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Role of Greenhouse Technology in Agricultural Engineering

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Abstract: The present study is concerned with the scope of greenhouse technology in agricultural engineering (cultivation, drying and space heating). The greenhouse can provide control environment for high value crops like medicinal plants, flowers etc. crops grown inside a greenhouse are healthy and give better results. The design of a greenhouse depends upon the latitude of the place and the requirement of crop. The main criteria for selection of greenhouse can be its value of solar fraction, which have been discussed in detail in the article. Depending upon the requirement of crops, different heating and cooling arrangements can be made in inside the greenhouse. Drying is a widely used practice in food preservation. Drying of crop/fruit/medicinal plants inside a greenhouse is also very useful technique for reducing postharvest losses, due to undesirable moisture contents. The study also highlights the application of greenhouse for drying under natural as well as forced mode.

Key words: Agricultural engineering, greenhouse technology, cultivation, drying

Introduction

Greenhouse Effect

Origin of life on earth explains the basic concept of greenhouse. Before origin of any living organism on the earth, the temperature of earth was around -18°C due to absence of atmosphere between earth and sun. Various gases namely nitrogen (N), carbon dioxide (CO₂), ozone (O₃), carbon monoxide (CO), oxygen (O₂), nitrous oxide (N₂O) etc. available inside earth came out through spaces between plates of earth and formed a porous layer around earth, known as atmosphere. The newly formed atmosphere around earth had a unique property that it absorbed ultraviolet and far-infrared radiation coming from sun and allowed only short wave length (0.3-3 μm) radiation emitted by sun to reach the earth surface. Further, the atmosphere did not allow long wavelength (> 3.0 μm) radiation emitted by earth (Cengel, 1998). Hence, the trapped thermal energy raised the temperature of earth and air between earth and atmosphere. The rise of temperature of air is known as greenhouse effect. According to Encyclopedia 2000 (Anonymous, 2000) the greenhouse effect for environment is defined as:

Greenhouse Effect - term for the role the atmosphere plays in insulating and warming the earth's surface. The atmosphere is largely transparent to incoming solar radiation. When this radiation strikes the earth's surface, some of it is absorbed, thereby warming the earth's surface. The surface of the earth emits some of this energy back out in the form of infrared radiation. As this infrared radiation travels

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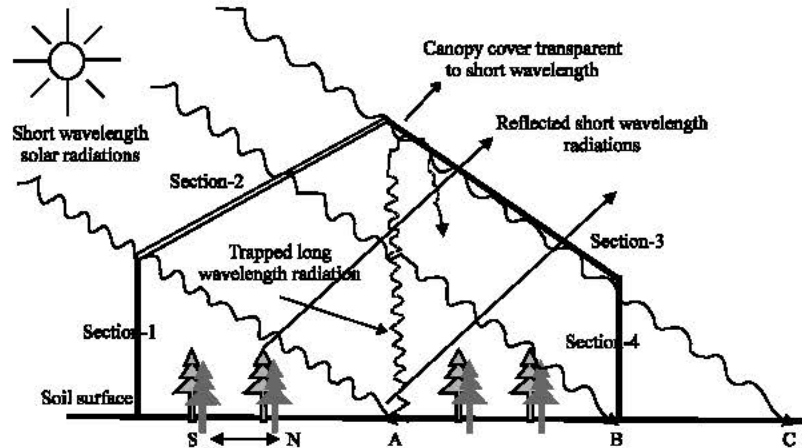


Fig. 1: Greenhouse effect at micro level

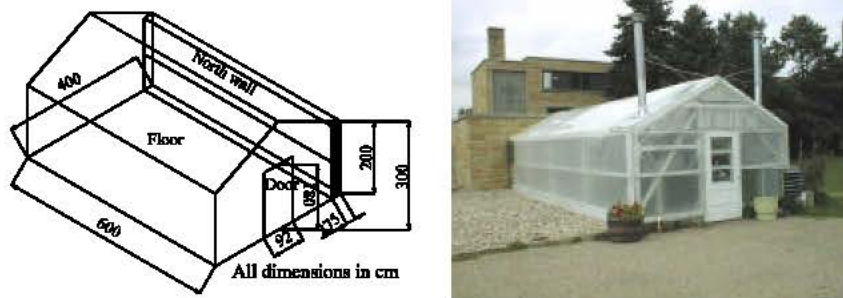


Fig. 2: Isometric view of greenhouse and space heating

through the atmosphere, much of it is absorbed by atmospheric gases such as carbon dioxide, methane, nitrous oxide and water vapor. These gases then re-emit infrared radiation, some of which strikes and is absorbed by the earth. The absorption of infrared energy by the atmosphere and the earth, called the greenhouse effect, maintains a temperature range on earth that is hospitable to life. Without the greenhouse effect, the earth would be a frozen planet with an average temperature of about -18°C (about 0°F)”.

