Practical Manual

Precision Farming & Protected Cultivation

c 3(2+1)

(For Undergraduate Horticulture students)

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2020

RANI LAKSHMI BAI CENTRAL AGRICULTURAL UNIVERSITY, Jhansi-284003

Syllabus: HVS 203 3(2+1):

Study of different types of greenhouses based on shape, construction and cladding materials; Calculation of air rate exchange in an active summer winter cooling system; Calculation of rate of air exchange in an active winter cooling system; Estimation of drying rate of agricultural products inside green house; Testing of soil and water to study its suitability for growing crops in greenhouses; The study of fertigation requirements for greenhouses crops and estimation of E.C. in the fertigation solution; The study of various growing media used in raising of greenhouse crops and their preparation and pasteurization / sterilization; Visit to commercial greenhouses; Economics of protected cultivation

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Practical No. 1

Objective: To study of different types of greenhouses based on shape

Exercise: Write about and draw diagram of different shapes of greenhouse

Classification of Greenhouses based on shape

Lean-to type greenhouse: ………………………………………………………………………………………

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Ridge and furrow type greenhouse: ………………………………………………………………………

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Even span type greenhouse: …………………………………………………………………………...……

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Uneven span type greenhouse: ………………………………………………………………………………

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Saw tooth type Greenhouse: ………………………………………………………………………………

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Practical No. 2

Objective: To study of different types of greenhouses based on construction

Exercise: Write different types of greenhouse according to the shapes

Classification of Greenhouses based on construction:

Wooden framed structures: …………………………………………………………………………………

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Pipe framed structures: …………………………………………………………………….……………

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Truss framed structures: ……………………………………….……………………………………

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Naturally Ventilated Greenhouse: ……………………………………………………………………………

Forced Ventilated Greenhouse: ……………………………………………………………………………

Practical No. 3

Objective: To Study of different types of greenhouses based on cladding materials

Exercise: Write down the features of different cladding material used in greenhouses

Classification of Greenhouses based on cladding material used:

Shade net house: ……………………………………………………………………………………………

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Transparent glass greenhouse: ………………………………………………………………………………

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Plastic film greenhouses: ………………………………………………………………………………………

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Rigid panel greenhouses: ………………………………………………………………………………………

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Practical No. 4

Objective: To calculate air rate exchange in an active summer winter cooling system.

Active summer cooling systems:

Fan-and Pad cooling system:

Fog cooling system:--

Practical No. 5

Objective: To calculate rate of air exchange in an active winter cooling system.

Active winter cooling systems:

Convection tube cooling:

Horizontal air flow cooling:

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Greenhouse dryers:

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Practical No. 8

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Practical No. 9

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Exercise 1: Write about basic requirements for applying fertigation in greenhouse crops.

Exercise 2: What are the criteria for selecting fertigation injector

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Practical No. 11

Objective: To study various growing media used in raising of greenhouse crops

Exercise: Write the important characters of growing media used in greenhouses

Growing media are primarily divided into organic and inorganic materials.

The inorganic growing media:

Sand: ……………………………..………………………………………………………………………………

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Tuff: ……………………………..………………………………………………………………………………

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Pumice: ……………………………..…………………………………………………………………………

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Expanded clay granules: ……………………………..………………………………………………………………
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Perlite: ……………………………..……………………………………………………………………………………
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Vermiculite: ……………………………..………………………………………………………………………………
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Rockwool: ……………………………………………………………………………………………

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Organic growing media

Compost: ……………………………………………………………………………………………

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Sphagnum Moss: ………………………………………………………………………………………

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Peat: ……………………………………………………………………………………

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Coco peat (Coir pith): ……………………………………………………………………

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Biochar: …………………………………………………………………………………

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Practical No. 12

Objective: To study preparation of various growing media used in raising of greenhouse crops

Material required: Soil, sand, cocopeat, vermicompost, perlite, vermiculite, pots, watering can.

Exercise: Prepare growing media and write the procedure with diagrammatic representation of steps followed.

Practical No. 13

Objective: To study about Soil sterilization by solarisation

Exercise: Write the step by step procedure of soil solarisation

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Practical No. 14

Objective: To study about Soil sterilization by chemicals

Exercise: Write the different methods of soil/media sterilization by chemical use

Soil Sterilization by Formaldehyde: ……………………………..…………………………………………

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Soil Sterilization by Hydrogen Peroxide: ……………………………..………………………………………

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Practical No. 15

Objective: To study the economics of cultivation in low cost protected structure

Exercise: Work out economics of any horticultural crop suitable for cultivating in low cost greenhouse

Practical No. 16

Objective: To study the economics of cultivation in medium cost protected structure

Exercise: Work out economics of any horticultural crop suitable for cultivating in medium cost greenhouse

Practical No. 17

Objective: To study the economics of cultivation in high cost protected structure

