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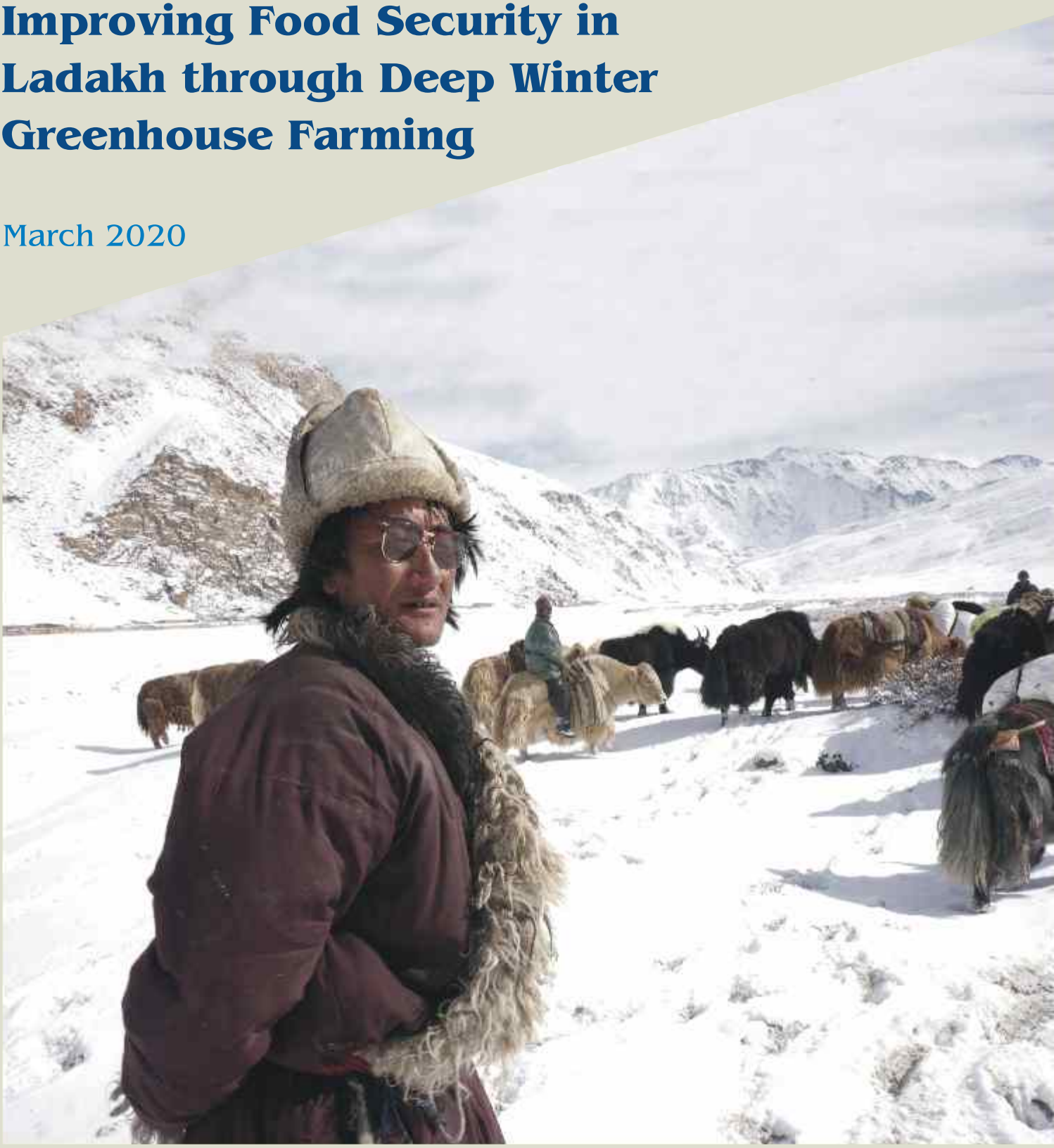
Ladakh Greenhouse Project

Improving Food Security in Ladakh through Deep Winter Greenhouse Farming

March 2020



THE ADMINISTRATION OF UNION TERRITORY OF LADAKH
UNION TERRITORY OF LADAKH

Cover photo by **Stanzin Dorjai, Gya**

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Executive Summary

Title of the Project

Improving Food Security in Ladakh through Deep Winter Greenhouse Farming

Project Duration

Two year (Apr 2020-Mar 2022)

Greenhouse Design

Ladakh Greenhouse (technology developed by Defence Institute of High Altitude Research)

Greenhouse size

1. Small greenhouses (32 feet×18 feet×8 feet; L×W×H) are suitable for small farmers and for those in remote areas.
2. Medium greenhouse (60 feet×24 feet×8 feet 6 inches; L×W×H) are best suited for large scale adoption.
3. Medium size greenhouse achieve a more uniform, stable and ultimately superior growing environment for the crop as compared to small size greenhouse.

Physical Target

- Medium Type Ladakh Greenhouse (60 feet x 24 feet): 1140 numbers [Leh: 570 nos.; Kargil: 570 nos.] (1st year: Leh: 285 nos., Kargil: 285 nos; 2nd year: Leh: 285 nos., Kargil: 285 nos).
- Domestic Type Ladakh Greenhouse (32 feet x 18 feet): 536 numbers [Leh: 268 nos.; Kargil: 268 nos.] (1st year: Leh: 134 nos., Kargil: 134 nos; 2nd year: Leh: 134 nos., Kargil: 134 nos.).

Estimated Cost

- Rs 76.44 crore [Leh: Rs 38.22 crore; Kargil: Rs 38.22 crore] (1st year: Rs 38.22 crore; 2nd year: Rs 38.22 crore)

Construction cost of Ladakh Greenhouse and financial assistance required in UT Ladakh

Greenhouse type	Greenhouse size	Construction cost per greenhouse	Financial assistance per greenhouse	Farmers' contribution
Domestic type	32 feet×18 feet	Rs. 3,78,666/-	Rs. 2,84,000/-	Rs 94,666/-
Medium type	60 feet×24 feet	Rs. 7,11,333/-	Rs. 5,33,500/-	Rs 1,77,833/-

*Financial assistance (Max upto @75% of the cost) will be used for supply and fixing of polycarbonate sheet, frames, GI roof, door, window and ventilators etc.

**Farmers' contribution will be used for eraction of the greenhouse walls.

Implementing Agencies

District	Agency
Leh	CEO LAHDC, Leh; UT Ladakh (through Chief Agriculture/ Horticulture Officer, Leh)
Kargil	CEO LAHDC, Kargil; UT Ladakh (through Chief Agriculture/ Horticulture Officer, Kargil)

Greenhouses in Ladakh: Current status

1. Greenhouses are the basic necessity for the farmers of Ladakh. Incentives in the form of subsidies may be made available from the Government for construction of greenhouses in Ladakh in view of its high cost.
2. The traditional Ladakhi Greenhouse has limited functionalties. There is a need to promote improvised passive solar greenhouse for the region.
3. The Government cost norms and pattern of assistance approved for construction of greenhouse in hilly areas are not suitable for the conditions of Ladakh.
4. The greenhouse designs prescribed for hilly areas are not suitable for mountainous region of Ladakh. Therefore, there is a need to draw a separate cost norms and pattern of assistance for Ladakh region.

Limitations of Traditional Greenhouses in Ladakh

- The temperature inside the greenhouse often drops to sub-zero at night in December and January, which limits growing of only freeze tolerant leafy vegetables.
- Vegetables such as Cole crops (cauliflower, cabbage, broccoli), cucurbits (pumpkin, squash), and Solanaceous (tomato, capsicum) cannot be grown due to freezing temperature at night inside the greenhouse during winter months.
- The cladding material needs to be removed from the greenhouse structure during summer months (June to October) due to excessive heat that builds up inside the greenhouse. Temperature as high as 64°C have been recorded in May inside the greenhouse.
- Average service span of polyethylene sheet is 3-5 years. High wind speed, uneven surface of supporting frames, frequent removal and extreme climatic condition reduces the durability of the cladding material.
- Rain and high humidity inside the greenhouse causes damage to the mud walls and the roof. High humidity inside the greenhouse also results in growth of moulds and fungus on wooden structures. Therefore, the mud walls and roof need frequent repair and maintenance.
- The wooden frame of door and ventilators is deformed due to high moisture and heavy load of the walls. The deformity leads to improper closing of the doors and ventilators resulting in heat leaks from the gaps. In most of the greenhouses the plastic siding is not properly secured resulting in infiltration of outside air into the greenhouse.
- Use of polyethylene sheet as cladding material is not suitable for regions receiving heavy snowfall, such as Changthang and Zanskar valley. The structure collapses due to sheer load of the snow.
- The average service period of a greenhouse is 10 years. The walls, wooden frame and wooden roof need major repair in intervals to keep the greenhouse functional.
- Majority of the farmers (over 91%) do not use greenhouse during summer months. Due to removal of polyethylene sheet during summer, there is no additional benefit from the structure as compared to open field conditions.

Advantages of Ladakh Greenhouse over Traditional Greenhouse

Ladakh Greenhouse is designed to overcome the limitations of traditional Ladakhi Greenhouse. Following advantages have been enumerated for Ladakh Greenhouse over Traditional Greenhouses in field trials with supporting scientific data:

Above freezing temperature: The temperature inside Ladakh Greenhouse remained above freezing points even in December and January in Leh condition in 2017-19. Therefore, plant growth is more vigorous in winters.

