Mission Report
Greenhouse Applications - Jomsom

Related to the area around Jomsom
Annapurna Conservation Area

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Report date: **Kathmandu, 18 March 2003**

ABSTRACT

In the windy and high altitude area of Jomsom, Nepal, at about 2700m above sea level, a new design of a greenhouse was introduced by a development organisation. The greenhouse design included a heavy thermal wall (Trombe wall) that would accumulate heat during the day and release it at night. UV-resistant plastic foil was stretched over bamboo frames and tied down with wire mesh. Details of the design are provided. The design was rather expensive in labour and materials. The report analysis the positive aspects and disadvantages of the realised design and suggests some design alternatives.

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OBJECTIVES

The mission was undertaken to collect background information for a proposed project to establish demonstration improvements in the field of Renewable Energy (RE), including applications related to solar energy. These applications have been identified as being required to reduce dependency on firewood and imported fuels.

The identified project regions are high altitude trekking areas (above 2000 meter) with similar tourist and climatic characteristics. Project developments realised in the Sagarmanta Conservation Area will also be applicable in the King Mahendra Trust for Nature Conservation (KMTNC) administered area of the Annapurna Conservation Area and other high mountain areas.

The objectives of the mission and the persons contacted are mentioned in the Mission Report on Renewable Energy (RE) Applications - Jomsom, dated 15 March 2003.

PROVIDING INFORMATION ON GREENHOUSES

The Annapurna Conservation Area Project (ACAP) has produced a small leaflet in the Nepali language providing detailed information with diagrams about the realised greenhouse construction[1], but giving no budgetary information (see Annexe I). Most persons are aware that such information could be obtained from the ACAP offices.

In the Jomsom region several greenhouses had been constructed by local businessmen differing from the ACAP model (see photo page 4). An overview of the alternative designs, estimated cost, advantages and disadvantages was not available. Comparative financial information of the purchase, subsidy, installation and maintenance cost is lacking so villagers (farmers) are unable to make a budgetary analysis. To improve food production such would be essential.

Recommendation

Both the ACAP office and the District Development Office are well established and should continue to act as focal points for dissemination of information. The KMTNC and ACAP have published an assortment of tourist information brochures on each main trekking destination, clean environment, etc. These are readily available at each ACAP office. Following the same model, a series of simple one-sheet leaflets (triptych) can be developed, one for each greenhouse design and vegetable production, covering such basics as:

- What greenhouse design and how does it work? (along with a simple drawing).
- Advantages and disadvantages of a greenhouse (when it is possible and when not).
- Business opportunities for local food production in greenhouses.
- Costs of purchase, installation and maintenance per type of greenhouse.
- Where to get more information or an application form for a loan.
- Detailed information on food production in greenhouses; one fact sheet per vegetable type.

At the national level this information can possibly be developed and distributed with the support of AEPC[2]. Each information contact point can be supplied with a stand to display the information material, application forms, lists of local manufacturers, subsidy schemes, etc.

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[1] This information was based on documents from GERES and Appropriate Technology Asia (ATA), a project that realised greenhouses and improved solar buildings during 2000-2003 in the Jomsom area.

[2] AEPC, Alternative Energy Promotion Centre, Department of Ministry of Science and Technology.

GREENHOUSES VISITED

With the assistance of GERES and ATA, 29 small greenhouses (costing about NRs. 30,000)[3] were realised in several of the surrounding villages.

These greenhouses have a 4 x 8 square meter floor surface (see Annexe I for design). The visited greenhouses were all in use for growing seedlings and spinach. Some of the greenhouses were in better condition than others. A commercial farmer in the region had used corrugated translucent plastic roof sheets[4] rather than the UV-resistant transparent plastic foil (Silpaulin[5]) used by the project.

The project design included stable (one-foot thick clay-soil rammed earth) head walls and a low wall on the northern side. In one head wall a door was located and in the other a vent window. The sunny side had a frame constructed of wooden poles and bamboo sticks over which UV-resistant foil was placed. The foil was tied down with galvanised wire.

Two-thirds of the roof on the sunny side was covered with UV foil, while the remaining one third was covered with an insulating soil layer cast on a plank structure.

[3] One Euro is about Nepalese Rupees (NRs.) 75. The greenhouses cost about Euro 400 each, excluding planting material.
[4] These roof sheets had become yellow in one year, but were still well resistant against the unleashed wind attack.
[5] Silpaulin is a brand name of an Indian manufacturer who produces UV-resistant polyethylene foil. The same foil can be obtained from the Horticulture Department in the region.

The mission observed the following points:

Positive Elements Requiring Enhancement or Further Elaboration in an Upgraded Design	Negative Elements Requiring Improvement or Adjustment in a New Design
1. Local materials were used for the thick mud wall construction. These walls stabilized the inside temperature. Because of the relatively small size (4 x 8 m^2) of the greenhouse, the heat storage wall had a good temperature stabilizing effect.	1. The wall was costly when constructed with paid labour. This means that the farmer should construct the walls from his/her own resources and labour. When paid labour is necessary to collect the materials, it becomes doubtful if the heavy thermal wall construction is an economical investment.
2. UV-resistant plastic foil used had a large sunlight transparency (70%) and was a low-cost investment, both for purchase and transport. A substantial part of the material cost is related to the transport cost. At 120 gr/m^2 the weight is only about 20 kg, or about NRs. 400 in transport.	2. Commercial farmers had large greenhouses built using corrugated translucent (glass-fibre reinforced) roof sheets rather than the UV foil, requiring a high investment. The corrugated sheets are heavier than the foil, adding higher transportation cost to the increased material cost.
3. UV foil, when stretched and well attached, causes little flapping in the wind and can last for up to seven years at 2500 m altitude. The investment cost of NRs. 8/sq. ft. equals about NRs. 1600, with transport cost of NRs. 2000 every 5 years and labour for installing the new UV foil.	3. In some greenhouses the UV foil was loose and already damaged with holes, thus leaking air. When improperly tied down, the UV foil will become damaged within one year, requiring either repairs or partial replacement, adding considerably to the exploitation costs.
4. The UV foil was (posterior to the construction of the greenhouse) tied down with a knotted galvanised iron mesh with 8-10" openings. This 3 mm galvanised mild wire is used for the local manufacturing of Gabions, and can also be used inside mud-stone walls for reinforcement.	4. In some greenhouses, the UV foil was tied down with wire mesh with 4" openings, using an excessive amount of galvanised wire, thus increasing cost. A better and cheaper alternative to the galvanised wire is the application of box straps or packing bands. These come in widths of ½ to ¾ inch.
5. The galvanised wire was well attached, stretched and anchored into the heavy end walls. Attachment was realised by metal piping and by concrete reinforcement bars hammered into the supporting head walls.	5. In one place the wire was not well anchored into the ground or head wall, causing excessive flapping of the UV foil and subsequent damage. The wire, being a hard material, in most cases will damage the delicate UV foil.
6. The junctions between the wood supports and bamboo sticks were covered with agricultural bags to protect the UV foil from damage. This would work well when the UV foil was adequately loaded with soil at the base, so the foil remained stretched over the support structure.	6. Some greenhouse support constructions were not adequately protected with jute or agricultural bags, causing damage to the UV foil. In some cases the UV foil was tied over the head walls and loaded with PP[6] bags filled with soil. These were completely deteriorated within one year.
7. The ventilation window was made with a glass frame and fitted with a plastic sheet, allowing regulation of air intake. Air ventilation is necessary to avoid overheating of the plants in the greenhouse during high sun intake.	7. Some greenhouses had neither a glass frame nor shutter, causing a permanent opening that cannot be regulated. The result was a constant and excessive cooling, making the heat retention wall ineffective.
8. Soil quality inside the greenhouse was enhanced with horse/cow dung and seedbeds were well tended. In the greenhouse the shadiest corner was dedicated to manure/compost production.	8. Soil quality was rather sandy and plant spacing seemed to be too wide. Seedling beds were uncovered, thus allowing additional evaporation and sharp drop of night temperatures.