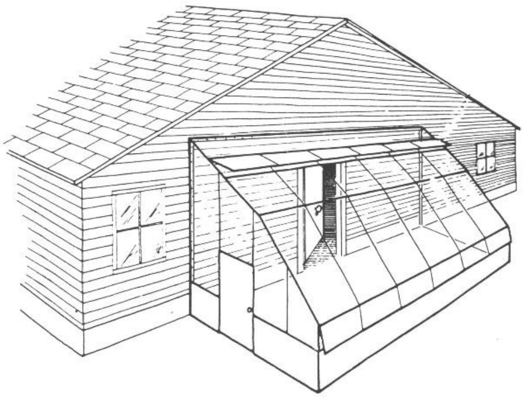
Exercise: Work out economics of any horticultural crop suitable for cultivating in high cost greenhouse

Practical No. 18

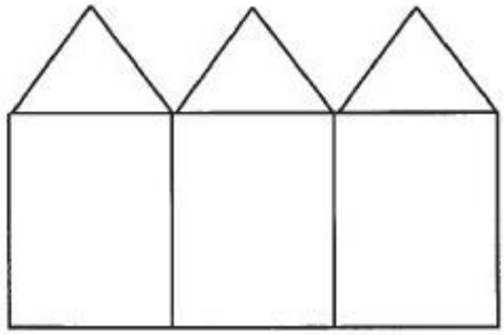
Objective: Visit to commercial greenhouses

Exercise: Write about the different types of greenhouses visited along with crops cultivated

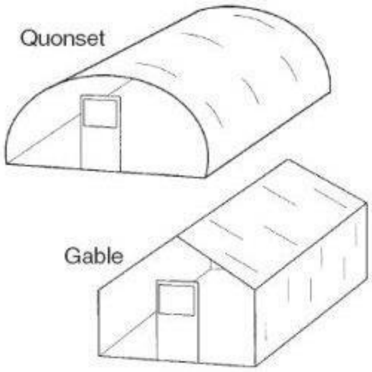
TYPES GREENHOUSES BASED ON SHAPES

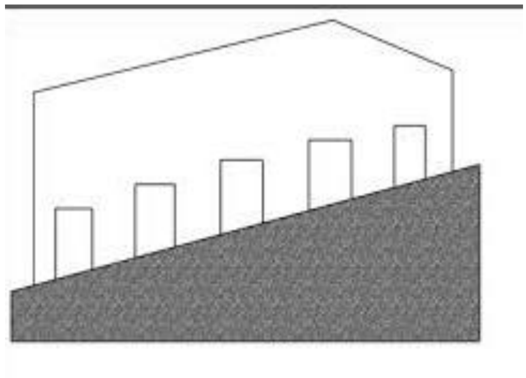


Lean to Greenhouse

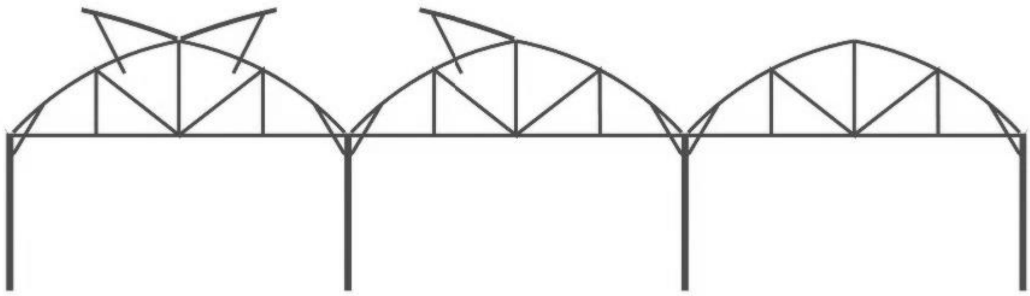


Ridge and Furrow



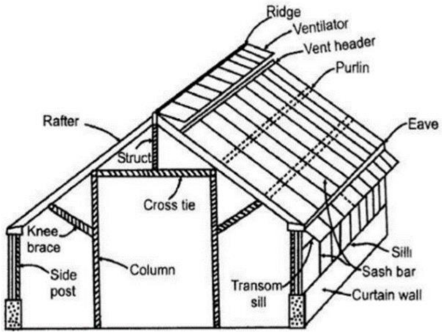


Uneven span type

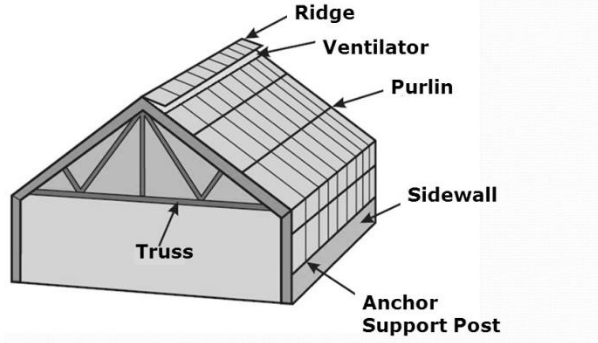


Saw tooth type Greenhouse

TYPES GREENHOUSES BASED ON STRUCTURES



Pipe type



Truss type

Naturally Ventilated Greenhouse: The climatic parameters such as temperature, humidity, carbon dioxide in these polyhouses are maintained and/or controlled through natural air convection without using any additional systems, and are mostly operated manually.