Increased variety of vegetables: Tomato, cauliflower and cabbage were successfully grown in peak winter in Ladakh Greenhouse, which otherwise is not possible in traditional Ladakhi Greenhouse.

Fixed cladding material: The polycarbonate sheet is fixed. There is no need to remove the cladding material even in summer months, unlike polyethylene sheet in traditional greenhouse. The ventilation does not allow building excessive heat inside the greenhouse even during summer months.

Durable cladding material: Average service span of polycarbonate sheet is 15-20 years in Ladakh condition. It withstands high wind speed and extreme climatic conditions of Ladakh region.

Withstand snow load: Triple layer polycarbonate as cladding material is suitable for regions receiving heavy snowfall. The smooth curved design allows snow to slips off. The structure withstands the load of snow which remains on it.

Maintenance free: The stone wall and metallic door and ventilator frame require minimal maintenance.

Judicious use of space: Racks are fixed on north wall inside the greenhouse. The racks can be used for a variety of purposes thus making use of above the ground space in the greenhouse.

Heat retention: The triple layer polycarbonate cover, fixed metallic structures and the use of the wall as thermal mass result in higher heat retention due to high thermal retention properties and minimal heat escaping gaps.

Long service period: The expected service life of Ladakh Greenhouse is 20-25 years. The walls, metallic frame and GI roof need minor maintenances to keep the greenhouse functional.

All year round crop cultivation: Three cycles of crops are grown in Ladakh Greenhouse (Cycle 1: Tomato, Cole crops and leafy vegetable-mid October to early March; Cycle 2: Vegetable nursery-late March to early May; Cycle 3: Summer vegetables-mid May to early October)

Transfer of Ladakh Greenhouse Technology

The technology of Ladakh Greenhouse, also known as DIHAR Greenhouse, has been formally transferred to Agriculture Department, Union Territory of Ladakh by Defence Institute of High Altitude Research on 29 August 2019.

Outcome of the Project

Farmers in Ladakh wil be able to grow a variety of vegetables such as tomato, cauliflower, cabbage, knol-khol apart from the conventional leafy vegetables during deep winter. This will increase the availability of a variety of locally grown vegetables during winter months and thus helps in overcoming hidden hunger in the region.

Chapter-1

Greenhouse in Ladakh: Current Status

1.1 Ladakh

The Union Territory of Ladakh comprises two districts namely Leh and Kargil. The high mountain region of Ladakh is characterized by a rugged topography at an average altitude of over 3000 m asl. The region is characterized by extreme temperature variations, low precipitation mostly in the form of snow, high wind velocity, sparse plant density, thin atmosphere with high UV-radiation and fragile ecosystem. The temperature drops down to -30ºC in winter. Long harsh winters reduce the cropping season to just four to five months in a year. Single-cropping is dominant, as double-cropping is possible only in a limited area falling below an altitude of approximately 3000 m. Agriculture production is entirely based on irrigation. The region remains cut-off for over six months in a year due to heavy snowfall. Availability of locally grown fresh vegetables is restricted to summer months and therefore, there are seasonal differences in dietary intake of food. The availability of fresh vegetable decreases significantly during the winter months, which has resulted in unbalanced diet. Micronutrient deficiencies including the lack of vitamin A, B6, B12 and folic acid are prevalent in the region. Seasonal shortfall and low dietary diversity among the local populace lead to micronutrient deficiencies, a phenomenon that has been described as 'hidden hunger'.

1.2 Need of Greenhouse in Ladakh

The cropping season in Ladakh is limited to just four to five months in a year. The minimum temperature drops to sub-zero from October to April (Table 1.1). The cropping season starts from mid-May and harvested by mid-September. Early planting of seedlings often get destroyed in spring frost while delays in harvesting of the crops beyond mid-September are equally damaging due to a rapid plummeting of the atmospheric temperature. Therefore, practically no crops can be grown in open-field conditions from October to April anywhere in Ladakh region. Self-sufficiency in food is, therefore, an important issue for the region. Filling the gap of the local demand of food from local production is a uphill task while importing of the same necessitates shipping of goods in trucks across the Himalayas, with passes as high as 5300 m asl, just to cover the distance between supply points at Manali or Srinagar and Leh only in summer months. Moreover, during winter a limited quantity of fresh vegetable is brought in by air paying as much as Rs 80-110 per kg just for the air freight from Delhi to Leh. In January 2019 the Leh District Administration has fixed the retail price of the fresh vegetables such as tomato (Rs 110 per kg), okra (Rs 130 per kg), brinjal (Rs 115 per kg), cauliflower (Rs 110 per kg), green peas (Rs 115 per kg) and spinach (Rs 110 per kg). A market survey conducted in Leh in February 2019 showed that cabbage and knol-khol were being sold at Rs 120 per kg whereas, the locally grown stored vegetables were fetching a relatively lower retail price (cabbage: Rs 60; turnip: Rs 55; radish Rs 45; carrot Rs 60 per kg). In comparison the retail price of fresh vegetables in metropolitan Delhi (Saket) was significantly lower during the period (tomato: Rs 38-42; okra: Rs 67-74; brinjal: Rs 51-56; cauliflower: Rs 28-30; cabbage: Rs 12-13; green peas: Rs 75-83; spinach: Rs 17-19; radish Rs 30-33; carrot Rs 49-55 per kg). Therefore, the retail price of the

select fresh vegetables (tomato, okra, brinjal, cauliflower, cabbage, peas and spinach) in February 2019 were 2.7-fold costlier in Leh as compared to Delhi. Besides, only a small quantity of fresh vegetable can be brought in by air, which is not sufficient to meet the local demand. Therefore, meeting the increasing demand of fresh vegetable at an affordable price in this remote mountain area is a formidable challenge. Therefore, greenhouse cultivation is the only option to meet the fresh vegetable requirement of the region in winter months.

Table 1.1: Average maximum and minimum temperature (°C) recorded at Leh (DIHAR, 34°08.3'N; 77°34.3'E, elevation 3344 m)

Month	2018		2019		Remarks
	Maximum	Minimum	Maximum	Minimum	
January	2.2±2.4	-13.7±2.7	-0.2±2.4	-11.9±6.2	Crops can be grown only under greenhouse condition
February	4.1±2.4	-8.8±2.9	0.5±2.5	-8.8±4.6	
March	8.5±2.4	-4.6±2.6	4.9±3.8	-6.7±3.9	
April	14.4±2.6	1.7±2.1	14.7±2.3	1.8±2.6	
May	16.7±2.4	3.5±1.8	18.4±2.5	5.1±2.3	Crop growing season in open field
June	23.6±3.4	10.9±3.0	20.1±1.9	6.9±1.5	
July	25.6±3.1	13.2±2.5	24.9±3.7	11.4±1.8	
August	25.6±2.7	13.0±1.7	26.3±2.6	12.5±1.9	
September	20.1±4.8	7.6±4.8	22.8±2.6	7.5±3.3	
October	12.0±2.8	-1.6±3.2	13.1±2.8	-1.2±2.6	Crops can be grown only under greenhouse condition
November	7.4±2.2	-6.5±2.4	8.5±2.6	-4.9±2.6	
December	2.7±2.1	-12.2±2.3	0.0±2.4	-13.9±3.3	

Greenhouse: a must in Ladakh

- Average altitude of Ladakh is over 3000 m asl.
- The temperature drops down to -30ºC in winter.
- Long harsh winters reduce the cropping season to just four to five months in a year.
- The region remains cut-off for over six months in a year due to heavy snowfall.
- The availability of fresh vegetable decreases significantly during the winter months.
- During winter, a limited quantity of fresh vegetable is brought in by air paying as much as Rs 80-110 per kg just for the air freight from Delhi to Leh.
- Fresh vegetables are 2.7-fold costlier in Leh as compared to Delhi during winter season.
- Meeting the increasing demand of fresh vegetable at an affordable price in this remote mountain area is a formidable challenge.

1.3 Traditional Greenhouse in Ladakh

Small to medium sized greenhouses having mud walls on three sides (north, east and west) with polyethylene cover on south facing side and a roof on north wall are popularly known as the Ladakhi Traditional Greenhouse. It is the most widely used passive solar greenhouse in Ladakh. It become popular due to its ease of construction and higher heat retention capability at night especially during winter. Modifications have been made in the Traditional Greenhouse by various agencies and are named as GERES Greenhouse, LEHO Greenhouse, LREDA Greenhouse, SKUAST-II etc. However, the mud wall on three sides, use of polyethylene sheet as cladding material, wooden angled roof on north wall are the common features in all these greenhouses. The cladding material is removed from the greenhouse structure during summer months (June to October) due to excessive heat that builds up inside the greenhouse. The increased use of greenhouse has not only improved dietary intake of vegetables during the winter months but also opened a new economic opportunity for sale of early season vegetables by the local farmers.

Basic components of Traditional Greenhouse

The Traditional Greenhouse including modified designs in east-west orientation has five main components:

Mud brick wall: Mud brick walls on east, west and north sides where the amount of incident solar energy is limited. Single or double wall mud brick or rammed earth wall is common. Insulating materials such as straw, sawdust, dry leaves are stuffed between the cavities of the double wall of the greenhouse. The thickness of the wall varies from 1 foot to 3 feet, majority being 1 foot thick. The main function of the wall apart from the load bearing is its ability to absorb solar energy during the day and release the conserved heat inside the greenhouse during night.