[6] PP is polypropylene, a synthetic fibre. Because the fibre of the agriculture bags is very thin, it becomes deteriorated in a few months by the strong sunlight.

Positive Elements Requiring Enhancement or Further Elaboration in an Upgraded Design	Negative Elements Requiring Improvement or Adjustment in a New Design
9. The North-facing roof construction was made with supporting girders and the UV foil extended over these poles. On top of the plastic an insulating soil layer was placed. This design economised the need for plank supports.	9. The North facing roof was made with planks. These were covered with plastic and soil. The planks are possibly expensive and not easily available. The support structure was straight, thus not allowing the UV foil to be stretched over the bamboo.
10. In one greenhouse a minimum-maximum thermometer was installed. By monitoring both the inside as well as the outside temperature, the positive thermal effect of the greenhouse can be demonstrated.	10. Temperatures were not monitored, thus not providing information to the project. Without monitoring there is no indication about the best planting period nor the economic differences between the various greenhouse designs.
11. The door was located at the opposite side of the main wind direction. This will avoid the door being blown open or, when the door is open, the UV foil is blown upwards.	12. The door was located on the windy side and opened inwards, causing a constant ventilation of the greenhouse and blowing the UV foil upwards when the door was opened during strong wind.

Local entrepreneurs made greenhouses with the use of transparent corrugated roof sheets.
These roof sheets were highly resistant against strong wind.
In the background, Mt. Nilgiri (7061m)

GREENHOUSE DESIGN

High wind velocity, particularly in Jomsom and the surrounding area, is a very important factor to consider in the greenhouse design.

- The stability of the greenhouse must be adequate to withstand the wind force.
- The flapping of the UV foil must be completely avoided by tying the foil down or applying other construction materials and techniques.
- Night cooling must be reduced in areas where the wind continues into the night.
- Placement of the entrance door and ventilation openings must adequately take into consideration the most important wind directions.

Stable Construction

The heavy three-sided wall construction of the rather small building provided adequate stability. Commercial farmers, who were growing crops for local marketing (not only for own production), had larger greenhouses. With lengthening the size of the greenhouse, the low (4-5 ft.) solid, thick (1 ft.) rear wall needs to have a stabilizing cross wall at every 20 feet or 6 meters.

Greenhouses built on slight slopes need to have horizontal plant beds inside. Depending on the orientation of the slope and the southern orientation of the greenhouse, the plant beds can be stepped, making interior terraces. The greenhouse can be partly built into the slope, thus providing additional stabilisation. Due attention must be given to ensure that water running off the slope does not flood the greenhouse.

At very high altitudes (over 3000 m) it is recommended to install night curtains in order to create an insulating air layer under the UV foil. The curtains can be hung on straight horizontal wires or pipes placed under the UV foil and anchored into the head walls. The head walls should be adequately stable to carry these additional forces. The connection points of the wires should be fitted to the head walls before the UV foil is stretched over the construction.

Thermal Storage Wall

The greenhouses constructed with the support from ACAP in the Jomsom region (2500 m) had two solid thermal storage head walls and rear wall. The walls were made in rammed clay soil, providing a natural thermal insulation. The inner surface of the wall was painted black and would warm up during the day, releasing heat during the night and thus stabilising the inside air temperature of the greenhouse. In addition, part of the roof on the northern side was a closed, insulated construction.

The greenhouses of the commercial farmers had walls and roofing constructed from corrugated translucent plastic roof sheeting with glass-fibre reinforcement, thus having as internal heat storage capacity only the soil inside the greenhouse. The choice of the corrugated plastic sheeting was mainly based on durability as it would not be damaged by the strong winds and would last for many years. Farmers who have the ability to make a capital investment can have such a choice. On the other hand, the small greenhouses (only 4 x 8 m^2) built with financial assistance of ACAP also cost about NRs. 30,000, mainly because of the high labour investment cost of the heavy wall construction.

In other high altitude areas with less wind, greenhouses are usually built without thermal storage walls and solely with the UV-resistant foil. Obviously, the overall construction and investment cost of these greenhouses is far less than either the thermal wall construction or the corrugated plastic roof sheet construction (see photo page 7).

Not all regions of Nepal will have the good clay soil quality to make a rammed earth construction. Stones, however, are abundantly available in all mountain regions. An alternative method for making a thermal storage wall is to construct a double stone cavity wall and pack the 2-3" cavity with straw. The inner wall of the cavity construction will stabilise the inside temperature of the greenhouse better than the rammed earth wall.

When the thermal wall is filled with straw (needed for altitudes over 3000 m or 9000 ft.), the double stone construction needs inside reinforcement to keep the two walls together. This reinforcement needs to be applied at about 2-ft. high intervals or maximum every three layers of stones. For cavity walls it is highly recommended to interconnect the two walls with a 2.3 mm galvanised wire mesh. With a 2-ft. thick wall, the wire reinforcement should be 1.5 ft. wide.

