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Palle Jayasurya

M.Sc. Student, Department of Horticulture, M S Swaminathan School of Agriculture (MSSSOA), Ceturion University of Technology and Management (CUTM), Paralakhemundi, Gajapati, Odisha, India

Subhrajyoti Chatterjee

Assistant Professor, Department of Horticulture, M S Swaminathan School of Agriculture (MSSSOA), Ceturion University of Technology and Management (CUTM), Paralakhemundi, Gajapati, Odisha, India

Amit Biswas

Assistant Professor, Department of Agricultural Engineering, School of Agriculture and Bio-Engineering (SOABE), Ceturion University of Technology and Management (CUTM), Paralakhemundi, Gajapati, Odisha, India

M Viswanath

Assistant Professor, Department of Horticulture, M S Swaminathan School of Agriculture (MSSSOA), Ceturion University of Technology and Management (CUTM), Paralakhemundi, Gajapati, Odisha, India

Anindita Roy

Assistant Professor, Department of Horticulture, M S Swaminathan School of Agriculture (MSSSOA), Ceturion University of Technology and Management (CUTM), Paralakhemundi, Gajapati, Odisha, India

Corresponding Author:

Subhrajyoti Chatterjee

Assistant Professor, Department of Horticulture, M S Swaminathan School of Agriculture (MSSSOA), Ceturion University of Technology and Management (CUTM), Paralakhemundi, Gajapati, Odisha, India

Low cost protected structures for off-season vegetable production: A review

Palle Jayasurya, Subhrajyoti Chatterjee, Amit Biswas, M Viswanath and Anindita Roy

Abstract

Cultivation of high value off-season vegetables under low cost protected structures has been found to be a viable technology for growing vegetables throughout the year. The crops grown in protected structures in off-season fetch higher prices in the market. Low cost protected technology like plastic low tunnels, walk in tunnels, shade net houses are used for off-season vegetable cultivation for getting high returns. Similarly insect proof net houses can also be used on a large scale for safe vegetable cultivation for minimizing the use of pesticides in vegetable cultivation and for production of virus-free seeding. Therefore to enhance income of the small and marginal farmers, off-season vegetables cultivation under low cost poly houses is found to be very economical and profitable venture. Alongside, this technology ensures availability of every kind of vegetables throughout the year which ultimately helps in nutritional security of the countrymen.

Keywords: Off-season cultivation, high value vegetables, quality seedlings, low cost protected structures, nutritional security

Introduction

Vegetables are considered as ‘protective food’ globally because of the abundance of vitamins, minerals, colour pigments, antioxidants and play an important role in food, nutrition and livelihood security. In India, because of increase in consumers’ awareness for health and high population pressure, the demand of vegetables is gradually increasing day by day. India is the second leading vegetable producing country in the world after China. Though total production of vegetables in our country is increased from 58.5 million tonnes in 1991-92 to 191.76 million tonnes in 2019-20 but still cultivation practices are restricted to seasonal and regional needs (NHB, 2020). Along with this, still the technologies used and practices followed for vegetable farming are pre-dominantly traditional which results in low yield, less productivity and inconsistent quality of produces (Navnath *et al.*, 2019) [2]. But now a days, the increasing demand of off-season and high quality vegetables in various markets of the county has got the attention of the vegetable growers for diversification from traditional way of vegetable cultivation to modern methods of vegetables cultivation in an agri-business model (Chauhan *et al.*, 2016) [3]. In this context, ‘Protected cultivation’, which in the past was considered only a mean of crop production only for some rich western countries having unfavorable environmental condition, is gaining momentum under Indian circumstances to enhance the total productivity and improve the quality which is a major problem of vegetables grown in open field condition specially in the rainy season. ‘Protected cultivation’ is defined as cropping techniques wherein the micro climate surrounding the plant body is controlled partially/fully, as per the requirement of the plant species grown, during their period of growth (Mccollum, 1992) [4].