Ladakhi Greenhouse

Polyethylene sheet: A translucent UV-stabilized polyethylene sheet covering the south face of the greenhouse transmits majority of incident solar radiation into the greenhouse. This warms the interior space and is absorbed by the plants, the ground and the walls. The polyethylene sheet is set at an angle and is supported by a wooden or metallic frame. The angle of the polyethylene cover is calculated in a manner so that maximum solar radiation is transmitted inside the greenhouse and the snow that falls on it slides off.

Roof: A sloped (to the north) wooden roof on the north side of the greenhouse regulates solar radiation absorption on the surface inside. In summer, when the sun is high in the sky, the roof partly shades the greenhouse and reduces overheating. During winter, when the sun is at low elevation, it allows solar radiation absorption inside the greenhouse. The wooden roof is covered with a layer of straw and earth for insulation.

Door: A wooden door is located on the east wall, opposite the wind direction, to avoid air infiltration.

Ventilation: The air inside the greenhouse becomes very hot on sunny days. Manually operated ventilators are provided either on the roof or on west wall. The door on the east wall is also used for ventilation during daytime.

Advantages of Traditional Greenhouse

- Construction cost of Traditional Greenhouse is low to moderate depending on the size of the greenhouse.
- The greenhouse is made of locally available resources except the cladding material.
- The earth walls on three sides and the floor store heat during day and release at night. Therefore, it remains much warmer as compared to Polycarbonate or FRP Greenhouse with no heat retention walls.
- The wooden frame of door and ventilators is deformed due to high moisture and heavy load of the walls. The deformity leads to improper closing of the doors and ventilators resulting in heat leaks from the gaps. In most of the greenhouses the plastic siding is not properly secured resulting in infiltration of outside air into the greenhouse.


Wooden frame

- Use of polyethylene sheet as cladding material is not suitable for regions receiving heavy snowfall, such as Changthang and Zanskar valley. The structure collapses due to sheer load of the snow.
- The average service period of a greenhouse is 10 years. The walls, wooden frame and wooden roof need major repair in intervals to keep the greenhouse functional.

- Majority of the farmers (over 91%) do not use greenhouse during summer months. Due to removal of polyethylene sheet during summer, there is no additional benefit from the structure as compared to open field conditions.

Limitations of Traditional Greenhouse

- The temperature inside the greenhouse often drops to sub-zero at night in December and January, which limits growing of only freeze tolerant leafy vegetables.
- Vegetables such as Cole crops (cauliflower, cabbage, broccoli), cucurbits (pumpkin, squash), and Solanaceous (tomato, capsicum) cannot be grown due to freezing temperature at night inside the greenhouse during winter months.
- The cladding material needs to be removed from the greenhouse structure during summer months (June to October) due to excessive heat that builds up inside the greenhouse. Temperature as high as 64°C have been recorded in May inside the greenhouse.
- Average service span of polyethylene sheet is 3-5 years. High wind speed, uneven surface of supporting frames, frequent removal and extreme climatic condition reduces the durability of the cladding material.
- Rain and high humidity inside the greenhouse causes damage to the mud walls and the roof. High humidity inside the greenhouse also results in growth of moulds and fungus on wooden structures. Therefore, the mud walls and roof need frequent repair and maintenance.


Mud Wall


Roof

1.4 Greenhouse in Ladakh: Current Status

Ever since the first greenhouse (glasshouse) in Ladakh was established in 1964 at Defence Institute of High Altitude Research (DIHAR), a large number of passive solar greenhouses have been studied. Trench greenhouse is widely recognized as the most economical and easy to establish passive solar greenhouse for Ladakh region. However, limitations of Trench greenhouse due to its starkness and devoid of retention wall above the ground level, the adoption rate of the Trench greenhouse was not up to the expectations. The Traditional Greenhouse with mud-brick walls on three sides (north, east and west) with polyethylene cover on south facing side and roof on north wall side has become popular due to its ease of construction and higher heat retention. Modifications in 'Traditional Greenhouse' has been made by various agencies and are named as GERES Greenhouse, LEHO Greenhouse, LREDA Greenhouse etc. Mud-brick wall on three sides, use of polyethylene sheet as cladding material, wooden angled roof on north wall are common features in all the modified 'Traditional Greenhouse'. It is now a common practice to


Traditional Greenhouse

grow leafy vegetables such as spinach, lettuce, coriander in Ladakhi Greenhouse during winter months. The increased use of this greenhouse has not only improved dietary intake of vegetables during the winter months but also provided an economic opportunity for sale of early season vegetables by the local farmers.

Promotion of passive solar greenhouse in Ladakh

Realizing the importance of greenhouse in Ladakh, there is a campaign for the promotion of passive solar greenhouse in the region (Table 1.2, 1.3). Incentives are being given in the form of subsidy by the Government, besides imparting trainings on greenhouse cultivation. Local non-governmental organizations (NGOs) also joined in campaign for promotion of greenhouse. Each year an average of 733 greenhouses covering 44313.4 m^2 area have been established between 2010 and 2018 in Leh district with the support of the Government.

Table 1.2: Number of passive solar greenhouses established with support from various Government agencies in Leh district during 2010-18

Greenhouse size (L×W)	Years								
	2018	2017	2016	2015	2014	2013	2012	2011	2010
A. Traditional Greenhouse (with roof, mud walls on three sides; polyethylene sheet as cladding material)									
Agency: Agriculture Department									
100'×22'	-	12	14	06	09	07	09	09	09
42'×18'	20	-	-	-	-	-	-	-	-

Agency: Horticulture Department									
32'×18'	230	596	115	29	250	576	19	17	38
Agency: Traditional Renewable Energy Development Agency (LREDA)									
63'×22'	-	-	-	-	-	100	100	550	-
B. Traditional Greenhouse (without roof, mud walls on three sides; polyethylene sheet as cladding									
Agency: Ladakh Renewable Energy Development Agency (LREDA)									
32'×18'	-	-	-	-	-	1000	1000	500	-
C. Tubular Greenhouse (without walls)									
Agency: Horticulture Department									
31'×13'	218	1043	-	44	75	-	-	-	-

Table 1.3: Number of passive solar greenhouses established with support from various Government agencies in Kargil district during 2014-19

Greenhouse size (L×W)	Years					
	2019	**2018**	**2017**	**2016**	**2015**	**2014**
A. Polycarbonate Greenhouse						
Agency: Agriculture Department						
21'×12'	96	278	-	-	-	-
B. Traditional Greenhouse (without roof, mud walls on three sides; polyethylene sheet as cladding						
Agency: Horticulture Department						
32'×18'	212	273	278	147	144	200
C. Tubular Greenhouse (without walls)						
Agency: Agriculture Department						
30'×14'	144	210	140	110	115	90
Agency: Horticulture Department						
31'×13'	500	224	347	19	51	-

Use of Traditional Greenhouse by Farmers

A door-to-door survey involving interviews with 157 farmers across seven villages (Gonpa, Saboo, Saspol, Thiksey, Chamshen, Sumoor, Hunder) were conducted in 2017 and 2018. The survey suggested that traditional passive solar greenhouse is being used mainly during winter months and for raising of seedlings in spring. However, majority of the farmers (91.7%) do not use the greenhouse during summer months. Insect-pest, irrigation in winter and frequent replacement of cladding materials are the major problems being faced by the farmers. Therefore, there is an immense scope to improve the greenhouse designs so that the constraint to grow a variety of crops is overcome. Key findings of the survey are shown in Table 1.4.

Table 1.4: Use of passive solar Traditional Greenhouse by farmers in Leh Ladakh

Query	Farmer's response (%)	Inference
Number of greenhouse owned	One greenhouse (92.4%); more than 1 greenhouse (7.6%)	Majority of the households have one greenhouse
Incentives (subsidy) received from various agencies for establishment of greenhouse	Incentives received from Government agencies (92.4%); incentives received from NGOs (3.8%); incentives not received (3.8%)	Majority of the households (92.4%) received monetary incentives from Government agencies for establishment of greenhouse
Size of greenhouse (length × width; unit: feet)	32'×18' (56.3%); 31'×13' (23.9%); 100'×32' (3.6%); 65'×24' (3.0%); 32'×16' (1.8%); 100'×23' (1.8%); 30'×15' (1.8%); others (7.8%)	Majority of the greenhouses established were small to medium size
Sale of greenhouse produce for income generation	Yes (59.8%); No (40.2%)	Majority of the households sold greenhouse produce for additional income generation
Glazing material (polyethylene sheet) is removed during summer months	Yes (96.2%); partly removed (3.8%)	Polyethylene sheet is removed during summer months (6-7 months) by majority of the farmers
Reason for removing polyethylene sheet during summer months	High temperature inside the greenhouse (93.0%); high wind speed (7.0%)	High temperature that buildup inside the greenhouse is the main reason for removal of the polyethylene sheet in summer
Crops grown inside greenhouse during summer months	Yes (8.3%); No (91.7%)	Majority of the farmers (91.7%) do not use greenhouse for growing crops in summer
Crops grown during winter (100% respondent)	Spinach (97.3%); coriander (84.0%); mint (38.6%); turnip (28.6%); celery (17.3%); lettuce (14.0%); radish (6.6%); carrot (3.3%)	Majority of farmers grow only leafy vegetables in winter months
Seedlings raised in spring (22.9% respondent)	Onion (80.5%), cabbage (58.3%), cauliflower (36.1%), knol-khol (30.5%), tomato (13.8%)	Onion and cabbage seedlings are mostly raised in the greenhouse
Crops grown during summer (8.3% respondents)	Tomato; capsicum; brinjal; cucumber; bottle gourd; spinach; others	Tomato, capsicum and brinjal were the most widely grown crops in summer

Query	Farmer's response (%)	Inference
Plan to construct green-house in coming two years	Yes (49.6%); No (50.4%)	50% of the farmers wants to establish more greenhouse in coming years
Main constraints in green-house cultivation	Insect-pest (27.7%); water scarcity in winter (15.9%); frequent replacement of polyethylene sheet (8.3%); others (25.2%); no problem (22.9%)	Insect-pest, irrigation in winter and frequent replacement of polyethylene sheet are the major problems being faced by the farmers

Chapter-2

Ladakh Greenhouse: An Improvised Passive Solar Greenhouse for Ladakh

2.1 Ladakh Greenhouse: An Improvised Passive Solar Greenhouse for Ladakh

Owing to the limitations of traditional Ladakhi Greenhouse, an improvised solar passive greenhouse was designed and evaluated by DIHAR (DRDO), Leh. The new design which is popularly known as Ladakh Greenhouse was studied both during winter and summer for growing a variety of vegetables in Leh Ladakh. A successful trial of the same led to making it in different sizes to cater to the needs of the farmers based on availability of land and resources with them.