Semi-dressed stone cavity wall of 2 ft. thickness and filled with straw

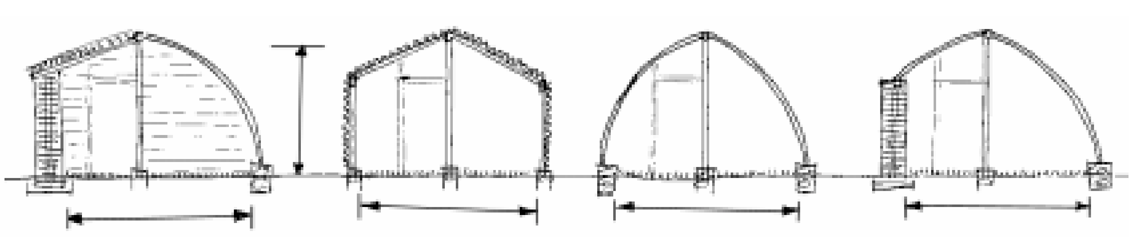
Galvanised 3 mm wire made into wall reinforcement strip, to be placed every two or three courses

With an improved construction design of the application of the UV foil, the possible damage from strong winds can be limited and a comparison can be made between four different designs, using plant growth as the indicator. Whatever the design and the investment are, the actual plant growth inside the greenhouse and the economic return of the produced crops will determine if one construction is a better investment than the other.

Recommendations on Economic Research

Four different greenhouse designs equal in usable internal floor area and height are placed next to each other in one area. Records of material, transport and construction costs, as well as construction time, must be kept in detail, specifying self-help components. Four such greenhouse designs can be:

1. One according to the wind-improved ACAP design, having the three thermal storage walls and partially covered roof on the northern side.
2. One using exclusively the translucent fibre-reinforced corrugated roof sheets.
3. One using the UV-resistant foil on all sides and the roof, but not having a thermal storage wall. This will be the cheapest construction.
4. One having only a low thermal storage wall on the northern side of the greenhouse and using UV foil for the whole roof and head walls.



ACAP design with bow ribs and three thermal walls

Design with corrugated transparent plastic roof sheets

Design with two bow ribs and four sides UV foil

Design with one thermal wall and three sides UV foil

- The minimum and maximum temperatures inside all of the greenhouses and the outside temperature need to be daily monitored.
- Plant seed development and plant growth, including watering and fertilisation, pest control, etc. should be similar in all four greenhouses.
- The total produce of seedlings and plants should be registered by number, weight and quality (including diseases) at the time of harvesting.
- Plant growth output and differences should be recorded.
- The annual production can then be compared with the construction cost and the expected lifespan of the construction. Green plant material can be used as fodder for cattle and therefore also has an economic value. With a good wind-resistant design, it can be estimated that the UV-resistant foil needs to be replaced after about 7 years.

Determining which of the various designs is the most economical for the farmer to invest in can only be realised following a comprehensive analysis of the construction cost, the above-mentioned recorded data, crop production and economic return. The temperature measurements will provide an indication to what extent the thermal heat store walls are effective and whether or not they are really needed.

Control Flapping

The outside shape of the greenhouse can be made in a bow shape. By doing so, the UV foil can be fixed to the topside, stretched over the bow and dug into the ground at the low side[7]. Bamboo is fixed at the bottom, bended over the supporting structure and tied down at the topside to the central girder. This requires bamboo of measured dimensions to provide sufficient strength and allow the needed bending. It was observed in one of the greenhouses that the 1" diameter bamboo sticks were broken by the force of the wind load. To prevent this from occurring, large 3" diameter round bamboo can be used, splitting it in two lengthwise, making two halves, or 4" diameter bamboo can be split lengthwise into four quarters. The bamboo sections can then be tied down onto the construction with their rounded side outwards. The binding material should preferably be 2 mm galvanised smooth wire[8] as other binding materials will be affected by the sun. Sharp edges on the outsides of the bamboo ribs should be removed with course sandpaper to avoid damage to the UV foil.

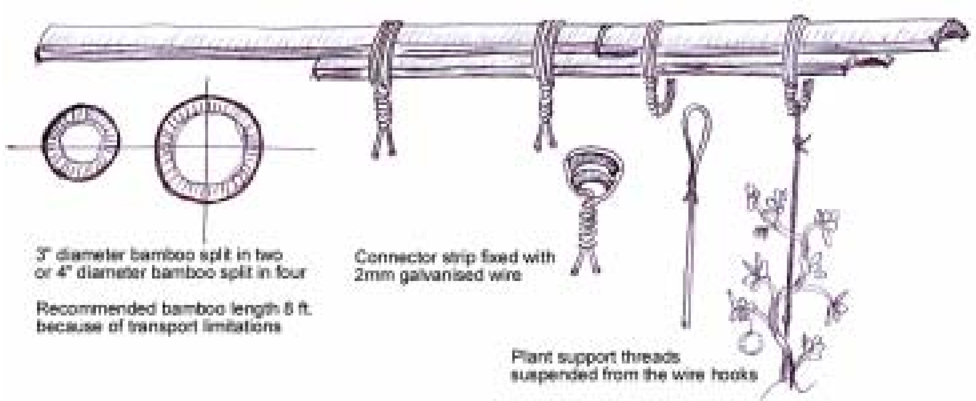
In this greenhouse in Pangdung, the foil is effectively tied down
with packing straps nailed to the wooden structure.

[7] This design is common in Tibet, partly because of the ability to work intelligent with bamboo constructions. These greenhouses are often built along the entire length of the house and also function as a heat collector for the house.

[8] Never use mild steel reinforced concrete binding wire as this will rust quickly due to the high humidity inside the greenhouse. Thin polypropylene rope (< 0.1 mm) will deteriorate with the sun.

Rib Length

Depending on the maximum length of materials that can be transported by donkey, several sections need to be connected to make the required rib length of the construction. Consequently the overall dimension of the greenhouse will be partly determined by the length of the various transportable pieces. From observation of the constructed greenhouses, it seems that prefabricated bamboo components with a length of 8 ft. are feasible. The 8-ft. long pieces should have the adequate strength and bending properties. Connections for tying the two pieces together at multiple points can be made with smooth 2 mm galvanised wire. The knotting end of the galvanised wire at the underside of the bamboo should not be cut off but instead bent into a hook from which strings can be suspended for supporting the growing plants.



