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Prospects of growing vegetables in India under protected environment structures

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Abstract
The importance of growing vegetables under protected structures improves its quality, quantity, appearance and, above all fetches the favorable market price to farmers. By adopting few changes in crop sequence, farmers can augment their income by off season growing in protected cultivation structures as compared to seasonal gluts leading to low prices. One of the most profitable technologies in North India is the raising of cucurbits, tomatoes, broccoli, capsicum and salad crops under low plastic tunnels. Walk-in tunnels can also provide favorable and efficient for increasing off-season cultivation due to lower initial costs. Insect-proof net houses can be used for cultivation of tomatoes, chilies, sweet peppers and other vegetables mainly during the monsoon season under virus-free environment. These low-cost protection structures are suitable for growing green vegetables without pesticides. Low-cost greenhouses are used for long (5-10 months) high-quality vegetable cultivation, mainly in the near-urban areas of the country. The poly trenches are most useful for growing vegetables in cold desert conditions of the upper regions of the Himalayas.

Keywords: Season, walk-in tunnels, precision agriculture, profitable, protected cultivation

Introduction
One of the best way to describe the greenhouse is a framed or raised structure covered with a transparent or translucent material, in which crops can be cultivated under partially or fully controlled environments (automated) and is large enough to allow individuals to perform agronomic intercultural activities [2]. The raising of high value crops have become the single most important technology to ensure high yield, improved quality and profitable returns. Two decades ago, this technology was considered the only means of production for wealthy western world that had unfavorable climates like Holland, Japan, Israel but is now established in many developing countries like India. The use of plastic has changed the scenario of horticultural production, leading to another revolution next to Green Revolution [3] called protected cultivation revolution under umbrella of precision agriculture.

Since ancient times, mankind is well known that intelligent change of the surroundings can improve the productivity of crops. For example, Romans were aware of the fact that a light-shelter could create a favorable environment for their Emperor who regularly consumed cucumber. In fact, the concept of controlled environmental farming is not a new concept and has been in practice for a long time. The first reported protected farming is of off-season cucumbers under the transparent stone for Emperor Tiberius in the first century. This technology was rarely used in the next 1500 years. In the 16th century, glass lanterns, bell jars, and glass-covered hot beds were used to protect garden crops from the cold. In the 17th century, low portable wooden frames covered with oily translucent paper were used to heat the plant's atmosphere [2].

In Japan, primitive techniques using oil-paper and straw mats were used in the early 1960s to protect crops from severe climate. In the same century, the greenhouses of France and England were heated with manure and covered with glass panes. The first greenhouse in the 1700s used only one side glass as a sloping roof. Later in the century, glass was used on both sides. Glasshouses are used for fruit crops such as melons, grapes, peaches and strawberries and rarely for vegetable production. Protected agriculture was fully established with the introduction of polyethylene after World War II. The first use of polyethylene as a greenhouse cover was in 1948 by Professor Emery Myers Emmert at University of Kentucky who used a less expensive material to replace expensive glass [2]. There are 115 countries in the world producing commercial greenhouse vegetables [4].

The protected area under the global scenario is approximately 6,23,302 hectares, while the total estimated global greenhouse vegetable production area is 4,02,981 hectares. In the entire global greenhouse vegetable area, soilless / hydroponic culture systems are in 95,000 hectares. The advent of protected farming technology in India began in the early nineties, after the globalization. In India, the protected area under cultivation is currently 25,000 hectares, while the greenhouse vegetable area is 2,000 hectares. Dutch Protected Cultivation is one of the most intensive farming systems in the world with high levels of production using the latest technologies [5].

It is now widely understood as a Controlled Environmental Agriculture (CEA) system with strict control over air and base temperature, water, humidity, plant nutrition, carbon dioxide and light. Today's greenhouses can be considered as factory of plant or vegetables. In this system almost every aspect of the input system is automatic; the artificial environment and the growing system are commanded by computer control [2].

Greenhouse effect

In general, the percentage of carbon dioxide in air is 0.035% (345 ppm). But, because of the emissions of pollutants and exhaust gases into the atmosphere, carbon dioxide percentage increases, which creates a blanket in the outer atmosphere which leads to the entrapment of solar radiation reflected from the earth's surface. Because of this, rising weather temperatures can cause global warming, ice caps melting and sea levels to sink to the coast. This phenomenon of ambient temperature rise due to the formation of a layer of carbon dioxide which is called the greenhouse effect. The greenhouse covering material works the same way because it is transparent to shortwave radiation and transparent to long wave radiation.