Ladakh Greenhouse (Domestic Type)

2.1 Salient features of Ladakh Greenhouse

Concrete Wall: The walls on east, west and north sides are build with stone and cement. The wall acts as a thermal mass stores energy in daytime and releases during the night. Minimal maintenance is required after construction. The wall on north side inside the greenhouse is used for fixing racks that can be used for different purposes. An outer mud-brick wall with insulation in between the two walls has also been studied.

Polycarbonate sheet: A transparent UV-stabilized 16 mm triple layer polycarbonate panel is used for covering the south face of the greenhouse. It transmits the majority of incident solar radiation into the greenhouse. It has better heat retention capacity. It retains an acceptable transparency even after 15 years of exposure to harsh climatic conditions of Ladakh.


Polycarbonate covering

GI roof: A sloped (to the north) rust resistant pre-coated GI sheet topped with a layer of hay and soil as insulating material on the north side regulate solar radiation absorption on the inside surface. The GI does not allow growth of molds and fungus, which otherwise is a major problem in Traditional Greenhouse with wooden roof. It is durable and adds to the aesthetics of the greenhouse.


Roof

Metallic or polycarbonate door: The metallic or polycarbonate door located on the east wall is durable and requires minimal maintenance.

Easily operated ventilators: Manually operated ventilators with metallic frame on south facing frame and on west wall allow easy operation. The ventilations can be conveniently operated from inside the greenhouse without the requirement of any additional supports.


Ventilator

Components of Ladakh Greenhouse

- **Stone walls on three sides**
- **Triple layer 16 mm polycarbonate sheet on the south face**
- **A slopping (to the north) GI sheet roof on the north side**
- **Metallic door and easily operated ventilators**

2.2 Advantages of Ladakh Greenhouse over Traditional Greenhouse

Ladakh Greenhouse is designed to overcome the limitations of Traditional Greenhouse. Following advantages have been enumerated for Ladakh Greenhouse over Traditional Greenhouses in field trials with supporting scientific data:

Above freezing temperature: The temperature inside Ladakh Greenhouse remained above freezing points even in December and January in Leh condition in 2017-20. Therefore, plant growth is more vigorous in winters.

Increased variety of vegetables: Tomato, cauliflower and cabbage were successfully grown in peak winter in Ladakh Greenhouse, which otherwise is not possible in traditional Ladakhi Greenhouse.

Fixed cladding material: The polycarbonate sheet is fixed. There is no need to remove the cladding material even in summer months, unlike polyethylene sheet in traditional greenhouse. The ventilation does not allow building excessive heat inside the greenhouse even during summer months.

Durable cladding material: Average service span of polycarbonate sheet is 15-20 years in Ladakh condition. It withstands high wind speed and extreme climatic conditions of Ladakh region.

Withstand snow load: Triple layer polycarbonate as cladding material is suitable for regions receiving heavy snowfall. The smooth curved design allows snow to slips off. The structure withstands the load of snow which remains on it.

Maintenance free: The stone wall and metallic door and ventilator frame require minimal maintenance.

Judicious use of space: Racks are fixed on north wall inside the greenhouse. The racks can be used for a variety of purposes thus making use of above the ground space in the greenhouse.

Heat retention: The triple layer polycarbonate cover, fixed metallic structures and the use of the wall as thermal mass result in higher heat retention due to high thermal retention properties and minimal heat escaping gaps.

Long service period: The expected service life of Ladakh Greenhouse is 20-25 years. The walls, metallic frame and GI roof need minor maintenances to keep the greenhouse functional.

All year round crop cultivation: Three cycles of crops are grown in Ladakh Greenhouse (Cycle 1: Tomato, Cole crops and leafy vegetable-mid October to early March; Cycle 2: Vegetable nursery-late March to early May; Cycle 3: Warm season vegetables-mid May to early October)

Advantages of Ladakh Greenhouse

- **Warm season crops, such as tomato, can be grown in winter months.**
- **Service life of the greenhouse is 20-25 years.**
- **The structure has higher heat retention properties with minimal heat escaping gaps.**
- **No need to remove the cladding material during summer.**
- **Little maintenance is required.**
- **Suitable for regions receiving heavy snowfall.**
- **Three crops are grown in a year.**

2.3 Temperature inside Ladakh Greenhouse

The minimum temperature inside Ladakh Greenhouse remained above freezing points during extreme periods in December and January (Table 2.1). The night temperature further increase by approximately 4°C when covered with thermal blanket at night during winter months.

Table 2.1: Mean monthly ambient temperature inside and outside Ladakh Greenhouse (60 feet ×24 feet; single stone wall) (DIHAR Leh; 34°08.3'N; 77°34.3'E, elevation 3345 m)

Month	Average Temperature (°C)					
	Open Field		Ladakh Greenhouse		Difference (Greenhouse-Open)	
	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum
Jan. 2019	-0.2±2.4	-11.9±6.2	23.9±6.2	2.3±4.7	24.1±3.8	14.2±1.5
Feb. 2019	0.5±2.5	-8.8±4.6	26.4±7.6	3.8±1.3	26.4±5.1	12.6±3.3
Mar. 2019	4.9±3.8	-6.7±3.9	38±5.2	9.2±2.0	33.1±1.4	15.9±1.9
Apr. 2019	14.7±2.3	1.8±2.6	39.8±4.3	12.1±2.6	25.1±0.3	10.3±0.0
May 2019	18.4±2.5	5.1±2.3	38.6±4.7	10.2±1.7	20.2±2.2	5.1±0.6
Jun. 2019	20.1±1.9	6.9±1.5	38.1±4.4	12.5±1.2	18.0±2.5	5.6±0.3
July 2019	24.9±3.7	11.4±4.6	42.1±4.0	16.1±1.3	17.1±0.3	4.7±3.3
Aug. 2019	26.2±2.6	10.4±2.8	39.4±2.7	15.0±3.2	13.2±1.9	4.6±0.4
Sep. 2019	22.8±2.6	7.5±3.3	42.6±4.5	13.5±4.2	19.8±1.9	6.0±0.9
Oct. 2019	13.1±2.8	-1.2±2.6	33.9±4.7	12.7±2.8	20.9±1.9	13.9±0.2
Nov. 2019	8.5±2.6	-4.9±2.6	28.5±4.7	7.6±2.0	20.0±2.1	12.5±0.6
Dec. 2019*	0.0±2.4	-13.9±3.3	24.7±6.3	5.3±1.1	24.7±3.9	19.2±2.2
Jan. 2020*	-2.8±1.1	-14.0±3.0	21.5±6.9	4.9±1.0	24.3±5.8	17.0±2.0
Feb. 2020*	3.7±3.5	-10.5±5.4	34.0±2.5	10.7±2.5	30.3±1.0	21.2±2.9

*Greenhouse covered with thermal blanket at night

2.4 Marketable yield and production of vegetable seedlings in Ladakh Greenhouse

The marketable yield of vegetables during winter; tropical and sub-tropical vegetables in summer; and production of seedlings in spring are shown in Table 2.2

Table 2.2: Marketable yield and production of vegetable seedlings
(per Ladakh Greenhouse; 60'×24'; L×W, single stone wall; without thermal blanket)
(DIHAR Leh; 34°08.3'N; 77°34.3'E, elevation 3345 m)

Season	Crop	Yield/greenhouse	Date of harvest
Winter (Mid October to early March)	Cauliflower	323 kg	Early Feb
	Cabbage	398 kg	Mid Mar
	Khol-khol	231 kg	Mid Jan
Spring (Late March to early May)	Vegetable seedlings	1.2 lakh numbers approx	Early May
Summer (Mid May to early October)	Tomato	743 kg	Late July onwards
	Capsicum	201 kg	Aug onwards
	Okra	66 kg	Mid July onwards
	Brinjal	195 kg	Aug onwards

2.5 Income generation and payback period

In general three crops are being grown in a greenhouse as against a single crop in open field condition. The main source of income is from raising nursery seedlings in early spring either for commercial purpose or for own use. The projected income has been calculated as per experimental data at DIHAR Leh and prevailing market price in Ladakh.

