भारतीय मानक

ग्रीनहाउस संरचना के लेआउट, डिजाइन और निर्माण की सिफारिश

Indian Standard

RECOMMENDATIONS FOR LAYOUT, DESIGN AND CONSTRUCTION OF GREENHOUSE STRUCTURES

ICS 65.040.30

BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

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Price Group 4

Surface Covered Cultivation Structures Sectional Committee, FAD 43

FOREWORD

This standard was adopted by the Bureau of Indian Standards, after the draft finalized by the Surface Covered Cultivation Structures Sectional Committee had been approved by the Food and Agriculture Division Council.

Development of greenhouse technology in India is of recent origin. Greenhouse technology permits the enhancement of horticultural crop productivity particularly those of vegetables and flowers. This technology requires a considerable energy input for environmental control. It is, therefore essential that adequate guidelines for the layout, design and construction of greenhouse structures and climate control system should be laid down. This standard has, therefore, been prepared with a view to providing necessary guidance in this area.

In preparation of this standard, assistance has been derived from ASAE EP 460 - 1995 Commercial Greenhouse Design and Layout, Published by American Society of Agricultural Engineers.

The composition of the technical committee responsible for the formulation of this standard is given in Annex A.

For the purpose of deciding whether a particular requirement of this standard is complied with the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

RECOMMENDATIONS FOR LAYOUT, DESIGN AND CONSTRUCTION OF GREENHOUSE STRUCTURES

1 SCOPE

This standard covers recommendations for layout, design and construction of greenhouse structures.

2 REFERENCES

The following Indian Standards contain provisions which through references in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below:

IS No.	*Title*
SP 7 : 1983	National Building Code of India
SP30 : 1986	National Electrical Code of India
875	Code of practice for design loads (other than earth quake) for buildings and structures
(Part 3) : 1987	Wind loads (*second revision*)
(Part 4) : 1987	Snow load (*second revision*)
2508 : 1984	Low density polyethylene films (*second revision*)
3034 : 1993	Code of practice for fire safety of industrial buildings: Electrical generating and distributing stations (*second revision*)
11264 : 1986	Guidelines for the quality of irrigation water
11731	Methods of test for determination of flammability of solid electrical insulating materials when exposed to and igniting source
(Part 1) : 1986	Horizontal specimen method
(Part 2) : 1986	Vertical specimen method
14461 : 1997	Surface covered cultivation structures—Glossary of terms
14485 : 1997	Recommendations for heating, ventilating and cooling of greenhouses

3 DEFINITIONS

For the purpose of this standard, the definitions given in IS 14461 shall apply.

4 DESIGN LOAD

4.1 The design load includes the weight of the structure (dead load), loads (equipment, etc) associated with building use (live load) and loads from snow and wind.

4.1.1 *Dead Load*

All fixed services equipment such as heating, ventilating, air circulation, electrical, lighting, watering, and energy conservation blankets should be included if supported by structural members. Long term crops such as tomatoes and cucumbers supported by the structure are also considered as dead loads. For estimation of dead load the actual mass of building materials and systems shall be taken into account.

4.1.2 *Live Load*

Live loads are temporary loads and shall include the mass of repair crews and hanging plants.

4.1.3 *Snow Load*

The greenhouse should be designed as to resist the snow load. In area of snow, a minimum distance of 3.0 m should be provided between greenhouses to allow for snow accumulation and to prevent side wall crushing from snow sliding off the roof. The snow load of greenhouse structures shall be estimated as prescribed in IS 875 (Part 4).

4.1.4 *Wind Load*

The greenhouse should be designed to resist the wind load. The wind load of the greenhouse structures shall be estimated as prescribed in IS 875 (Part 3). Since the deadweight of most greenhouses structures is very small, special attention should be given to ensure that enough ground may be there to resist the upward lift force created by the wind. The minimum design loads for the greenhouses structures mainframes is given in Table 1 and may be used for reference only. Actual design values should be calculated for each greenhouse structures.