During the day, low-wave radiation enters the greenhouse and reflects off the earth's surface. This reflected radiation turns into long-wave radiation and is trapped by the covering material inside the greenhouse. This causes an increase in greenhouse temperature. This is a desirable effect from a crop growth perspective in colder regions.

Worldwide, more than 50% of the Mediterranean area is covered with plastic mulch sheets, which are commonly used to control weeds, raise temperatures, and retain soil moisture. Mostly low density polyethylene (LDPE) or linear low density polyethylene (LLDPE) films are used. Recently, the use of infra-red transmitting mulches (IRT) and bio-degradable mulches have been promising to reduce the problem of disposal and environmental pollution.

Row covers or plastic row tunnels were originally used in Europe, USA and Japan to protect the crops from frost and to create favorable conditions for plants to achieve early production. Prior to the introduction of polyethylene, early spring crops such as cucumbers were grown in muslin covered frames [2] an expensive but effective method getting early fruits from 1935 to 1945 [10]. In many countries, vinyl or polyethylene films are used as a cover. However, there are historical and economic reasons for the choice of polyvinyl chloride (PVC) or polyethylene film for the same purpose. Poly Vinyl Chloride films have better thermal retention efficiency than polyethylene, but are more expensive. However, many countries, including China and India, use polyethylene as a cover. This row cover is very useful in cold and hilly areas.

The most straightforward and economical form of row cover is direct or floating with no fixed wires or hoops. Germany in the 1970s introduced it first and later adopted in other counties. Currently, non-woven series covers are common worldwide. The low weight and permeability of these films allows for gas exchange and rain penetration, temperature control, which enhances early crop growth, provides protection from low temperature and eliminates hand ventilation [13]. Jensen *et al*. [11] suggested the use of floating cover over summer squash to prevent the occurrence of white fly (*Bemisia tabaci*), a vector of Gemini viruses. Overall, floating covers along with plastic mulch can increase the yield of high value crops such as vegetables and flowers by 100 to 160 percent.

Protected cultivation or surface cover cultivation is mainly focused on growing flowers and ornamental nursery, fruit plant nursery and some vegetables (capsicum, tomato, parthenocarpic slicing and pickling cucumber and lettuce) in Europe, North America, South America, Asia and Australia, which offers unique advantages such as off-seasonality, high productivity, improved quality, extended availability, year-round production and low pesticide use. Nursery production of high value crops, ornamental, fruit plants and cut flowers ensure higher and profitable returns than vegetables. However, due to excessive use of pesticides, climate change and unpredictable weather conditions, public cultivation of these high value crops, especially vegetables, can be hazardous to health due to indiscriminate use of various pesticides. Therefore, greenhouse technology-methods that provide optimum or close-to-plant conditions for the plant by conserving soil and water, promise to reduce the impact of various biotic and abiotic stresses, thereby improving the yeild and quality of the product.

Protected cultivation, consisting of glasshouse, greenhouse, polyhouse, low tunnel, high tunnel, row cover, shade house, screen house, net house and plastic mulch, faces increasing competition and therefore, new crop diversification (product innovation), Reduction in cost of production, low dependence on energy, yield growth, product security and minimal environmental pollution are major issues that require the immediate attention of greenhouse growers for long-term sustainability in domestic and foreign countries markets.

A variety of protective structures have been constructed for cut flowers, vegetables, ornamental fruit plants. In USA, greenhouses are mainly used for floriculture, in Spain and Italy; they are mainly used for growing vegetables. In Spain, tunnel type greenhouses are commonly used with cladding material containing polyethylene. In Canada, greenhouses are used for the production of flowers and vegetables. Hydroponically grown vegetables are sold in Canada at a premium. In Netherlands, the greenhouse industry is highly developed and the country is traditional exporter of greenhouse grown vegetables and flowers. However, lately, greenhouse production of potential crops is given priority over areas that require the least amount of energy and due to diverse climate and topography; India and China have tremendous potential for this technology. Israel and Turkey have a significant area of flower and vegetable greenhouse cultivation with more than 90% of the total production of cucumber and tomato in Saudi Arabia. In greenhouses of Egypt tomatoes, cucumbers, peppers, melons and various crops are planted in nurseries. In Asia, China and Japan have considerable area under greenhouses. Chinese use

local material of frames and polyethylene films for cladding. They also use grass mats to improve heat retention inside the polyhouse. Greenhouses in Japan and South Korea are used for growing vegetables and flowers, and high demand for these is met only from greenhouse production. In many countries greenhouses are used to grow commercial crops especially in Philippines (high rainfall) and in some temperate climates.

