

Design, Development and Evaluation of Low Cost Greenhouse Technology to Suit Cold Desert Conditions

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Abstract

Study of climatic parameters and application of greenhouse technology for crop production in cold desert region of Spiti Valley area was done. The study revealed that modifying environmental conditions in cold desert region adapting greenhouse technology could grow vegetable crops. Different shaped greenhouse structures were constructed and flexibility of growing vegetable crops like beet leaf, coriander, lettuce, tomato, brinjal, mint, methi, cabbage, cucumber were studied. Trench type greenhouse provided better yield than other types of greenhouse structures and production of beet leaf vegetable was found to be highest among all vegetables. It was concluded that greenhouse technology is a successful technology for cold desert area and problems of people could be reduced to a greater extent.

Key words : Climate, Greenhouse, Crop production, Benefit-cost, Desert conditions.

A greenhouse is a framed or an inflated structure covered with transparent or translucent materials such as polyethylene, glass or polycarbonate in which crops may be grown under the conditions of partial to fully controlled environment (1). Depending upon the cladding material and its transparency major fractions of sunlight is absorbed by vegetable crops and other objects. The cladding material acts as a selective radiation filter in the sense that, solar radiation (short wave) can pass through it, but traps thermal radiation (long wave) emitted by objects within (2). The rise in temperature and CO₂ level in the greenhouse is responsible for vegetable and other crop production force in cold climate conditions. Low cost greenhouse is a simple structure, constructed with locally available materials, such as bamboo and timber (3). The UV-stabilised LDPE film is used as cladding materials. Unlike conventional greenhouse, no specific control devices for regulating environmental factors inside the greenhouse are provided. However simple techniques are adopted for manipulating temperature and relative humidity. Using shading materials and nets can reduce even light intensity. The temperature can be reduced during warm season by opening all side walls. Such structure is also used as rain shelter for raising crop. Otherwise inside temperature is increased in the greenhouse when side walls are

covered with plastic film.

Cold desert zone of India lies in the high altitude ranges of North-Western Himalayas in the northern most latitudes of the country covering Ladakh Province of Jammu and Kashmir and Lahul-Spiti division of Himachal Pradesh. The region is characterized by high altitude (2,700–4,600 m), sandy mountains, extremely low temperature (–40 C), low relative humidity (20 to 40%), low oxygen concentration in the air and low precipitation (80–300 mm), mostly in the form of snow and short duration (120–150 days) of cropping season (May to September). The zone exhibits greater diversity of soil, topography and climate with severe winter, high wind and low rainfall.

India is having about 74,809 km² of cold desert area in states of Jammu and Kashmir and Himachal Pradesh. Jammu and Kashmir representing 87.4% of total cold arid region whereas Himachal Pradesh covers 12.60% (4). Similar climatic conditions are also met in small pockets of Gharhwal beyond Badrinath (Niti and Mana) and Nelang region in Uttarkashi of Uttaranchal (5). Cold arid environment are harshing, unstable and unpredictable. It is not possible to grow any crop in open fields in these zones during winter. Therefore, self-sustenance is not only desired for this region but also mandatory aspect of development. Greenhouse technology implies production of plants

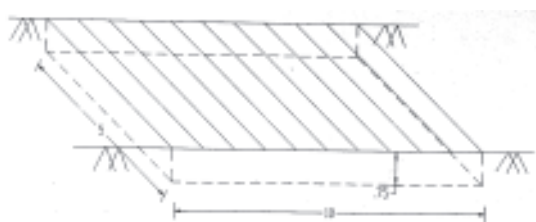


Figure 1. Trench type polyhouse.

for economic use in covered structure that allows rapid harvesting of solar radiation and modification of agro-climate conditions conducive for plant growth and development. The technology embraces infrastructure, modeling, and selection of crops for adoption, production economics, agronomic management and commercial potential. Low-cost greenhouse technology can gear up the economic growth by several ways like more vegetable production and green vegetables in winter (6). Greenhouse technology is a viable alternative for these problems. By adopting greenhouse technology, the climatic parameters could be modified and conditions could be made favorable for some crop production activity. An attempt was made to study the response of crop growth/ yield under greenhouse in cold desert condition.

