Original Article

"Studies Of Protected Cultivation Of Vegetables In Indian Arena: A Review"

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Abstract

Protected cultivation of high value vegetables and cut-flowers has shown tremendous potential during the last decade or so. With the progress of liberalized economy and the advent of newer technologies in agriculture, protected cultivation opens up avenues in agriculture hitherto not seen. Many methods of protected agriculture are used to modify the growing environment of plants. Ideally, plant production would take place in regions that do not require protective structures, regions that present ideal temperatures, no harsh extremes, and sufficient but not excess precipitation. This is not the case however, as most countries, save for a select few, require various forms of controlled environment agriculture to protect crops against climatic and environmental extremes. Although the greenhouse industry has developed vast amounts of technology for the temperate climate regions of our planet, much remains to be improved in terms of protected agriculture in the more extreme climates. Tropical, arid, polar and urban locations offer contrasting environments that present various challenges for plant growth. Some challenges are specific to each location, while others are common across them. Tropical and arid climates offer high solar radiation, but present harsh temperature and relative humidity conditions. Most protected agriculture structures are relatively open in nature to ventilate and discharge heat, but are susceptible to pests and diseases. On the other hand, polar climates and urban environments often lack solar radiation and require a high level of control of the air quality. The structures used in these environments are relatively enclosed to entrap heat (polar) and to make efficient use of space.

Keywords: Greenhouse, Evaporative cooling, Natural ventilation, Protected agriculture, Tropical climate greenhouse and Urban agriculture.

INTRODUCTION:

Protected cultivation or greenhouse cultivation is the most contemporary approach to produce mainly, horticultural crops qualitatively and quantitatively and has spread extensively the old over in the last few decades. Protected cultivation also known as controlled environment agriculture (CEA) is highly productive, conservative of water and land and also protective of the environment [1].

The technology involves the cultivation of horticultural crops in a controlled environment wherein the factors like the temperature, humidity, light, soil, water, fertilizers etc. are manipulated to attain maximum produce as well as allow a regular supply of them even during off-season [2].

By adopting protected cultivation technology, the growers can look forward to a better and additional remuneration for high quality produce. About 115 countries in the world are into greenhouse vegetable production commercially [3]. The advent of protected cultivation technology in India materialized during the early nineties, post globalization.

CHALLENGES IN PROTECTED CULTIVATION IN INDIA:

1. Lack of trained professional and skilled man power for designing, fabrication of protected structure thereafter, maintenance of the structure and for protected cultivation of various high value crops.
2. Non –availability of region specific design of protected structure for varied agro climatic condition.
3. Lack of practical training institutions and advisory services in the area of protected cultivation.
4. Fabrication of protected structure has come up as a big business, taking an opportunity small industries are sacrificing with the quality of material to be used to gain more profit and also lack of understanding of quality of basic steel and cladding material used for fabrication of structure.
5. Lack of availability of crop varitires and planting material specific to protected cultivation specifically with public sector institutions, its management practices etc as the available planting material/seeds with private sector companies to costly.
6. Lack of demand driven cultivation without proper marketing strategy creates problem for proper disposal of the quality produce and farmers cannot get low premium price, therefore cluster approach for taking up protected cultivation as a whole is required.

7. Increasing threat of soil borne fungus like Fusarium and root knot nematodes for protected cultivation of vegetables.

Fig 1. Protected cultivation at Sharda University, Greater Noida under trail condition

INCOME:

The evidence around SAPSs' impact on farmers' incomes remains insufficient, both in terms of geographical coverage as well as the number of long-term assessments. Notwithstanding this critical limitation, the literature indicates the potential of a few SAPSs to enhance income through a reduction in production costs (CA, natural farming), diversification of agricultural production (IFS, intercropping), and premium prices (organic produce) [4].

YIELDS:

Notwithstanding the conceptual limitations to adequately estimate farm productivity, we find some emerging patterns for yields under a few SAPSs. For organic farming, at least in the short-term (2-3 years), yields are lower than conventional farming. Beyond this period, some studies show equal and even higher yields for some crops, particularly once the soil form and structure evolve after a few years of applying biological inputs. The short-duration studies of natural farming indicate no statistically significant changes in yields for most crops. For SRI, yield impacts are well documented, showing a statistically significant increase in various paddy varieties. Resource-conserving practices, such as vermicomposting, agroforestry, and crop diversification, have positively impacted yields. However, the lack of studies documenting the long-term impacts of SAPSs on yields makes it difficult to generalise results [5].

