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Potentials and prospects of protected cultivation under Hilly Conditions

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Abstract
Protected cultivation is the concept of growing potential crops in the modified natural environment for ensuring optimum growth of the crop plants without any or least stress and hence offers great scope to harness this potential of growing the high value crops by achieving independence of climate and weather, and to grow these crops during off -season and in marginal environments. Globally, there is a need to increase productivity and quality of the produce to meet the demand of ever increasing quality and health conscious consumers. Hence, a breakthrough in production technology of high value crops such as, vegetables that integrates market driven safe foods/ products driven quality parameters with the production system by ensuring vertical growth in the productivity.

Keywords: poly tunnels, green house technology, high-tech polyhouse

Introduction
With globalization of markets, shrinking land and climate change, the protected cultivation of high value crops has emerged as the single most important technology for ensuring, high productivity, improved quality and lucrative returns. Protected cultivation on commercial scale is undertaken in over 50 countries across the globe. First modern greenhouses were built in Italy in the thirteenth century to house the exotic plants. In India, green house technology started in 1980 and initially it was used for research only. The National Committee on Use of Plastics in Agriculture (NCPA, 1982) recommended specific trials of greenhouse technology in various regions of the country. In India, first polyhouse was designed and set up in 1985 at Leh (Jammu & Kashmir).

Protected Cultivation
It is a technique wherein the microclimate around the plant is controlled fully, partially or modified to protect the crop from adverse weather. Protected cultivation ensures conservation of soil moisture and efficient use of energy mainly solar. Protected Agriculture (PA) is combination of horticultural and engineering techniques to optimize crop production, crop quality and production efficiency.

Table 1: Present Scenario

Country	ha (‘000)
China	81.0
Spain	70.4
South Korea	47.0
Japan	36.0
Turkey	25.0
India	25.0
Italy	16.5
(Hickman 2011) [1]	

Highest area under protected cultivation is in China (81000 ha) followed by Spain (70000 ha). In India area under protected cultivation is 25000 ha. However, Himachal Pradesh has more than 300 hectare area under protected cultivation.

Need of protected cultivation
There is need for protected cultivation because of these following points, they are as follows:
1. Higher yield
2. Better quality

3. Off-season production
4. Assured production
5. Least pesticide residues
6. Controlled pollination
7. Vagaries of weather
8. Easier plant protection
9. Weed free cultivation

Protected cultivation in hills

Agriculture in the hilly regions of the country is at subsistence level and, gains of green revolution have not reached the hill farmers. Scattered and small land holdings, difficult terrain, fluctuating and unpredictable weather, prevalence of low temperature during autumn winter and spring reduces profit margin of the hill farmers in open environment. There is a great variation in agro-climatic conditions in H.P. This ranges from sub-humid, sub-tropical to dry temperate. Due to these climatic variations, varieties of crops are grown during different periods of the year. Majority of cash crops mainly vegetables grown in the Himachal Pradesh are exported and consumed by the neighboring States of plains. There is lot of demand for off season vegetables grown in the Himachal Pradesh and also there is a great export potential. Implementation of HTM and RKVY projects in hill states further gave a boost for popularization of polyhouse cultivation for growing high value vegetables and flowers. Approximately 16,500 polyhouses have been constructed under state funded scheme "Pandit Deen Dyal Kisan Bagwan Samridhi Yojna" in H.P (Anonymous 2013) [2].

Principle of polyhouse

The green house is generally covered by transparent or translucent material such as glass or plastic. The green house covered with simple plastic sheet is termed as poly house. The green house generally reflects back 43% of the net solar radiation incident upon it allowing the transmittance of the "photosynthetically active solar radiation" in the range of 400-700 Nm wave length. The sunlight admitted to the green house is absorbed by the crops, floor, and other objects. These objects in turn emit long wave thermal radiation in the infra red region for which the glazing material has lower transparency. As a result the solar energy remains trapped in the green house, thus raising its temperature. This phenomenon is called the "Green house Effect". This condition of natural rise in green house air temperature is utilized in the cold regions to grow crops successfully.