Table 2.3: Projected income from sale of greenhouse vegetables
(Ladakh Greenhouse: 60′×24′; single stone wall)

Period	Crop	Yield (kg)/ greenhouse	Prevailing market price (Rs)	Income per Greenhouse (Rs.)
Winter (Mid October to early March)	Cauliflower	323 kg	100/kg	32,300/-
	Cabbage	398 kg	100/kg	39,800/-
	Khol-khol	231 kg	100/kg	23,100/-
Spring (Late March to early May)	Vegetable seedlings	1.2 lakh approx	Rs 0.5/seedling	60,000/-
Summer (Mid May to early October)	Tomato	743 kg	Rs 30/kg	22,290/-
	Capsicum	201 kg	Rs 60/kg	12,060/-
	Okra	66 kg	Rs 60/kg	3,960/-
	Brinjal	195 kg	Rs 50/kg	9,750/-

Rs 1,14,590/- per year if cauliflower (winter), vegetable seedlings (spring) and tomato (summer) are grown in a year.

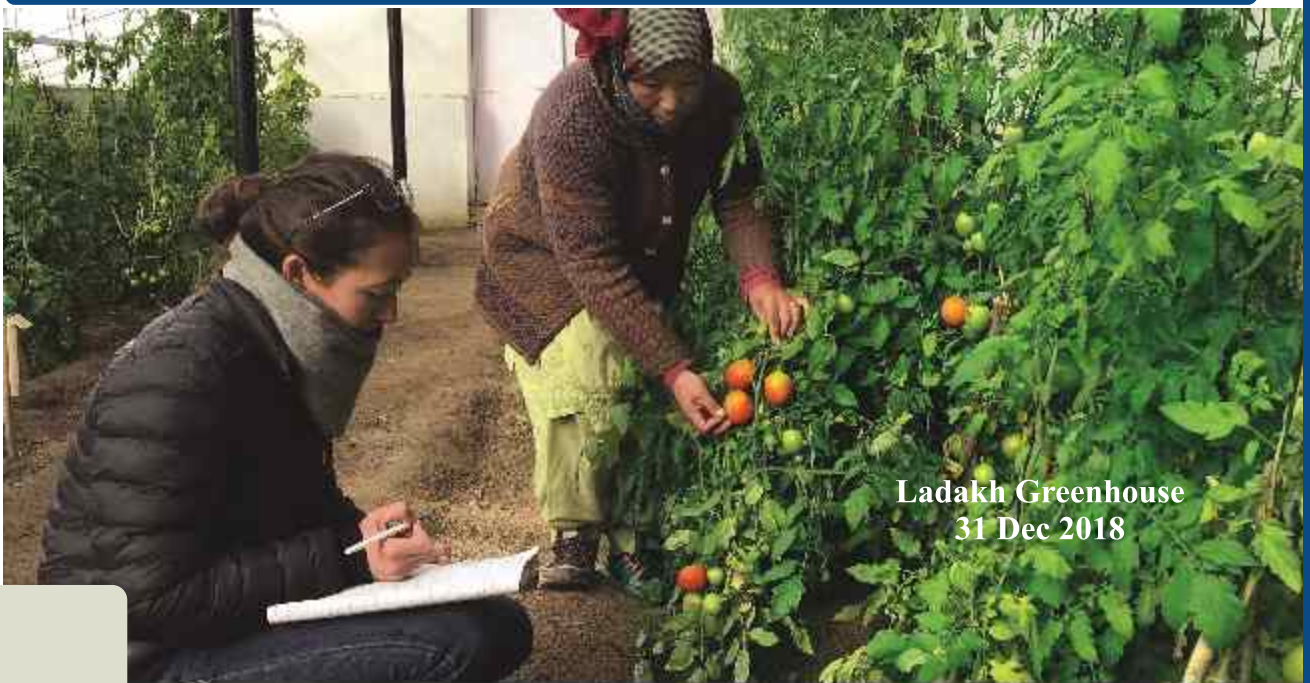
Harvest from Ladakh Greenhouse;
21 Feb 2019

Table 2.4: Payback period of Ladakh Greenhouse (60′×24′; single stone wall)

Asset's value	: Rs 6.41 lakh	**Gross income in 1st year**	: Rs 1,14,590/-
Inflation	: 7%	**Recurring cost in 1st year**	: Rs 25,000/-

Year	Cash inflow (Rs)	Recurring cost (Rs)	Net cash inflow (Rs)	Uncovered investment balance (Rs)
1	1,14,590	25,000	89,590	5,51,410
2	1,22,611	26,750	95,861	4,55,549
3	1,31,194	28,623	1,02,571	3,52,978
4	1,40,378	30,627	1,09,751	2,43,227
5	1,50,204	38,284	1,11,920	1,31,307
6	1,60,718	40,964	1,19,754	11,553

Payback period of a medium type Ladakh Greenhouse is 6 years 1 months without any financial support; and 2 years if 75% financial assistance is given to the farmers.



Ladakh Greenhouse
31 Dec 2018

Chapter-3

Crop Selection for Greenhouse Production

- Crop and varietal selection is important to achieve optimal utilization of the greenhouse structure.
- Crops should be selected appropriate for the season. Vegetables like tomatoes, cucumbers and capsicum do well in greenhouses during the summer season, and cold-hardy greens like spinach and kale thrive in the late autumn/winter/early spring seasons.
- To ensure a regular supply of vegetable from a greenhouse, cultivation of 'cut-and-come-again' types or crops that can be harvested multiple times such as spinach and beet leaf as opposed to lettuce heads; indeterminate tomatoes as opposed to determinate or bush varieties needs to be encouraged.
- Choose varieties which have been bred and selected to perform best in the growing conditions of a greenhouse, including a greenhouse-specific parthenocarpic or self-fertilizing types of crops.
- While selecting crops in greenhouse, the vertical space of the structure should be kept in mind especially for the crops which needs to be pruned and trellised such as indeterminate tomatoes and cucumbers.
- Consider multiple succession plantings or planting of crops in staggered manner for optimal utilisation of the greenhouse and to prolong the harvesting period.

Table 3.1: Recommended crops and varieties for greenhouse production for villages below 11,500 ft amsl

Option-I: Three crop cycle per year

A. Winter (Early October to early March)				
Crop	**Variety**	**Nursery raising**	**Transplanting**	**Crop harvesting**
Beet leaf	Delta	1st week of Sept	1st week of Oct	Nov onwards
Cauliflower	WS909, Shentha			Jan-Feb
Cabbage	Megaton, KGMR			Feb-Mar
Broccoli	Fiesta			Jan-Feb
Knol-khol	White Vienna			Dec-Jan

B. Spring (Late March to early May): Commercial vegetable and flower				
Crop	**Variety**	**Nursery raising**	**Transplanting**	**Crop harvesting**
Vegetable and flower	--	Mid Mar	--	Nursery ready for sale in Apr ending

C. **Summer** (Mid May to early October): Warm season crops				
Crop	**Variety**	**Nursery raising**	**Transplanting**	**Crop harvesting**
Brinjal	Janak, Shalimar Hybrid-1, Anupam, Pusa Purple Long	Late Mar	Mid May	Jul onwards
Capsicum	California Wonder, Shalimar Capsicum, Nisat			
Chilli	Saundarya, Garima			
Cucumber	BSS-647, BSS-89, Aviva, Claudia			
Paprika	KTPL			
Tomato	Tolstoi, Sioux, Arka Takshak, Roma			
Okra	Arka Anamika			

Option-II: Two crop cycle per year

A. **Winter** (Mid September to early March)				
Crop	**Variety**	**Nursery raising**	**Transplanting**	**Crop harvesting**
Tomato	Tolstoi, Roma	Early Aug	Mid Sept	Dec-Jan
Beet leaf	Delta	Early Sept	Early Oct	Nov onwards
Cauliflower	WS909, Shentha			Jan-Feb
Cabbage	Megaton, KGMR			Feb-Mar
Broccoli	Fiesta			Jan-Feb
Knol-khol	White Vienna			Dec-Jan

B. **Summer** (Mid March to early September): Warm season crops				
Crop	**Variety**	**Nursery raising**	**Transplanting**	**Crop harvesting**
Brinjal	Janak, Shalimar Hybrid-1, Anupam, Pusa Purple Long	Early Feb	Late Mar	Jun onwards
Capsicum	California Wonder, Shalimar Capsicum, Nisat			
Chilli	Saundarya, Garima			
Cucumber	BSS-647, BSS-89, Aviva, Claudia			
Paprika	KTPL			
Tomato	Tolstoi, Sioux, Arka Takshak, Roma			
Okra	Arka Anamika			

Table 3.2: Recommended crops and varieties for greenhouse production for villages above 11,500 ft amsl

A. Winter (Mid September to early March)				
Crop	**Variety**	**Nursery raising**	**Transplanting**	**Crop harvesting**
Beet leaf	Delta	Mid Aug	Mid Sept	Nov onwards
Lettuce, spinach, turnip, carrot	--			

B. Summer (Mid March to early September): Warm season crops				
Crop	**Variety**	**Nursery raising**	**Transplanting**	**Crop harvesting**
Brinjal	Janak, Shalimar Hybrid-1, Anupam, Pusa Purple Long	Early Mar	Early Apr	Jul onwards
Capsicum	California Wonder, Shalimar Capsicum, Nisat			
Chilli	Saundarya, Garima			
Cucumber	BSS-647, BSS-89, Aviva, Claudia			
Paprika	KTPL			
Tomato	Tolstoi, Sioux, Arka Takshak, Roma			
Okra	Arka Anamika			

Chapter-4

Physical Targets and Financial Assistance Required

4.1 Physical Targets

It is proposed to establish 1140 numbers of Medium Type Ladakh Greenhouse (60 feet x 24 feet) [Leh: 570 nos.; Kargil: 570 nos.] and 536 numbers of Domestic Type Ladakh Greenhouse (32 feet x 18 feet) [Leh: 268 nos.; Kargil: 268 nos.] during the financial year 2020-22.