Fig 2. Protected cultivation at Sharda University, Greater Noida under trail condition.

WATER-USE:

Several studies in literature capture the impact of various SAPSs on water-use efficiency. In particular, SRI, CA, precision farming, rainwater harvesting, contour farming, cover crops, mulching, crop rotation, and agroforestry have positively impacted water conservation. Rainwater harvesting and SRI appeal to smallholder farmers because of their ease of adoption. Pre-monsoon dry sowing in natural farming is considered a breakthrough in the drought-prone regions of Andhra Pradesh, warranting further assessments [6].

GHG EMISSIONS:

Among SAPSs, agroforestry, SRI, and CA have the most evidence for climate mitigation. Evidence associated with agroforestry's carbon-sequestering abilities (above and below ground) is well established. A growing body of evidence suggests that the SRI promotes aerobic soil conditions reducing methane emissions. However, intermittent irrigation, an intrinsic component of SRI, can increase nitrous oxide emissions. Overall, long-term carbon sequestration impacts of the SAPSs need evaluation in India [7].

BIODIVERSITY:

Several SAPSs like agroforestry, IFS, permaculture, natural farming, organic farming, conservation agriculture, and crop diversification strategies (rotation, intercropping, mixed) tend to increase the spatial, vertical, and temporal diversity of species at a farm (and landscape) level. While research articles mention the impact on biodiversity, studies offering substantive empirical evidence are missing [8].

HEALTH:

We only find anecdotal evidence mentioning positive health impacts of various SAPSs, mainly through dietary diversity and less exposure to harmful chemicals such as pesticides. Empirical studies comparing SAPSs with conventional agriculture for health outcomes are missing.

PLANT ENVIRONMENT AND GREENHOUSE CLIMATE:

A plant grows best when exposed to an environment that is optimal for that particular plant species. The aerial environment for the plant growth can be specified by the following four factors:
i) Heat or temperature
ii) Light
iii) Relative humidity
iv) Carbon dioxide

While plants have precise optimum environmental conditions for best growth, most are tolerant to variations in these conditions within some limits. However, permanent damage would occur when they are exposed to conditions outside these limits. At the same time, plants are subject to attack by pests and diseases. Greenhouse crop production provides protection against adverse environmental conditions and allows pests and diseases to be excluded or controlled. Besides providing a protective enclosure, a greenhouse also acts as a 'heat trap'. It admits solar radiation and converts this energy into heat by raising the temperature of the greenhouse air [9].

While this is the basis of the greenhouse's ability to perform its tasks, it also affects other environmental factors. Environmental conditions inside the greenhouse can be modified suiting to the potential growth of plants. The extent of climate modification will, however, depend on the design of greenhouse and is generally related with its cost. Higher the capability of greenhouse to modify its climate, higher is the cost of its construction.

The way in which a greenhouse gets heated when exposed to sunlight is similar to heating of the earth's surface and its adjacent atmosphere. When solar radiation reaches the earth, a small portion is reflected back into the space while the remainder is absorbed at the surface raising its temperature. In the same way, when solar radiation reaches the greenhouse cover surface, a small amount (normally 15-20%) is reflected back from the surface while the remainder is transmitted to the interior. Plants, soil and other objects absorb most of this transmitted radiation and remainder is reflected as shown. The absorbed radiation raises the temperature of absorbing surfaces and objects with the heat energy being immediately transferred to the greenhouse air by convection and evaporation thereby increasing the temperature and humidity [10].

GREENHOUSES LOSE HEAT IN THREE WAYS:

i) Warm air moves out the greenhouse and is replaced by cooler outside air.
ii) Heat is transferred through the covering material itself.
iii) Heat is lost through the soil / floor.

Increasing the temperature of the growing environment in a greenhouse is unavoidable, but it is also the most important function of a greenhouse. Enhanced temperatures accelerate plant growth, and allow sustaining plant growth even when outside ambient temperatures are unfavourably low. However, during summers, inside temperatures rise higher than the optimum levels and, therefore, cooling/ventilation provisions are necessary. Most plants grow better within 60 - 85% relative humidity (RH) of air.

Low RH increases the evaporative demand on the plant, while high RH can depress this demand inhibiting the uptake of nutrients, particularly of calcium. In general, the RH inside the greenhouses is higher than the outside, mainly due to transpiration load. Effective ventilation is required to control higher RH levels. In most parts of the country, solar radiation is not a limiting factor for plant growth.