Methods

The research activity was carried out at Choudhari Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya (CSKHPKV), Palampur research station, Lari (30°42' N and 70°37' E) in Lahaul and Spiti district of Himachal Pradesh (India) under NATP for different types of traditionally modified Ladakhi polyhouses. Studies were undertaken to design and evaluation of various types of low cost greenhouse structures. Also climatic parameters like ambient air temperature, relative humidity, evaporation were

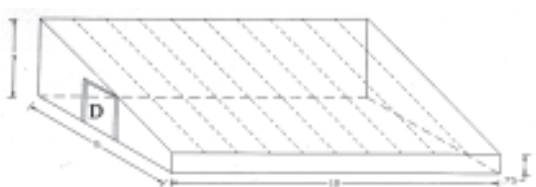


Figure 2. Mud wall type greenhouse.

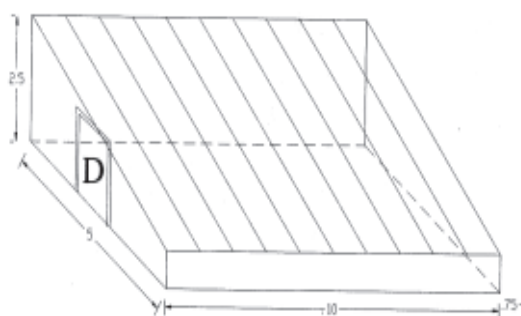


Figure 3. Polyench type greenhouse.

evaluated inside and outside the greenhouse.

Construction of Low-Cost Greenhouse Structures

Peculiarity of cold desert weathers i.e. high temperature fluctuations ; strong winds and high light intensity coupled with UV radiation needs of different type of greenhouse for the region. Generally the region is isolated from main land and remain land locked for most of the months in a year hence all the required materials for greenhouse must be locally available and cheap in cost so that poor tribal farmers can afford the expenditure. The greenhouse must be capable enough to trap the solar energy and produce vegetables even at sub-zero temperatures (7). It should also be strong enough to resist the strong cold waves and extremely low temperatures. The structure should be simple and easily manageable so that even a layman can built and manage it without any difficulty. Keeping these points in mind different types of greenhouses were constructed and the performance was evaluated by growing vegetable crops inside the designed structures.

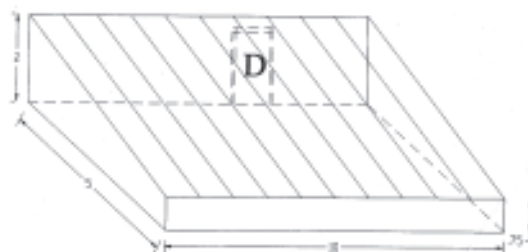


Figure 4. Cavity wall type greenhouse.

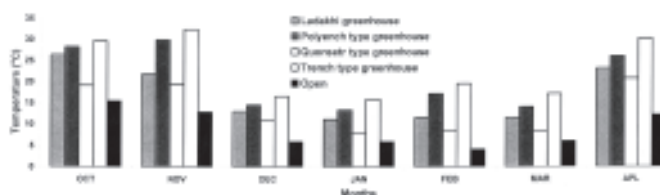


Figure 5. Maximum temperature (C) observation in different structures during winter season.

Material Requirements. The materials required for the construction of low cost greenhouse were : Wooden poles (a smaller 5 cm and larger 7 to 10 cmΦ), GI pipes (2–6 mmΦ), MS strips, metallic hooks, wooden supports (5 cmΦ and 15 cm length), UV stabilized LDPE film, black LDPE film, coal tar or bitumen or creosote, Ordinary LDPE film roll and miscellaneous items like wooden pegs ropes nails.