Forced Ventilated Greenhouse: The climatic parameters such as temperature, humidity, carbon dioxide in these polyhouses are maintained and/ or controlled through forced air circulation using fan and pad systems (for hot regions)/heaters (for temperate regions), foggers, curtain actuators (mechanism that makes the system work) that are controlled with automatic sensors. These systems are mostly operated automatically, however, these can be operated manually as well. These structures require continuous power supply and backup.

Types of cladding materials in greenhouses

Type of greenhouse	Cladding materials used
Glass greenhouses	Transparent glass
Plastic film greenhouses	Polyethylene, polyester and polyvinyl chloride
Rigid panel greenhouses	Polyvinyl chloride rigid panels, fibre glass-reinforced plastic, acrylic and polycarbonate
Shading nets	UV stabilized shade nets

Media for greenhouses

The organic materials include synthetic (like phenolic resin and polyurethane) and natural organic matters (peat, coconut based and composted organic wastes). Inorganic substrates can be classified as natural unmodified sources (sand, tuff and pumice), processed materials (expanded clay, perlite and vermiculite) and mineral wool (rockwool, glasswool). Based on the surface charge activity of materials, these can be distinguished in active (peat, tuff) or inert (rockwool and sand). Some of the desirable properties of growing media to be used are as follows:

- The medium should be well drained.
- A desirable medium should be a good balance between physical properties like water holding capacity and porosity.
- Highly porous medium will have low water and nutrient holding capacity, affects the plant growth and development.
- Medium which is too compact creates problems of drainage and aeration which will lead to poor root growth and may harbour disease causing organisms.
- The media reaction (pH of 5.0 to 7.0 and the soluble salt (EC) level of 0.4 to 1.4 dS/m is optimum for most of the greenhouse crops).
- A low media pH (7.5) causes deficiency of micronutrients including boron.
- A low pH of the growth media can be raised to a desired level by using amendments like lime (calcium carbonate) and dolomite (Ca-Mg carbonate) and basic, fertilizers like calcium nitrate, calcium cyanamide, sodium nitrate and potassium nitrate.
- A high pH of the media can be reduced by amendments like sulphur, gypsum and Epsom salts, acidic fertilizers like urea, ammonium sulphate, ammonium nitrate, mono ammonium phosphate and aqua ammonia and acids like phosphoric and sulphuric acids.
- The pH of water and mix should be monitored regularly


Cocopeat


Vermiculite


Perlite


Rockwool

PREPARING GROWING MEDIA FOR HI-TECH NURSERY

Growing media in greenhouses are used in containers (organic substrates, perlite etc.). However, sometimes they are used in the form of prepared cubes (rockwool cubes for seedling and transplant production), bags and slabs (peat-based substrates and rockwool, respectively), mats (polyurethane foam) and troughs (rockwool). The last three are also used generally for production in soil-less culture systems.

Commercially available materials like peat, sphagnum moss, vermiculite, perlite and locally available materials like sand, red soil, common manure/ compost and rice husk can be used in different proportions to grow greenhouse crops. These ingredients should be of high quality to prepare a good mix. They should be free from undesirable toxic elements like nickel, chromium, cadmium, lead etc. The most common media used in greenhouse production today are mixtures of peat, vermiculite and perlite. The media are designed to achieve high porosity and water retention while providing adequate aeration. A nutrient charge is added and the pH adjusted to approximately 6.0. A non-ionic wetting agent is generally added to peat media to improve initial wetting. Formulations without wetting agents are available for growing sensitive plants, such as seedlings. Different types of media combination for plug trays hi-tech nursery:

i) Cocopeat: Sand: FYM: vermicompost
ii) Cocopeat: Vermiculite: Perlite (3:1:1)
iii) Fine soil: Sphagnum Peat Moss: Perlite (2:1:2)
iv) Sand: Soil: FYM: Rice Husk Ash (1:1:1:1)

TYPES OF GREENHOUSE BASED ON ESTABLISHMENT COST

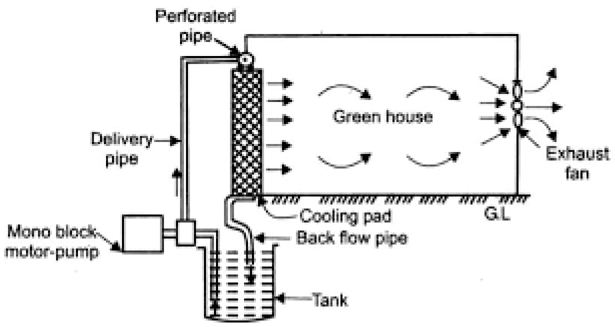
Low-cost greenhouse: It is fabricated mainly using local and low-cost available material like wooden logs or bamboos. The protection of wooden structures from insects and termites is a major challenge. These structures are small in size and have a short life-span. Since the height of the structure is lesser as compared to those with steel frames, maintaining proper temperatures in summer becomes difficult. Therefore, they are recommended mostly in cold climatic zones and low wind speed regions. The approximate cost of establishing such greenhouse units ranges between Rs. 450–620 per sq m.

