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Vertical and terraced farming for higher vegetable production

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Vertical and terraced farming, supported by protected cultivation technologies such as polyhouses, net-houses, and plasticulture, offers innovative solutions for addressing climate challenges and resource constraints in horticulture. These methods enhance productivity, improve crop quality, and provide economic benefits, particularly in high-value vegetable crops. Key advantages include efficient water use, increased crop yield, protection from biotic and abiotic stresses, and the potential for off-season production. These technologies support the livelihood and nutritional security of farmers, especially in urban, peri-urban, and hilly regions, while also promoting sustainable agricultural practices and entrepreneurial opportunities for youth.

Keywords: Aeroponics, High value crops, Polyhouse, Terrace farming

AGRICULTURE in India often finds itself confronted by various constraints under changing dimensions that are currently manifested in the form of rapid climate change, soil degradation, population pressure, land fragmentation, water scarcity, marketing and entrepreneurship etc. Horticulture is fast emerging as one of the most dominant faces of Indian agriculture. India is second largest producer of the vegetable crops after China. Indian horticulture estimated to produce around 146 mt from 8.4 mha area making India the largest producer of the fruit crops. There is little possibility of addition to the overall cultivable area though area under horticulture has been increased during the last two decades largely at the cost of other crops. Of all the horticultural technologies, Plasticulture-cum-protected cultivation, is emerging as one of the most promising fields particularly in terms of higher productivity, quality, increased income, entrepreneurship etc. Though the area coverage of about 60,000 ha alone appears abysmal, the progress of area coverage under protected technologies in terms of percent coverage is highly satisfying. The other major reason behind its higher adoption includes – promotion of hi-tech horticulture by public financial institutions. Although, despite indubitable potential of protected cultivation, its spread has not been linked concomitantly with dissemination of technology, quality inputs, post-harvest management and processing units besides overall market linkages. Net result is that despite the technology performing exceedingly well by up-to-date farmers, majority of them keep facing challenges to cope up with the demands of hi-end horticulture. This article deals with overall gamut of technology, its potential, suitable areas and crops, tackling the challenges of biotic and abiotic stresses, market linkages and overall empowerment of farmers in terms of knowledge, input availability and use-efficiency, plant protection, post-harvest loss management, and market linkages etc. It can be safely presumed, that, if adopted, in right earnest, plasticulture in horticulture has immense potential in realizing the sustainable solutions for higher productivity, better livelihood and nutritional security to the farmers who adopt the technology, particularly as clusters of hi-tech farming cooperates.

Relevance of protected horticulture with government policy

Policy initiatives for doubling the farmers income, '*Pradhan Mantri Sinchai Yojana*' invoking 'more crop per drop' and '*Pradhan Mantri Rozgar Yojana*' are some of the encores of the Government assertions in the quest for the overall development of the nation including agriculture. Incidentally, plasticulture or protected cultivation or covered cultivation can make cognizable and tangible contribution in all of these policy initiatives of the government, both directly and indirectly, in the horticultural sector.

It is interesting to note that plasticulture including protected cultivation is apparently the only sector of agriculture which can act as a solution for most of the inherent constraints of ideal system and could address

Terraced farming complex on protected cultivation technology at KVK, Lohaghat, Champawat, Uttrakhand

them as modules of systematic and sustainable farming including healthy planting material, quality seed production, conservation and optimization and input use efficiency of water and other resources, precision farming, Good Agricultural Practices (GAP), Integrated Pest Management (IPM), Integrated Nutrient Management (INM), grafting, soilless cultivation besides minimizing impaction the climate change aberrations etc. which all find convergence to strengthen farming into a hub of profitable horticulture. Apart from this, the hi-tech agriculture encourages better yields from fragmented land, entrepreneurship potential, GAP produce, export potential etc. The potential of addressing soil erosion, recycling abilities, as well as amelioration of soil and water pollution are additional boons to the ecosystem besides strengthening the economy of agriculture. Also, protected cultivation is the most amenable to hi-tech supply chain networks in horticulture which ensures higher income to the growers. Over and above of these advantages, plasticulture is very amenable to women workforce.