Table 1 Minimum Design Loads for Greenhouse Mainframes

Load Description	Minimum Value N/m^2
Dead -	
pipe frame, polyethylene cover	100
truss frame, lapped glass	250
supported crops-tomatoes, cucumbers, etc	200
Live-workers, repair materials	250
Snow−10°C minimum greenhouse temperature	750
Wind-load acts perpendicular to surfaces	500

5 SITE SELECTION AND LAYOUT

5.1 Selection of Site and Location

The site shall be located away from industrial and vehicular pollution to prevent plant injury from possible pollutants and to ensure light levels. The functional and environmental operation of a greenhouse structure may be affected by the building site selected. Ground slope for drainage of water is important and may be provided. Greenhouses shall be placed on gravel base 150 mm to 300 mm above grade. Swales between greenhouses structures are necessary to direct the water from the area. A topographic map of the area will indicate surface drainage routes. The ideal greenhouse structures site would have a slightly southern facing slope(less than 3 percent) for good winter light and protection from northern winds.

Location with respect to highways shall be considered. Location on near a highway and residential area may increase business for a retail operation.

5.2 Site Layout

The following points should be considered in developing a layout for greenhouse structure:

a) locate the head house to the north of the greenhouse to reduce shading;
b) locate windbreaks at least 30 m away to the side of the prevailing winter winds to reduce energy consumption;
c) separate supplier and customer traffic. Provide for convenient consumer parking ;
d) locate and screen any residence to insure privacy;
e) place the outdoor storage area where the area is convenient to access for materials delivery and movement to the work area;
f) locate the retail sales area to keep customers away from the production area to reduce chances for disease introduction and prevent interruption of work routines.

The layout of the greenhouse range will depend to some extent on the crop or crops to be grown. Two basic systems are in use.

a) Single span greenhouse structures may be left separate or the end walls attached to central headhouse. Expansion or contraction of the operation may be accomplished easily by moving each greenhouse into or out of production as needed. They may be operated with different environments depending on plant needs. More heat is required per unit of floor area than with a gutter-connected greenhouse.
b) The gutter-connected keeps all growing space inside one building, and a central heating plant can easily serve all areas. A minimum area of 1 000 m^2 should be considered to efficiently use materials and equipment. It may not be as easy to expand or contract space use as with single span greenhouses. A headhouse may be attached to the end or sides, or in large operations a central location reduces travel distances for plants and personnel.

Planning process provisions shall be made for expansion. Land shall be available for additional greenhouses and headhouse area. Water, electrical, and environment control systems shall be installed to allow for expansion.

5.3 Orientation

The ridge in either single span greenhouse structures or gutter-connected range shall be east-west in areas above 40° north latitude to transmit maximum winter sunlight to the plants. Gutter shading the same area during each day may result in uneven growth in some plants. Uneven growth in east-west ridge orientation is a trade off against general reduction in winter light, if the ridges run north-south.

5.4 Headhouse and Storage Facilities

A headhouse should be built to house the office, utilities, work areas, employee areas, storage, and dispatch. The size of the headhouse can be approximated from Table 4. This value should be adjusted depending on the indoor storage needed and the amount of mechanization used.

A good headhouse layout helps the system operate smoothly and efficiently. Materials flow should be such that there is minimum of handling or cross traffic in moving the components through the system. Typical example of headhouse area corresponding to various greenhouse structures sizes is given in Table 2.

Table 2 Sizing the Headhouse

Greenhouse Size	Approximate Headhouse Area Needed Per 100 m^2 of Greenhouse Area
m^2	m^2
1 000 to 3 999	14
4 000 to 7 999	9
Over 8 000	7

Although it is often impractical to store all growing media under cover. It is convenient to have some of it protected from rain and snow. The amount of space needed is determined by the type of operation, kind of media being used, and the local climate. Calculate space requirements based on the amount that is needed for one crop or a specific time period.

Locate the storage area for bulk materials and truck loads where there is good access by all weather road. Allow adequate space for trucks for shunting. The storage should be located close to the work area to reduce handling time and costs. Provide drainage in the storage area. Materials stored without cover should drain quickly, provide a paved area for handling with a bucket loader or fork lift. A clear span storage building allows freedom of movement for tractors and trucks and allows arrangement of equipment to be easily changed. For ease in maneuvering tractors and trucks, a minimum width of 7.0 m is required.