In India, greenhouse technology began in the 1980s and was initially only used for research. The National Committee on the Use of Plastics in Agriculture (NCPA, 1982) recommended specific tests of greenhouse technology in different parts of the country. Our country has a variety of agro-ecological conditions in various areas, so low-cost low and medium-sized greenhouses, low tunnels and other related facilities should be developed accordingly. Greenhouses have been built in Ladakh and other cold areas of country to extend the growing season of vegetables. In the Northeast, greenhouses are built as rain shelters to allow off-season production. The coastal and southern areas require naturally ventilated polyhouses and can be used yearly for the cultivation of vegetables and flowers. The northern region with hot and cold weather requires cooling (fan pad) and heating equipment. At least 40 mesh of net households have been successfully used in the summer to raise capsicum, tomatoes, beans, etc. in Indian plains. Various cucurbits (cucumber, muskmelon and watermelon) can be planted in plastic low tunnels / poly tunnels, and at the time of flowering, the plastic film can be removed mechanically or manually. Farmers can pony up this crop 30-40 days in advance. High value in greenhouses and production of new crops, however, is an intensive enterprise that requires skilled man power, regular oversight and capital inputs. Therefore, local climatic conditions, topography, etc., play a major role in the design / construction of polyhouses and the selection of cladding materials based on different characteristics according to agro-ecological conditions. The commercial use of greenhouses dates back to 1988. Currently, many corporate companies have set up export oriented units, especially around Pune, Bangalore, Hyderabad, Delhi, Ludhiana and Amritsar. At present, the protected area under horticultural crops in India is over 2000 hectares and protected cultivation extends to many other states. In the hilly areas, over 200 hectares of protected cultivation in Himachal Pradesh is being implemented due to the implementation of RKVY and HTM schemes.

Effective Design and Structure of Polyhouses (Location-Specific) Greenhouse technology is a prerequisite for success by utilizing appropriate and need-based cladding material that combines the desirable properties of various materials [9]. Common trends that improve greenhouse designs include increasing the slope of the roof to increase the reduction in airflow and evaporating condensed water [6], and build a higher structure suitable for local conditions for increased ventilation [12]. An ideal polyhouse or greenhouse can be standardized under agro- ecological conditions to utilize the true potential of greenhouse technology. Many new crops may be introduced, but the likelihood of significantly affecting the biological structure of protected cultivars appears to be limited. Types of greenhouse cultivation and tolerance to various biotic and biotic stresses are gradually increasing, resulting in higher productivity, better quality, less pesticide use, and environmental pollution than open cultivation.

Continuous and intensive cultivation of greenhouses causes increased incidence of nematodes and diseases, and therefore, grafting of Solanaceous and Cucurbitaceous vegetable crops is widely practiced in Korea and Japan, and also in India. Soil-less cultivation in a mild climate can change nutrient solubility in closed systems and reduce water and environmental pollution [14]. The use of latest equipment and innovative methodologies for more accurate and judicious quantification of irrigation and fertilizer requirements (fertigation) can drastically reduce the production cost of polyhouse cultivation besides assuring judicious use of vital inputs *viz*. fertilizer and water.

Greenhouse tomato

Tomato is a universal greenhouse vegetable crop found in diverse agro-climatic regions around the world and is used in salad, vegetables, fruits and canning processes. Tomato varieties harvested under greenhouse conditions (cluster, heirloom, cherry, etc.) are of uncertain type because they grow fruit year-round for plant life [7]. Apart from the new and high yielding hybrids, grafting technology is the latest technology popular in greenhouse tomato cultivation worldwide. Large-sized fruits are grown in the same way with their calyx attached, while some smaller varieties are planted in inflorescences.