Light control inside the greenhouse can be affected conveniently either by shading or by supplementary lighting whenever required. Growers in northern India should, however, be careful in monitoring light levels in winters especially during prolonged foggy conditions. In peri -urban areas, particulate pollutants get deposited on the plastic roof thereby reducing the light transmission significantly [11].

This problem is compounded in winters. In such conditions, it is necessary to wash the roof frequently to maintain adequate light levels inside the greenhouse.

Plants use carbon dioxide from the atmosphere for photosynthesis. Carbon dioxide concentration inside the greenhouse in the early morning is always higher than the outside.

With the onset of sun, this level quickly depletes and goes down the normal level during the day if adequate air exchanges are not maintained. Carbon dioxide enrichment is general lee accomplished by burning suitable fuels like propane.

TYPE OF GREENHOUSES

The greenhouses design and cost range from a simple plastic walk -in tunnel costing about Rs.100/ - per sq. meter to a climate-controlled, saw-tooth greenhouse with automatic heating, ventilation and cooling, costing more than Rs. 3000/- per sq meter. The selection of the greenhouse design should be determined by the grower's expectations, need, experience, and above all its cost-effectiveness in relation to the available market for the produce. Obviously, cost of greenhouse is very important and may outweigh all other considerations. Greenhouses are classified in different shapes, which also determine their cost, climate control and use in terms of crop production. Commonly use d structural designs are briefly described below:

Gable: This is the most basic structure similar to a hut -like construction and was perhaps the first version of a greenhouse with glass as the covering material. The roof-frame can be inclined at any angle to present an almost perpendicular face to the sun to minimize losses due to external reflection. The structure also allows large openings in the side-walls and at the ridge for high rates of natural ventilation. Modern gable-shaped greenhouses are multi -span units with bay widths of 6-12 meters.

Gambrel: These structures are similar to the gable but have high strength to withstand high wind loads during storms. This design is more suitable where wood or bamboos are to be used for the greenhouse construction.

Skillion: In this kind of structure, the roof cons it's of a single sloping surface. This is because the greenhouse is built as the southward extension of a building with a solid wall on the northern side. Such greenhouses have the advantage of low structural requirements.

Curved-roof: The semi-circular tunnel greenhouse structures appeared with the introduction of polyethylene film as the covering material. These structures, besides being most simple and easy to construct, have the advantage of high strength with a relatively light frame due to inherent s trength of the curved arch. But these structures have the disadvantage of poor ventilation efficiency since the curved roof is not amenable to the incorporation of ridge ventilators. In an attempt to improve the ventilation efficiency of curved roof greenhouses, raised arch type of structures have been adopted. This design has vertical sidewalls, which permit high head room and improved ventilation due to the wind velocity.

Saw-tooth: In these structures, the roof consists of a series of vertical surfaces separated by a series of sloping surfaces, all of which are pitched at the same angle and facing in the same direction [12].

MULCHING:

Mulching is done to cover the soil around plants with a protective material, which may be organic or synthetic. Organic mulches, like leaves, 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. Transparent polyethylene mulch raises the s oil temperature. This effect derives mostly from the suppression of latent heat loss through evaporation. The mean difference in soil temperature between transparent film mulched and bare soil in early February in Delhi was observed to be 5°C in the top 7 cm of soil where most of the root zone of young muskmelon existed. It increased the plant growth by about 15% during the same period [13].

Mulching conserves the soil moisture and fertility. The former is higher with black plastic than under the transparent pl astic. Mulching prevents the leaching of fertilizer, because it acts as a physical barrier to rainfall, thereby conserving the fertility. 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.

Transparent film, on the other hand, has little effect on weed control unless the film is coated with weedicides. Plastic mulch is also effective in the control of pests and diseases. Silver-colored film is used as mulch to suppress the increase in soil temperature and to control pests and diseases. The silver color acts as a repellent to aphids, which transmit viruses. On the other hand, yellow colored mulches attract insects, which could be killed easily. Muskmelons, tomatoes, peppers, cucumbers, squash, eggplant, watermelons and okra are vegetable crops that have shown significant increases in earliness, yield, and fruit quality when grown on plastic mulch [14].

SHADE HOUSES:

Shade nets are perforated plastic materials used to cut down the solar radiation and prevent scorching or wilting of leaves caused by marked temperature increases within the leaf tissue from strong sunlight. These nets are available in different shading intensities ranging from 25% to 75%. Leafy vegetables and ornamental greens are recommended to be grown under shade nets whose growth rates are significantly enhanced compared to unshaded plants when sunlight isstrong.