Once the layout within the building has been established, service and perspnnel doors can be located. Service doors should be a minimum of 0.5 m wider than the largest piece of equipment and the ceilings a minimum of 3.5 m or higher. Headroom should be a minimum of 3.5 m with higher ceilings, if bucket loaders are to be used. For convenience, locate a personnel door next to an overhead door.

Concrete floors inside the building and paved areas outside make movement of vehicles easy in all types of weather. Elevate building floors at least 150 mm above outside grade, and slope the ground surface away from the walls or the doorways. Provide drainage for roof gutters and snow melt.

5.5 Interior Layout

The choice between production on the floor or on the benches depends on the crop and the production schedule. Benches are usually provided for pot plant production. Bedding plants are generally grown on the floor. Beds, either ground or raised are needed for cut flowers. Benches may be fabricated of wood, metal, or plastic with a either solid or mesh bottom. Benches should be placed at a convenient height above the floor, usually 500 to 1 000 mm.

Benches improve labour efficiency, permit more effective display and inspection, and assist air circulation. Bench arrangement depends on dimensions of the greenhouse, walkways, and doors and on materials handling and heating system type and location.Total aisle space should be less that 25 percent of the total area. Longitudinal arrangements with benches extending the length of the house permits continuous runs of water lines, heat pipes, and plant support systems. Width of bench can be up to 0.9 m for tending from one side and 2 m when aisles are on both sides. Minimum aisle width should be 500 mm .

A peninsular arrangement with one main center aisle extending the length of the greenhouse and perpendicular side aisles usually results in more growing space. A main aisle width of 1.0 to 1.5 m and side aisles of about 500 mm is recommended.

Movable benches allow the use of all the area except one or two work aisles. Bench tops are supported on rollers and allowed to move sideways 500 mm to provide a work aisle. Connections for water, heat, and electrical systems that are attached to the bench must be made flexible.

6 CONSTRUCTION

6.1 Foundations

Pier foundation may be adequate for primary greenhouse frame, consisting of hoops spaced one meter or more. A curtain wall can be used to close the area between the piers. If primary frame members are spaced less than 1.2 m, a continuous masonry or poured concrete wall should be used.

The footing should be set below frost level or to a minimum depth of 600 mm below the ground surface whichever is greater. Consult SP 7 building code for local requirements. It should rest on level, undisturbed soil, or adequately compacted fill. Individual pier footings should be sized to fit the load and soil conditions.The pier may be of reinforced concrete, galvanized steel, treated wood, or concrete masonry. The wall between galvanized piers can be poured or precast concrete, masonry, fibre reinforced cement panels, aluminium clad insulating board, or any moisture and decay resistant material. A continuous foundation wall should be set on a poured concrete footing. The wall can be concrete or masonry. A 150 mm wall is usually sufficient for building spans up to 7.5 m. Use a 200 mm wall for wider building spans. Typical foundation construction are shown in Fig. 1 Pier footing dimensions given in Table 3.