Medium-cost greenhouse: It is generally fabricated using galvanised iron (GI) square or rectangular or round pipes or lipped channel or their combinations. The whole structure is firmly fixed in the ground to withstand high speed wind up to 140 km/hr. Such greenhouses are suitable for dry and composite climatic zones. The normal height of these structures ranges between 6.5–7 m and these are mostly naturally ventilated. The climate inside the structure is regulated by opening and closing of side curtains (which are rolled above permanently fixed insect-proof net on windows). Thus, air circulation can be regulated. Humidity is maintained through operation of foggers/ misters. Light intensity can be controlled with the use of internal collapsible shading nets. The approximate cost of establishing such naturally ventilated polyhouse unit ranges between Rs. 900–1000 per sq m depending upon the size of the structure.

High cost greenhouse: For the production of sensitive, off-season, exotic or quality crops, high-cost greenhouses are required to deliver the requisite quality. Therefore, high-cost greenhouse structures, which can precisely regulate climatic and nutritional needs of the plants, are required. The greenhouse climate parameters are regulated through passive cooling by operating fan and pad systems and sensor-based controlled systems. The approximate cost of establishing such greenhouse units ranges between Rs.1500– 2500 per sq m depending upon the size of the structure.

Active summer cooling systems: Active summer cooling is achieved by evaporative cooling process. The evaporative cooling systems developed are to reduce the problem of excess heat in green house. In this process cooling takes place when the heat required for moisture evaporation is derived from the surrounding environment causing a depression in its temperature. The two active summer cooling systems in use presently are fan-and pad and fog systems. In the evaporative cooling process the cooling is possible only up to the wet bulb temperature of the incoming air.

Fan-and Pad cooling system: The fan and pad evaporative cooling system has been available since 1954 and is still the most common summer cooling system in green houses. Along one wall of the green house, water is passed through a pad that is usually placed vertically in the wall. Traditionally, the pad was composed of excelsior (wood shreds), but today it is commonly made of a cross-fluted cellulose material somewhat similar in appearance to corrugated cardboard. Exhaust fans are placed on the opposite wall. Warm outside air is drawn in through the pad. The supplied water in the pad, through the process of evaporation, absorbs heat from the air passing through the pad as well as from surroundings of the pad and frame, thus causing the cooling effect. Khus-khus grass mats can also be used as cooling pads.



Fog cooling system: The fog evaporative cooling system, introduced in green houses in 1980, operates on the same cooling principle as the fan and pad cooling system but uses quite different arrangement. A high pressure pumping apparatus generates fog containing water droplets with a mean size of less than 10 microns using suitable nozzles. These droplets are sufficiently small to stay suspended in air while they are evaporating. Fog is dispersed throughout the green house, cooling the air everywhere. As this system does not wet the foliage, there is less scope for disease and pest attack. The plants stay dry throughout the process. This system is equally useful for seed germination and propagation since it eliminates the need for a mist system. Both types of summer evaporative cooling system can reduce the greenhouse air temperature.

The fan-and pad system can lower the temperature of incoming air by about 80% of the difference between the dry and wet bulb temperatures while the fog cooling system can lower the temperature by nearly 100% difference. This is, due to the fact that complete evaporation of the water is not taking place because of bigger droplet size in fad and pad, whereas in the fog cooling system, there will be complete evaporation because of the minute size of the water droplets. Thus, lesser the dryness of the air, greater evaporative cooling is possible.

Active winter cooling systems: Excess heat can be a problem during the winter. In the winter, the ambient temperature will be below the desired temperature inside the green house. Owing to the greenhouse effect the entrapment of solar heat can rise the temperature to an injurious level if the green house is not ventilated. The actual process in winter cooling is tempering the excessively cold ambient air before it reaches the plant zone. Otherwise, hot and cold spots in the green house will lead to uneven crop timing and quality .This mixing of low temperature ambient air with the warm inside air cools the green house in the winter. Two active winter cooling systems commonly employed are convection tube cooling and horizontal air flow (HAF) fan cooling systems.

Convection tube cooling: The general components of convection tube are the louvered air inlet, a polyethylene convection tube with air distribution holes, a pressurizing fan to direct air in to the tube under pressure, and an exhaust fan to create vacuum. When the air temperature inside the green house exceeds the set point, the exhaust fan starts functioning thus creating vacuum inside the green house. The louver of the inlet in the gable is then opened through which cold air enters due to the vacuum. The pressurizing fan at the end of the clear polyethylene convection tube, operates to pick up the cool air entering the louver. A proper gap is available for the air entry, as the end of the convection tube is separated from the louvered inlet by 0.3 to 0.6m and the other end of the tube is sealed. Round holes of 5 to 8 cm in diameter are provided in pairs at opposite sides of the tube spaced at 0.5 to 1m along the length of the tube.