Types of polyhouses

1. Low cost or naturally ventilated polyhouses
2. Medium cost or partial climate controlled polyhouses
3. High cost or fully climate controlled polyhouses
4. Plastic low tunnels
5. Net houses
6. Plastic mulches

Low cost or naturally ventilated polyhouse

These are simple greenhouses with low initial investment. The frame may be galvanized iron pipes, bamboos, wooden logs or steel pipes, or any other local material but no heating or cooling systems are provided for the structure. The top of the greenhouses is covered with the plastic and the sidewalls have the insect proof nets from ground or at 2-4' to a height of 5 to 8' with or without manually roll-able plastic cover. The initial cost of these greenhouses is less than half to that of semi climate controlled greenhouses. Modified naturally ventilated polyhouses offer great potential for commercial cultivation of high value vegetables including raising of seedlings in plug trays. Since climate in hilly regions is mild except temperate zone and low hills, so very simple and low cost greenhouses can be constructed to raise the vegetable and flower crops almost round the year and of- season thereby providing enough opportunities to the polyhouse growers to fetch early and remunerative price of the quality produce. The ideal polyhouses have been found very effective in low and mid hills, which need ventilation, shading and misting during summer and rainy season (depending upon prevailing weather and location) to bring down the temperature and regulation of humidity whereas vents can be closed during winters. These greenhouses with certain modifications are also suited for growing crops in high hills and cold deserts of the country. In the higher hills, the low cost but ideal polyhouses are very useful as climate is mild during summer and rainy season and high value crops *viz*., capsicum, tomato, cucumber, beans, sarda melon *etc.* can be more profitable as compared to open cultivation. Likewise, farmers of cold desserts have been immensely benefited from this technology due to availability of an additional growing season to the inhabitants besides assuring supply of fresh vegetables to the defence personnel during winters. In North-East parts, simple bamboo structures have been found useful to raise vegetable crops for domestic consumption and supply to local markets.

Medium cost or partial climate controlled polyhouses

The structural frame is made up of galvanized iron pipes, like the climate controlled green house, but only the exhaust fans with evaporative cooling pads are provided to maintain the favorable temperature and humidity during summer. These types of greenhouses are suitable for vegetable cultivation in low and mid hills in North India. The basic cost of installation of these greenhouses is half to that of high tech or fully climate-controlled greenhouses.

High cost or fully climate controlled polyhouses

This type of greenhouse is constructed to achieve higher degree of climate control to enhance the cultivation period of the crops. Evaporative cooling and the heaters are used to maintain the required temperatures inside greenhouse as and when needed. The greenhouse consists of a sensor, a comparator and an operator. The temperature humidity and light are automatically controlled. These greenhouses are mostly used for cultivation of tomato and sweet pepper over a longer period of time. The greenhouses are made up of plastic except in cold places where rigid plastic or glasshouses are used.

Plastic low tunnels

Miniature form of polyhouse to protect the plants from rains, winds, low temperature, frost and other vagaries of weather. These provide the best way for off season vegetable nursery production by modifying the microclimate around the plants. These structures, with location specific modifications, are highly suitable for growing vegetables in the peri-urban areas of the northern plains, cold desert (Ladakhi polyhouses) areas as well as other areas of the hilly states like Himachal Pradesh, Jammu and Kashmir, Uttarakhand and North Eastern states. In this type of nursery production a nursery bed of size 3x1x0.15 cm size is prepared and the sowing of the seeds is done as per recommended traditional method of nursery raising. A portable low plastic tunnel of size 3.5x1.20x1.0 m size with polythene sheet of 120GSM is put on the nursery bed. Seedlings germinate faster and their hardening is done simultaneously by removing the portable tunnels during day time or when the weather conditions are favourable. These portable tunnels are cheaper and the cost for the size 3.5x1.25x1.0 m with polythene sheet of 120GSM is approximately Rs.3000/tunnel and they can be easily handled and can be transported from one place to another with ease.