Erection of Structures. Site selection and orientation of greenhouse play an important role in its efficiency, therefore, an ideal site with proper drainage system of surface water was selected. The east-west orientation of the length of the greenhouse was taken because it maintains better light level in winter as compared to the north-south oriented one. The floor area to be covered by the greenhouse was first determined by marking four corners on the ground based on the dimension. Wooden pegs were inserted at the corner points and tied a rope all around to mark the rectangular area of the greenhouse. Ridge line (central line) was also marked at the same time and depending upon the bay distance, marked other points on the ground for digging the holes for the wooden poles. Creosote a dark oily wood preservative distilled from coal tar was used for protecting the stems from termite attack. Larger poles were erected in the length-wise direction and compacted the foundation by using gravel and stones. Wooden supports, the blocks which support the poles at joints were pre-

pared and nailed them to the larger poles for building up the structure. All the bays together were joined with the smaller diameter poles by using MS strip which provided firm grip and better strength. Now the structure was covered with a net work of GI pipe to support the cladding materials. Ten types of traditionally modified low-cost greenhouse structures, a few of them trench type greenhouse, mud wall greenhouse, polyench type greenhouse, cavity wall greenhouse, quonset greenhouse were erected at the site and production of crops inside these were evaluated.

Weather Parameters

Temperature. Maximum and minimum temperatures were recorded three times in a day with the help of digital thermometer (C). The least count of the digital thermometer was 0.1 C.

Relative Humidity. Relative humidity (RH) was measured with the help of temperature-RH digital meter with 1% least count. Range of the instrument was 0 to 100%.

Soil Temperature. Soil temperature was measured at 5 cm depth with the help of digital temperature probe at 1100 hours in open field and inside the greenhouse.

Temperature Variation in Different Greenhouses. Temperature data inside four constructed polyhouses (Ladakhi, polyench, quinset shape and trench type



Figure 6. Minimum temperature (C) observation in different structures during winter season.

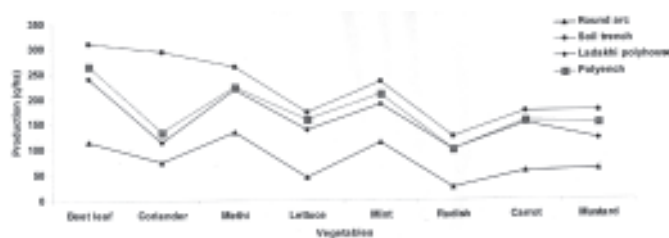


Figure 7. Comparison of different vegetables production in different structures.

greenhouse) were recorded during winter season (October to April) to observe the variation inside these structures.

Crop Production

Selection of Crops. As discussed earlier, in cold desert region temperature goes beyond 50 C in summer and touches -30 C to -40C during peak winter (December/January) season which also affects the growth of crops. Under these circumstances selection of crops is really a challenging task. Crops in winter cultivation should not only be able to tolerate the sub-zero temperature but also grow under the cover where very little and diffused sun light is available. Fast growing and ratoon yielding crops should be preferred so that more number of cutting/harvesting can be taken. After studying these factors in winter crops like beet leaf, coriander, methi, lettuce, mint, radish, carrot and cabbage and in summer capsicum, brinjal, tomato, french bean, cucumber were selected and grown in greenhouses.

Cropping sequences capsicum-spinach-radish, tomato- methi- radish, cucumber-spinach-spinach, brinjal- green onion- methi, cauliflower- tomato, cabbage-capsicum were taken for monetary cost return evaluation.

Statistical Analysis

Field data of crop production were analyzed through randomized block design factorial statistical tool. The analysis was done at 5% probability.

Results and Discussion

Construction of Traditionally Modified Greenhouses

Following types of low-cost greenhouse struc-

tures were erected and evaluated for crop production at research site.

Trench Type Greenhouse. A soil trench having dimension (10 m × 5 m × 0.75 m) (Fig. 1) was made. Wooden poles were provided at 1 m distances on the top of the trench to hold UV stabilized polythene sheet. Black poly film was provided over UV stabilized polythene sheet to conserve more heat and to minimize heat losses. For improving the soil structure, the lower 0.15 m soil was replaced with clay loam soil and FYM.

