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Protected cultivation to boost the income of farmers in Bundelkhand region of Uttar Pradesh

Annual requirement of vegetables at the present rate of 180 g/day/capita is estimated to be about 135 MT against the obtained 125 MT, which clearly indicates that there is a short-fall of 10 MT of vegetables. Whereas, if the per capita consumption of FAO (300 g/day capita) is to be taken into consideration, there would be a large gap in demand and production. The actual problem of low productivity has been attributed to the extremes of temperatures ranging from 5-48^{0}C during the year which does not allow year-round vegetable cultivation at large scale. In India, this production gap is an opportunity of growing horticultural crops in protected cultivation and the area under high-tech horticulture is growing larger day-by-day and the productivity and exports have both tremendously improved. Vegetables can now be cultivated in off-season, with the induction of an artificial technique like greenhouse technology, in which temperature and moisture is controlled for specific growth of vegetables.

DURING summer and winter season in north India in general and Bundelkhand in particular, it is extremely difficult to grow vegetables in open field conditions; however, with creation of false micro-climate through modified protected structures, some high-value crops and vegetables could easily be grown continuously. In northern India particularly at semi-arid region like Bundelkhand, the summer (April to July), the rainy (July to October) and the winter (November to February) are the major hot-spot seasons. However, in protected cultivation, growing season can easily be extended and one or two more short duration crops could easily be taken which further adds to increased crop yield per unit per day as compared to open field conditions. Moreover, the cultivation of high value crops/vegetables in protected condition can play a better role in improving quality and advancing maturity as well as increasing fruiting span.

In Uttar Pradesh, at poor resourced farmers' level, the popularity of protected cultivation has not been encouraging. This could be due to unawareness about its significance, unavailability of working capital for developing infrastructure, illiteracy of farmers', deprived communication channels and tormented glitches in transportation and lack of sound resources. In Uttar Pradesh, the Bundelkhand region comprising of two mandals i.e. Chitrakootdham mandal (Banda, Chitrakoot, Hamirpur and Mahoba districts) and Jhansi mandal (Jalaun Jhansi, Lalitpur districts) lags behind than other regions of the state in general and country in particular with respect to all socio-economic indicators.

Bundelkhand with its wide variability of climate and soil type is highly favourable for growing a large number of vegetables crops. The economy of Bundelkhand is primarily and largely dependent on agriculture and its allied sectors owing to its predominantly rural inhabitants. Regional inhabitants' livelihood is mainly based on subsistence, rainfed, and single/mixed farming system. To overcome with long-lasting agricultural problems of this region, the Govternment of Uttar Pradesh has established Banda University of Agriculture and Technology (BUAT), Banda (UP).

View of protected structure at BUAT, Banda

The university has formed 8 different protected structures such as natural ventilated polyhouse, insect proof net, green shade net and mist chamber with hardening chamber under the project 'Centre of Excellence on Dryland Agriculture' for cultivation of high

Table 1. Different vegetable crops for Bundelkhand region in protected structures

Protected structure	Suitable crops	Season
Naturally ventilated polyhouse (NVPH)	Cucumber, Tomato, Capsicum etc.	August to April
Green shade net-house	Cucumber, leafy and root vegetables	Last August to November and February to May (Cucumber) and April to August (leafy and root vegetables)
Insect proof net-houses (IPNH)	Capsicum, Cucumber, Tomato, Brinjal and cucurbits, etc.	Round the year
Plastic low tunnels	Cucurbits	Mid November to February
Plastic mulch	All vegetable crops	Round the year

value vegetable crops (Table 1). Simultaneously, BUAT Banda organizes trainings, conducts field day on low cost protected cultivation, and creates awareness among the farmers to adopt low cost protected cultivation technology at their fields and gradually progressive farmers of the Banda District have been showing their interest and started creating low cost protected infrastructure at their field for commercial cultivation and large dissemination. With this limited effort, some of the farmers are ensuring better yields, greater price and are saving their input resources (water, labour and fertilizer costs) year after year that helped them to uplift their socio-economic livelihood in the region.