Rib Spacing

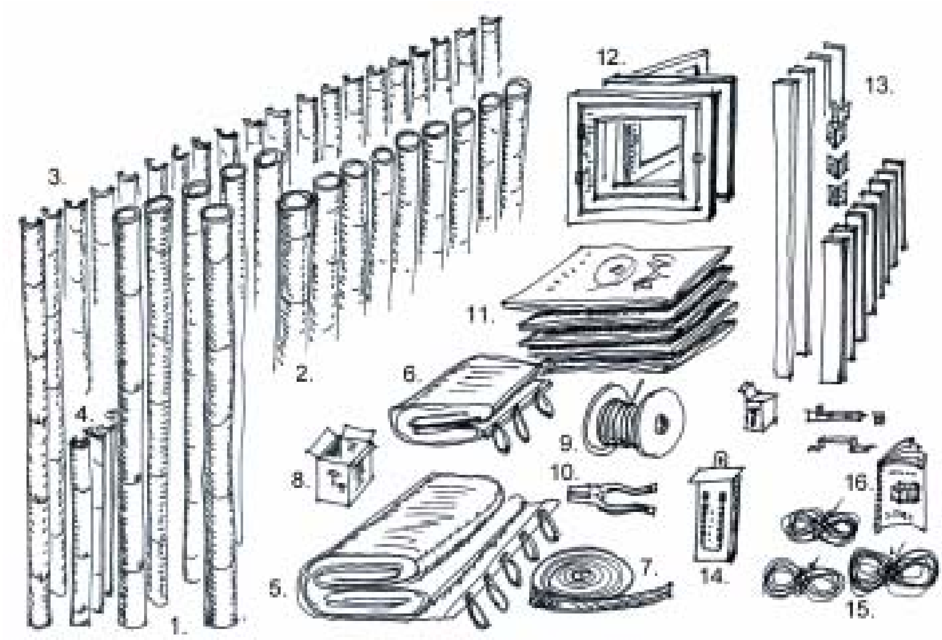
The spacing of the UV-foil supporting ribs of the greenhouse depends mainly on the wind load. Firstly, the higher the wind load, the smaller the spacing. Secondly, the rib spacing can depend on the future plant growing inside the greenhouse. Most of the greenhouse vegetables and fruits require vertical leading strings along which the plant grows upward. This will enhance effective space utilisation, pest control, watering and harvesting, thus improving overall efficiency of the greenhouse. This means that the ribs not only need to carry the wind load but also the big, round, fat tomatoes, cucumbers, etc.

With high wind load it is recommended to use ¼ strips of the 4" diameter bamboo and make a spacing of about one foot. With low wind load ½ strips of the 3" diameter bamboo can be used with a spacing of about two feet. In both cases the packing straps need to be stretched over the UV foil on each of the bamboo ribs.

In some greenhouse designs, supporting ropes are placed under the plastic in between the ribs when the rib spacing is 3-4 ft. or even larger. This is only useful when a zero wind situation allows large rib spacing and the ribs are straight. With warm weather the plastic will expand and hang loose in between the ribs. The packing straps will in this case support the UV foil. This is not a useful option with the bow construction.

Planning

The location and total surface of the to be planned greenhouse need to be recorded on a planning chart. The slope should be detailed to indicate whether or not the greenhouse needs to be terraced inside. On the same chart the expected wind load needs to be indicated. On the basis of this information all the to be imported components, such as the support structure, ribs, UV foil, ventilation window and door, can be pre-manufactured. The entire package, with an assembling/construction manual, can be delivered to the site. This way the transportation costs will remain the smallest.



1. Central supports	5. Large UV foil	9. Galvanised 2 mm wire	13. Door and frame
2. Roof beams	6. Small thick foil	10. Pliers	14. Thermometer
3. Ribs	7. Packing strap	11. Agriculture bags	15. String for plants
4. Rib connectors	8. Nails	12. Ventilation windows	16. Construction manual

Without a strong bow frame rib construction and with improper fixing of the UV foil, the wind will rapidly damage the plastic foil.

Fitting the UV Foil

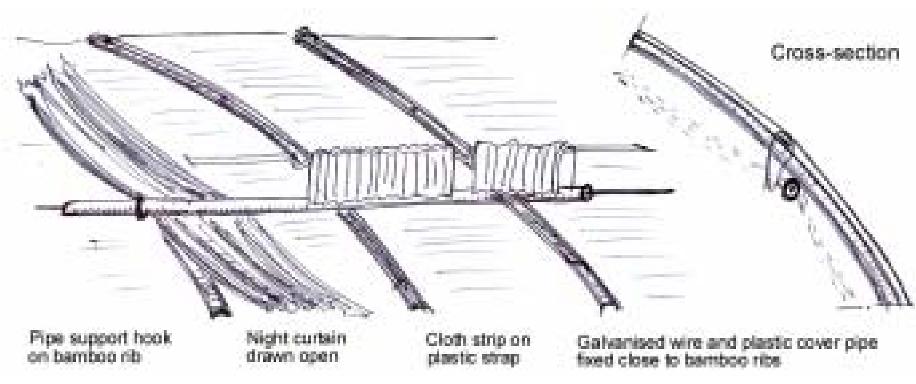
The UV foil can be prefabricated with incorporated ringed holes along a reinforced border. Sufficient holes should be available to tie the UV foil at the given or planned rib intervals[9].

1. The wired junctions between the top ends of the ribs and the support structure are covered with PP agricultural bags or jute bags to avoid damaging the UV foil. The tops of the head walls are equally smoothened and rounded off with a soft (clay) soil cover.
2. The top of the UV foil is tied to the top ridge with wire or jute rope. Here two sides come together. The shaded side (1/3 of the roof facing North) is to be covered with thick foil (250 gr/m^2) and an insulating soil layer. The sunny side (2/3 of the roof facing South) uses the thin UV foil (120 gr/m^2).
3. The UV foil is then fitted during the warmest period of the day, after the entire foil has been warmed and is expanded by the sun. If the foil is fixed while expanded, once cooled it will become tight and stretched.
4. The foil is tied down on the low side to stones sitting on the ground. On the sides the foil is tied down over the side walls and well anchored into the head wall. For elastic fixing, 1-inch wide rings from old tire inner tubes can be inserted into the eyes. This way the UV foil remains stretched.
5. The ½-inch packing straps can be attached over the foil at each bended bamboo rib. This holds the foil tightly down onto the ribs. The same strap is also fixed to the bottom stones.
6. When the construction is well tied in place, the bottom part of the UV foil and the stones are covered with soil to make a 1-ft. high dike along the outside.
7. The roof construction is finished on the northern side.

Because the UV foil is now stretched without allowing movement, the lifespan can easily be extended to seven years before it needs to be replaced because of deterioration by the UV-solar radiation.

Night Curtain

Depending on the altitude and the amount of wind cooling at night, the greenhouse may need an additional thermal insulation by means of a thin curtain on the inside against the UV foil. This is recommended for all altitudes over 3000 m.



Wires are stretched from head wall to head wall to form the support for the night curtain. Due to the bow design, four wires will be necessary to allow an air cushion of maximum one foot. To protect the cloth of the night curtain from damage, the wires should be protected. Passing a hard thin plastic pipe over them is a good solution (15 mm HDP electric conduct piping). As an alternative metal or plastic-coated piping can be used, but piping may be more costly in purchase and transport. Besides, for straight pipes, the total length cannot exceed 8 ft., being the maximum transport length for most remote regions.

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[9] In some cases it was noted that the spacing of the eyes was over 3 ft., far too wide for good attachment. The result was that farmers started to nail the foil in between the eyes. Nailing causes damage to the UV foil.