Mud Wall Greenhouse. Mud wall greenhouse of flour area (10 m × 5 m) was constructed with two mud walls measuring 3 m height on one side and one meter on opposite side (Fig.2). The foundation was made one meter deep. GI pipes were fixed in slanting at one-meter distance and were joined with metallic wires and electric welding. The entire structure was centrally supported by one GI pipe having 5 cm diameter. A wooden door (1.2 × 0.75) m was fixed at the Western side. A wooden ventilator (0.6 × 0.45) m was fixed on the southern side of the structure. Wooden strips were provided at the top of both the mud wall, wooden strips were provided for fixing the UV stabilized polyethylene sheet (200 micron). The wooden framework was developed to support the polyethylene sheet on the other sides.

Polytunnels Type Greenhouse. Three-side mud wall greenhouse triangular in shape with a wall of 3-m height on one side was constructed. A trench (10 × 5 × 0.75) m was made inside the walls. The foundation was kept one meter deep (Fig.3). GI pipes were fixed in slanting at one-meter distance and were joined with metallic wires and electric welding. The entire structure was centrally supported by one GI pipe having 5 cm diameter. A wooden door (0.6 × 0.45) m was fixed at the western side. A wooden ventilator (1.2 × 0.75) m was fixed on the eastern side of the structure.

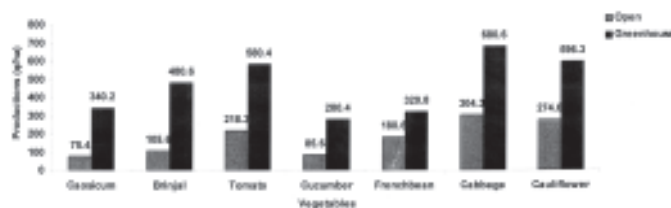


Figure 8. Comparison between open and greenhouse crop production of different vegetables.

Wooden strips were provided at the top of both the mud wall, wooden strips were provided for fixing the UV stabilized polyethylene sheet (200 micron). The wooden framework was done to support the polyethylene sheet on the other sides.

Cavity Wall Greenhouse. It is also known as double wall greenhouse. It consisted of two mud walls running parallel at 30 cm distance on three sides of trench ($10 \times 5 \times 0.75$ m). It is a triangular shape with a double wall of 2 m height on northern side and one double wall of 5 m width each on eastern and western side (Fig.4). Gap between the walls was filled with hay (30 cm width) as an insulating material. The main aim of double wall greenhouse was to minimize the temperature loss through the walls. Wooden poles were fixed in slanting position at one meter distance and were joined with the help of the mud walls. A wooden door (1.2×0.75 m) was fixed at the western side. A wooden ventilator (0.45×0.30 m) was fixed on the eastern side of the structure. Wooden strips were provided at the top of both the mud wall, wooden strips were provided for fixing the UV stabilized polyethylene sheet (200 micron).

Quonset Greenhouse. The foundation of this greenhouse was also pit foundation type. The pits of 10 cm Φ and 60 cm depth were made. The GI pipes 25 mm Φ , 70 cm length and was fixed in pits. Hoops were made by bending of GI pipes (15 mm Φ and 6.1 m length), keeping 30 cm length straight from each end. The spacing between hoops was kept 1 m. To keep the hoops equidistant from the top and to increase structural stability, the hoops were fastened with straight GI pipe of 10 m length using GI wire (2 mm Φ). The end frames were made from square pipes and GI pipes. The plain galvanized sheet (22 gauge) were cut into pieces of width 15 cm and 5 cm for making poly grip assembly. A 15 cm piece was used to make the channel and 5 cm piece was used to make angle. The UV stabilized film was gripped between channel

and angle, using 6 cm iron rods. UV stabilized polyethylene film (200 μ thickness) was used to cover the greenhouse. The sheet was anchored with poly grip assembly on the sides and remaining portion of sheet was buried in the soil. On both the end sheet was fastened to end frames using batten of 2.5 cm width.

Weather Parameters

Temperature. The average increases in maximum and minimum temperature inside the greenhouse was 9.3 C and 14.5 C respectively. The variation in the maximum air temperature was 4.5 C (minimum) in March and 12.6 C (maximum) in July. The variation in average minimum air temperature inside greenhouse was 2.8 C (minimum) in January—February and 13.3 C (maximum) in November—December. The variation of average maximum and minimum air temperature inside and outside of greenhouse during winter season is presented in Figs. 5 and 6. During December, January and February, sub-zero temperature was recorded inside the greenhouse.