Net houses

In the present scenario of perpetual demand for better quality vegetables and continuously shrinking land holdings, Net-house cultivation is the best choice for quality produce and efficient use of land and other resources. Net-house cultivation means some level of control over plant microclimate to alleviate one or more of abiotic and biotic stresses for optimum plant growth. Crop yields can be higher than those under open field conditions, quality of produce is superior, higher input use efficiencies are achieved and vegetable export can be enhanced.

Net house is a framed structure consisting of GI pipes covered with ultra violet (UV) stabilized net of 40-mesh size and large enough to grow vegetables under protective cover. To get the benefit of the sunlight, net house should preferably be constructed in the East-West direction.

Extreme weather conditions under the open field conditions are the major limiting factors for achieving higher yield and better quality of vegetables. Under such circumstances, protected cultivation is best option. The net house cultivation is an alternative and feasible option to produce vegetables with minimum use of pesticides. It also provide better environment to improve yield and quality. Net-house cultivation can play a better role in improving productivity, advancing maturity and increasing fruiting span.

Plastic mulches

Mulching is a practice of covering the soil around plants to improve crop growth and development. Mulch material may be organic (leaves, straw, grass etc.) or synthetic (plastic). Now day’s plastic mulches are commercially used in protected cultivation. Black plastic mulch used in winters. White plastic mulch of 30-40 μ used in summers. Yellow plastic mulch is used in reduction of virus incidence in several vegetables like solanaceous crops.

Table 2: Size and investment patterns in polyhouses (Rs.)

Investments	100 sq. m.	250 sq. m.	500 sq. m.
Estimated cost of polyhouse	88000	192500	434000
Assistance on polyhouse	70400	154000	347200
Estimated cost of drip and fogger	12500	23750	47600
Assistance on drip and fogger	10000	19000	38080
Total cost of polyhouse	100500	216250	481600
Total assistance (80%)	80400	173000	385280
Farmer’s Investment (20%)	20100	43250	96320

(Bala 2013) [3]

Potentials of protected cultivation

There is great potential of protected cultivation, in case of tomato and cucumber, there is two times more yields in polyhouse conditions (98.5 t/ha and 21.33 t/ha respectively) as compared to open conditions (42.3 t/ha and10.53 t/ha) and four time yield increase in capsicum as it is 20.02 t/ha in open conditions and 80.0 t/ha in protected conditions (Nagalakshmi [4] *et al*. 2000 and Sharma *et al*. 2000 [5]). BT-117-5-3-1 variety is a promising variety under polyhouse conditions with more yield as compared to other varieties (Sanwal *et al*. 2008) [6]. Sweet pepper crop performs better in protected cultivation as compared to open field conditions. The insect pest problem is also low and net returns are more in case of protected cultivation as compared to open field (Singh et.al. 2011) [7]. “Poinset” variety of cucumber is a promising variety for polyhouse conditions with more yield as compared to other varieties (Sharma *et al*. 2000) [5].

Greenhouse frameworks

- The greenhouse frame can be constructed from different types of material. The selection of right framing material will depend upon capital investment, size of greenhouse, height of greenhouse and availability of material. The most common materials for greenhouse frameworks are bamboo, wood, mild steel (MS) pipes, galvanized pipe and aluminium.
- The framework should be strong enough to bear wind, snow and dead load including the load required for training of plants as well as for hanging of plant pots.
- It should allow the maximum amount of light to reach the plants.
- It should require little maintenance. Avoid the use of MS pipes as it will require frequent painting and its rusting will damage the greenhouse cover.