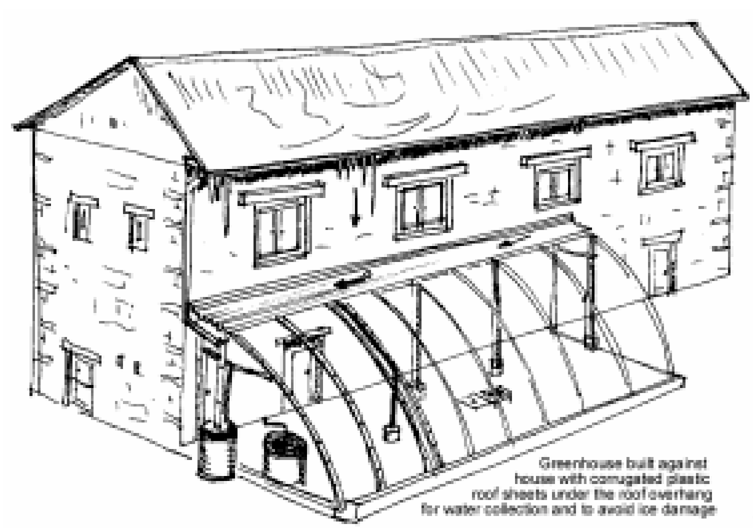
The wire or pipe should be supported every 6-8 ft., otherwise it will bend down too much. The width of the curtains should correspond to the support distances. The curtain should be lightweight, airtight and sun resistant. On the top and bottom wire plastic rings are fitted (shower curtain rings). When closed, the night curtain should fit tight on all sides to minimise air circulation between the UV foil and curtain. At the height of the intermediate support wires/tubes, cloth strips can be hung to further reduce air circulation behind the night curtain.

Natural Ventilation

Ventilation inside the greenhouse is essential if the inside temperature reaches above 28º Celsius. The higher the temperature can rise, the larger the amount of ventilation air that needs to pass through the greenhouse. At the moment the temperature drops below 28º Celsius, ventilation must be stopped. This means that a minimum-maximum thermometer should be standard equipment in each greenhouse, not only to check the minimum night temperatures, but also to know when ventilation should be realised. Temperatures over 30º Celsius will easily damage crops.

In the Jomsom area natural ventilation is easily available by opening a door and/or ventilation window in one of the head walls because of the strong wind during the afternoons. In other areas where no strong winds occur, the ventilation openings may need to be larger and placed above the door and near the roof in both head walls. Ventilators can also be placed in the roof.

The exact location of the ventilators and the size depends on the principal wind directions during the warmest periods of the day[10] and the amount of heat generated during the day. With the prefabrication of the greenhouse in the large cities, the order form and purchase contract should specify the exact location of the ventilation openings and the sizes per farm situation.


Greenhouse built against house with corrugated plastic roof sheets under the roof overhang for water collection and to avoid ice damage

House Attached Greenhouse

Greenhouses can be free-standing or attached to the house, forming a conservatory. Such a design may only be possible when sufficient room is available around the house.

Building the greenhouse against the house has several advantages.

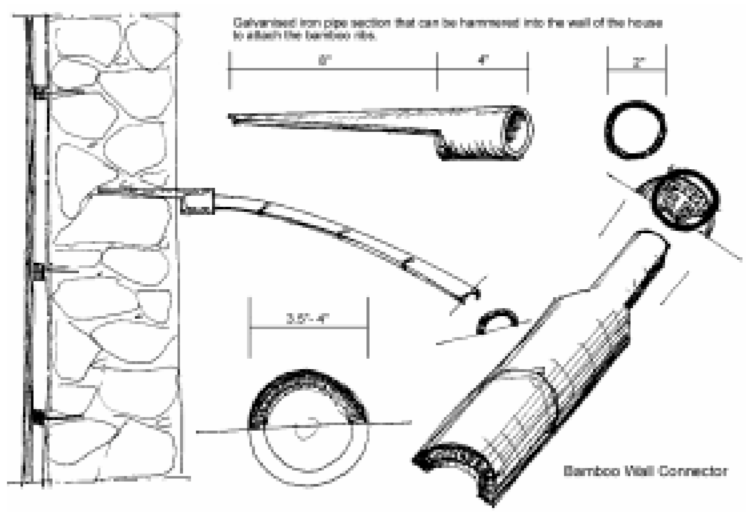
- The stability of the greenhouse is assured by the main wall of the house. The house will in some cases also shield the greenhouse from strong winds from the North.
- The greenhouse will be less costly as compared to a free-standing greenhouse because one side is formed by the house.

[10] In several mountain regions the wind direction changes 180 degrees between day and night. Ventilation openings should consider the time of day when the greenhouse may become the hottest.

- The greenhouse warms the wall of the house and the wall will function as a heat storage wall during day, stabilizing the greenhouse temperature during the night.
- Because of the heated greenhouse, the house itself will also be warmer; cooling at night on the side of the greenhouse will be strongly reduced.
- In the winter part of a large attached greenhouse can function as a sunny outside sitting area.
- The plants and vegetables in the greenhouse are nearby (the kitchen) and close control can be maintained on the plant growth.
- Water from the roof can be harvested and directly stored inside the greenhouse.

The following disadvantage can exist:

- Ice falling from the roof can damage the greenhouse when no sufficient protection is made under the roof edge. A possible solution is to place corrugated plastic roof sheets.



Vegetable Production

The value of a greenhouse becomes evident at altitudes over 1700 m because vegetables grow better in an environment that has an increased humidity and temperature during daytime, and the temperature differences between day and night are reduced. Also the greenhouse reduces (diffuses) direct sun radiation to about 70%, eliminates wind and limits strong cooling during the night.

The economy of the independently constructed greenhouse depends on the value of the crops or seedlings that can be produced and subsequently marketed. The greenhouse allows seedlings to be germinated and grown before these are transplanted inside the same greenhouse or outside in the "cold" soil. Better quality crops can be produced in the greenhouse than vegetables grown in the "cold" soil, thus fetching a better price. Saplings of fruit and forest trees can be rapidly grown to several feet in height and then transplanted to outside locations.

The quality of the vegetables in some greenhouses was noted to be of rather poor quality. Tomatoes and cucumbers were strangling themselves on the ground, producing little and occupying a lot of ground space, making the greenhouse inefficient. By attaching the climbing plants to strings suspended from the ribs, considerably more plants can be grown and plants can be better controlled. Depending on the altitude and type of crop, the height of the plants and the greenhouse can become two meters or higher.