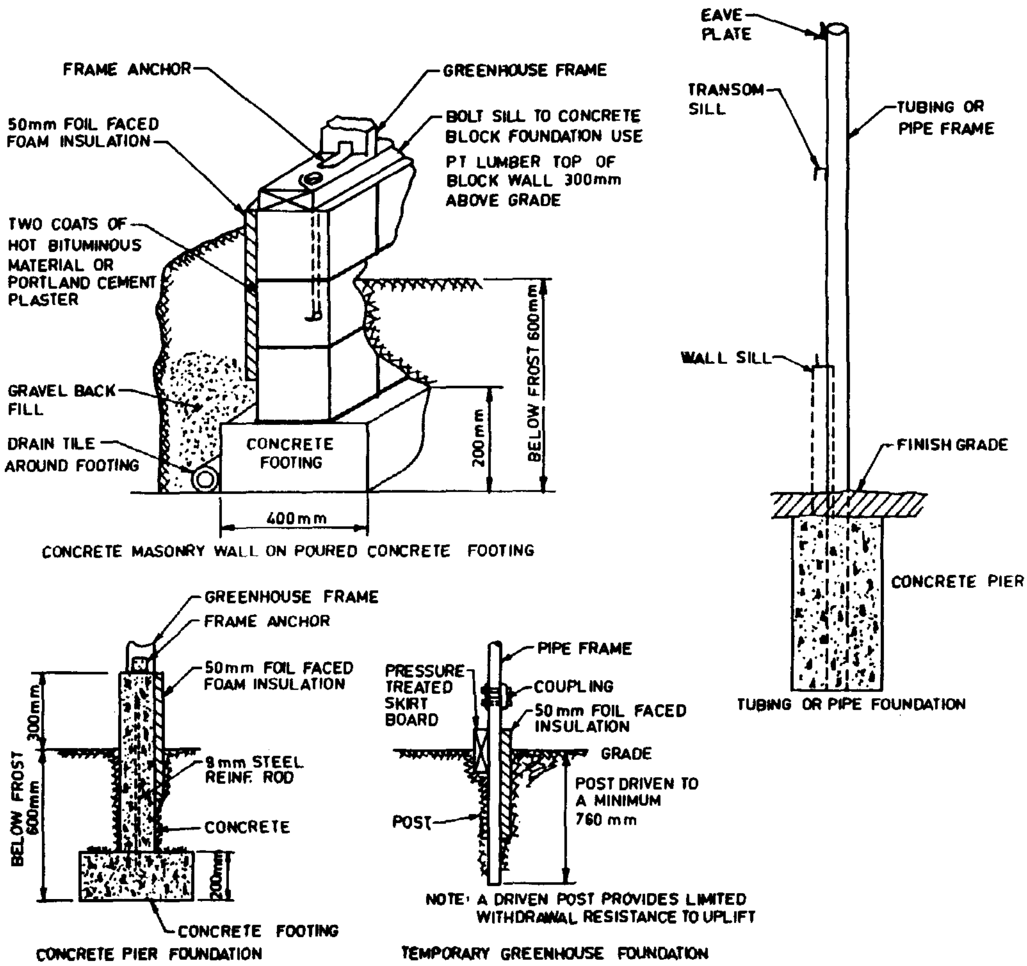

FIG. 1 TYPICAL FOUNDATION FOR GREEN HOUSES

Table 3 Pier Footing Diameters for Average Soil for Design Gravity Loads*
(Check for Uplift due to Wind)

Greenhouse Span (m)	Pier Spacing (m)					
	1.2	1.8	2.4	3.0	3.7	4.6
	Pier dia (mm)					
6.1	150	230	300	300	300	380
7.3	230	300	300	300	380	380
8.5	230	300	300	380	380	460
9.5	230	300	300	380	380	460
11.0	230	300	380	380	460	**
12.2	300	300	380	380	460	**
14.0	300	380	380	460	460	**
18.3	300	460	460	460	**	**

* 122 050 N/m^2 average bearing capacity.

** Requires special design.

6.2 Floors

Gravel, pea stone, and trap rock make a good floor material. A thickness of 150 to 200 mm is needed for drainage and weed control. Where a hard, smooth surface is desired a 50 to 75 mm thickness of porous concrete may be used. This is made from uniform sized aggregate and a cement water paste. Aisles and heavy traffic areas should be concrete . Thickness depends on the traffic load but usually 75 to 100 mm is sufficient. Concrete walks should have a broom finish for safety. Floors should slope to assure surface drainage and be sufficiently even to prevent puddling.

6.3 Frame

Wood, steel, aluminium, and reinforced concrete may be used to build frames for greenhouses. Some frames use combinations of the materials. Wood may be painted or otherwise preserved for protection against decay and also to improve light conditions within the buildings. Preservatives shall be used to protect any wood in contact with soil against decay but they must be free of chemicals that are toxic to plants or humans. Heartwood has natural decay resistance.

Woodframes include post beam and rafter systems, postsand trusses, glued laminated arches and rigid frames. Steel and aluminium are used for posts, beams, girts, purlins, trusses, and arches. Both materials shall be protected from direct contact with ground to prevent corrosion. White paint on either material will improve the light reflection in a greenhouse structure. The rate of heat loss through steel or aluminium is much higher than through wood, so metal frames may need special insulation. To avoid such heat loss through steel or aluminium, composite materials are sometimes used, such as a trussed beam of wood and steel or a member made of fibreglass reinforced plastic may be used.