Greenhouse glazing

The covering of the greenhouse is referred to as the *glazing.* The considerations in choosing a glazing material include durability, light transmission, cost, and heating and cooling costs. The solar radiation spectrum can be divided in several specific wavebands, which are defined by their range of wavelengths or energy content (e.g., radio and TV radiation, microwave radiation, visible light, etc.). The higher the wavelength, the smaller the energy content. Typically, the wavelength of light used by plants is expressed in the units of nanometer (nm). Not all components of sunlight are useful for plant growth and development. In general, ultraviolet (UV; less than 380 nm) and excessive infrared (IR; above 770 nm) or heat radiation can be harmful to plants and should be avoided. Plants use Photosynthetically Active Radiation (PAR; 400-700 nm), as their energy source for the process of photosynthesis. Therefore, greenhouse structures and especially the glazing material should have a high transmittance of PAR radiation. The common materials for greenhouse glazing (covering) are: glass, plastic films and rigid plastics (poly carbonate and acrylic).

Table 3: Comparison of different kinds of covering materials

S. No.	Type	Durability	Transmission		Maintenance
			Light	Heat	
1.	Poly ethylene	One year	90%	70%	Very high
2.	Poly ethylene UV resistant	Two years	90%	70%	High
3.	Fiber Glass	Seven years	90%	5%	Low
4.	Tedlar coated Fiber Glass	Fifteen years	90%	5%	Low
5.	Double strength Glass	Fifty years	90%	5%	Low
6.	Poly carbonate	Fifty years	90%	5%	Very low

Procedure for construction

- Select the site
- Mark the boundary of greenhouse.
- Make excavation for foundation pipes
- Fix foundation pipes with cement concrete
- Fix all the hoops with foundation pipes
- Construct a ridge line by fastening/welding with hoops.
- Fix the glazing material with thin MS strip/screws
- Secure excess sheet in the channel around GH
- Construct a drainage channel around greenhouse.

The greenhouse glazing should properly secure with greenhouse for its long-life. The properly constructed greenhouse with quality construction material will last many years.

Potential crops for protected cultivation

Ornamental flowers (cut rose, carnation, chrysanthemum, gerbera, orchids, anthurium, gypsophila, daisies and lilies) and vegetables (tomato, brinjal, capsicum, cucurbits, lettuce, beans) can be grown successfully in controlled temperature, light, wind, humidity and CO_2Swithout any damage caused by insect pests, diseases and heavy rains. More plants per unit area can be accommodated in polyhouse than open field conditions.

Training

1. Single or two stems.
2. In early stage the shoots should remove by snapping them off.
3. Plants are supported by plastic twine, loosely anchored on the base of plants.
4. The twine is not wrapped around the growing tip otherwise the tip may break.
5. The plants must be pruned on regular basis for entire life cycle of the crop.
6. This will provide air circulation, which helps to reduce the incidence of the diseases.

Pruning

- Pruning is removal of all lateral branches.
- Pruning must be done on a frequent schedule (every 3 to 4 days).
- Pruning is done early in the day when plants are turgid but dry.
- Care should be taken to remove only suckers and not the main terminal bud.
- The pruning time should be used to inspect plants for obvious problems such as disease, nutritional deficiencies, insects etc.
- All pruned plant material should be placed in a container and removed from the greenhouse.

Grafting in vegetable crops

Grafting of vegetable seedlings is a unique horticultural technology to overcome soil-borne diseases and nematodes and to add extra vigour to the plants under various environmental stresses. It is a process involving the choice of rootstock and scion species, creation of a graft union by physical manipulations, healing of the union and acclimation of the grafted plant (Lee and Oda 2003) [8].

Environment control

- Double door
- Height (at least 4 m from side) with side bent at 60-75 cm height
- Ensure proper top ventilation
- Use rolling type shade nets (top/ inside)
- Install fan system especially in low hills and plain areas
- Maintain humidity between 60 and 80%
- Maintain optimum temperature between 18 to 25 ^oC

Hygienic cultivation

- Double door
- Use yellow sticky/ water traps
- Avoid frequent opening and closing of doors
- Remove infected leaves/fruits immediately
- Use disinfectant at entry points
- Close crevices and other openings for avoiding insect entry
- Disinfect the soil after every 3 years
- Disinfect tools and implements

Climate control

- Maintain humidity 60-80%
- Maintain optimum temperature 18-24 ^oC (avoid >35 and <12 ^oC)
- Use agro shade net to control temperature and light
- Ensure sufficient air circulation around the plants
- Ensure carbon dioxide concentration >300 ppm

Production systems and media for protected cultivation

1). **Soil System or Geoponics:** The crop grown in natural soil is known as geoponics.