Cold air under pressure in the convection tube shoots out of holes on either side of the tube in turbulent jets. In this system, the cold air mixes with the warm greenhouse air well above the plant height. The cool mixed air, being heavier gently flows down to the floor level, effects the complete cooling of the plant area. The pressurizing fan forcing the incoming cold air in to the convection tube must be capable of moving at least the same volume of air as that of the exhaust fan, thereby avoiding the development of cold spots in the house. When cooling is not required, the inlet louver closes and the pressurizing fan continues to circulate the air within the greenhouse. The process minimizes the temperature gradient at difference levels. The circulation of air using convection tube consumes more power than a circulation system.

Horizontal air flow cooling: HAF cooling system uses small horizontal fans for moving the air mass and is considered to be an alternative to convection tube for the air distribution. In this method the green house may be visualized as a large box containing air and the fans located strategically moves the air in a circular pattern. This system should move air at 0.6 to 0.9 $m^3/min/m^2$ of the green house floor area. Fractional horse power of fans is 31 to 62 W (1/30 to 1/15hp) with a blade diameter of 41cm are sufficient for operation. The fans should be arranged in such a way that air flows are directed along the length of the greenhouse and parallel to the ground. The fans are placed at 0.6 to 0.9m above plant height and at intervals of 15m.They are arranged such that the air flow is directed by one row of the fans along the length of the greenhouse down one side to the opposite end and then back along the other side by another row of fans. Greenhouses of larger widths may require a greater number of rows of fans along its length.

Temperatures at plant height are more uniform with HAF system than with convection tube system. The HAF system makes use of the same exhaust fans, inlet louvers and controls as the convection tube system. The only difference is the use of HAF fans in the place of convection tubes for the air distribution. Cold air entering through the louvers located at the higher level in the gables of the green house is drawn by the air circulation created by the network of HAF fans and to complete the cycle, proper quantity of air is let out through the exhaust fans. The combined action of louvered inlet, HAF fans and the exhaust fans distribute the cold air throughout the greenhouse.

Similarly, to the convection tubes, the HAF fans can be used to distribute heat in the green house When neither cooling nor heating is required, the HAF fans or convection tube can be used to bring warm air down from the upper level of the gable and to provide uniform temperature in the plant zone. It is possible to integrate summer and winter cooling systems with heating arrangements inside a greenhouse for the complete temperature control requirements for certain days of the season.

SOIL TESTING FOR SUITABILITY IN GREENHOUSES

Saturated media extract (SME): SME is currently "the" method of testing soilless greenhouse media and it is almost universally done by commercial and university labs, including the UMass Soil and Plant Tissue Testing Lab. In this test a paste is made using soil and water and then the liquid portion (the extract) is separated from the solid portion for pH, soluble salt, and nutrient analysis. Special skills and laboratory equipment are required to perform this test. SME is probably not suitable for a grower to use unless the greenhouse operation is large enough to support a lab, a technically trained person is hired to carry out the tests, and there is a commitment to frequent testing and tracking of the results.

Dilution method: This method has been used for many years and has good interpretative data to back it up. In this test an air-dried sample of soil and water are mixed together in the volume ratio of 1 part soil to 2 parts water (e.g., using a measuring cup, 1 fl. oz. of soil + 2 fl. oz. of water). The liquid extract is then separated from the solids using laboratory grade filter paper or a common coffee filter. The extract is then ready for analysis. This is a very easy test to master and quite suitable for on-site greenhouse testing of pH and soluble salt using meters available from greenhouse suppliers. The 1:2 methods are a very good choice for occasional pH and soluble salts testing by growers on-site.

Leachate Pour Thru Method: In addition to collecting a soil sample to test, growers can collect leachate from container grown plants using the Pour Thru method. One of the major advantages to leachate pour thru is that there is no media sampling or preparation. Unlike SME and 1:2 methods, plants do not have to be sacrificed or disturbed for testing because the extract is the leachate collected from the container during routine irrigation. The leachate can be analyzed on-site using the pH and EC pens or it can be sent to a commercial laboratory for a complete nutrient analysis.

Leachate pour thru is best used for continuous monitoring and graphical tracking of pH and soluble salts. To make this method work best an irrigation and leachate protocol must be established and carefully followed when sampling takes place. Leachate pour thru is not a good choice for casual checks (use 1:2 method for this). Unfortunately, with casual use, the "numbers" are often quite variable, inconclusive, and probably unreliable.

Sampling Instructions for Media Testing: A soil test can aid in the diagnosis of plant problems and in quality plant production. Sampling can be done at any time; but if pH adjustments are necessary, test as early as possible prior to planting. Avoid sampling soils that have been fertilized very recently. Follow instructions for specific testing methods.

Sampling for 1:2 and SME testing methods: The goal of sampling for a soil test is to efficiently collect sample which best represent the nutrient status of the crop or the problem to be diagnosed. The first step is to identify the crop unit(s) to be sampled - bench, greenhouse, etc. In a mixed greenhouse, crops of different species must be sampled separately for the tests to have any value. If a problem is being diagnosed, it is best to have a sample from both normal and abnormal plants for comparison.