6.4 Structural Forms

6.4.1 *Gable Type*

The greenhouse structures with a straight sidewall and a gable roof is the most common shape and has advantages in framing and space utilization. Post and beam, post and truss, and arches are used to form the gable structure.

6.4.2 *Quonset Type*

In the quonset type shape, the part of the circle arch is easily formed from rolled sections of steel or aluminium or from glue laminated wood. It makes better structural use of frame material than a gable building, but in some applications there is unused space because of the curvature of the sidewalls.

6.4.3 *Gothic Type*

The Gothic frame may be formed from metal sections or glue laminated wood. With proper design it may provide adequate sidewall height without loss of strength. Any of the forms may be used to build a single span greenhouse or a large range of gutter-connected units.

6.4.4 *Gutter-Connected*

The ridge and furrow or gutter-connected greenhouse structure consists of several single span houses connected together. The advantages include greater uninterrupted interior growing space and lower heating costs per unit area covered. Heat should be provided immediately below the gutter to prevent any snow accumulation. The structural forms commonly used are given in Fig. 2.

There must be adequate fasteners at sill plate and ridge to resist loads from any direction. A snow load acts downward but a wind load may act in any direction. Sills should be bolted to the foundation and metal connectors should be used to secure the wall frame to the sill. Metal connectors should be used at the plate and ridge also.

6.5 Covering Materials and Glazings

Light is responsible for plant growth, therefore, light transmittance of glazing materials should be high. In most of the materials the transmitted light is direct, but in some materials such as fibreglass reinforced plastics a high percentage is diffused. Structural support reduce installed glazing transmission values. Glazing materials do not transmit all wavelengths equally and this can affect plant growth and flowering. Thermal radiation transmittance is important in evaluating heat loss from a greenhouse during cold weather.

6.5.1 *Material Selection and Glazing*

The various glazing materials to cover the greenhouse structures are recommended to be used as mentioned below.

6.5.1.1 *Glass*

This traditional long life material has been improved by increasing pane size and strength. Construction costs have been reduced through use of extruded glazing bars, bar caps and strip caulking. Double and triple glazing may be used to reduce heat loss.

6.5.1.2 *Acrylic structural sheet*

Extruded double skinned sheets contain an internal rib and two surfaces providing some additional thermal insulation. Sheet sizes of 1.2 m × 12 m and several thicknesses may be used. Installation is made by using extruded attachment components.

6.5.1.3 *Polycarbonate structured sheet*

It is similar in configuration and installation to the acrylic material. Sheets as wide as 2.4 m may be used. To resist yellowing and light transmission, coated or treated material is recommended. The coated side shall face to the outside.

6.5.1.4 *Fibreglass reinforced plastic*

Large corrugated sheets and different thicknesses are available. Surface erosion may require recoating every 5 to 6 year to retain high light transmittance.

6.5.1.5 *Polyethylene film*

Low density polyethylene film is the most common covering material because of low cost and large sheet size. Agricultural grades are good for covering for less than six months period. Ultraviolet inhibited, stronger plastic may also be used, as it has 2 to 3 year life. IR absorbing films reduce heat loss. Application generally consists of a double layer with air inflation between the layers from a small