The promotion of greenhouses should go together with good information about food production:

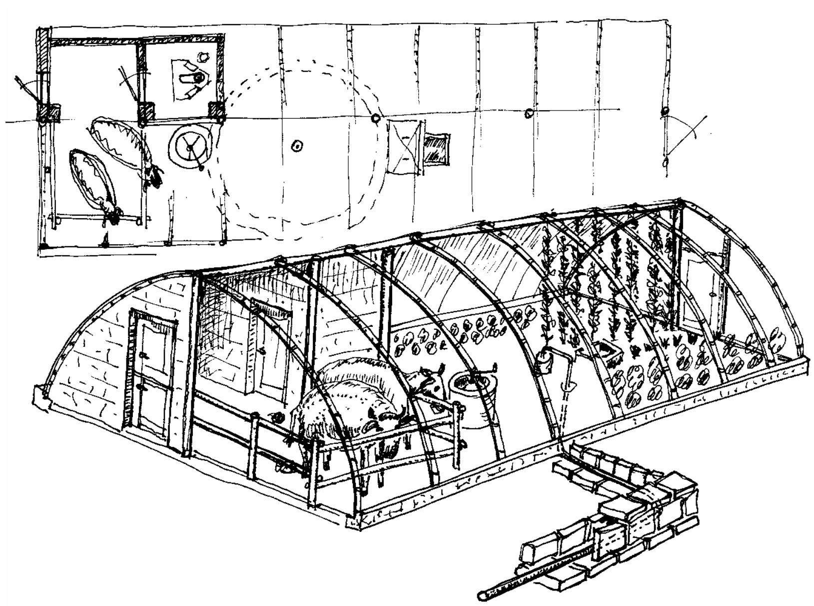
- Where to buy the seeds and how to germinate these in seedbeds so that spreading of crop output can be realised. It should be avoided that all plants need to be harvested at the same time if these cannot be economically sold or consumed at the same time.
- What plants to sow in what season to obtain maximum benefit from local marketing opportunities. This is important in tourist trekking areas during specific seasons.
- How to take care of plants in terms of weeding, pest control, growth control, fertiliser, etc.
- How to make the best compost and fertiliser for greenhouse crops.

Biogas Reactors and Greenhouses

For altitudes above 2000 m biogas reactors can be realised for people who own three or more cattle. The cow dung is fed into the biogas reactor on a daily basis to produce gas for cooking or lighting. Among other things this means that the farmer needs to own the land on which the biogas reactor is built and guarantee the continuous care for the cattle and biogas reactor.

These biogas reactors should be well shielded from cold wind, thermally insulated and built in combination with greenhouses to allow improved production of vegetables and/or animal fodder. Once installed, the farmer's family will have free cooking gas for the following twenty years or more, as long as the family keeps feeding the biogas reactor with dung. Free gas for cooking means a saving of about 3,000 kg of firewood per year. Saving this large amount of firewood each year signifies considerable saving in time in wood collection and chopping the wood into small pieces to tend the fire. In addition, no more smoke in the kitchen and with a gas lamp also instant light.

Because the biogas reactor has such clear benefits, its economic feasibility should be precisely assessed for all farmers wanting to have free cooking gas for twenty years or longer. The investment cost of the High Altitude Biogas Reactor (HABR) not only depends on the construction cost of a thermally insulated biogas reactor inside the ground, but also on the greenhouse that is built over the entire biogas reactor. The slurry produced from the outlet of the biogas reactor is an excellent fertilizer and should be used to its optimal benefit in plant growing, either inside the greenhouse or for outside farming. This means that the HABR is an integrated package of biogas reactor and greenhouse.



SOLAR DRYING

With an increase of greenhouses and food crop production, the possibility of solar drying needs to be developed, first on a domestic scale and subsequently on a commercial scale. The Jomsom mission report provides some information on the requirements for marketing of solar dried produce.

Information about solar drying equipment should be made available in the region so that the farmer knows how to dry excess food production for sale or consumption later in the year. Detailed information about different types of solar drying equipment should be readily available to the farmer:

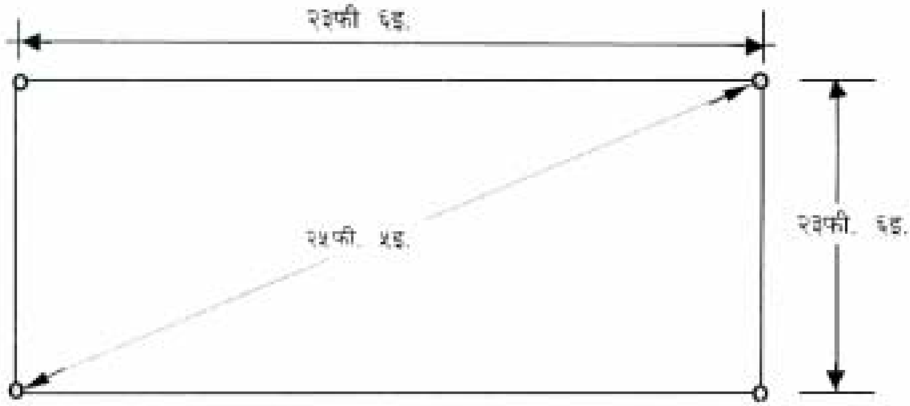
- What size equipment can dry how much farm produce?
- How much work does a solar dryer require?
- Can a solar dryer be operated by a group of farmers?
- Where can it be bought or manufactured?
- What does it cost? What does it cost to operate?
- What vegetables or fruits can be dried and what are the drying procedures? One specific instruction should be available for each type of vegetable or fruit.
- How can the dried food be stored and re-processed for consumption?
- What are the best recipes for making appetizing dishes from the dried vegetables and fruits?

Locally manufactured solar dryer cabinet and apples dried in Jomsom District.

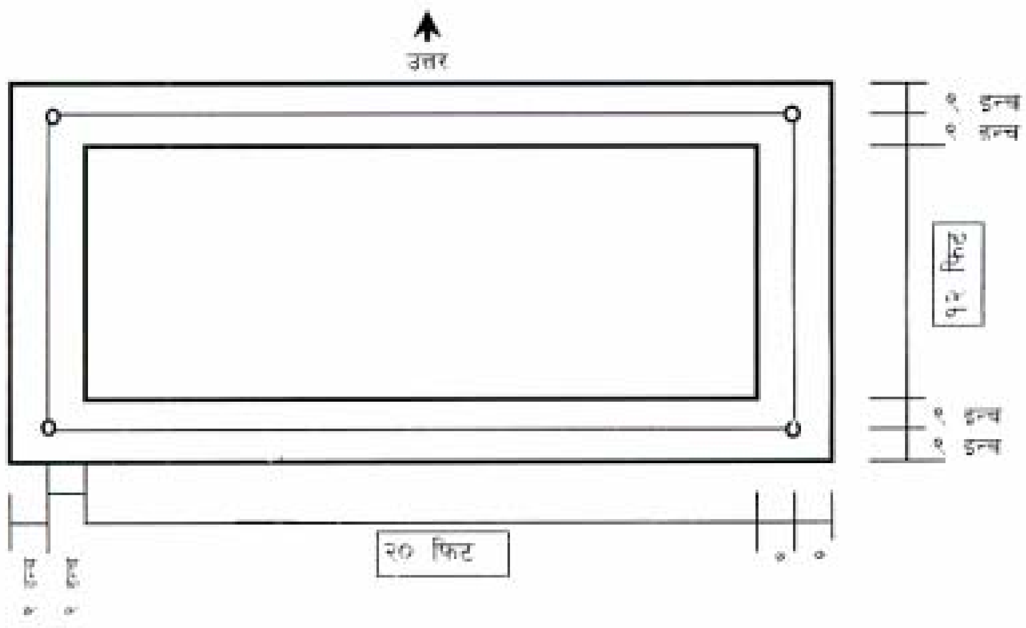
ANNEXE I: ACAP GREENHOUSE

ग्रीनहाउस बनाउने तरिका (Method of Greenhouse Construction)