After selecting and recording the crop unit, take several samples of soil at root depth from several pots or from several areas of bag culture or bed (cut flowers, greenhouse vegetables) and mix it together in a clean container. Sampling in this fashion is important because a sample from one pot or flat could be an anomaly (values too high or too low) which does not represent the crop as a whole. Sampling and analyzing soil *separately* from 10 *different* pots would be the best way but also the most expensive way!

For the 1:2 and SME tests the actual soil sample is taken by either a core or composite sample from all depths in the pot or from the root zone only (i.e., portion where roots are most active). Never sample from just the surface 1-2" of the pot - nutrient and soluble salts levels will be always be much higher here than in the root zone and composite samples and, as a result, will overestimate fertility.

Sample about 2 hours after fertilizing or at least on the same day. If slow-release fertilizer pellets are present, carefully pick them out of the sample. If the pellets are left in, they can break during testing and this may result in an overestimation of fertility.

Finally, be consistent in all sampling procedures each time you sample. A lot of variability can be introduced to tests due to inconsistent sampling and this diminishes the value of testing especially if you are trying to track fertility.

PROCEDURE FOR COLLECTING AND TESTING LEACHATE FROM CONTAINERS FOR POUR THRU METHOD

Irrigate your crop one hour before testing. Make sure the substrate is saturated. If the automatic irrigation system is variable, water the pots/flats by hand. If using constant liquid feed, irrigate as usual. If using periodic feeding (weekly, etc.): a) irrigate with clear water, b) test a day or two before you are to fertilize, and c) test on the same day in the fertilizing cycle each time. *Consistency is very important!*

Place saucer under container. After the container has drained for an hour, place a plastic saucer under the container

Pour enough distilled water on the surface of the substrate to get 1.5 oz of leachate. The amount of water needed will vary with container size, crop and environmental conditions. Use values in Table 1 as a guide.

Amount of water to apply to various containers to obtain 1.5 ounces (50 ml of leachate

Container Size	Water to Add: milliliters	Water to Add: ounces
4 Inch, 5 inch, 6 inch	75	2.5
6.5 inch azalea	100	3.5
1 quart	75	2.5
1 gal.	150	5.0
Flats: 606 (36 plants); 1203 (36 plants); 1204 (48 plants)	50	2.0
Containers should be brought to container capacity 30 to 60 minutes before applying these amounts. ***These amounts are estimates. Actual amounts will vary depending on crop, substrate type, and environmental conditions.*		

Collect leachate for pH and EC. Make sure to get about 1.5 oz (50 ml) of leachate each time. Leachate volumes over that amount will begin to dilute the sample and give you lower EC readings. Either send the leachate to a soil test laboratory or test the leachate on-site using a meter and following steps 5 and 6.

Calibrate your pH and EC meters prior to testing. The test results are only as good as the last calibrations. Calibrate the instruments every day that they are used. Always usefresh standard solutions. Never pour used solution back in the original bottle.

Measure pH and EC of your samples. Test the extracts as soon as possible. EC will not vary much over time provided there is no evaporation of the sample. The pH will change within 2 hours. Record the values on the charts specific to each crop.

WATER ANALYSIS

Water Analysis: Once the source of water is identified, water to be used for irrigation should be tested by a reputable laboratory to determine the quality of the water to be used for irrigation, to aid in the choice of fertilizers for optimum plant growth, and to minimize the risk of discharging pollutants to surface or ground water.

Prior to new construction, potential irrigation water should be tested. Monthly analysis is recommended for new water sources. Existing greenhouse operations should monitor water quality at least twice a year (summer and winter); more frequent monitoring is needed to alter production practices in response to changes in water quality.

Collecting a Water Sample: When collecting a water sample, runs the water at full flow for five minutes before collecting one pint of water in a tightly sealed plastic bottle. For best results, fill a clean 5 gallon bucket with water and submerge the sample bottle, then seal with the cap under water. Do not use metal lids. The bottle should be totally full with no air space remaining.

Testing by Laboratories: Analysis for inorganic elements should include electrical conductivity (soluble salts), pH, alkalinity, nitrate nitrogen, ammonium nitrogen, calcium, magnesium, sodium, potassium, phosphorus, zinc, copper and aluminum. Testing water for pesticides, herbicides or fuel oil is very expensive, particularly if the contaminant is unknown. Analysis for biological or disease organisms is not generally recommended since many plant pathogens are always present in water at some level.

On-Site Water Testing: Electrical conductivity and pH are two characteristics of water quality that can be tested periodically at the growing facility. This helps the grower get an indication of the consistency of the water supply and check the results of treatments to reduce pH or soluble salts. pH meters range from inexpensive pen types to more sophisticated units. It is recommended to purchase one that can be calibrated using calibration solutions. This ensures that the meter is giving correct readings. Electrical conductivity meters are generally more expensive than pH meters. However, they are very useful for testing water quality and media fertilizer levels during crop growth.

Target range and Acceptable range of nutrients and other components of irrigation water. Note: The target range is desirable levels, while acceptable levels are broader.