Greenhouse

It is clear that for survival of living plants on the earth, there should be a favorable environment in terrestrial region controlled by short wave length radiation transmitted by the atmosphere. However, using the concept for optimum growth of living plants, a micro climate can also be created for maximum medicinal crops production in a controlled environment (Fig. 1).

Greenhouse is structure having the transparent walls and roofs (glass, FRP, polyethylene film) for maintaining suitable environment for the growth of plants, then this enclosure is called a greenhouse.

In rural areas a greenhouse can be use for crop production, crop drying as well as for space heating (for living of human being as well as for animals) as shown in Fig. 1 and 2, respectively.

Importance of Greenhouse Technology

Crop Production

Around 80% of the world population lives in the developing countries (Anonymous, 1995). Undoubtedly, the agricultural production must be increased to guarantee the food demand of the fast growing population. In the next 25 years around 50% more food has to be produced, mainly in developing countries (Brown, 1995).

India has attained the self-sufficiency in food and food products. The food grains production has increased from 50.8 million tones in year 1951 to 208.9 million tones in year 2000 (Anonymous, 2001a) whereas, the area has increased from 97.3 to 123.1 million ha under food grains over these 50 years. India accounts for nearly 10% of world production of fruit crops with annual production of about 44-46 million tones. India is the second largest producer of vegetables, next to China. In 1998-99, an estimated production of 87.5 million tones, accounted for 14.4% of the world production of vegetables (Anonymous, 2001a).

The country, now has reached a plateau in respect of area devoted to crop production (Anonymous, 2001a). However, the population has increased from 361.1 million to around 1000 million in the past 50 years (1951-2000) (Anonymous, 2001b). The increasing population puts pressure on land and food. Thus sustaining the self-sufficiency in food is next challenge for scientists to think over. The population-food imbalance can obviously be solved by increasing food production or by limiting the population. Another most viable solution to the food problem involves reducing the food losses, which occur during the food production, harvest, post harvest and marketing. In the developing countries, 10 to 40% of the crops harvested never reach the consumers due to poor post harvest management (Sodha *et al.*, 1987; Esper and Mühlbauer, 1998). Therefore, it is imperative to increase productivity as well as develop efficient post harvest handling technologies to combat post harvest losses of food to ensure the supply the food through the year.

In the present scenario, to meet the worldwide demand of enhanced production, greenhouse cultivation could serve as a viable solution, facilitating off-season cultivation and protecting crop from unfavorable outdoor conditions. Apart from these, a greenhouse could be a better option for nursery raising, hardening of tissue culture plants, cultivation in regions which are prone to soil problems and extreme climates, also for cultivation of rare as well as medicinal plants.

The demand of fresh as well as processed vegetables and cut flowers at Global level is also increasing in order to strengthen the export potential and economy of a country. But the cultivated area is decreasing due to construction of new roads, buildings particularly through urbanization and industrialization. This calls for increasing productivity at a higher rate. The increased demand cannot be met through the traditional method of agricultural production. It necessitates improved and new alternative technologies to enhance production under normal as well as adverse climatic conditions and to bridge the gap between demand as well as existing production of vegetables, fruits and flowers.

Greenhouse cultivation helps to create favorable microclimates where production of vegetables and flowers is made possible through out the year or part of the year as per the requirement. Greenhouse not only creates suitable environment for the plants but also encourages proper growth and fruiting as compared to open field cultivation. The greenhouse technology has also tremendous scope in horticultural sector, especially for production of hybrid seeds, high value vegetables, ornamental plants, medicinal plants, cut flowers and fruits, which fetch more prices in domestic as well as international markets. The different processes of heat transfer occurring inside the greenhouse during crop cultivation are shown in Fig. 3.