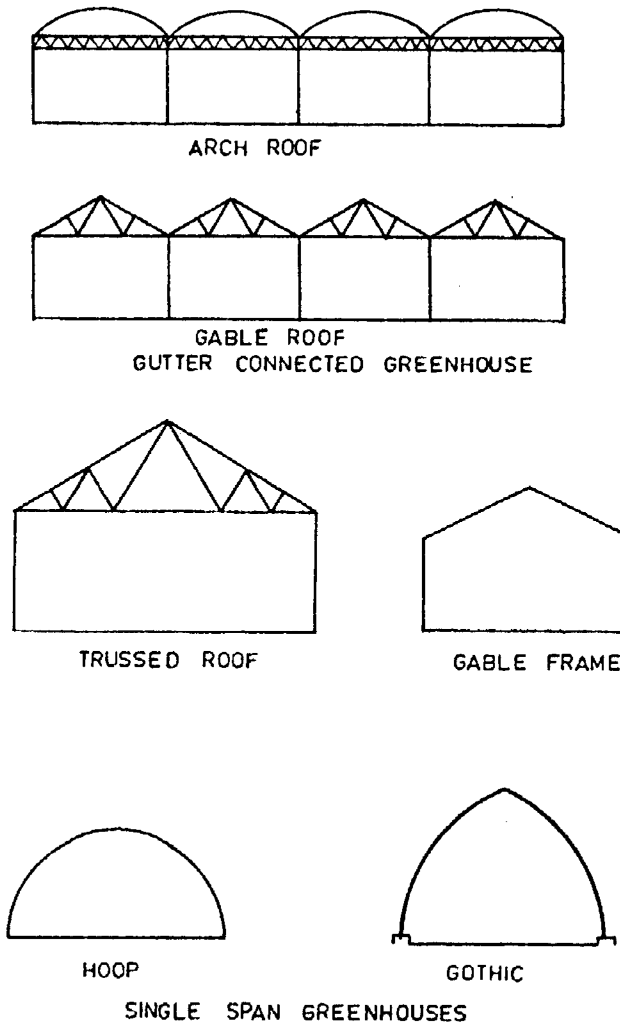

FIG. 2 SOME TYPICAL GREENHOUSE FRAMES

squirrel cage blower. Air pressure should be maintained at 50 to 75 Pa. The polyethylene film shall conform to IS 2508.

6.5.1.6 *Polyvinyl fluoride film*

This is a long-life film with high light transmission and strength.This film may be placed over aluminium extruded or steel frames.

6.6 Safety

6.6.1 *Fire Safety*

Fire safety is important in selection and use of glazing materials. Flammability of plastic materials when exposed to an igniting source shall be as prescribed in IS 11731 (Part 1 and 2).

6.6.2 *Mechanical Safety*

There shall not be any projections of sharp points or edges which may cause cuts/lacerations. Adequate guarding against entrapment of limbs in moving and stationary equipment shall be provided.

6.6.3 *Electrical Safety*

There shall be no breakdown of insulation and current leakage in from electrical fittings inside the greenhouse. Greenhouse frame shall be protected from contact with parts normally at hazardous voltage.

6.6.4 *Chemical Safety*

Inside the greenhouse there shall be full protection against potential injury or damage to health resulting from inhalation, ingestation, or contact with harmful chemical agents.

7 UTILITIES

7.1 Electricity

An adequate electrical supply and distribution system should be provided to serve the environment control and mechanization needs of the greenhouse. To determine the size of the services, the size and the number of motors and other electrical components should be known. Provisions should be made for an alarm system to indicate when a power failure has occurred or an environment control system has failed. An auxiliary generating system should be available and installed with the proper transfer switch to prevent feedback of power to the utility lines. Locate the electrical system inside or adjacent to the headhouse.

Utility lines should be buried to improve appearance, avoid damage, and reduce hazards. Electric, phone, and fuel lines should be buried at least 500 mm deep to avoid damage from surface traffic. Location of the utility lines should be recorded on a map for future reference. For distribution system within the greenhouse structure, the National Electrical Code may be taken in account.

7.2 Climate Control System in Greenhouse Structures

Cooling of the greenhouse is necessary wherever the outside temperature goes beyond 30°C and also when temperate crops are to be grown. Depending upon the glazing material and the ventilation, once the greenhouse structures are covered the inside temperature may be at least 5 to 10°C higher than the outside temperature, if it is not cooled. In order to create better growing conditions, it is necessary to cool the greenhouse structures.

Heating required in places where the winter temperature is very low. Similarly, in places where the climate is extreme cold and warm, both cooling and heating are required at higher elevations, where temperatures do not normally go above 30°C, cooling may not be necessary, only providing proper ventilation will serve the purpose. However, these places may require heating during winter for successful crop production. Heating, ventilating and the cooling of the greenhouse structures shall be done as prescribed in IS 14485.