- Disadvantages of geoponics or soil system:
- Presence of disease, insect and weeds in the soil
- Excessive nutrient level could leach into ground water tables
- Flooding of irrigation water cause high water table which reduces aeration, thereby root growth

2). **Soil less culture:** Growing of vegetables in the media other than soil is known as soil less culture. Media used are cocopeat, perlite, vermiculite, saw dust, rockwool, peanut hulls, rice hulls or the mixtures.

3). **Hydroponics or water culture:** The system of growing plant in nutrient solution is known as hydroponics.

4). **Aeroponics:** It involves the growing of plants in a trough or container in which the roots are suspended and sprayed with a nutrient mist. The rooted plants are placed in a special type of box with computer controlled humid atmosphere. It is a relatively new production system used especially for research purpose.

Plug tray nursery

Plug or cell transplants are seedlings or small vegetatively propagated plants which are raised in individual small cells, called plugs. The plugs are filled with a cohesive medium, and are eventually transplanted into other growing systems. In a plug system, seeds are usually sown by an automated seeder into plug trays. These may have from several dozen to hundreds of cells. With a few exceptions, only one plant is raised per cell. This technique is capable of vigorous root development, suitable for nursery raising without any damage to the seedlings. This technology is quite economical for the vegetable growers of the northern plains of India, because with the introduction of this technique, farmers can grow a large number of seedlings as per requirement for off-season cultivation of these cucurbits for fetching high price of the off-season produce. The plug-tray nursery raising technology by using soil less media can be extended to the growers in various parts of northern India for growing off-season vegetables. But economic returns from these crops can be greatly enhanced if grown out season.

The plug-tray nursery raising technology is better in comparison to the traditional methods/polybags due to the limitations of the existing traditional methods of nursery raising summarized as under:

i. It is nearly impossible to raise virus free nursery during rainy and post rainy season.
ii. Development of soil borne fungus and nematodes mainly during high temperature period, which adversely affect crop growth.
iii. Duration of nursery raising during winter is long (50-60 days) due to poor germination in low temperature.
iv. Since there is no competition among plants, therefore greater uniformity in seedlings is obtained under this system.
v. It is suitable for raising the nursery of sexually and asexually propagated vegetables and also of ornamental plants.
vi. Economizes hybrid vegetable nursery by raising by way of reducing the seed rate by 30-40% compared to traditional system.
vii. Easy for transportation after packing for long distances.
viii. Nursery of vegetables like cucurbits is not at all possible under traditional system.
ix. Off season nursery cannot be raised due to abiotic factors

Fertigation

Fertigation is the application of chemical fertilizers with irrigation water. Drip irrigation provides possibilities for precise application of fertilizer and other chemicals. The high efficiency of water application reached in drip irrigation systems is ideal for the high efficiency of applied nutrients in fertigation (Bressler, 1977) [9]. This improved use efficiency of fertilizers (Bar-Yosef *et al*. 1976) [10], reducing nutrient losses due to leaching thereby limiting groundwater pollution, better control of the soil solution nutrient contents (Bar-Yosef, 1971) [11], reducing soil solution salinity due to fertilizers and ease of application, reducing labour and saving energy, are the prevailing potential advantages of fertigation. But, some of these potential benefits can reverse into disadvantages when the irrigation system design or management is not correct (non-uniform nutrient distribution, over fertigation, excessive leaching, clogging). Therefore, it is most important for a proper fertigation to reach an adequate and efficient irrigation.