Crops/Fruit Drying

Open sun drying (OSD) is the most primitive crop drying, under which the solar radiation falls directly on the crop surface and it is absorbed. The absorbed radiation heats the crop and evaporates

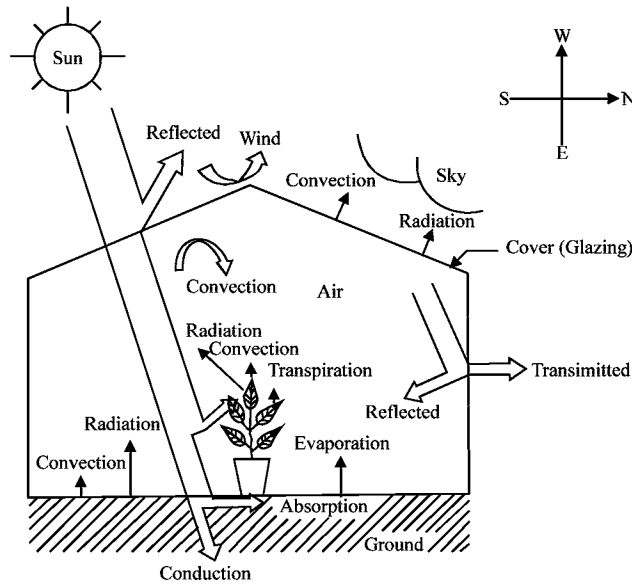


Fig. 3: Energy flow processes in greenhouse system

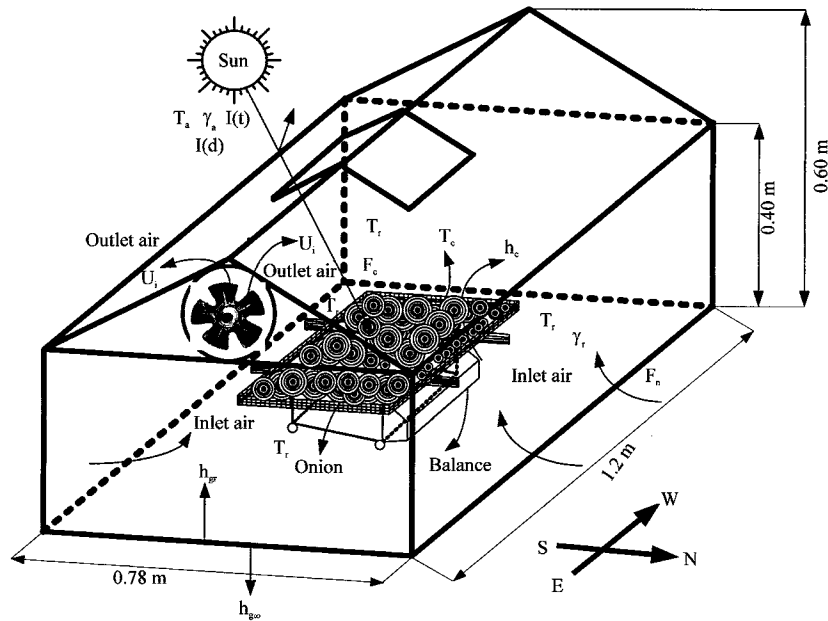


Fig. 4: Schematic view of greenhouse dryer

the moisture from crop. During this process, the amount of solar energy received at the crop surface is lost at various stages through reflection, radiation, convection and conduction. Also the quality of the product is lowered significantly. In general, open sun dried products do not fulfill the international quality standard and therefore can not sell on international markets (Lutz *et al.*, 1987; Tiris *et al.*, 1994; Esper and Muhlbauer, 1998).

Greenhouse systems can play a vital role in post harvest drying of crop produce. The greenhouse drying technology produce good quality product over open sun drying (Kumar and Tiwari, 2006). This highlights that the comprehensive understanding of greenhouse effect is important to enhance production and drying of crops. Figure 4 shows the principle of greenhouse crop drying. In this case too, microclimate is created inside the greenhouse. Solar radiation incident on the glass cover is transmitted inside greenhouse after reflection from the glass cover. Further, a part of transmitted radiation is reflected back in the form of short wavelength from the surface of the crop, which is again transmitted to atmosphere through the glass cover. The remaining part is absorbed by the surface of the crop. Due to the absorption of solar radiation, the crop temperature increases and the crop start emitting

- Long wavelength radiation, which is not allowed to escape to atmosphere due to presence of glass cover unlike open sun drying. Thus the temperature above the crop inside greenhouse becomes higher,
- The glass cover serves one more purpose of reducing direct convective losses to the ambient which further becomes beneficial for rise in crop and greenhouse air temperature respectively
- The convective and evaporative losses occur inside the chamber from heated crop simultaneously. The moisture (the vapour formed due to evaporation) is escaping through air vent provided at the roof for natural convection and for forced convection a fan is provided on the sidewall of the greenhouse as shown in Fig. 4.