Table 1. Comparative yield of various crops grown in green house and open field conditions.

Sl. No.	Crops	Yield in green house m-2	Yield outside the green house m-2
1.	Tomato	30 Kg	7 Kg
2.	Chilli	37 Kg	8 Kg
3.	Rose	700 flowers	250 Kg
4.	Carnation	400 flowers	No yield

Source: Patil. 2013

INTEGRATED PEST MANAGEMENT AND BIOLOGICAL CONTROL:

Regular plant scouting is the leading management tool for crop health, pest anddisease control and growing pesticide-free in a protected agriculture system. Eachgreenhouse operation should use a common scouting record sheet among its personnel and follow similar routines [6] using the proper monitoring tools, such as a 10-20X hand lens, insect traps, indicator plants, and yellowand/or blue sticky cards [1].Broadmites *Polyphagotarsonemus latus*), twospotted spider mites (TSM, *Tetranychus urticae*), western-flower thrips (*Frankliniella occidentalis*), cotton or melonaphids (*Aphis gossypii*), and whiteflies (*Bemisia tabaci*) are the most prevalent pests in the Florida greenhouse vegetable industry. Of these five species, broadmites are the mostdifficult to detect because of their small size (body length is between 100-200 microns) and detection generally occurs once feeding has already damaged the apical growth. Since infestation can easily occur during transplant production, itis recommended that plants commonly affected by broadmites be treated preventatively. Applications with pesticides, such as sulphur, may cause phytotoxicity to youngtransplants and is thus discouraged [5]. Preventative releases of the predatory mite (PdM) *Neoseiulus californicus*, have been shown to effectively control broadmites in pepper when released at a rate of 2 PdM per plant 6 days prior totransplanting or a rate of 4 PdM per plant at 6 days prior to, at, or 4 days after transplanting [5]

CHOICE OF THE CROP:

Under mild winter climatic conditions, cold greenhouses and protected cultivations concentrate on vegetable productions belonging to the *Solanaceae* (tomato, pepper, eggplant) and *Cucurbitaceae* (melon, summer squash, watermelon, cucumber) families. These crops (accounting for > 80% of the protected area in most Mediterranean countries) suit cold greenhouse conditions and meet local market requirements [13].

Their success in protected cultivation is due to: wide consumption; good adaption to unsteady climatic conditions inside cold greenhouses as a result of the crops' indeterminate growth habits; and long cultivation cycles (more continuous use of greenhouses during the year). Leafy determinate plants, on the other hand, do not share the above characteristics, and may therefore encounter problems related to bolting control, with effects on yield and product quality.

Sl. No.	Crop	Grafting method used
1.	Cucumber	Tongue approach, splice
2.	Watermelon	Hole insertion, tongue approach
3.	Tomato	Pin grafting, tongue approach
4.	Eggplant	Cleft, pin grafting
5.	Pepper	Splice

Source: Lee and Oda 2003

COMPONENTS OF CROP WATER REQUIREMENTS WITHIN GREENHOUSES:

Crop water requirement is the total volume of water that a crop needs to maintain maximum rates of crop evapotranspiration (ETc); it is calculated as the difference between ETc and water obtained from rainfall and soil water. Technically, the water required to maintain ETc is the "net" crop water requirement, with the "gross" crop water requirement taking into account extra irrigation to consider salinity and application uniformity. In this section, crop water requirements are "net" crop water requirements. Since no rainfall enters greenhouses and seasonal soil water extraction is negligible because the soil is continuously close to field capacity from high frequency drip irrigation, it can generally be assumed that the crop water requirement of greenhouse-grown crops is equivalent to ETc [14]

CROP EVAPOTRANSPIRATION OF MEDITERRANEAN GREENHOUSE CROPS:

The ETc of major vegetable crops grown in soil in unheated plastic greenhouses in the Mediterranean Basin has been determined. Many of these data were obtained using drainage lysi meters in Almeria, SE Spain [15&16]. Seasonal crop water requirements (i.e. ETc) determined in Almeria range from 170 to 371 mm. The lowest values are generally for spring grown melon and watermelon crops with 3–4-month growing periods, and the highest values for pepper crops with a growing season from September to late May. Reported ETc values for soil-grown tomato, one of the most important greenhouse crops, range from 231 mm for a spring cycle to 260 mm. [17].

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