The demand for fresh summer vegetables like bitter gourd, lady’s finger, cucumber, bottle gourd etc. is increased significantly during winter months for increasing diversity in diet. Apart from this, under north Indian conditions during winter season, it is extremely difficult to grow crops like tomato, capsicum, cucurbits, French bean, amaranth etc. in open field condition. Especially in cold desert areas like Leh and Ladakh, where the temperature is extremely low (- 10⁰ C to -30⁰ C) during winter season and communication is totally cut off from rest part of the country from November to March due to very heavy snowfall, it is very difficult to cultivate and supply vegetables in these areas (Chauhan *et al.*, 2016) [3]. Similarly, supply of winter vegetables like cabbage, cauliflower, carrot, radish, tumip etc. become restricted during summer months because of curtail in production and as a result the price of

those vegetables become very high in the off-season. Growing winter vegetables during late spring months and summer vegetables in cold weather months is only achievable by adopting the 'protected cultivation' technology. In a country like India, where most of the farmers are marginal, it is not possible for them to construct a high cost fully automated protected structure by investing a lot of money. In this scenario, the 'low cost protected structure' is found to be most economical for small and marginal farmers for off-season vegetable cultivation.

Importance of Off Season Vegetable Crops

The demand of vegetable in India is quite high because a large portion of people are vegetarian and dieticians also recommend consumption of 300 g of vegetables/ day/ person which includes 125 g leafy vegetables, 75g alternate/ other vegetables and 100 g root and tuber for a balanced diet (Sharma *et al.*, 2021) [5]. But supply is much lower than the demand because all type of vegetables cannot be grown throughout the year. Such a situation creates a dire need to find an alternative solution for year round production of vegetables. Thus off season vegetable cultivation is emerging out as a strong option to meet this demand as it can play a vital role in avoiding the scarcity of a vegetable in a particular state in a particular season. It can control the hike of price of vegetables in its off season as well. So, the vegetables known as the 'protective food' can be easily available and purchasable to all classes of people throughout the year. Thus it can play a vital role in alleviating the nutritional deficiency among people. Apart from this, many times farmers produce good amount of vegetable crops during its main season, which eventually leads to the severe market glut and fall in price. So production of off-season vegetable apart from its main season under low cost protected structures can assure higher economic return to the farmers.

Characteristics of Lowcost Polyhouse

- It is made principally by utilizing minimal expense accessible material in the local area like wooden logs or bamboos.
- These are small in size and having a short life-span.
- The size of the low technology greenhouses is less than 3 meters in total height.
- The most common type low technology greenhouses provide poor ventilation as they do not have vertical walls.
- This sort of design is generally economical because of practically no mechanization is utilized. Nonetheless, this kind of design gives fundamental benefits of protected cultivation when contrasted with open field condition.
- Low technology greenhouses generally provide suboptimal growing environment and little reduction in the incidence of pests and diseases.

Types of Low Cost Procted Structure

Low tunnel

These are also called 'miniature greenhouses'. This type of structures covers rows of plants so they are also known as 'row cover'. Clean plastic or nets are stretched over the low wire hoops (arcs up to 1.0 m high) to protect plants especially against insect and wind etc. Cultivation of crops like tomato, summer squash, melons, capsicum are very difficult in open field during winter months under north Indian condition due to prevalence of cold wind. In such condition, these crops are generally cultivated in low tunnels/ row cover. This polyethylene is removed from the trenches when the plants start flowering to enable pollination facilitated by insects. Harvests of different cucurbits like muskmelon, round melon, bottle gourd, cucumber, watermelon grown in low tunnels can be advanced by 30-40 days over their ordinary developing season. Plastic low tunnels are flexible transparent coverings that are installed over single or multiple rows of vegetables to enhance the plant growth by warming the air around the plants in the open field during winter season when the temperature is very low i.e. 8 °C or below. Plastic low passages are frequently used to advance the development of plants during the time of winter season. Low tunnels are supported above the plants by using hoops of GI wire and a clear or transparent plastic of 20-30 micron is stretched over the hoops and the sides are secured by placing in soil. In the growing season of the crop, the plastic is vented or slitted as the temperature increase within the tunnels. The farmers can grow different varieties of summer squash (round fruited, long fruited) which is an emerging crop along with cultivation of netted muskmelon varieties in place of traditional varieties. Round melon and bitter gourd are two other crops with increasing demand and usually fetches very high price during off-season and can be grown successfully by using the plastic low tunnel technology. This technology is highly suitable and profitable for the farmers living in northern plains of India (Chauhan *et al.*, 2016) [3].