Table 4.1: Number of Ladakh Greenhouse to be establish by CEO LAHDC, Leh/ Kargil through Agriculture and Horticulture Departments

Heads	Number of Ladakh Greenhouse												Total
	Leh District by CEO LAHDC, Leh through						Kargil District by CEO LAHDC, Kargil through						
	Agriculture Deptt			Horticulture Deptt			Agriculture Deptt			Horticulture Deptt			
	1st Year	2nd Year	Total	1st Year	2nd Year	Total	1st Year	2nd Year	Total	1st Year	2nd Year	Total	
Ladakh Greenhouse (Medium type: 60ft. x 24ft)	242	243	485	43	42	85	190	190	380	95	95	190	1140
Ladakh Greenhouse (Domestic type: 32ft. x 18ft.)	12	13	25	122	121	243	89	89	178	45	45	90	536
Total	254	256	510	165	163	328	279	279	558	140	140	280	1676

4.2 Areas Assigned to Agriculture and Horticulture Department

It is proposed that the Ladakh Greenhouse will be establish by CEO LAHDC Leh/Kargil through Agriculture and Horticulture Departments in Leh and Kargil districts. The agencies will be responsible for establishment and functioning of the greenhouses.

Table 4.2: Establishment of Ladakh Greenhouse in different blocks through Agriculture and Horticulture Departments

District	Name of the Block	
	Agriculture Deptt, Leh	Horticulture Deptt, Leh
Leh District	Chushot	Khaltsi
	Leh	Skurbuchan
	Thiksay	Nimo
	Kharu	Saspol
	Nyoma	Singay Lalok
	Rupsho	-
	Rong	-
	Durbuk	-
	Turtuk	-
	Diskit	-
	Panamik	-

District	Name of the Block	
	Agriculture Deptt, Kargil	Horticulture Deptt, Kargil
Kargil	Shargole	Drass
	Shaker Chicktan	Bhimbat
	TSG	Kargil
	Sankoo	Soth
	Barsoo	Pashkum
	Taisuru	-
	Longnaq	-
	Karsha	-
	Padum	-
	Lotchum	-

4.3 Financial Assistance Required

Funds required to establish 1140 numbers of Medium Type Ladakh Greenhouse (60 feet x 24 feet) [Leh: 570 nos.; Kargil: 570 nos.] and 536 numbers of Domestic Type Ladakh Greenhouse (32 feet x 18 feet) [Leh: 268 nos.; Kargil: 268 nos.] during the financial year 2020-22 is shown in Table 4.3.

Table 4.3: Funds requirement for establishment and functioning of Ladakh Greenhouse (Rs. in Lakh)

Heads	Financial assistance per greenhouse	Inputs and contin-gency	Leh District						Kargil District						Total
			Agriculture Deptt			Horticulture Deptt			Agriculture Deptt			Horticulture Deptt			
			1st Year	2nd Year	Total	1st Year	2nd Year	Total	1st Year	2nd Year	Total	1st Year	2nd Year	Total	
Establishment of Ladakh Greenhouse (Medium type: 60 ft. x 24 ft.)	Rs 5,33,500/-	-	1291	1296	2587	229	225	454	1014	1013	2027	507	507	1014	6082
Establishment of Ladakh Greenhouse (Domestic type: 32 ft. x 18 ft.)	Rs 2,84,000/-	-	34	37	71	346	344	690	254	253	507	127	127	254	1522
Inputs and contingency	-	As per actual cost	7	7	14	3	3	6	6	6	12	4	4	8	40
Total	-	-	1332	1340	2672	578	572	1150	1274	1272	2546	638	638	1276	7644

Table 4.4: Technical specification of Ladakh Greenhouse

Components	Domestic Type Greenhouse	Medium Type Greenhouse
Size (outside)	32 feet x 18 feet	60 feet x 24 feet
Size (outside)	29 feet x 14 feet	57 feet x 20 feet
Orientation	East - West	57 feet x 20 feet
Base from ground level	Ground level	Semi underground
North wall	8 feet high	8 feet 6 inches high
	Stone wall; 2 feet thick	
East and west wall	Stone wall; 1 feet 6 inches thick	
Roof	Width : 3 feet	
	Rust proof pre-coated GI sheet with a layer of hay and soil on top for insulation	
Door	Polycarbonate door panel with metallic frame on east wall with hooks for supporting extra protective covering for the winter	
Ventilators	2 numbers on frame facing south, 1 number on west wall	3 numbers on frame facing north, 1 number on west wall
Cladding material	Triple layer polycarbonate sheet, 16 mm thick; Anti UV protected both sides; Clear white	
Frame to support cladding material	Rectangular hollow metallic pipe	
Supporting vertical poles	Two poles	4 poles each in two rows

Annexure - I

Fig 1(a): Side view (East) of Medium Type Ladakh Greenhouse (60′×24′; single stone wall)