Advantages of protected cultivation

- It provides conducive micro-climatic conditions for production of high-quality vegetables and allows to grow multiple crops on the same piece of land in a year.
- It gives opportunity to fetch a better price of the produce by growing them in off-season.
- It supports well to easily raise nurseries of different

Natural ventilated polyhouse

Green shade net-house

Insect proof net-house

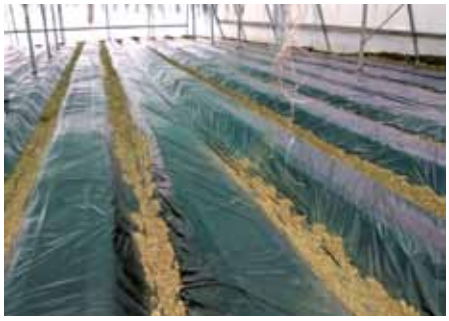
Mist chamber

Hardening chamber

Walk-in-tunnel

Low tunnel

Tomato seedlings under low tunnel



Mulching

vegetable crops, hybrid seed production and also protects them.

- It increases the yield productivity with better quality and attracts enhanced return per unit resource invested.
- It provides alternative venture to cultivate the vegetables in non-growing areas such as high altitudes and deserts.
- It gives shelters from the wind, rain, snow, birds, hail etc.
- It promotes advanced agriculture techniques (hydroponics, aeroponics, vertical cultivation of vegetables).
- It also fulfils the demand of producing nutritionally rich and hygienically healthy vegetables due to lesser use of toxic pesticides.
- Required less irrigation due to moisture conservation.
- It facilitates effective control to pests and diseases and becomes easier to produce disease and insects' free seeds of costly vegetables.
- It enables to develop propagation of elite planting material of different horticultural crops.
- Low cost protected structures are ideally suited for progressive farmers having small holdings.
- It is a labour-intensive technology and generates labour-employability at the source for educated youth.
- It improves better acclimatization of developed plantlets through tissue culture techniques.
- It helps to maintain the stock plants, grafted plantlets and micro-propagated plant.

Protected structures at BUAT, Banda

Natural ventilated polyhouse

It is manually operated and comes under mid-range cost. Naturally ventilated polyhouse are the protected structures where no heating or cooling devices are provided for climate control. Cost of these structures is less than hi-tech structure but higher than others (Table 2). These greenhouses can efficiently be used year-round for growing parthenocarpic slicing cucumber, off-season muskmelon, tomato and sweet pepper for 8–9 months duration. This structure is made up of stainless steel and wall and roof with plastic walls. Polythene sheet (150 gm thick) used in construction further prevents entry of ultraviolet light, conserves CO_2 and enhances plant growth and development. Temperature and moisture inside the polyhouse are comparatively higher than the outside condition, which improves photosynthesis and uniform plant growth.

But now, the time has come when unemployed educated youths should be motivated and trained in Bundelkhand of Uttar Pradesh to use naturally ventilated greenhouse technology for cultivation of high value vegetables for higher profits. The basic prerequisite of implementing the technology is the selection of appropriate design based on the climatic conditions, available market and the type of vegetables. Under extreme hot periods (May–July), rooftops of the greenhouses should be covered with shade nets (preferably with black colour) allowing a space between the shade net and roof surface for air movement.

Shade nethouse

The Bundelkhand region encounters high solar radiation and high temperature that adversely affect crop production. Therefore, the use of shade net-houses is essentially required. In general, shade net-house comes with different shading intensity shade-nets (40-75% shading intensity depending upon different crops) of different colours, i.e. black, green and white that can easily allow us to grow vegetable and ornamental crops. Shade net-house

Cocopeat, vermiculite and perlite

Filling of pro-tray with cocopeat, vermiculite and perlite

Seed sown in pro-tray with media of cocopeat, vermiculite and perlite

Healthy seed germination

Healthy seedlings

Large scale seedlings production

Tomato in polyhouse

Tomato in insect proof net-house

Tomato in polyhouse

Tomato in insect proof net-house

is considered as one of the real innovations to provide development of healthy seedlings for various horticultural crops irrespective of climatic conditions. These structures are less costly than above structures. It not only protects the crops from harmful ultraviolet and infrared radiation but also protects from the extreme temperatures and helps to maintain air and soil moisture. Large-scale use of shade net-houses during harsh summer months is advised for cultivation of different horticultural crops. Black colour shade nets are most efficient in reduction of temperature compared to other colours like green, white or silver, etc. as the black colour absorbs the maximum amount of heat. Mostly leafy vegetables like beet leaf and green coriander are preferred to be grown under shade-nets, but it is also suitable for growing early cauliflower and radish cultivation during June to September months.