Advantages

- The structure protects the crop from damage caused by wind.
- It helps in heat retention.
- Nutrient uptake capacity of plants grown under low tunnels is improved several folds than open field condition.
- Fruit yield under row cover can be increased up to the extent of 25% in many cucurbits namely summer squash, cucumbers, melons etc. over open field condition during adverse climatic conditions (Helbacka, 2002) [6].
- Earlier production and yield increment in cool season crops like leaf lettuce and spinach under row covers was reported by Dickerson (2014) [7].

Table 1: Performance of vegetable crops grown under low tunnel (Singh *et al.*, 1999) [8].

Sl. No	Crop	Transplanting time	Harvesting time	Crop Advancement	Expected Cost benefit Ratio
1	Summer Squash	Frist week of December	First week of February	60 days	1:3 to 1:4
2	Muskmelon	Third week of January to First week of February	Second week of April to Last week of April	30-40 days	1:2.5 to 1:3.5
3	Bottle gourd	Third week of January to First week of February	Second week of April to Last week of April	30-40 days	1:2.5 to 1:3.5
4	Bitter gourd	Third week of January to First week of February	Second week of April to Last week of April	30-40 days	1:3 to 1:4
5	Water melon	Third week of January to	Second week of April to Last week of April	30-40 days	1:2 to 1:2.5

		First week of February			
6	Cucumber	Third week of January to First week of February	First week of February	30 days	1:3 to 1:4

Shade net houses

A shade house is a low cost protected structure enclosed by shade nets or any other woven material to allow required moisture, sunlight and air to pass through the gaps. It creates an appropriate micro climate which is considered to be very much conducive to the plant growth. A shade house structure is made up of two basic components i.e. frame and cladding material. The shade house frame provides support for cladding material and designed to protect against rain, wind and crop load. The life span of shade net house can be expected maximum up to 5 years depending on the climatic condition and the structural material utilized. Shade nets are available in the market in a wide range of shade percentages viz. 25%, 30%, 35%, 50%, 60%, 75% and 90%. Leafy vegetables and several ornamental greens are recommended for cultivation under shade nets. The basic objective of shade net is to cut down radiation and temperature up to a certain extent during critical summer months (May-Sept.). Black colour shade nets are considered to be most efficient in reduction of temperature compared to other colours like white or silver, green etc. as because the black colour is the maximum absorbent of heat. Leafy vegetables like beet leaf and green coriander very successfully grown under shade nets, but it is also suitable for growing early cauliflower and

radish cultivation during June to September months.

Advantages

- The partial shade and ventilation reduce the temperature inside the structure and provide favourable environment for crop production.
- The structures also protect the crop against pest attack and natural weather disturbances.
- The structures can also be utilized for raising seedlings of different winter vegetable for early season open field cultivation.
- Yield maximization of several vegetable crops is possible under high altitude. Maximum increase in yield was recorded for pea (286%), followed by capsicum (70%) and tomato (58.66%). Similarly, under low altitudes situation the maximum fruit yield was found for brinjal (169.33%) followed by capsicum (136%) (Negi *et al.*, 2013) [9].
- Apart from yield, quality of fruit can be enhanced under shade net condition.
- Cheema *et al.* (2004) [11] observed that cultivation of off-season vegetable crops under shade net can produce higher yield and advance the maturity.

Table 2: Performance of vegetable crops inside agro shade net (Sindhu and Chatterjee, 2020) [12]

Net House	Tomato					Capsicum	
	Fruit Weight (g)	Yield Kg/pt	TSS (0 Brix)	Vit. C (mg/100g)	Acidity (%)	Fruit Weight(g)	Yield Kg/pt
NH-1	54.0	3.62	5.8	32.76	0.78	45.7	2.7
NH-2	57.9	3.83	6.3	34.02	0.78	57.4	2.5
NH-3	48.8	3.97	6.1	34.18	0.92	77.6	2.6
NH-4	45.6	3.71	7.0	36.18	1.03	62.5	2.7
Open field	42.0	2.17	5.6	32.72	0.72	35.8	1.3

Walk in tunnels

Walk in tunnel is a temporary structure made by using GI pipes or bamboo and covered with different cladding material depending upon the season in which the cultivation is proposed. It is mainly used for off-season cultivation of vegetables like bottle gourd, summer squash, cucumber etc. during winter season (December-mid February). The ideal size of a walk in tunnel can be of 4.0 m width and 30 m length (120 m²) and total cost of fabrication may be Rs.12000-14000/- (Chauhan *et al.*, 2016) [3]. Overall, the height of this type of structure is enough for the workers to walk comfortably during inter-cultural operations.