Basket of technologies covered under plasticulture are being discussed below with relevant details:

Scope and advantages polyhouse technology

Two types of polyhouses are designed as per the Indian condition, one is called naturally ventilated polyhouse and the other is called force ventilated (fan-pad) polyhouse. Naturally ventilated polyhouses are used mainly in temperate and moderate climate conditions while force ventilated (fan-pad) polyhouses are suitable for tropical, sub-tropical and arid zone farming systems. Polyhouse is the main structure of protected -cum-covered cultivation groups. It is made by GI pipe and covered by ultra-violet (UV) stabilized plastic sheet with a service life of 3-4 years. These sheets are generally available in 7 and 9 m widths with 200 micron thickness. Polyhouse technology is the most intensive form of commercial cultivation. Presently, Central as well as various state Govt. make extend financial support in the form of subsidies to the growers limited to a ceiling of 1 acre of structures costing approximately ₹ 38-40 lakh of which about 50% of the cost is borne by Central government with sizable and additional subsidies from State government. This includes the cost of structure, drip irrigation and fertigation system and seed/planting material etc. The polyhouse structures provide 4-5 times higher yields with export quality produce; high water and fertilizer use efficiency and round the year production facility in any part of the country. Drip irrigation is mandatory for polyhouse crop cultivation along with fertigation technique because drip technology enhances water availability and crop productivity and minimizes diseases, weeds, moisture fluctuations, irrigation frequency, resulting in judicial use of water and fertilizer.

Need of protected agriculture for vertical cum terraced farming

- Minimizes biotic and abiotic stress induced incidences
- Enhances earliness and crop period
- Production can be ensured off-season or as per market demands
- Saves land and water for others crops
- Promotes Hydroponics/Aeroponic/Aquaponics technology
- Can be used at roof with pot cultivation
- Helpful for breeding works and enhances seed industry
- Increases employment or livelihood
- Appropriate technology for hill farmers due to extreme climatic conditions

Protected structure: Naturally ventilated polyhouse

Suitable horticultural crops for polyhouse farming and their seasonal rotations for profitable farming

Horticulture-based farming systems are highly diverse having more than 300 species, depending upon the climate, culture, season, size of landholdings, knowledge, market etc. Being high value crops with higher nutritional contents, besides having a higher demand in urban and peri-urban areas, horticultural crops provide a paradise for the both progressive grower and marginal farmers. Major crops for these systems are indeterminate tomato, cherry tomato, cucumber, capsicum, bitter gourd, musk melon, summer squash, vegetable nursery etc. in vegetable groups. Among flower crops, Rose, Gerbera, Lilium, Tulip, Anthurium, Carnations, Orchids, Chrysanthemum, and their nursery. Among, fruit crops group, strawberry, papaya and all fruit-nursery propagation or hardening are used for economically profitable horticulture-based farming systems.

Crop diversity and rotation for horticulture-based polyhouse farming and their impacts

After years of field experiences and feedback from the interaction with farmers following crops appear to give higher yield and better quality that ensure more income for improving livelihood and nutritional security of farmers. Wherein, indeterminate tomato hybrids (GS-600, ID-32 and ID-37, Rakshita, Himsona, Himsikhar, Snehlata, Naveen etc.) on an average give quality yield of 80-100 t/acre/crop with net returns nearing ₹3.0-4.0 lakh/acre/yr which is about 2-3 times higher yield and income as compared to traditional open farming systems. In the case of coloured capsicum (known as solanaceous apple) hybrids like Natasha, Swarna, Indra, Bombi, Orobelle, Bachata, Inspiration etc. in green, red and yellow colours produce 40-50 t/acre/crop yielding, 6-7 times higher yield and income as compared to open cultivation of capsicum. As the coloured capsicum cannot be grown properly in open condition, this crop, therefore, demands to be produced under protected horticultural environment. Among vegetables, cucurbits appear to be the most suitable for protected cultivation both in terms of season and number of crops for better utilization of structures. 2-3 crops per year of parthenocarpic cucumber (cv. Isatis, Kian, Hilton, Sun Star, Multistar, Fadia, Mini Angel etc), summer squash (cv Pusa Alankar, Pusa Pasand, Australian Green, Seoul Green, Kora, Yellow Zucchini, Himanshu, etc), bitter gourd (Pusa Rasdar) or musk melon (Pusa Sarda) and yellow musk melon can be taken in polyhouses during early and off-seasons.

Average production of 120-150 t/acre/year can be obtained in cucumber. These vegetables are transplanted during July to August and harvested from May to June in the plain conditions. However, in hill areas, transplanting is done in the month of February to March and harvesting during October These vegetables result in better livelihood and nutritional security as compared to traditional vegetable farming in the open.