Classification of Greenhouse System

Greenhouses may be classified on the basis of several criteria as given below:

Based on the Material Used

- Glass house
- Plastic film greenhouse
- Rigid panel greenhouse

Based on the Shape of the Cover

Greenhouses are available in various shapes and sizes (Tiwari, 2003).

- Spherical dome
- Hyperbolic paraboloid
- Quonset
- Modified Quonset (Modified IARI model)
- Gothic arch
- Mansard roof
- Evenspan
- Unevenspan
- Vinary
- Modified arch

Shapes of greenhouses of are described in Fig. 5. The evenspan greenhouse is most common in application. Therefore an evenspan greenhouse has been chosen for the present study.

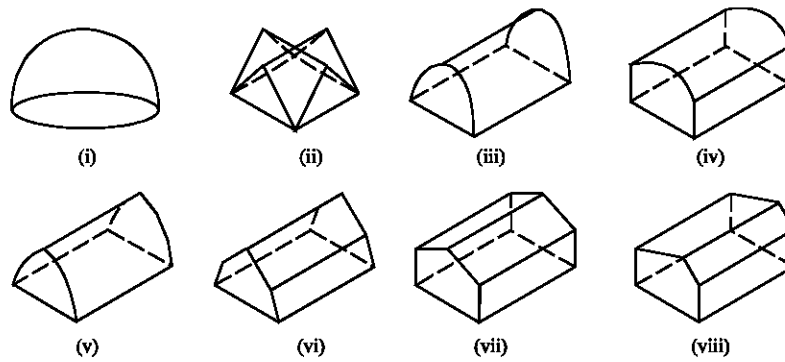


Fig. 5: Classification of greenhouse on the basis of shape; (i) Spherical dome, (ii) Hyperbolic paraboloid, (iii) Quonset, (iv) Modified Quonset, (v) Gothic arch, (vi) Mansard roof, (vii) Evenspan and (viii) Unevenspan

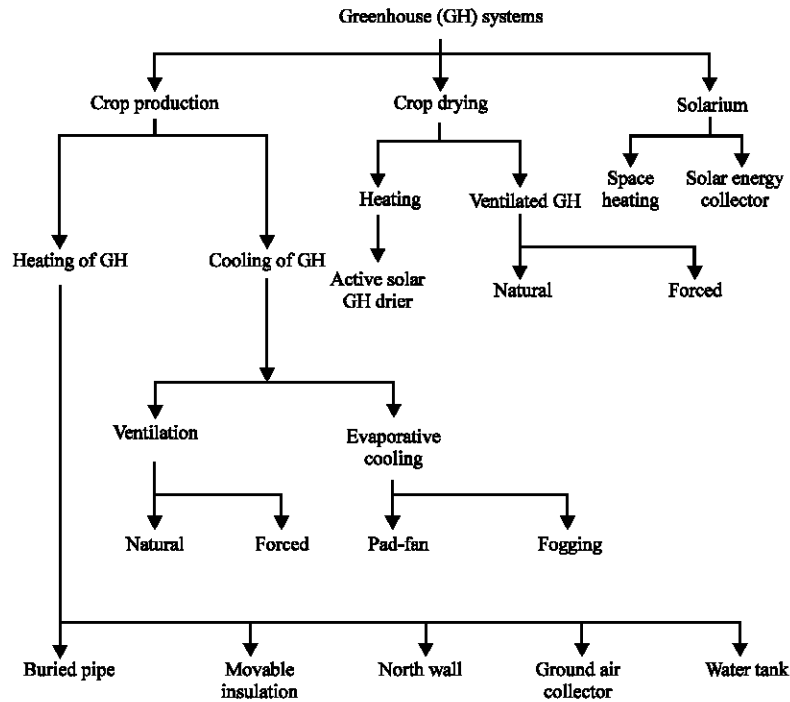


Fig. 6: Classification of greenhouse systems

Based on Cost Factor or Technology Involved

- Low cost / Low-tech greenhouse.
- Medium cost /Medium - tech Greenhouse
- High cost / Hi-tech Greenhouse