Advantages

- The workers can easily walk-in to look after the crop.
- The cultivators get higher returns from off-season cultivation of vegetables.
- These are temporary structures which can be constructed by the cultivators themselves at the village level with the help of rural artisans.

Vegetable cultivation under rain shelters

Due to prolonged shower and high soil moisture, the price of the vegetable crops remains very high during rainy season. Disease and insect pest attack increases during rainy season which drastically reduce the crop yield and quality. Especially north eastern parts of India face severe challenges in

vegetable cultivation due to extended rainy season. Rain shelter may provide a great opportunity to grow different types of vegetable inside the structure which is not possible in the open field condition. These structures are roofed with plastic film and other waterproof materials to protect the crops from rain. The structures are commonly constructed using GI pipes or bamboo poles with roofs made up of transparent UV-stabilised low density polyethylene film. The structures are naturally ventilated and protect the crops from direct shower. Cultivation of crops like French bean, cabbage, cauliflower, radish, palak, coriander have been successfully achieved through rain shelter. The structure can also be successfully used for growing seedlings of winter vegetable to catch the early season.

Cloches

Potted plants and small group plants during summer months can be protected from high temperature and hot wind during initial growth stage by using cloches. When the adverse climatic condition is over, the cloches are removed. During hot summer, cloches are generally employed to provide protections to young transplants in vegetable gardens. As cloches are easy to transport so these types of structures are preferred over using a permanent structure. The structure also helps in early maturation of the crops. Poly vinyl films and low density polyethylene are most commonly used glazing materials for cloches.

Use of insect proof net house technology for safe vegetable cultivation

During rainy season, most of the farmers grow the vegetables like tomato, sweet pepper, chilli, okra etc. under open field condition but it becomes very difficult to grow these crops successfully due to attack of various types of viruses. Viruses are mostly spread by insect vectors like white flies, aphids, thrips, jassids and sometimes also by hoppers. To control these vectors, the farmers spray several insecticides for several times, even though those can't properly control the vectors and ultimately their crops remain highly infected with viruses. The only way to control the virus is putting a mechanical barrier between crop and open environment i.e. insect proof net of 40 or 50 meshes in form of net houses or

insect proof nets covered walk in tunnels. But for growing these crops under insect proof net houses, it is the pre-requisite to raise virus free seedlings of those crops either in the low cost protected structures or by covering the nursery beds with insect proof net. The farmer can erect insect proof net houses by using the half inch size GI pipes after bending them in half circle shape. Other insect proof net houses can also be made by covering all sides and top with insect proof net of 40 or 50 meshes, but the net should be UV stabilized. Under the net houses, crops like sweet pepper, tomato, chili or okra can be grown successfully without infestation of viruses and some other borers. Thus, the growers can save a huge amount of money on spending pesticides.

Table 3: Off-season vegetable production under low cost polyhouse of 1000 m² (Yadav *et al.*, 2014) ^[13]

Crop	Variety	Spacing (cm)	Crop Duration (Months)	Total Production (kg 1000 m ²)	Estimated sale Price(Rs/Kg)		Cost of Cultivation (Rs)	Total Income (Rs)	Net Profit (Rs)
					Farmer	Market			
Gherkin	DG-6	50×50	4	2,300	30	50-60	25,500	69,000	43,500
Cherry Tomato	Cherry Red Cherry Yellow	60×50	5	2,000	30	80-100	26,250	60,000	33,750
Bitter gourd	Gynoecious	60×50	4	2,000	25	50- 60	26,250	50,000	23,750
Cucumber	Parthenoca-rpic	50×50	4	2,500	25	40-50	25,500	62,000	37,000

Second year onwards profit: Gherkin: Rs.59000/-, Cherry tomato: Rs.50000/-, Bitter gourd: Rs.40000/-, Cucumber: Rs.52500/-