	Target Range in ppm (parts per million) except for pH and EC (electrical conductivity)	**Acceptable Range (in ppm except for pH and EC)**
pH	5.5 to 7.0	4 to 10
EC	0.2 to 0.8 mS (milliSiemen)	0 to 1.5 mS (milliSiemen)
Sodium	0 to 20	less 50
Chloride	0 to 20	less 140
Alkalinity[y]	40 to 160	0 to 400
Ammonia N	NA	less 10
Boron	less 0.1	less 0.5
Nitrate N[z]	NA	less 75
Phosphate	NA	less 30
Potassium	NA	less 100
Magnesium	10 to 30	less 50
Calcium	25 to 75	less 150
Sulfate	0 to 40	less 100
Manganese	less 1	less 2
Iron	less 1	less 4
Boron	less 0.1	less 0.5
Copper	less 0.1	less 0.2
Zinc	less 0.5	less 0.3
Fluoride	less 0.1	less 1
Molybdenum	less 0.1	less 1

CRITERIA FOR SELECTING A FERTIGATION INJECTOR

There are several important factors that need to be considered when choosing a fertilizer injector for a greenhouse irrigation system. Some of the more important factors are: water flow, injection ratio, types of chemicals, number of injection heads, water quality, mobility, and maintenance.

Water Flow: It is important to choose an injector carefully based on the water flow rate of the greenhouse irrigation system. Select the injector that matches the flow rate (gpm) that your irrigation system uses. Flow rate can be determined by pipe size and water pressure, which is measured in PSI (pounds of pressure per square inch). The water flow rate falls into three categories: low (0.05 to 12 gallons per minute), medium (12 to 40 gallons per minute), or high (more than 40 gallons per minute). Knowing your irrigation flow rates is essential to effective operation of injectors.

Checking Water Flow Rate: Water flow rate can be measured easily if a water flow meter is installed. Turn the irrigation system on full and read the meter at a noted time. Take a second reading after the water has run for several minutes. Convert the difference between the beginning and ending meter readings from cubic feet, the typical water meter unit, into gallons by using the formula.

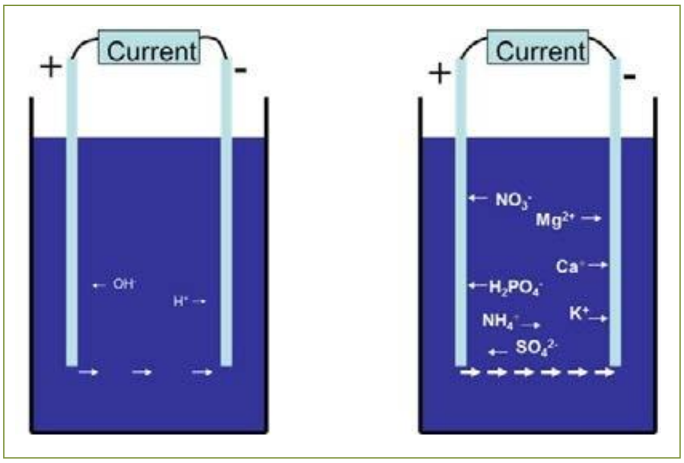
Multiple Parallel Injectors: In some situations, being able to fertilize a few plants at a low flow rate is just as important as being able to irrigate a large crop at a high flow rate. For these situations, more than one injector can be connected in parallel. This increases the maximum flow rate by the sum of the connected injectors while maintaining the low minimum flow rate from one injector.

Injection Ratio: Fertilizer stock solutions are mixed according to the fertilizer injector ratio: each injector will deliver a certain amount of stock solution for each increment of irrigation water that passes through the injector. The injection ratio can be expressed as a ratio (1:50, 1:100, 1:200, etc.) or as a percentage (2%, 1%, 0.5%, etc.). The equivalence between those two are 1:50 = (1 unit/50 units) x 100 = 2%; 1:100 = (1 unit/100 units) x 100 = 1%; and 1:200 = (1 unit/200 units) x 100 = 0.5%. The ratio of 1:50 means that there is one unit of stock solution injected into fifty units of water.

ELECTRICAL CONDUCTIVITY MEASUREMENTS IN GREENHOUSE PRODUCTION

EC: Electrical conductivity (EC) measures how well a fluid (water in the substrate) accommodates transport of electric charge (we'll discuss why this is important a little later). Figure illustrates the concept of EC. When measured, solution to the left has a low EC value than the solution to the right. This is because, fertilizer ions (in the solution to the right) carry electrical charge and their presence increases conductivity of electricity through the solution.

Electrical conductivity is measured in Siemens (S) but 'mho's (opposite of 'ohm', the unit for resistance) are also occasionally used. Note that S = mho and one mS/cm = 1 dS/m = 1,000 μS/cm, where 'm' stands for 'milli', 'd' stands for 'deci' and 'μ' stands for 'micro'.



This illustration describes the concept of electrical conductivity in solutions. The solution on the left is pure water and does not contain fertilizer ions. The one on the right contains dissolved fertilizer salts. If you apply an electric current to the solution, the electrical charges carry that current in the solution. The more electrical charge the greater the electrical conductivity. The conductivity of the solution on the left is influenced by hydrogen and hydroxyl ions. The dissolved fertilizer salts in the solution on the right carry additional electrical charge. More electricity is conducted through the fertilizer solution, because there are more charged particles in it than in pure water.