Off-season Sharda melon production in protected structure

Off-season hi-value vegetable vertical farming production in protected structure

Cropping sequence-cum-rotation–cum-cropping intensity of vegetable crops for polyhouse farming

Different crop cycles of polyhouse vegetables in a year	Returns/1,000 sq.m. (₹ In lakhs)
• Year round Veg./fruits/flower crops nursery	5-10
• Veg. Nursery + Cucumber or Capsicum or Tomato or Bitter gourd or Musk melon or Long melon	3-4
• Spinach or Coriander leaf + Tomato (or Capsicum or Cucumber)	2-3
• Cucumber + Tomato (or Capsicum)	2-3
• Spinach or Coriander leaf + Cucumber + Cucumber + Cucumber	3-4
• Cucumber + Strawberry + Cucumber (or Bitter gourd/ Muskmelon/ Leafy vegetable)	4-5
• Veg. nursery or Spinach or Coriander leaf + Cucumber + Lettuce + Musk melon	3-4
• Spinach or Coriander leaf + Bitter gourd + Lettuce + Musk melon	3-4
• Spinach or Coriander leaf + Bitter gourd + Lettuce + Bitter gourd	3-4
• Spinach or Coriander leaf + Musk melon + Lettuce + Musk melon	4-5
• Spinach or Coriander leaf + *Kakri* + Lettuce + Musk melon	3-4
• Spinach or Coriander leaf + Summer squash + Lettuce + Musk Melon or Cucumber	3-4
• Nursery + Spinach or Coriander Leaf + Chilli or Brinjal	2-3
• Veg. Nursery + Lettuce or Spinach or Coriander leaf + Cucumber or Musk melon	2-3
• Vegetable Nursery + Leafy vegetable + French bean (or okra) + Cucumber (or Musk Melon)	2-3

Flowers in protected structures

Polyhouse flower crops like rose, gerbera, tulip, anthodium, carnations, orchids, lilium, and chrysanthemum and their nursery are mostly annual or perennial crops and hence seasonal crop rotations are not required. Most of these cut flowers are required round the year as per the market demand can be cut. Floriculture crops are highly remunerative as the quality, colour and shelf-life as well as freshness is very important and can

Rose production in protected structure

Annual flower production in protected structure

give annual returns of 8-10 times more than the open field conditions. They are also more important from export perspective, making them critically important for the country's economy. Floriculture industry is led by produce from polyhouse growers mainly in Europe and developed nations. Thus, floriculture can ensure more income which in turn promotes better livelihood and nutritional security of farming families undertaking horticulture-based farming.

Fruits in protected structures

Major fruit crops recommended under polyhouse cultivation include papaya, strawberry, mango, guava, pomegranate and propagation materials of high value orchards or breeding material. These fruit crops can be cultivated for fresh and disease-free seedlings or plant production. Papaya fruits and seeds are in high demand in the market. Best quality papaya fruits yield on average 45-50 kg/plant with net returns of about to ₹ 5-6 lakh/ acre. However, strawberries fruit yield of 15-20 tonnes/ acre is harvested in the 10 plants per sq. m. All fruit crops are more effective in minimizing malnourishment by being nutrient rich. Strawberry runners, virus-free papaya seed, budded and grafted plants and meadow orcharding fruits are more economical and safe produce for livelihood and nutritional security. Papaya can be cultivated in polyhouse as intercropping with leafy vegetable crops like spinach, coriander, lettuce, mustard

Strawberry production in protected structure

Papaya production in protected structure

or French been and or strawberry crops. Strawberry transplanted in the August-September and harvested in April followed by papaya transplanted twice, first in July to August and later in January-February month per year. Crop rotation can be used with strawberry crop, i.e. leafy vegetable or vegetables nursery or cucumber + Strawberry + cucumber (or bitter gourd or muskmelon or leafy vegetable) can be taken.