Insect proof net-houses

It is used to minimize the use of pesticides in crop production. It also enables us to produce healthy and hygienic vegetables and good quality seeds. Insect proof net-houses are preferred structure for several vegetables (brinjal, capsicum, cauliflower, tomato, okra and cucurbits etc,) and some fruit crops like papaya etc. which have more problems of pest or viruses. Insect management by use of these structures will reduce the load of pesticides in the crop and will increase the demand in market as consumer prefer no/low pesticide exposed crop specifically vegetables and fruits. Nets of 40 and higher mesh are effective means of controlling most of the flying insects. Pests and other vectors population can effectively be checked by using insect proof net-houses that creates a physical barrier between crop and open environment. These insect proof net-houses can be erected by providing an aluminium coated shade-nets (aluminet) approximately 1.0 m above the roof top of the net-houses with movable facility and with two door waiting area facility. The structures can be fabricated with a cost of 700–800/m^2 having 40–50% shading net covering during critical summer months (April–June) and with transparent plastic covering during critical winter months (December–February) under arid and semi-arid climatic conditions. High value vegetables like tomato, cherry tomato (crop duration 7–8 months), two crops of parthenocarpic cucumber (summer and post rainy season) and capsicum (crop duration 7–8 months) can be produced.

Walk-in tunnels

These are simple, temporary and low-cost structures erected on half-inch GI pipes covered with transparent plastic with 200-micron thickness and the height of the tunnel is around 2.0-2.5 m with a width of around 4 m and accommodate almost 2 to 3 beds. This structure is covered with UV film, suitable for all types of crops, flowers and vegetables. These structures are small in size and low in cost therefore are generally acceptable by farmers. Basically, these are temporary and really low-cost structures since the fixed investment made on plastic can last for 5–6 years and the investment made on GI pipes can last for more than 20 years if proper care is taken. The ideal size has been standardized for optimum cross ventilation, to have a single piece coverage of above sized structure with plastic commonly manufactured by firms of dimension 7 × 30 m or 7 × 36 m and a length of nearly 25–30 m is very suitable for honey bees to fly from one end to other for pollination. Walk-in tunnels can be used for off-season cultivation of vegetables by protecting them against extreme low temperature during the peak winter months. Mainly, cucurbitaceous vegetables are grown under these structures, but these structures can also be used for other crops which will have erect and compact canopy like capsicum, lettuce, bush type beans, etc. They are also suitable for nursery raising.

Plastic low tunnels

Low temperature is causing significant loss to *rabi* or late *rabi* crops in the region. A physical barrier in way of the air flow and use of plastic sheet can reduce the

Green capsicum

Red capsicum

Green, Red and Yellow capsicum

Yellow capsicum

Cucumber fruits

extent of loss to the crop. These structures are laid in open fields to cover rows of plants with transparent plastic film stretched over steel hoops of about 50 cm height and about 1 m width. Low tunnels are supported above the plants by using hoops of GI wire and a clear or transparent plastic sheet of 20–30 micron is covered/stretched over the hoops and the sides are secured by placing in soil. These are also called miniature greenhouses. The concept of using plastic low tunnel is very effective in early crop stage when the crop is having low strength to face low temperature stress. It protects plants from harsh climatic conditions such as rain, wind, hailstorm and snow etc. These are mainly used for raising nursery and also helps in early seed germination. 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. Bitter gourd and round melon are two other crops with increasing demand and which 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.

Plastic mulching

Plastic mulching technology, also called surface covered cultivation, largely involves mulching with polythene sheets for addressing three major issues, viz. soil and water conservation, leaching of nutrients as well as reduction of weeds and to some extent insect pest damage. Drip irrigation is an integral part of mulching technology. Mulching involves covering the soil around the plant base with an organic or inorganic material which makes condition more favourable for plant growth and development. Organic mulches, like leaves, straw, sawdust etc. add nutrients and humus to the soil as they decompose, improving its tilth and moisture holding capacity. Synthetic or plastic mulches have various beneficial effects on crop production. Plastic mulch accelerates plant growth by increasing soil temperature, conserving soil moisture, weed control, production of quality produce and reduction in leaching of nutrients. The plastic mulch is available in different colours and each colour has its own significance. Transparent polyethylene mulch raises the soil temperature by soil solarization used mainly for managing soil-borne diseases and nematodes. This effect derives mostly from the suppression of latent heat loss through evaporation. Black polyethylene film also gives effective weed control by cutting down solar radiation by more than 90%, resulting in etiolated growth and the eventual death of weeds under the film. The yellow plastic mulch attracts insects so it can be used to attract and kill insects. The silver-reflective type of plastic mulch associated with higher reflectance causes insect disorientation and repels aphids. The different types of mulches are reflective plastic mulches, infra-red transmitting mulches and biodegradable plastic mulches. Suitable horticultural crops that can take advantage of mulching include plants growing vertically by nature and not the creeping types e.g. solanaceous crops and cole crops. This technology is again useful for areas with water scarcity or rainfed ecosystems, and can conserve moisture to the extent of 50% water saving and 30% nutrient saving. Thus, we can conserve resources, economise input use and efficiency and harvest 25-30% higher yields as also the quality, playing a significant role increase in income and overall upliftment of livelihood of farming families.