१.एक्याप (ACAP) प्राविधिकको सहायतामा चार किल्ला गाड्ने ।



२. किल्ला बीचमा पर्ने गरी तल देखाए जसरी १.५ फीट चौडा र ठाडो हेरी १ देखि १.५ फीट सम्म गहिरो जग खन्ने ।

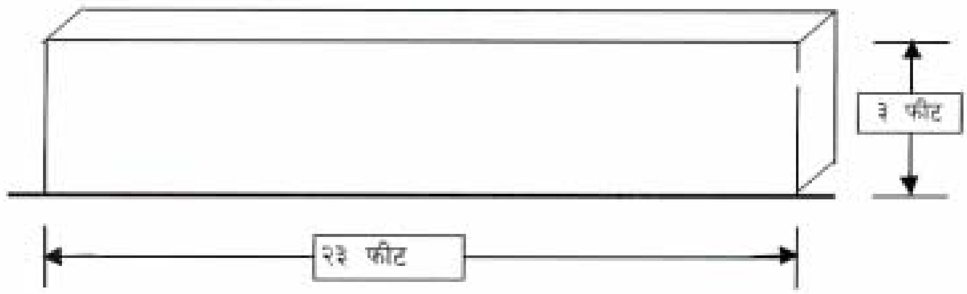


३. जग खने पछि ढुंगाको आसन राख्ने ।

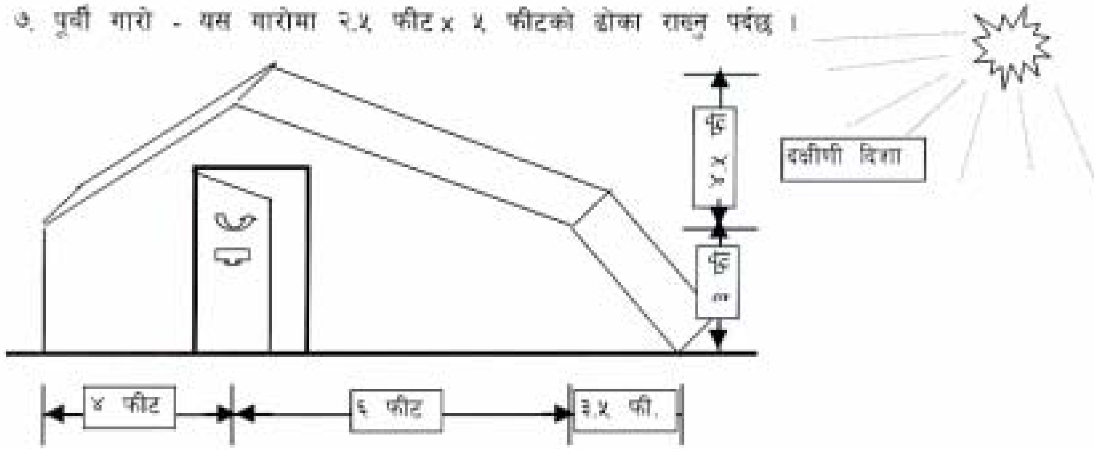
४. जमिनको सतहभन्दा ६ इन्च देखि १ फिट माथि सम्म १.५ फिट चौडा ढुंगाको गारो लगाउने ।

५. अब माटो (घ्याङ्ग) को १.५ फिट चौडा गारो तीनतिर (पूर्व, पश्चिम र उत्तर) लगाउनु पर्दछ ।

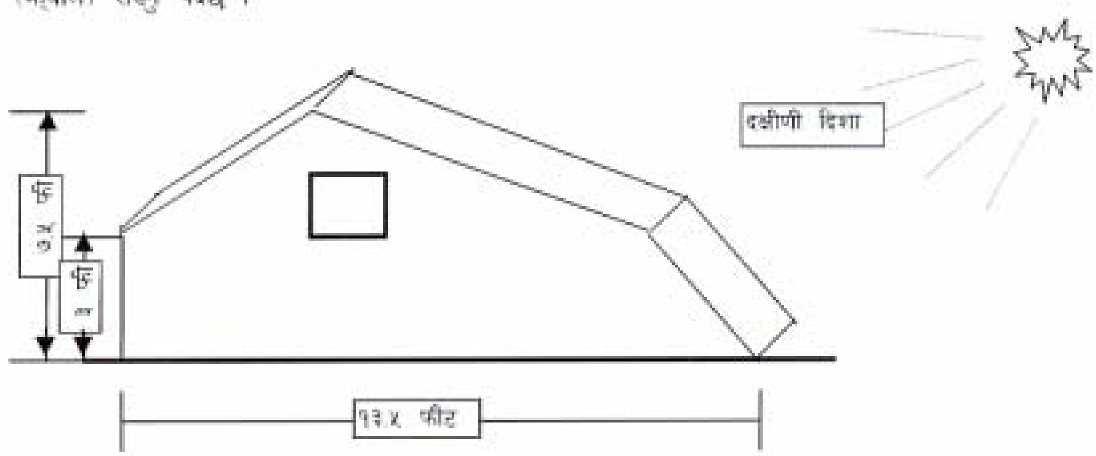
६. उत्तरी गारो जगबाट ३ फिट मात्र अग्लो हुन्छ । तल देखाए जस्तै ।