Advantages

- Relatively uniform fertilizer applications
- Flexibility in timing of applications
- Less fertilizer used
- Reduced costs

Disadvantages

- Potential contamination hazard from equipment malfunctions
- Backflow prevention devices required
- Careful handling of liquid fertilizers required

Objectives of fertigation

1. Maximize profit by applying the right amount of water and fertilizer.
2. Minimize adverse environmental effects by reducing leaching of fertilizers and other chemicals below the root zone.

Table 4: Low nutrient use efficiency

Nutrient	Efficiency (%)	Cause of low efficiency
Nitrogen	30-50	Immobilization, volatilization, denitrification, Leaching
Phosphorus	15-20	Fixation in soils Al – P, Fe – P, Ca – P
Potassium	70-80	Fixation in clay – lattices
Sulphur	8-10	Immobilization, Leaching with water
Micro nutrients (Zn, Fe, Cu, Mn, B)	1-2	Fixation in soils

Benefits of protected cultivation

1. Environment control allows raising plants anywhere in the world at any time of the year.
2. The crop yields are at the maximum level per unit area, per unit volume and per unit input basis.
3. The control of the microcosm allows the production of higher quality products which are free from insect attack, pathogens and chemical residue.
4. High value and high quality crops could be grown for export markets.
5. Income from the small and the marginal land holdings maintained by the farmer can be increased by producing crops meant for the export markets.
6. It can be used to generate self-employment for the educated rural youth in the farm sector.

Important insect pest and diseases of polyhouse

Table 5: The different insects of polyhouse and insecticides for their control:

Insect	Insecticide
White fly	Acetamiprid
Thrips	Metasysstox
Aphids	Roger
Spodoptera	Spodocyte
Mites	Dicofol
Nematode	Carbofuron

Table 6: The different diseases and fungicides for their control:

Diseases	Fungicides
Bacterial wilt	Captan(2.5gm)+bavistin (1gm)
Powdery mildew	Carathane (1gm/lt)
Damping off	Indofil M-45 (2.5gm/kg seed)
Alternaria leaf spot	Blitox (3 gm/lt)
Fusarium wilt	Carathane (1gm/lt)
Blossom end rot	Calcium chloride (5gm/lt)

Constraints
1. Basic cost and operational cost is very high
2. Irregular power supply
3. Little work on designing in different locations
4. Cladding material quality/availability
5. Lack of indigenous technology (Zone/region)
6. Lack of suitable vars. / hybrids for greenhouse cultivation
7. Bacterial wilt, downy mildew, collar rot and powdery mildew
8. Exotic seeds very costly
9. Poor performance of indigenous varieties
10. No specific research programme on greenhouse vegetable production
11. Foggy winter and prolonged rainy season hamper vegetable production

Future needs
Polyhouse vegetable production in the country is still in infancy and for its rapid commercialization, there is urgent need to redress the following issues related to this technology:
1. Standardizing proper design of construction of polyhouses including cost effective and indigenously available cladding and glazing material.
2. Developing cost effective agro-techniques for growing of different vegetable crops in the different types of polyhouses and lowering energy costs of the green house environment management.
3. Major research activities on growing of vegetables under protected covers should be launched by ICAR and SAU's.
4. Import of planting materials, structural designs and production technologies which are not relevant under Indian conditions should be stopped and in turn emphasis should be given to develop own F_1 hybrid varieties so that seed are made available to the growers in time and at cheaper rates.

Conclusion
Protected cultivation of high value crops has become irreplaceable both from economic and environment points of view. It offers several advantages to grow high value crops with improved quality even under unfavourable and marginal environments. However, due to high training needs of the green house growers and some poor quality produce with pesticide residues has been a matter of great concern. These issues can easily be addressed by integrating various production and protection practices including location specific designing and construction of the polyhouses for efficient input use. Creating awareness among the greenhouse growers for judicious use of pesticides for safe production can be instrumental in providing quality products without polluting the environment. Protected cultivation- every day farming.

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