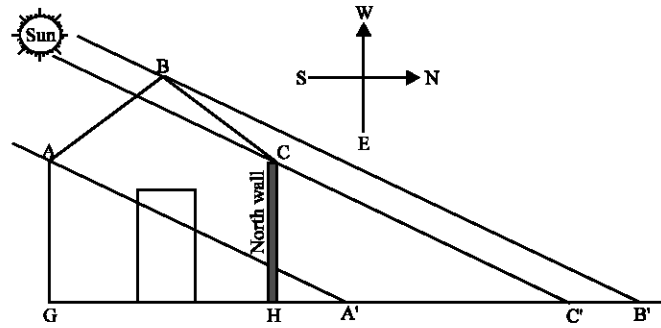


Fig. 7: Schematic view of greenhouse showing numerator and denominator of north-wall for south-roof of a greenhouse

Based on Application of Greenhouse Systems

On the basis of working and principal applications, greenhouse may be broadly classified in the three categories: (i) greenhouse for crop cultivation, (ii) greenhouse for crop drying and (iii) greenhouse as the solar energy collector. The detailed classification on this basis is shown in Fig. 6.

Selection of Greenhouse

The design of a greenhouse depends upon the latitude of the place and the requirement of crop. The main criteria for selection of greenhouse can be its value of solar fraction.

Solar Fraction

The concept of solar fraction is very important in thermal analysis of a greenhouse system. It gives an idea regarding the distribution of solar radiation on walls and floor of greenhouse as compare to total incoming solar radiation. When the incoming short wavelength solar radiations, falling on one section of a greenhouse, intercepts the other side (internal) of the greenhouse before falling on to ground; it passes through the canopy cover of that side because it consists of short wavelength only (Fig. 1). Whenever solar radiation falls on a section, after absorption, reflection and transmittance by canopy cover, the rest of the radiation either falls on the ground or on the internal side of any other section. For an east - west oriented greenhouse, solar fraction for north wall is defined as the fraction of total radiation falling on north wall (Fig. 7).

For an east-west oriented greenhouse particularly in northern hemisphere, solar radiation that falls on the north wall is transmitted to atmosphere through the glazed cover. This becomes a loss especially during the month of winter, for area falling on the north of north tropic sun line. For efficient design of greenhouse under the above condition, it is necessary to make the glazed north wall opaque. Solar radiation transmitted through north wall can be retained and utilized by constructing north brick wall (Santamouris *et al.*, 1994; Mercier, 1982; Singh and Tiwari, 2000). It is required to incorporate the effect of solar fraction for north wall of an east-west oriented greenhouse in developing its thermal model.

The solar fraction for north wall is defined as follows:

$$F_n = \frac{\text{Solar radiation available on north wall inside the greenhouse for a given time}}{\text{Solar radiation measured on the north wall and floor of the greenhouse for same time}}$$

For a six-section greenhouse (Fig. 7), mathematically it can be expressed as follows:

$$F_n = \frac{(F_{n1} + F_{n2} + F_{n3} + F_{n4} + F_{n5} + F_{n6})}{(F_{n1} + \dots + F_{n6}) + \{(1 - F_{n1}) + (1 - F_{n2}) + (1 - F_{n3}) + \dots + (1 - F_{n6})\}} \quad (1)$$

or,

$$F_n = \frac{(F_{n1} + F_{n2} + F_{n3} + F_{n4} + F_{n5} + F_{n6})}{6} \quad (2)$$

The above equation can be rewritten as follows:

$$F_n = \frac{\sum_{j=1}^6 F_{nj}}{6} \quad (3)$$

F_n on north wall due to south wall = HA'/GA'
 F_n on the north due to south roof = A'C/A'B'

Conclusions

Greenhouse can be used for crop production as well as for drying of crop/fruit/medicinal plants of high economic value. It has tremendous scopes in space heating for human and cattle. Solar fraction of a greenhouse can be sole criteria for selection of greenhouse. For thermal heating of the greenhouse the solar fraction should be minimum.

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