Temporary protected low height polyhouse

Several vegetable crops like French bean, amaranthus and summer squash can be grown during winter season successfully under low cost and low height temporary poly structures during off season from November to February when it is very difficult to grow under open field. French bean can be harvested during first week of February. From French bean a net profit of Rs. 18,500/- during first year and Rs. 33,000/- from second year can be achieved. Harvesting of

summer squash, a bush type cucurbit, can be started from second week of February and a net profit of Rs. 47,250/- in first year from an area of 1000 m² and Rs. 59,500/- from second year onwards may be obtained out of this cop. Amaranthus harvesting can be started from last week of January and it recorded Rs. 15,000/- and Rs. 25,000/- profit from 1000 m² area during first year and second year respectively (Yadav *et al.*, 2014) ^[13].

Table 4: Off-season vegetable production under temporary protected low height polyhouse

Crop	Variety	Spacing (cm)	Crop Duration (Months)	Total Production (kg 1000m ²)	Estimated sale Price (Rs/Kg)		Cost of Cultivation (Rs)	Total Income (Rs)	Net Profit (Rs)
					Farmer	Market			
French bean	Contender Pusa Parvathi	50×7	110	950	40	70-80	20,000	38,000	18,500
Summer Squash	Pusa Alankar Australian Green DS-8	50×50 50×50	115	4500	15	40- 50	20,250	67,500	47,250
Amaranthus	Pusa Lal Chaulai Pusa Kiran	50×50	120	1500	20	40 – 50	15,000	30,000	15,000

Second year onwards profit: French bean: Rs.33,000/-, Summer squash: Rs.59,500/-, Amaranth: Rs.25,000/-

Zero energy naturally ventilated greenhouses for cultivation of high value vegetables

Protected structures where no heating or cooling devices are utilized for climate control is called zero energy naturally ventilated greenhouses. These are considered as simple and medium cost greenhouses which can be erected with a cost of Rs. 650-700/ sq. meter and these greenhouses can be used successfully and efficiently for growing off season muskmelon, year round parthenocarpic and slicing cucumber, tomato and sweet pepper crops for a duration of 8-9 months . These structures are equipped with a manually operated cross ventilation system as and when required. Looking to the increasing year round demand of high quality parthenocarpic slicing cucumber in markets of the metro and other big cities

of the country, it is one of the most suitable, profitable and remunerative crop for cultivation under naturally ventilated green houses in peri-urban areas of the country. In a period of one year, three successful crops of cucumber can be grown in a naturally ventilated greenhouse. Muskmelon is another crop, which can be successfully cultivated for its complete off-season availability and it can fetch very high price as the off-season produce in the markets of the metro and other big cities of the northern parts of the country. Similarly high value vegetables like tomatoes, cherry tomatoes and coloured peppers can be grown very successfully for long duration (8-10 months period) under zero energy naturally ventilated greenhouse conditions.

Table 5: Suitable vegetable varieties for year round cultivation under low cost poly house (Phookan and Saikia, 2003)

Crops	Varieties	Season
I-Year		
Tomato	Naveen, Karnataka	May-Aug
French bean	Kentucky Wonder, Contender	Sept-Nov
Cauliflower	White Marble, Indam	Dec-Feb
Coriander	CO-1, Mehak	May-April
Green manure	<i>Sesbania</i> Spp.	May
II-Year		
Tomato	Naveen, Karnataka	June-Sept
French bean	Kentucky Wonder, Contender	Oct-Dec
Chilli	KA-2, Arka Lohit	Jan-April
Cowpea	Arka Suman	May-June
Other crops		
Okra	Arka Anamika	May- June
Palak	All Green, Pusa Jyoti	June-July

Table 6: Comparison of cost of production of vegetables under different low cost protected structures (Chauhan *et al.*, 2016) ^[3]

S. No	Kind of protected structures	Cost (Rs/ m ²)	Suitable crops	Duration of crops (days)	Yield (t/ 1000 m ²)	Cost (Rs./ Kg)
1	Insect proof net house	80-100	Sweet pepper	200-240	3.5-4.0	15-16
2	Plastic low tunnels	5-6	Summer squash	90-95	5.0-6.0	1.5-2.0
			Musk melon	110-120	2.0-3.0	3.0-4.0
			Bitter gourd	110-120	1.0-1.5	4.0-5.0
			Bottle gourd	80-90	2.0-3.0	3.0-4.0