Crop	Tomato
Variety	Navin, Avtar 7711, Navin 2000, 7730, 513, RK123, Amarsha,
	Solan Garima, Solan Sindhur, Solan Gola, Yashwant A2, Palam Pink,
	Anubhav, BSS 366, Cherry 1, Cherry 2.
	Nun7711, Ns 646, Arka Vardan, Arka Vishal
Seed count	4000 seeds/10 gm
Transplanting time	3-4 weeks old plants of 16-20 cm long.
Seedling treatment	With Bavistin 2% solution
Planting design	Zigzag
Spacing	40 cm plant to plant 50 cm row to row
Plant population	2.5-3.5 plants /sqmts For 560 sqmts poly house : 1400-1960 plants For 1008 sq mts polyhouse:2520-3528 plants
Plants heights	3-3.5 mts
Other operations	Removing suckers, training, mulching
	Topping
	Pollination manually/ by keeping bumble bees
	Thinning of fruits to attain proper sizes
Fertigation	Liquid fertilizers are supplied with water through drip irrigation system for best use of water and fertilizers. Excess N may lead to excessive vegetative growth and delayed maturity. Fertigation is mostly done @ 6.0 m^3 per

	1000 m^2 area at an interval of 6-8 days during September, October and November after that the interval of fertigation is again increased and it is done at an interval of 10-12 days and further reduced from 6-8 days to twice a week during May and June months. Fertilizer solution of 5: 3: 6 ratio of N: P: K can be applied through drip irrigation @ 5-8 litre solution per m^3 of water according to growth and season of the crop.
Yields	Truss tomato : 25-30 kg/sq mts Cherry tomato: 15-20 kg/sq mts
Fruit weight	Beef stick; 180-250g Truss type; 120-160g Cherry; 12-20 g
Crop duration	8-9 months
Ideal time	Jan & Feb for winters, May & June for summer

Greenhouse peppers

Greenhouse capsicum production is more labor intensive than growing tomatoes. Although it is a valuable crop with excellent possibilities, it is slow growing, requires a high temperature to grow, occurs during a set period of fruits, and the fruits are ripened in flush

Crop	**Capsicum**
Variety	
Green capsicum	Indra, Sinduri, Lario, Natasha, California Wonder
Yellow capsicum	Orobelle, NS281, Swarna, US 26, Yellow Wonder,Nun 3020 Golden Summer
Red capsicum	Mahabharat, Bomby, NS280, US 181, Nun 3019, Bharat, Heera
Lemon capsicum	Bioton, pusa deepti
Seed Company	Nunhems, Indo ammerican, mahyco.
Seed rate	50gms /1008 sq mts
Seed count	600 seeds/10 gm
Transplanting time	35-40 days old plants of 16-20 cm long 4-6 leaves stage
Seedling treatment	With Bavistin 2% solution
Planting design	Zigzag
Spacing	40 cm plant to plant 50 cm row to row
Plant population	2.5-3.5 plants /sqmts For 560 sqmts poly house : 1400-1960 plants For 1008 sq mts polyhouse:2520-3528 plants
Plants heights	3-3.5 mts
Other operations	Topping after 1 month
	Training for keeping 2 leader or 4 leader system
	Thinning of fruits to attain proper sizes
Irrigation	Weekly in summer (Sep-Oct) (March-April), fortnight in winters(nov-feb), two times/week in may june
Fertigation	a basal application of 50 Kg NPK/hectare and 150 Kg NPK with water soluble fertilizers (Polyfeed 19:19:19) starting from 3rd week after transplanting and terminating 15 days prior to harvest can be applied as adhoc recommendation. Polyfeed (19:19:19) should be applied @2.22 g/sq m by dissolving 7 g/10 litres of water
Yields	4-5 kg/plant 8-10 kg/sq mts 10-12 fruits/ sqmts
Fruit weight	180-220 g/bell shaped piece
Crop duration	9-12 months
Ideal time	Sep-Oct (but in polyhouse year round plantaion can be done)

Greenhouse cucumber

Cucumbers are greenhouse vegetable crops grown worldwide. It is a warm-season vegetable that grows best under high light, humidity, humidity, temperature and beneficial conditions of fertilizer. Planting seedlings in the nursery at protrusion ensures minimal root loss when a single seed is planted. The seeds are ready for planting within 2-3 weeks after planting.