Vegetable nursery raising

Growing of off-season vegetable nurseries under protected structure has become profitable to the farmers. The cost of hybrid seeds of different vegetable crops is very high so, it is necessary that every seed must be germinated with maximum germination and it requires controlled conditions. The main purpose of raising nursery in the controlled condition is to get higher profit and disease-free seedlings in off-season to bring the early crop. Raising of vegetable nursery in protected structures has manifold

Ripe fruits of tomato in NVPH

benefits such as easy management, early nursery and protection from biotic and abiotic stresses. Cucurbits are warm season crops and they are sown in last week of March to April when night temperature is around 18-20°C. But in controlled conditions, their seedlings can be raised during December and January in polythene bags and planted, during end of February and 1st week of March in the field and fruits obtained in 1.0-1.5 months in advance than the normal method of direct sowing. It results in the bonus price due to marketing of produce in the off-season. Similarly, the seedlings of tomato, chilli, capsicum, brinjal, cucumber, cabbage, cauliflower and broccoli can be grown under plastic cover protecting structure. Income generated through the production of vegetable seedlings in polyhouse was more, followed by shade net-house and open field units of the same area. Nursery growing under polyhouse showed a significant result. In the polyhouse technique, a greater number of plants per unit area and the crop growth from it gave higher early and total fruit yields.

Challenges

- High temperature being the major challenge allows to grow only limited crops in summer months and the grown crops withstand scorching heat of sun with heat storms.
- High level of radiations encounters the sudden increase in temperature and encourage water deficit stress and both reduces the adaptability of newly introduced crops.
- The quantity and quality of underground water is limited for irrigation however, the quality of water deteriorate due to presence of salts (saline and brackish).
- This region possesses rugged and undulated topography and the soils are poorly fertile being very low in organic carbon (i.e. 0.1-0.4% only), nitrogen, phosphorus and zinc and has high degree of erodibility. Therefore, surface and sub-surface runoff is very common during rainy season.
- Low and scattered vegetation cover in these regions are very common which favours frequent dust storms ultimately causing significant loss to the crops.
- This region commonly has erratic and uneven rainfall (750-1020 mm), however, recurrent monsoon failure makes this region a drought prone area. Scarcity of water gives cause to the need for its more efficient use. Therefore, *in situ* and *ex situ* rain water harvesting and afforestation is the only key to manage challenged environment.
- Protected cultivation technology requires very careful planning, maintenance and management about timing of production and further, harvest time to coincide with the shortage period of availability of vegetables and high market prices, choice of varieties adopted to off season environments, and able to produce higher and economical yields of high-quality produce, etc.

Opportunities

- The escalating population and economy has resulted in a continuous increasing demand for vegetables and high valued crops.
- Creation of huge self-employments for unemployed educated youths.
- Raising the national economy by sale of high-quality produce in domestic and international markets.
- Unproductive lands can be converted for good quality production of horticultural crops.
- Protected cultivation possesses high potential for enhancing the income of farmers opting for quality and off-season vegetable and cut flower cultivation.
- An increased water efficiency is possible solely with protected cultivation.
- Developing climate-resilient vegetables suitable for protected cultivation.
- Focusing on local values, indigenous knowledge and uses: such an approach will strengthen the link between diversity and sustainable uses and is important in considering marketability.

Strategies

- Standardizing proper designing of low-medium cost polyhouse including cladding and glazing material.
- Developing cost effective agro-techniques for growing different vegetables and reducing input costs of the greenhouse management.
- Revalidating the developed agro-techniques under harsh climatic condition and refining the technologies developed as per need and demand.
- Developing young professional and skilled polyhouse manufacturers.
- Creating awareness among farmers pertaining to the potential of protected vegetable production.