Relative Humidity. The average relative humidity variation recorded was 5.5%. The increase in maximum and minimum relative humidity was 13.1 and 2.8% in February and April, respectively.

Evaporation. The evaporation inside the greenhouse was more than outside the greenhouse. The average increase in evaporation was found to be 1.9 mm/day. The evaporation difference between inside and outside the greenhouse varies from 0.7 to 3.0 mm/day.

Soil Temperature. Soil temperature was measured at 5 cm depth with the help of digital temperature probe at 1100 hours in open field and greenhouse. The average increase in soil temperature was 3.2 C. The increase in soil temperature inside the greenhouse varied from 3.0 to 6.3 C.

Table 1. Effect of planting dates and spacing on the productivity of different vegetable crops (q/ha).

| Treatment | Tomato | Capsicum | Cucumber | Cauliflower |
|-------------------|------------------|--------------------|----------|-------------|
| | Date of planting | | | |
| 15 Apr | 493.3 | 365.4 | 296.6 | 528.8 |
| 15 May | 486.6 | 360.3 | 302.4 | 518.6 |
| 15 Jun | 284.3 | 145.9 | 103.2 | 380.4 |
| 15 Jul | 115.6 | 68.3 | 85.4 | 325.3 |
| CD ($P = 0.05$) | 10.6 | 8.5 | 10.8 | 12.4 |
| Varieties | | | | |
| V ₁ | 339.6 | 221.3 | 180.5 | 428.3 |
| V ₂ | 349.3 | 248.6 | 214.3 | 448.2 |
| CD 0.05 | 8.4 | 9.9 | 8.4 | 8.6 |
| Row spacing (cm) | | | | |
| 40 | 404.3 | 245.4 | 225.6 | 460.3 |
| 60 | 285.6 | 224.5 | 169.2 | 416.2 |
| CD ($P = 0.05$) | 8.4 | 9.9 | 8.4 | 8.6 |
| Variety | V ₁ | V ₂ | | |
| Tomato | Rupali | Naveen | | |
| Capsicum | Yellow wonder | California wonder | | |
| Cucumber | Green long | Poinset | | |
| Cauliflower | Pusa snow ball-1 | Pusa snow ball-K-1 | | |

Temperature Variation in Different Greenhouses During Winter Season. A study was conducted to compare the maximum and minimum temperature inside different types of greenhouses during winter period (October—April). It was found that the performance of trench type greenhouse was better compared to others. The maximum and minimum average temperature difference inside trench type greenhouse and outside was 14.3 and 9.2 C, respectively. Trench type greenhouse recorded the highest temperature (maximum and minimum) during winter followed by polyench greenhouse. Hence, the leafy vegetables can be grown inside these greenhouses during winter (October–April). On an average, trench type greenhouse and polyench greenhouse recorded 6.2 and 3.5 C higher temperature (maximum) over Ladakhi greenhouse, respectively. The corresponding increase in minimum temperature recorded was 2.4 and 0.8 C respectively.

Crop Production

Crop Production Under Covered Structures. Crops like spinach, mint, coriander, methi, lettuce, radish, carrot and cauliflower were grown inside the greenhouse in cold desert area during winter and an experiment was conducted to test the performance of

vegetables in terms of yield inside different greenhouses viz. polyhouse, soil trench, Ladakhi polyhouse, polyench. Among these greenhouses, soil trench type was found to be best for growing off season leafy vegetables during winter (October–April) as it recorded the highest yield for all the vegetables followed by polyench greenhouse (Fig.7). On an average, soil trench recorded 27.3 and 66.3% higher yield over Ladakhi and round arc greenhouse, respectively. Among different vegetable crops, beet leaf recorded the maximum yield in all the greenhouses. Cabbage fails to grow in round arc polyhouse due to low average minimum temperature inside the greenhouse. Yield of different vegetables crops inside greenhouse were also evaluated during summer season and it was found that 2 to 5 times higher yield as compared to open. The production of capsicum and brinjal were 2.5 times higher than open whereas French bean was 5 times (Fig.8).