Crop	Cucumber
Variety	
Hybrid seedless (parthenocarpic)	Khiya, Akameer, Nun-9729 (Summer), Saintis (Winter) No Pollination Is Required
Others	Japanesh Long Green,Poinsett, KH1, KH2, Khira 75, Khira 90,
	PCPH 4, PCPH 5, Isatish, Miltana.
	Malini, Malti, Pusa Sanyog (Both Type Flowers)
Seed rate	2 seeds/pit (later one healthy plant is kept) 60 g seed/1000 sm
Seed count	400 seed/10 g
Transplanting time	30 days old winter 18-20 days summer 2 leaf stage
Seedling treatment	With Bavistin 2% solution
Planting design	Zigzag
Spacing	60 cm plant to plant (30-60 cm) 60 cm row to row (70-150)
Plants heights	9-10 feet
Other operations	Training, Trellising avoid fruits upto 1.5 to 2.0 feet above the ground Removing dry leaves

Irrigation	3-4 lts/sqmts weekly summer 2-3 lts /sqmts weekly winter
Fertigation	A basal application of 50-100 kg NPK/ha with The polyhouse soils should be analyzed for the nutritional status for ensuring judicious and economic use of liquid fertilizers, water soluble fertilizers like Samadhan or polyfeed (19:19:19) with the irrigation water
Yields	8-10 kg/plant 4-5 kg /sqmts
Crop duration	Yd start 50-65 days upto 12 weeks. 3/3.5 month crop Three crops can be taken annually.
Ideal time	Feb, June, Oct

Greenhouse lettuce

Spinach is specially planted for salads, sandwiches and fresh market for garnish. Its product is popular in greenhouses and is a venture. Greenhouse lettuce was harvested mainly in soilless media, using using rookwool, perlite or a hydroponic nutrient film technique (NFT) (8). Hydroponic lettuce is produced by the Nutrient Film Technique (NFT) or the Floating Raft method, both closed systems

Crop	Lettuce
Variety	
Butter head	Boston, Bibb, Butter crunch, Tom Thumb, Dark Green Boston, Red Butter head.
Crisp head	Garishma, Dublin and Salinas
Loose-leaf	Oak leaf, lollo rosso, Revolution, Bergamo, Dark Ruby Red
Seed rate	375 to 500g per hectare
Seed count	9000 seeds/10 gm
Transplanting time	
Seedling treatment	With Bavistin 2% solution
Planting design	Square
Spacing	30 cm plant to plant 45 cm row to row
Fertigation	FYM or vermicompost @ 10tonnes/ha or 5 @ 10tonnes/ha along with 60:40:40 Kg NPK/ha is recommended. Fertigation with water soluble fertilizers @2g/litre of water twice a week should be done under protected conditions.

Integrated Production and Protection Technologies (IPPM) Vegetable Greenhouse Cultivation, Cut Flowers and Agro-ecological conditions in nursery are ideal greenhouse construction, good hybrid cultivation, healthy seed production, fair irrigation and fertilizer application, optimum spacing between growing beds and timely pruning and plant training, Plant Protection (use of various mechanical means (yellow adhesive traps, yellow water loops, pheromone traps, light traps, double door, fair fogging / misting); botanicals (neem / plant extract based pesticides), bio- pesticides and safe pesticides and by ensuring safe and healthy food for a quality conscious society House rin go so far as to maintain the product. To ensure high quality and safety of late, the product of the verification process and the production of greenhouse production to another.

Protected cultivation of high yielding crops is irreversible from both economic and environmental perspectives. It offers many advantages for growing high value crops with better quality even in unfavorable and marginal environment. However, due to the high training needs of greenhouse growers and trainers, especially in some developing countries, quality product with pesticide residues is a lots.

However, due to the high training needs of greenhouse breeders and trainers, especially in developing countries, quality production with pesticide residues is an important concern. These problems can be easily solved by integrating various production and protection techniques, including location specific effective design and construction of polyhouse. Therefore, adopting a systematic approach based on the involvement of greenhouse engineers, breeders, crop production and protection scientists and harvesting technicians can help increase the sustainability and value of protected cultivation worldwide. Awareness of safe food production among greenhouse breeders and the use of safe pesticides are crucial in providing quality products without polluting the environment.

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