MEASUREMENT OF ELECTRICAL CONDUCTIVITY

There are three methods available to collect pore water for substrate EC measurements

The 1:2 dilution method: With this method, a sample solution is collected from the top of the container by mixing one part of the substrate in two parts of distilled water and allowing substrate to settle at the bottom.

The SME method: With this method, you collect solution by slowly mixing distilled water, stirring the substrate until it is saturated (a glistening water layer appears on top of the substrate). Then filter the solution from the saturated paste.

The pour-through method: With thismethod, collect leachate from the bottom holesof the container by pouring a small volume of still water at the top of a substrate, which s thoroughly irrigated, pushing water out of the substrate pores.

Comparative values from different methods of measuring substrate EC.

Substrate-based EC Measurement Techniques			
1: 2	**SME**	**Pour-through**	**Indication**
0-0.3	0-0.8	0-1.0	Very Low
0.4-0.8	0.9-2.0	1.1-2.6	Low
0.9-1.3	2.1-3.5	2.7-4.6	Normal
1.4-1.8	3.6-5.0	4.7-6.5	High
1.9-2.3	5.1-6.0	6.6-7.8	Very High
> 2.3	> 6.0	>7.8	Extreme

Soil Solarisation: High intensity solar radiation during summer (April–June) is used as a lethal agent for the control of plant pathogenic organisms, insects, nematodes and weeds through the use of transparent polyethylene films and this is known as soil solarisation. The procedure of soil solarisation includes:

- Soil should be ploughed first
- Irrigate the field very lightly
- Cover the field with transparent UV-stabilised 25 micron polyfilm for 20–30 days.
- The sides of the film should be covered with soil to avoid entry of outside air.
- Soil solarisation is not a foolproof method for sterilization.

Other sterilisation methods include heat or steam sterilization, which have limitation of application under field conditions due to high expenditure.

Soil Sterilization by Formaldehyde: It is an excellent sterilizing agent for controlling harmful soil microbes. It is marketed in aqueous solution as formalin which contains 37–40 per cent formaldehyde.

The soil or root substrate to be sterilised is loosened and the solution prepared by mixing 4 L formalin in 19 L of water is poured or sprayed on the soil @5 ml/sq m area. The rate of application depends upon the moisture content, depth of soil and type of soil. The land is covered with thin plastic film to retain the fumes generated. Removal of plasti film (after 7 days), complete evaporation of smell of formaldehyde will take place in about 15–20 days. After that, sowing or planting should be done. It has limited effect against nematodes and should not be used in standing crops. Its use has to be preferably avoided as it is a general biocide (a substance that destroys or inhibits the growth or activity of living organisms), detrimental to the health and safety of the production system.

Soil Sterilization by Hydrogen Peroxide: Hydrogen peroxide with nanoparticle silver can be used for sterilization. Since this solution is in liquid form, it can be applied using drip irrigation system. The recommended dose of the solution is 35–40 ml/ sqm, however care should be taken that the soil beds are gently watered beforehand. The main advantage of using this solution is that sowing/planting can be done the very next day.

TYPES OF GREENHOUSE BASED ON ESTABLISHMENT COST

Low-cost greenhouse: It is fabricated mainly using local and low-cost available material like wooden logs or bamboos. The protection of wooden structures from insects and termites is a major challenge. These structures are small in size and have a short life-span. Since the height of the structure is lesser as compared to those with steel frames, maintaining proper temperatures in summer becomes difficult. Therefore, they are recommended mostly in cold climatic zones and low wind speed regions. The approximate cost of establishing such greenhouse units ranges between Rs. 450–620 per sq m.

Medium-cost greenhouse: It is generally fabricated using galvanised iron (GI) square or rectangular or round pipes or lipped channel or their combinations. The whole structure is firmly fixed in the ground to withstand high speed wind up to 140 km/hr. Such greenhouses are suitable for dry and composite climatic zones. The normal height of these structures ranges between 6.5–7 m and these are mostly naturally ventilated. The climate inside the structure is regulated by opening and closing of side curtains (which are rolled above permanently fixed insect-proof net on windows). Thus, air circulation can be regulated. Humidity is maintained through operation of foggers/ misters. Light intensity can be controlled with the use of internal collapsible shading nets. The approximate cost of establishing such naturally ventilated polyhouse unit ranges between Rs. 900–1000 per sq m depending upon the size of the structure.

High cost greenhouse: For the production of sensitive, off-season, exotic or quality crops, high-cost greenhouses are required to deliver the requisite quality. Therefore, high-cost greenhouse structures, which can precisely regulate climatic and nutritional needs of the plants, are required. The greenhouse climate parameters are regulated through passive cooling by operating fan and pad systems and sensor-based controlled systems. The approximate cost of establishing such greenhouse units ranges between Rs.1500– 2500 per sq m depending upon the size of the structure.