology and got success in subsequent capsicum (Pict.-22 to Pict.-27), off-season coriander leaf, off-season Spinach Beet and off-season cauliflower (Pict.-28 and Pict.-29) cultivation.

Pict.-22: Capsicum in vegetative growth phase

Pict.-23: Scientists visiting the capsicum house

Pict.-24: Capsicum under protected structure

Pict.-25: Capsicum in open field

Pict.-26: Farmer wih produce at Uttar Chokowakheti

Pict.-27: Farmer wih produce at Dhalaguri

Pict.-28: Management of cauliflower

Pict.-29: Full grown cauliflower

Realizing the profit generation through protected cultivation technique the farmers of the village Dhalaguri developed another big-sized zero energy polyhouse for vegetable cultivation by their own (Pict.-30).

Pict. – 30: Farmers developing their own polyhouse

11. Lesson learnt:

Selection of crop with an eye to efficient water management includes the choice of low water requiring crops as well as introduction of competent irrigation system and at the same time the crop must be a high value one to compensate the additional investments. Here drip irrigation system is utilized as the proficient irrigation system to harness more crop per drop. In both the sites namely Dhalaguri and Uttar Chokowakheti demonstration units of drip irrigation system have been established to sensitize the growers. But actually due to very low rate of evaporation in the polyhouses causing reduced escape of moisture through evapotranspiration coupled with high soil moisture due to high natural precipitation in the surrounding areas, it was found that use of drip for once or twice during a cropping period was sufficient to maintain satisfactory soil moisture regime. So in those villages simple polyhouses will do effectively for off-season vegetable production. Protected cultivation of off season vegetable crops has been established itself as a remunerative agro-enterprise in both the villages of study. Sanwal *et, al*. (2004) noted that protected cultivation of vegetables utilizing low cost technology with bamboo frame hold a good potential in North Eastern Hill Region of India.

12. References used:

Agrawal, N., Mehta, N., Sharma, H.G., Dixit, A. and Dubey, P. (2003). Cultivation of Cole Crops under Protected Environment. *Karnataka Journal of Agricultural Science*. **16**(2): 332-334.

Dhaliwal, M.S., Sharma, S.P., Jindal, S.K., Dhaliwal, L.K. and Gaikwad, A.K. (2017). Growth and yield of bell pepper as influenced by growing environment, mulch and planting date. *Journal of Crop Improvement*. **31**(6): 830–846.

Kaddi,G., Tomar, B.S., Singh, B. and Kumar, S. (2014). Effect of growing conditions on seed yield and quality of cucumber (*Cucumis sativus*) hybrid. *Indian Journal of Agricultural Sciences*. **84** (5): 624–627.

Kuswardhani, N., Soni, P. and Shivakoti, G.P. (2014). Development Protected Cultivation in Horticulture Product: Feasibility Analysis in West Java Province. *International Journal on advanced science engineering information technology*. **4**(5): 66-70.

Lal,G., Mehta, R.S., Singh,R., Kakani, R.K., Meena, N.K. and Maheria, S.P. (2016). Effects of nitrogen levels on plant growth and leaf yield of off season coriander under shade nets. *International Journal of Seed Spices.* **6**(2): 46-49.

Maitra, S.and De, L.C.(2016). Protected cultivation of medicinal plants. In :*Protected cultivation of ornamental plants*. Ed. De, L. C. ISBN – 978-81-7910-532-0. Aavishkar Publishers, Distributors, Jaipur, India. pp. 316-327.

Mishra, G.P., Singh, N., Kumar, H. and Singh, S.B. (2010). Protected cultivation for food and nutritional security at Ladakh. *Defence Science Journal*. **61**(2): 219-225.

Negi, V.S., Maikhuri R.K., Rawat L.S. and Parshwan, D. (2013). Protected cultivation as an option of livelihood in mountain region of central Himalaya, India. *International Journal of Sustainable Development & World Ecology*. **20**(5): 416–425.

Sanwal, S.K., Patel, K.K. and Yadav, D.S. (2004). Vegetable production under protected conditions in NEH region : problems and prospects. *ENVIS Bulletin: Himalayan Ecology*. **12**(2): 2004.

Singh, B. (2014). Protected cultivation of horticultural crops in India: Challenges and opportunities. *Agrotechnol* (3rd International Conference on Agriculture & Horticulture, October 27-29, 2014, Hyderabad International Convention Centre, India). 2(4): 51.

Singh, B.and Hasan, M. (2011). Low pressure drip irrigation system: A success story (In Hindi). *Agriculture Extension Review*. **21**(2): 11–12.

Singh, B. and Sirohi, N.P.S. (2006). Protected cultivation of vegetables in India: problems and future prospects. *Acta Horticulturae*. **710**(1): 355-358.

Spehia, R.S. (2015).Status and impact of protected cultivation in Himachal Pradesh, India. *Current science*. **108**(12): 2254-2257.