Constraints/Limitations in protected cultivation

- Higher initial investment cost, short life of polysheet and non-availability of cladding materials is one the major constraint to adoption of this technology by the farmers for commercial cultivation.
- Lack of minimum support price, high price fluctuations and lack of market information were the major

Table 2. Cost of cultivation of hi-value vegetable crops in ventilated polyhouse (NVPH), insect proof net-house and green shade net-house (200 m^2)

Protected structure	Name of crops	Fruit yield (kg)	Cost of cultivation with structure (₹)	Gross income (₹)	Net income (₹)	B: C ratio
Natural ventilated polyhouse (NVPH)	Coloured Capsicum	2160	48,376.80	1,01,400	53,023.20	1:2.09
	Indeterminate Tomato	5200	51,629.16	1,04,000	52,370.84	1:2.01
	English Cucumber	3360	35,803.20	1,00,800	64,996.80	1:2.81
Insect proof net-house	Coloured Capsicum	1760	44,483.52	82,800	38,316.48	1:1.85
	Indeterminate Tomato	4720	47,526.16	94,400	46,473.84	1:1.98
	English Cucumber	2640	32,775.20	79,200	46,424.50	1:2.41
Green shade net-house	Coloured Capsicum	1540	44,243.52	72,400	31,596.48	1:1.63
	Indeterminate Tomato	4120	47,256.16	82,400	35,143.84	1:1.74
	English Cucumber	2280	32775.20	68,400	35,624.80	1:2.08

of marketing constraints in the way of protected cultivation.

- The components of polyhouse such as fibre glass, cooling pads, fans, etc have to be imported at high costs including freight and custom duty.
- Greenhouse and other structures design for different agro-climatic of the region is not standardized.
- Lengthy loan procedure, a high cost of production, and non-availability of quality seedlings.
- Lack of technical guidance, high cost of pesticides and fertilizers create the low production.
- In marketing channel of produce, the major constraints faced by the farmers include non-payment of prices by commission agents in time and the high cost of transportation also.
- Lack of appropriate tools and machinery one of the constraints for quality production of horticultural crops.
- Lack of awareness among farmers, relating to potentials of protected vegetable production and also lack of significant research programme for protected cultivation.
- The initial cost of structure looks unaffordable to the farmers, because he has zero risk affordability so do not come forward to adopt this technology.
- The protected growers face the attack of minute insects like mites, whiteflies, especially the white fly menace, nematode infestation, frequent occurrence of windstorms, hailstorms, lack of cold storage facilities in villages, high cost of refrigerated vehicle are the serious constraints.

Suggestions

- Use of local materials such as bamboo/wood instead of expensive steel pipes to reduce the initial cost of greenhouse installation.
- To regulate the temperature and humidity in such low-cost greenhouses, open the polyethylene sheet on one side manually when the temperature increases inside and irrigate or sprinkle the beds to increase the humidity and reduce the temperature.
- Subsidy rate on polyhouse already given to the farmers should be increased for popularization of greenhouses in these areas.
- Farmers should form their own co-operative societies to make best use of greenhouse in arranging materials jointly at cheap rates for their installation and further taking the produce to the market to get good returns.
- Regular training programmes should be organized to transfer the appropriate technology to the farmers.

Crop performance at BUAT, Banda in protected structure

The Banda University of Agriculture and Technology (BUAT), Banda, Uttar Pradesh has formed the different protected structures for cultivation of high value vegetable crop. At Banda, under natural ventilated playhouse (NVPH), red and yellow capsicum *var.* Natasha and Swarna, respectively were sown in first week of August and further transplanted in second week of September and crop is harvested up to April. The average weight of harvested green fruits was 245 g and 330 g, respectively. At present, in Banda, the sale rate of marketable green fruit of capsicum is around ₹40/kg and red and yellow capsicum can easily be sold off at 20-25% higher price i.e. ₹50-60/kg. The average fruits per square meter were 7-10 kg, 7.50-11 kg and 8.50-12 kg in capsicum hybrid Indira, Natasha and Swarna, respectively. Likewise, hybrid tomato (NS-4266) also transplanted in the second week of September and harvested up to April, the matured fruits are pulpy with tight pericarp and highly suitable for long transportation. It can simply be stored for 10-15 days at normal room temperature and can easily be sold off in local market at a price of ₹20-25/kg. The per square meter average yield was 20-26 kg. Similarly, the parthenocarpy cucumber was sown in the 2nd fortnight of September in green shade net which later fruited well at each and every node, the harvested fruits was dark green in colour and the market acceptance was excellent as it was seedless and was sold off in local market at a price of ₹40/kg in November.

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