Performance and Evaluation of Nursery. The performance of different vegetable crop nurseries (tomato, capsicum, cucumber, cabbage, cauliflower) were evaluated in open, Ladakhi and soil trench type greenhouses. It was observed that germination of all seeds were 10 to 20 days earlier in soil trench type greenhouse as compared to open and Ladakhi type greenhouse. Also the seedlings were ready 20 to 30 days earlier for transplantation in soil trench type greenhouse. Nursery sown on 15 March or 30 March failed to grow in open field due to low temperature (-15 C).

Effect of Dates of Planting and Spacing. The effect of different dates of planting for crops on their productivity was evaluated (Table 1). The productivity of vegetable crops in cavity wall greenhouse was 2 to 3 times higher at all planting dates as compared to quonset type greenhouse. Among planting dates 15 April was the most suitable for tomato, capsicum, cucumber and cauliflower production. Productivity of cabbage and tomato was maximum when it was planted on 15 May and 15 April, respectively. The production of all vegetable crops except cabbage on 15 April planting was approximately 1.2 to 3 times higher as compared to 15 March and 15 June planting dates. An experiment was also conducted to study the effect of date of planting and row spacing for different vegetable crops. The results show that the yield of crops planted on 15 April of 40 cm spacing recorded higher yield as compared to 5 May, 15 June

Table 2. Effect of crop sequences on gross returns and net returns per rupee invested.

| Crop sequence | Gross return (Rs/ha) | Cost of production (Rs/ha) | Net return (Rs/ha) | Benefit : cost ratio |
|---------------------------|----------------------|----------------------------|--------------------|----------------------|
| Capsicum-spinach-radish | 982100 | 215130 | 766970 | 3.56 |
| Tomato-methi-radish | 911900 | 219189 | 692711 | 3.16 |
| Cucumber-spinach-spinach | 1134080 | 218035 | 916045 | 4.20 |
| Brinjal-green onion-methi | 1123300 | 212068 | 911232 | 4.30 |
| Cauliflower-tomato | 1320650 | 156289 | 1164361 | 7.45 |
| Cabbage-capsicum | 985560 | 147930 | 837630 | 5.66 |

and 15 July with 60 cm spacing plated crop. Among the varieties, Naveen variety of tomato, Poinset of cucumber, California wonder of capsicum and Pusa snow ball-K₁ of cauliflower recorded significantly higher yield than the other varieties.

Row spacing had also marked effect on the yield of various crops and it was observed that 40 cm row spacing recovered significantly higher yield than 60 cm row spacing. The highest yield recorded at 40 cm row spacing may be due to the more number of plants per unit area, which might be resulted in higher yield.

Cropping Sequences and Monetary Cost Returns. A field experiment with following cropping sequences was done to identify the most appropriate vegetable production system with high productivity by using greenhouse technology.

Table 2 indicates that cauliflower-tomato sequence gave significantly highest net return of Rs 1164,361 per ha over all other sequences. It was followed by cucumber-spinach-spinach sequence, which gave net return of Rs 916,045 per ha. The lowest net return Rs 692,711 per ha was obtained in tomato-methi-radish cropping sequence. Crop sequence cauliflower-tomato gave highest benefit cost ratio of 7.45 followed by cabbage-capsicum sequence (5.66). Tomato-methi-radish cropping sequence resulted in lowest benefit cost ratio of 3.16 (Table 3).

Conclusion

It may be concluded that the weather parameters in cold desert region can be controlled by greenhouse technology and production of vegetables could be made possible during winter season. Greenhouses

were constructed with little modification over traditional greenhouse structure at experimental site and found soil trench type provided the best result for growing off-season leafing vegetable followed by Ladakhi greenhouse. The beet leaf vegetable recorded highest yield over all other leafy vegetable. The trench type greenhouse performed better than Ladakhi greenhouse with respect to earliness, whereas open condition nursery raising was not possible. The performance of different varieties of vegetables under greenhouse were evaluated. Naveen variety of tomato, Poinset of cucumber, California wonder of capsicum and Pusa snow ball-K₁ of cauliflower recorded significantly higher yield.

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