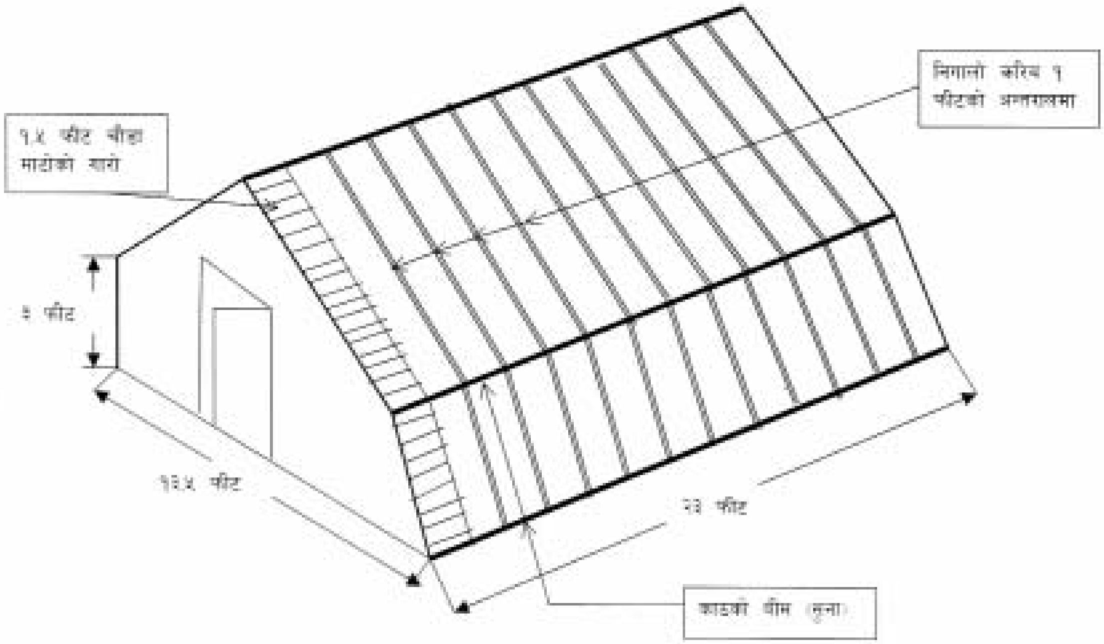


७. पूर्वी गारो - यस गारोमा २.५ फीट x ५ फीटको ढोका राख्नु पर्दछ ।



८. पश्चिमी गारो - यो पूर्वी गारो जसरी नै बनाइन्छ तर यसमा १.५फी x १.५फी.का भेन्टिलेशन (झ्याल) राख्नु पर्दछ ।





९. गारो तयार भए पछि, ग्रीनहाउसको घरको उत्तरी पाखोलाई माटोले छाउनु पर्दछ ।

१०. दक्षिणी पाखामा तल चित्रमा देखाए जस्तै निगालो राखेर त्यसमाथि प्लाष्टिकले (सकभर गमामा झिकन मिल्ने गरी) छाउनु पर्दछ । हावा वा अन्य बाह्य प्रभावबाट बचाउन प्लाष्टिकलाई माथिबाट ग्याबियन तारको जालीले ढाक्नु पर्दछ ।

११. उदाहरणको लागि लेते, चिमाङ, स्याङ, जोमसोम, खिङा, फल्याक आदि ठाउँको ग्रीनहाउस हेर्न सकिन्छ ।

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ANNEXE II: CONSTRUCTION MATERIALS

UV Foil

Silpaulin is a brand name of UV-resistant greenhouse foil, marketed in Nepal by:
Saurabh International Concern, Kalimati, Kathmandu, Nepal
Tel: +977-1-4270071 Fax: 4274650 E-mail: rbajoria@sarawagi.wlink.com.np
The material comes in 120 gr/m^2 (NRs. 7/sq.ft.), 150 gr/m^2 (NRs. 10/sq ft.), 200 gr/m^2 (NRs. 14/sq ft.) and 250 gr/m^2 (NRs. 16/sq ft.). Approximate wholesale prices.
Silpaulin Ultra-Violet Stabilized Multi-layer Film comprises several layers of plastic film placed crisscrossed one over the other and bonded by a patented Cold Roll technique, enhancing strength. The diffused light transmission of the 120 gr/m^2 type, which is most commonly used for greenhouses, is about 70%, and excellent for plant growth at high altitudes. Thicker qualities can be used for durable fish pond lining or biogas reactors, being fully water and sewerage sludge resistant.
The Silpaulin is highly resistant against acids, organic materials and a wide variety of chemicals. It cannot be used for storage of petrol, diesel, benzene and some other plastic solvents.
At high altitudes, the 120 gr/m^2 foil used on greenhouses has shown to resist the sun's UV radiation for more than 7 years, provided it is not mechanically damaged by wind and rubbing.

Straps

Packing Belt and Box Strap are user names of the woven polypropylene bands used for strapping cardboard and other boxes. The straps come in rolls of various widths (12 mm, ¾ inch) and come in various colours (natural, white, red, green, blue and yellow). Thickness is between 0.6 – 0.7 mm.
12 mm Box Strap in Nepal sells at NRs. 120/kg. A lower quality strap with a percentage of recycled PP material costs NRs. 100/kg.
Ujjal Plastic Industries, Kalanki Bafel Ring Road, Kathmandu, Nepal
Tel: +977-1-4271333 Fax: 4284284
The straps come in rolls of 4 kg (NRs. 480). The approximate length is 140 m/kg (560 m/roll) for the 12 mm width. The ¾-inch width is imported from China.
For greenhouses the light-coloured straps (white, yellow) are recommended above the natural type because these are less affected by sunlight. The straps have high UV resistance.
The Box Straps are knotted to the construction or nailed with large-headed galvanised roofing nails to wooden beams. Nailing into bamboo is not possible as the bamboo will split.

Roof Sheets

Polyglass Fiberglass Sheets is a brand name of corrugated translucent fibreglass reinforced resin roof sheets manufactured in Nepal from imported Polyester Sheet Resin (from India). Everlight is another brand name from another local manufacturer.
Polyglass Industries, Sanepa, P.O. Box 55, Lalitpur-2, Kathmandu, Nepal
Tel: +977-1-526583 Fax: 5545119 E-mail: polyglass@wlink.com.np
The translucent corrugated roof sheets come in two thickness: 1 mm (commercial, 190 gr/m^2) and 1.2 mm (standard 220 gr/m^2). In most greenhouses (in Mustang) the commercial 1 mm thickness is used. The light transmission of the sheet drops from 85% at new purchase to less than 60% in one year, but the resin is well UV resistant.
Tensile strength between 880 - 1120 Kp/cm^2. Impact resistance 69 Kp/cm^2. [11]
Transverse strength 108 kg/sq.ft. On a span of 24 inches, load being applied at ¼ point of span.
Thermal expansion 1.1 x 10.5ºF. Resistant against gasoline oils, acids, alkalies and other solvents.
Corrugations according to standard GI roof sheeting or fibre-cement roof sheeting.
Retail price of commercial type is NRs. 70/sq.ft. and standard type NRs. 77/sq.ft., including VAT.
Sizes of panels are 32" (81.3 cm) with lengths of 6 ft., 7 ft., 8ft., 9ft., 10 ft. and 12 ft.
The factory does not supply attachment materials. Nailing the sheets onto a wooden beam with a 1-1.5 inch diameter washer cut from a car tire is commonly done.

[11] Figures provided by factory, probably meaning kg/cm^2.