7.3 Watering

7.3.1 The amount of water needed depends on the water requirement of the cultivation medium, area to be irrigated, crop grown, weather conditions, and whether the heating and/or ventilating system is operating. The maximum requirement during the summer is about 2 000 litre per 100 m^2 per watering (*see* Table 4).

Table 4 Estimated Maximum Daily Water Requirements

Crop	Water Required litres/m^2
Bench crops	16.0
Bedding plants	20.0
Pot plants	20.0
Chrysanthenum	41.0
Roses, tomatoes	29.0

7.3.2 The water system for the greenhouse should have the capacity to supply the total daily needs in a 6 hour application period. This allows the plants to be watered during the morning and early afternoon and with time for the foliage to dry before sunset.

7.3.3 Ground water is usually the most reliable source of water. It is available from drilled wells, dug wells, etc. Surface water ponds, lakes and streams may also be used, but precautions shall be taken to insure against contamination injurious to the plants. For greenhouse crops *p*H of irrigation water shall be between 6.5 to 7.5. Irrigation water may contain impurities that adversely affect the growth of the plants. Therefore, quality of the water shall be ensured before irrigation. Micro irrigation system is the most suitable method for irrigation to the greenhouse groups.The quality of irrigation water shall conform to IS 11624.

ANNEX A

(Foreword)

COMMITTEE COMPOSITION

Surface Covered Cultivation Structures Sectional Committee, FAD 43

Chairman	*Representing*
DR A. ALAM	Indira Gandhi Agricultural University, Raipur
Members	
DIRECTOR	Indian Council of Forestry Research, Dehra Dun
DIRECTOR	Appropriate Eco-Technology Development Group, Garwal
DIRECTOR	Defence Agriculture Research Laboratories, Almora
DIRECTOR (IN CHARGE) [MANAGER (TECHNICAL)]	Jain Irrigation System Ltd, Jalgaon
DIRECTOR	Vivekanand Parvatiya Krishi Anusandhanshala, Almora
HEAD (DEPTT OF SOIL AND WATER ENGG)	Punjab Agricultural University, Ludhiana
DR P. P. SINGH (*Alternate*)	
DR B. P. KACHRU	Indian Council of Agricultural Research, New Delhi
SHRIMATI KHOSY SHOBA	Ministry of Petroleum Chemical and Fertilizers, New Delhi
MANAGING DIRECTOR	Indo American Hybrid Seeds, Bangalore
MARKETING MANAGER (PLASTICULTURE)	Indian Petrochemical Corporation Ltd, Vadodara
DR G. N. MIR (CHIEF SCIENTIST WATER MANAGEMENT)	S. K. University of Agril Science and Technology, Srinagar
DR D. MUKHERJEE	CSIR Research Complex, Palampur
SHRI PRASHANT MISHRA	National Committee on Use of Plastic, New Delhi
SHRI O. P. GARG (*Alternate*)	
PROJECT DIRECTOR	National Mushroom Research Centre, Solan
DR J. S. PANWAR	Indian Agricultural Research Institute, New Delhi
DR PITAM CHANDRA (*Alternate*)	
DR M. M. SAWANT	NTB Bowsmith Irrigation Ltd, Pune
DR K. N. SHUKLA	G. B. Pant University of Agriculture and Technology, Pantnagar
DR K. K. SINGH (*Alternate*)	
DR JAI SINGH	Central Institute of Post Harvest Engineering and Technology, Ludhiana
DR O. D. WANJARI (*Alternate*)	
DR N. S. L. SRIVASTAVA	Central Institute of Agricultural Engineering, Bhopal
Dr M. SHYAM (*Alternate*)	
SHRI DEEPAK SOOD	Deepak Sood and Associate, New Delhi
SHRI G. K. VADODARIA	National Organic Chemical Industries Limited, Thane
SHRI DEEPAK SEHGAL (*Alternate*)	
DR I. S. YADAV	Indian Institute of Horticultural Research, Bangalore
SHRI R. N. SHARMA, Director (Food and Agri)	Director General, BIS (*Ex-officio Member*)

Member Secretary

SHRI KAUSHAL KUMAR
Joint Director (Food & Agri)