Off season rice straw mushroom (*Volvariella volvacea* L.) cultivation in coastal Odisha

The rice straw mushroom is preferably a tropical mushroom requiring a temperature range of 25-40°C, however, cultivation has been made possible in off-season (winter) also by manipulating the growing conditions. A field experiment was conducted in the farmers' field in Ratanpur, Marshaghai block of Kendrapara district in Odisha. The poly house, shade

net and thatched roof systems were all constructed with ground area of 120 sq. ft (15 ft × 8 ft). The ground area taken in case of open system was also same as of the former systems to maintain uniformity. The poly house was a low cost one made of bamboo and LDPE films (white colour), whereas the nets replaced the polythene sheets in shade net system. B:C ratio was found to be highest in polyhouse condition.

Table 7: Income from off season rice straw mushroom cultivation (Mahapatra *et al.*, 2020)

Cultivation system	Gross cost (Rs)	Gross returns (Rs)	Net returns (Rs)	B:C ratio
T ₁ -Shade net	4125	6757	2632	1.64
T ₂ - Poly house	4200	7488	3288	1.78
T ₃ - Thatched house	3900	5958	2058	1.53
T ₄ - Open	3600	4230	630	1.18

Advantages of protected vegetable cultivation:

- Vegetables can be produced year round regardless of season. Adverse climate for production of vegetables can be overcome by growing them inside the protected structure.
- Multiple cropping on the same piece of land is possible through this.
- Off season production of vegetables is possible which can significantly increase the farmers' income.
- It allows production of high quality and healthy seedling of vegetables and supports early crop, strong and resistant crop stands.
- Protective structures provide protection to high value crops from unfavourable weather conditions and also from detrimental pests and diseases.
- Use of low cost protected structures for vegetable cultivation can increase production by approximately four times and increase productivity per unit of land.
- Protected cultivation supports the production of high quality and clean vegetable production.
- It makes cultivation of vegetables possible in areas where it is not possible in open condition such as high altitudes desert.
- Disease free seed production is possible under protected

structures.

Limitations

- Various construction materials like GI pipes, polyethylene sheet etc. are not generally available in local market every time and need to be imported at high costs including freight and custom duty.
- Sometimes for installation, monitoring and supervision, skilled workers are required which is not easily available in the village areas.
- The package of practices of different vegetable crops for round the year cultivation have not been standardized, hence the recommendation of one region may not work for other region.
- Lack of awareness among farmers about the potentials of protected vegetable production hampering the large scale cultivation.
- Very limited research work has been initiated on protected vegetable farming of different commercial crops.

Conclusion

Due to rapid urbanization and industrialization, total cultivable land area is gradually depleting in our country. On

the other hand climate change and population growth impede progress toward achieving food and nutritional security (Chatterjee *et al.*, 2019) ^[16, 17]. It is assumed that by 2050, we have to produce double the amount of vegetables what we are producing today to feed the total population. So, it is the high time to think about cultivation of vegetables beyond open field condition. For maximum utilization of available land and to enhance the productivity as well as to minimize the use of harmful agrochemicals i.e. pesticides and fungicides, protected structures offers immense scope for the farming community of India. Above all, upon realizing the need to pay special attention for the welfare of farmers and to reduce agrarian distress our honourable Prime Minister set a goal to double farmers' income by 2022-23 when the country will complete 75 years of its independence (Chatterjee and Mukherjee, 2019) ^[16, 17]. In this regard, promotion of this kind of new age technology and its proper implementation in the farmers' field can definitely reduce the agrarian distress caused due to climatic vagaries and thus can make the farming more remunerative. But as we know, 80 % of the total Indian farmers belong to the marginal category so effort should be made to minimize the initial investment of establishment of protected structures. In this regard, promotion of different low cost protected structures with natural ventilation must be encouraged. Government subsidies as well as intervention of NGOs for financial help and arrangement of skill development programmes on protected cultivation will help to increase the area under protected cultivation. Farmer producer organizations (FPO) can also play a vital role in popularization of this technology among the farmers. Supply of improved package of practices for protected cultivation through leaflets, farmers training through KVKs will definitely help to create more awareness about the protected cultivation among the farming community.

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