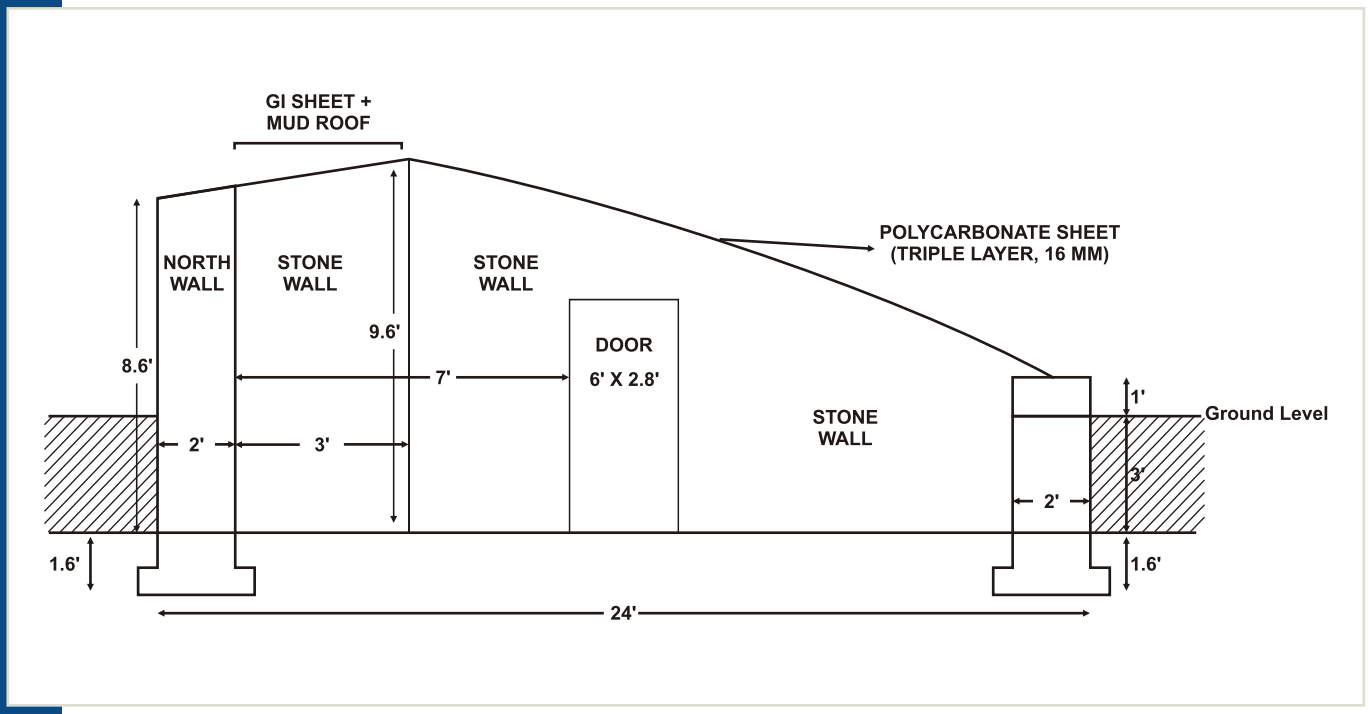
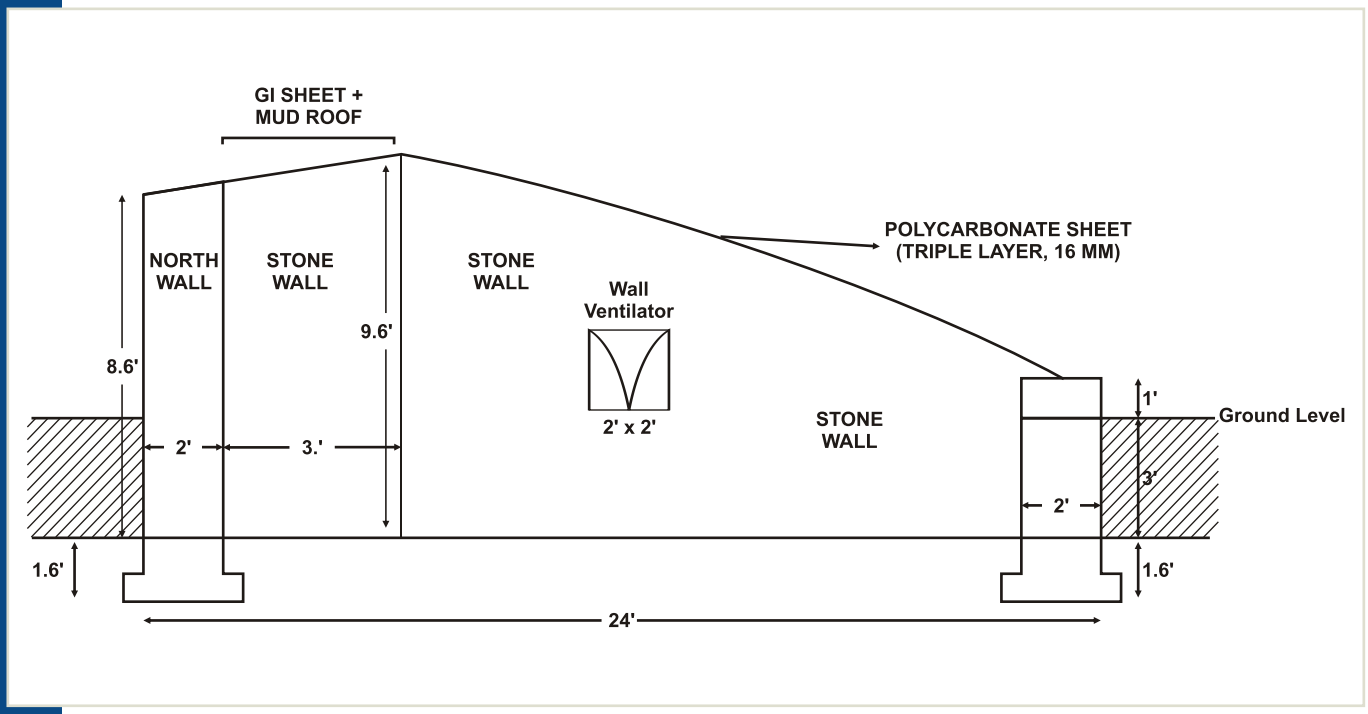
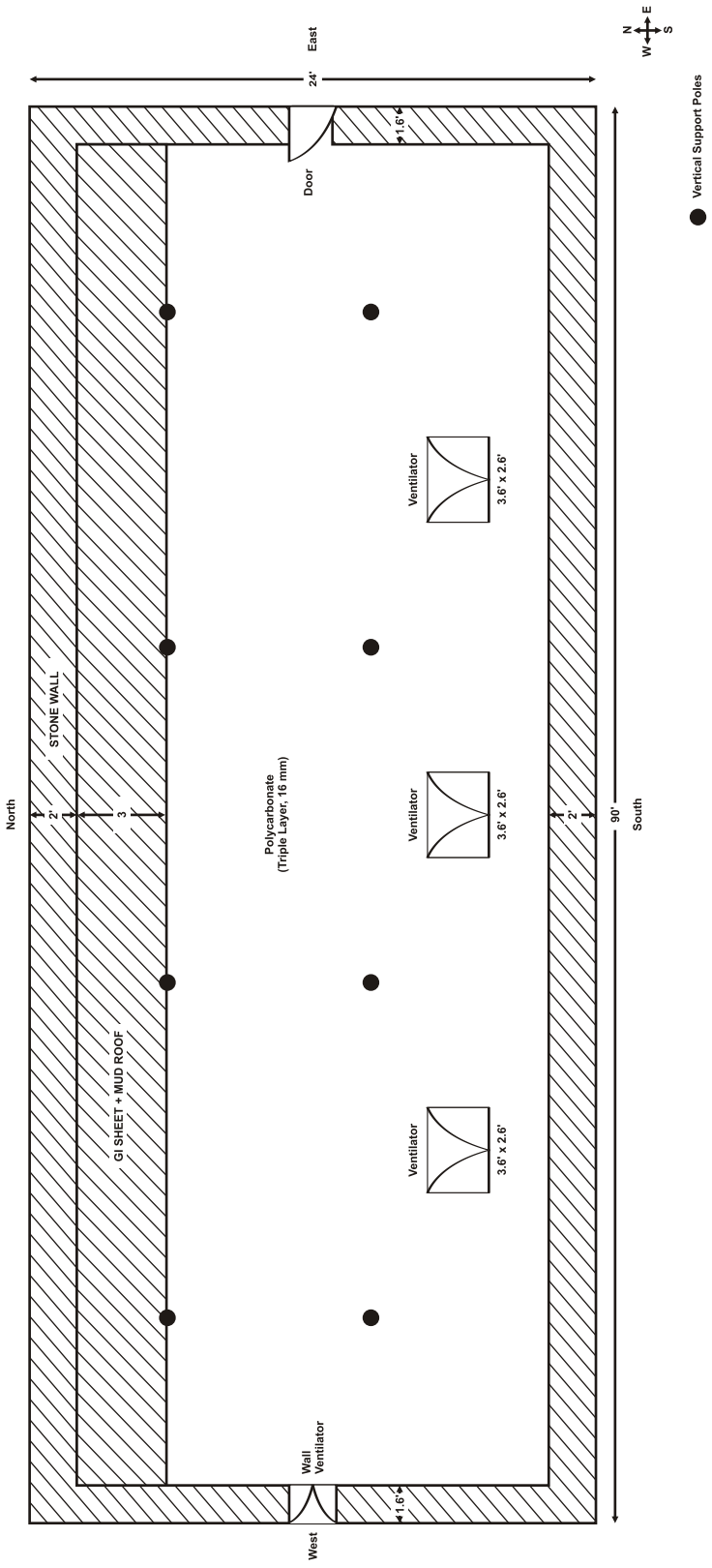


Fig 1(b): Side view (West) of Medium Type Ladakh Greenhouse (60′×24′; single stone wall)



Annexure

Fig 1(c): Top view of Medium Type Ladakh Greenhouse (60′×24′; single stone wall)



Annexure - II

Fig 2(a): Side view (East) of Domestic Type Ladakh Greenhouse (32'×18'; single stone wall)