Crop diversity and rotations for horticulture farming under net-built structures and their impacts

Generally, two types of net-built structures are used, viz., shade-net and insect-proof net houses often termed synonymously. However, a shade net is primarily a covering of UV stabilized coloured plastic net whose main objective is to provide protection to the horticultural nurseries and plants from harsh sunlight and hot winds during summer seasons. On the other hand, insect-proof net houses are built with the primary objective of screening out the entry of insects or other pests by the physical barrier of nets of various mesh sizes depending upon crop and season. Both the net houses can be made by iron, GI pipe, bamboo, wood or stone pillars etc. and are one of the most feasible forms of protected cultivation. Basic cost of fabrication of these structures may range from ₹ 8-10 lakhs/acre.

Shade net protected structures during summer season

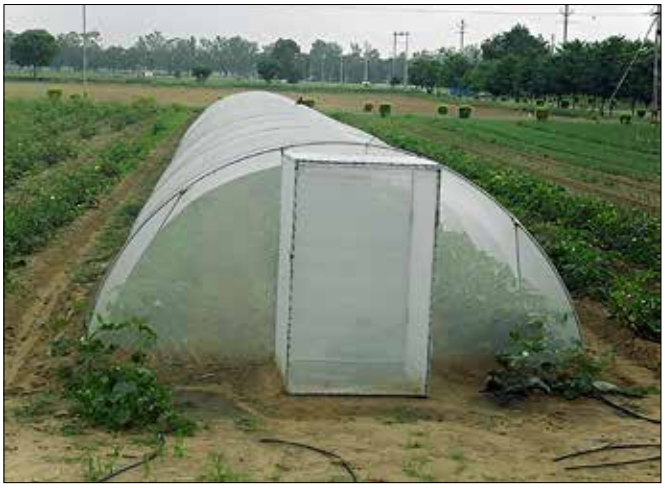
Shade nets generally use two colour nets (green and black) in horticulture-based farming systems. Both colour shade nets are available in 30, 50, 75 and 90% capacity of shading protection, wherein the percentage means the percentage of reduction in sunlight. In vegetable crops 30-50% capacity of either colour or 50-90% shade nets are used for fruit-propagation in horticultural crops. Shade nets cut down the sunlight, in turn minimizing evapo-transpiration losses of moisture in general as well as reduced transpiration from plants. The total effect creates an altered relative humidity and temperature regime of microclimate favouring the plant growth. That is why these structures are especially useful for dry-land and arid areas with water scarcity, as they increase water-use efficiency when used in combination with drip irrigation. Shade nets are the perforated plastic materials used to provide relief to the plants from the scorching sunlight, hot winds, direct rainfall, hails, birds and animals as well as insects and other pests. Nets of 25% to 75% shading capacity are being used for raising nursery, indoor plants, hardening of tissue cultured plants and growing of vegetables. During high light intensities, leafy vegetables and ornamental greens are recommended to be grown under shade nets. This structure enhances 25-35% more yield as compared to traditional methods during peak summer season.

Insect-proof net protected structures

Insect-proof nylon net-based cultivation is newer concept more suitable for rainfed areas with much fewer days of precipitation. These structures make use of insect proof screens of different intensities of perforations, ranging from 25 to 60 mesh. IPP nets of 40 or higher mesh are effective to control entry of most of the flying insects and save crop from diseases. As compared to

Growing vegetables through Shade-net technology round the year

polyhouses, these structures are almost equally capable of screening out the insects and birds thereby avoiding the use of pesticides. These structures permit early planting of tomatoes and cucumber, bitter gourd, musk melon, summer squash, brinjal and chilli etc. without the risk of vectors. Higher mesh size (i.e. above 50), however, reduces the air exchange within the structure. UV-stabilized white coloured nets are now available which have a longer life. This structure enhances 25-35% more yield as compared to traditional methods during peak summer season. IP net structures can be used successfully for seed production in rainfed areas. Crops suitable for these structures include tomato, cherry tomato, cucumber, bitter gourd, musk melon, summer squash, papaya, meadow and high density orcharding of mango, guava and pomegranate and strawberry etc. besides very few flower crops. In irrigated areas, these structures may face problems during rainy season as it tends to flood the crop inside.



Growing vegetables through insect-proof net technology round the year

SUMMARY

Vertical farming is a new innovation in protected cultivation technologies is proving to be a boon for hi-value vegetable crops in respect of increased quantity, quality, colour, freshness, shelf-life, market demand, income, livelihood security, nutritional security and socioeconomic empowerment of farmers and unemployed youth. These technologies can save natural resources and agricultural inputs and prove to be the backbone of urban and peri-urban farmers/growers for plain and hill conditions.

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