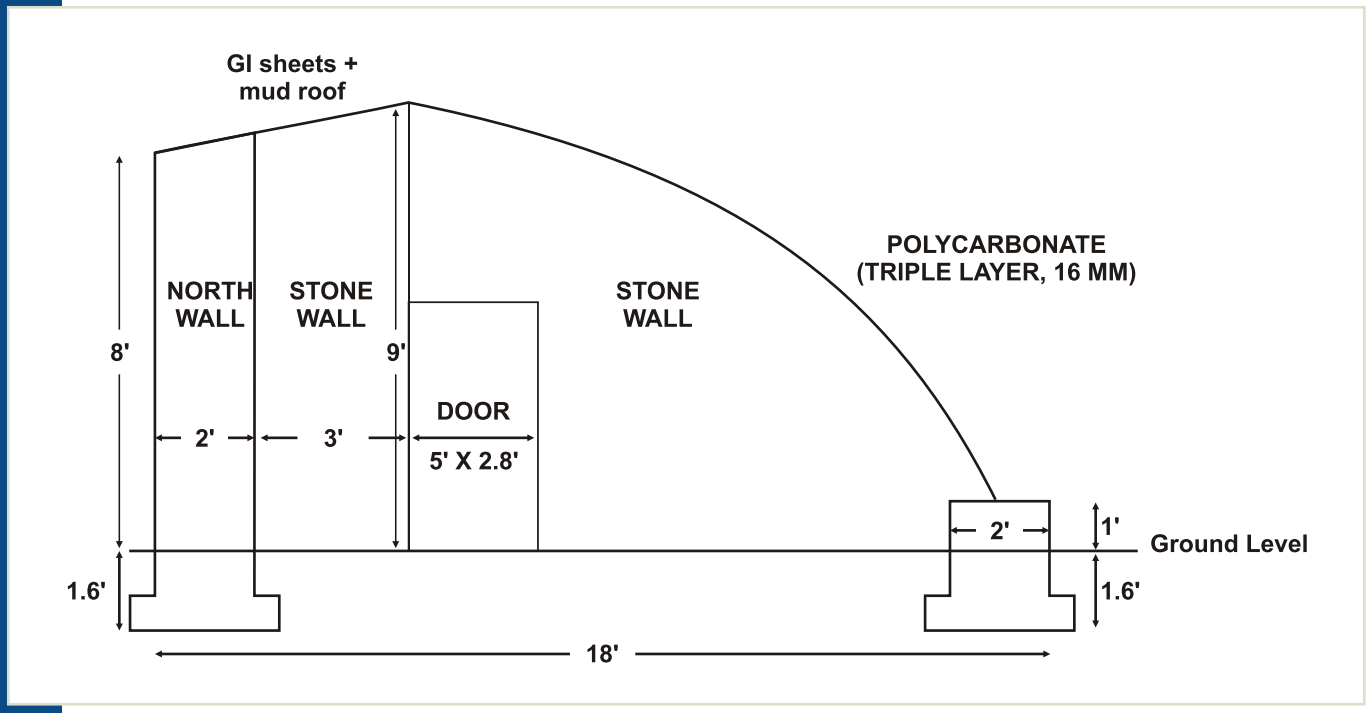
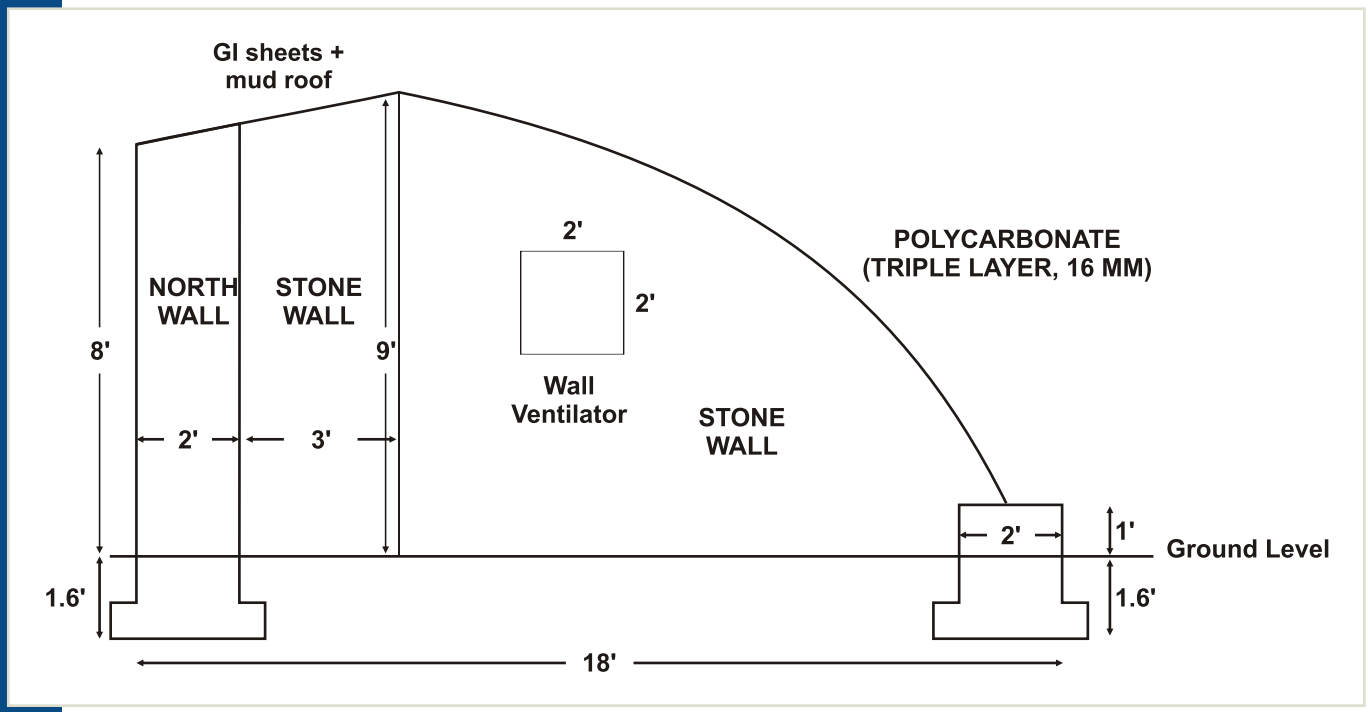
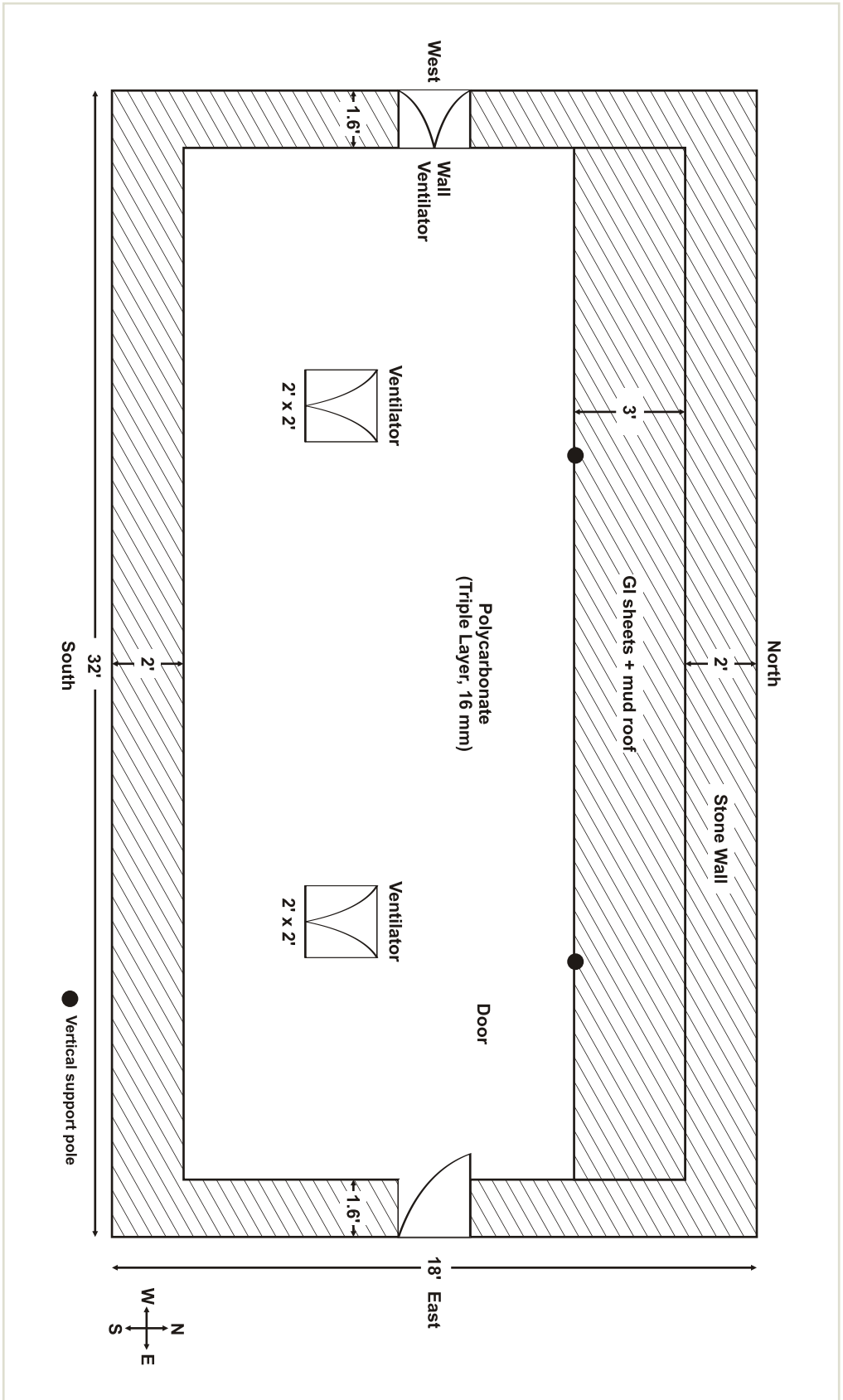


Fig 2(b): Side view (West) of Domestic Type Ladakh Greenhouse (32'×18'; single stone wall)



Annexure

Fig 2(c): Top view of Domestic Type Ladakh Greenhouse (32'×18'; single stone wall)



Annexure - III

Implementing agencies and guidelines for selection of beneficiaries

- Deputy Commissioner/ CEO LAHDC, Administration of Union Territory of Ladakh will be the implementing agencies for the project in their respective districts. The Implementing agency will be responsible for final selection of beneficiaries as well as for procurement of materials/ establishment of greenhouses.
- Hand holding for project implementation will be provided by the Directorate of Horticulture/ Directorate of Agriculture of UT Ladakh through their field officials.

Beneficiaries Selection:

- Transparent and objective selection of beneficiaries is of paramount importance not only to generate confidence of the farmers but also to ensure the success of the project. Therefore, the objectives of the project shall be widely advertised/publicized through print and electronic media and through special awareness campaigns for greater participation by farmers and to ensure transparency.
- Interested people shall apply online or write an application to the Chief Agriculture Officer/Chief Horticulture Officer of respective districts within the specified time. The application shall contain contact details, details of the family members, their occupation, amount of land holding, details of existing greenhouses if in possession etc.
- The applicant should have in his/her possession a sufficient land with independent irrigation facilities suitable for construction and running of the greenhouse.
- The applicant/farmer should be a resident of the village/place where the greenhouse will be installed.
- The application must have a recommendation of Hon'ble Chief Executive Councillor/ Executive Councillors/ Councillors of LAHDC / Chairperson, Block Development Councils of the area of the applicant.
- Chief Agriculture Officer/ Chief Horticulture Officer, Leh/Kargil will scrutinize the applications received and prepare a list of the eligible applicants. The above officers will personally visit the locations where greenhouses are proposed to be constructed to verify the suitability mainly the orientation of the site for maximum solar radiation.
- A committee under the chairmanship of Deputy Commissioner/ CEO, LAHDC of respective districts will issue the final list of beneficiaries. Sanction orders for availing assistance shall be issued by the Chief Agriculture Officer/Chief Horticulture Officer of the district.
- Preferences will be given to the villages/places where a cluster of greenhouses can be created.
- The beneficiaries shall ensure maximum utilization of the greenhouse for round the year crop production as per crop calendar issued by the department from time-to-time.
- The greenhouses shall be constructed as per the approved design under the project. The beneficiary will be responsible for construction of the foundation and the wall of the greenhouse strictly as per the design specifications.
- Non-compliance with designs or failing to complete the works on the part of the beneficiary within the stipulated time will automatically cancel the assistance.

THE ADMINISTRATION OF UNION TERRITORY OF LADAKH
UNION TERRITORY OF LADAKH