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A Novel Plan of Solar Greenhouse for Deserts of Iran

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Abstract: The country of Iran includes 1,648,195 square kilometers of area in the Middle East, around 50% of Iran's area is covered with deserts and dry lands. Due to water shortage and unsuitable weather conditions in these areas, cultivation and growth of plants and flowers are restricted. Since, there is enough solar radiation in these areas, it is feasible to use potential of solar energy to make good conditions for cultivation and growth of plants. Present plan is a new idea to utilize solar energy as a source of energy to provide suitable condition for growth of plants and flowers in deserts. By implementing such a solar greenhouse, it is possible to employ cooling, heating and ventilation system, water distillation, dripped irrigation and automatic control system as well as providing enough light. In this type of solar greenhouse, using transparent glass covers and concrete basins, saline water can be distillated with the use of adjusting incident angle and cover slop. Electricity required for ventilation and irrigation can be provided using photovoltaic panel and storage system. For increasing energy efficiency some related sensors are used to control ventilation, irrigation, temperature, and relative humidity in the greenhouse chamber. Using passive solar system such as rock bed, heating of this greenhouse during winter is possible, whilst cooling of the system is done by wind tower and under-ground tunnel. Some advantages of this greenhouse are possibility of plant production in desert with unsuitable condition, independency to other sources of energy except solar energy, being environmental friendly, and having high efficiency. In this paper, design of aforementioned system regarding Iran's desert climate conditions has been presented.

Key words: Iran's deserts, solar greenhouse, cultivation and growth of plants, water distillation

INTRODUCTION

A green house is a growth chamber which offers the possibilities of year round plant production and provides crop cultivation under controlled environment. A green house is a structure covered with transparent material that utilizes solar radiant energy to grow plants and may have heating, cooling and ventilating equipments for temperature control.

Depending on climatic conditions, green house structure can be divided in two categories as winter green house and summer green house. The winter green house is constructed in those countries where the outside ambient temperature is very low compared to requirement of plant growth; obviously it is to be used for heating purposes. Summer green houses are constructed in those countries where the outside ambient temperature is very high compared to the plant growth temperature. Therefore the green house should be designed in a way that inside temperature would not reach very high.

Parameters for plant growth

In general, various parameters affect the plant growth; their discussions will help in design analysis of the green house construction (Rai, 1994).

Light

It is essentially required in plant growth. At intensities of about 16500 lux, a good plant growth has been observed. However, plants grow quite well at intensities of 27500 lux (only a quarter of full sunlight). Plants are found to use only radiant energy in the visible and near visible portion of the spectrum.

Temperature

In plant grow the temperature is a dominant environmental factor. There is different optimum temperature for each stage of plan development. This optimum value is related to other environmental factors. In controlled environments, however plants are grown at temperature between 10 and 25^{0}C.

Soil temperature

For most plants, the soil temperature of 20 to 25^0C has been reported to be optimum. This temperature determines the ability of a plant to absorb water from the soil since low soil temperatures are widely reported as detrimental in young plants, a high soil temperatures are recommended for rooting plants or germinating seeds.

Air movement

It influences transpiration, evaporation of water from soil, availability of carbon dioxide etc. this causes alteration of leaf size, internode length and other aspects of plant growth. In plant growth facilities, at speed of 0.8 to 2 cm/s, optimum growth has been reported.

Humidity

It affects plant growth significantly while low as well as high values may causes the plant to be more susceptible to diseases due to pathogenic organisms, high humidity result in taller plants. The low humidity cause increase in evaporation rate and so more water is required. In many plant growth facilities humidity between 55 and 65 percent at 21^0C to 25^0C is maintained. As mentioned, several important factors have effects on plants growth including light, ambient temperature and relative humidity, CO_2 to O_2 ratio and soil temperature. Due to water shortage and unsuitable weather conditions in dry land and deserts, cultivation and growth of plants and flowers are restricted. Since, there is enough solar radiation in these areas; it is feasible to use potential of solar energy to make good conditions for cultivation and growth of plants. The objective of the present plan is to design a green house to make good conditions for cultivation and growth of plants in the desert and dry lands of Iran.

MATERAILS AND METHODS

Design principles for different components of the plan are presented in details as follow:

Type of Green House

There are various designs of green house however the pit type structural design is suggested for the present plan. As shown in Fig 1. The pit type being sunk into the ground and has the advantage of being in contact with the temperature stability of the deep earth. Furthermore, the temperature of the ground in winter is higher than ambient temperature and vise versa for summer. This feature helps in controlling important plant growth parameters such as temperature, humidity, and air movement during plants production.

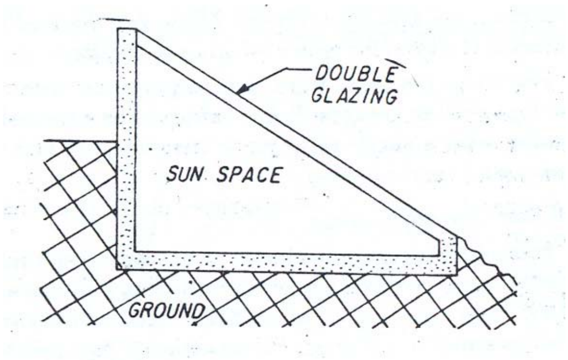

Fig. 1. The pit type structural design

Shape and Orientation of green house

The shape of truly passive solar green house is almost self determining, but will vary according to location and weather conditions. Iran is located between latitude of 25^0 $3^{'}$ N to 39^0 $47^{'}$ N and longitude of 44^0 $5^{'}$ E to 63^0 $18^{'}$ E. A useful theoretical rule of thumb which eliminates the calculation of numerous variables is simply to add only 20^0 to location latitude to determine the desired roof slop. For example, at 30^0N, the roof angle to the ground should be 50^0. Like any other solar collectors, the solar green house should be oriented in a southerly direction, but deviation from true south may be more generally tolerated and for plant growth may even be desirable. A south-easterly direction which would allow the green house to benefit more from the early morning sun, especially immediately after a long cold winter night attributed to desert where the location experience clear morning. So many weather factors and the varying nature of crops can influence the sitting of green house that is essential for the user to study closely local weather patterns and meteorological data to provide maximum protection from prevailing winds. For example for cold weather condition, the long axis of green house should be elongated along the east-west axis for better use of solar radiation and the south-east or south west end walls should almost be glazed. Glazed east-west end walls can allow light to pass straight through from the south glazing. In the present plan these points were considered regarding geographical location of the greenhouse.

Transparent cover

Depending on climate condition number of glazing varies. If movable insulation is used at night, one layer of glazing can be applied.

Heating and cooling of the green house

For heating of the green house during winter the rock bed-passive solar system is suggested. Fig 2. shows the working principle of rock bed storage system integrated with green house. Hot air from collector is allowed to enter the green house as shown in figure and cooled air is returned to the collector through basement and rock bed. In the case of hot air not allowed to the greenhouse, the available thermal energy is stored in the rock bed for later use, preferably during the night time.

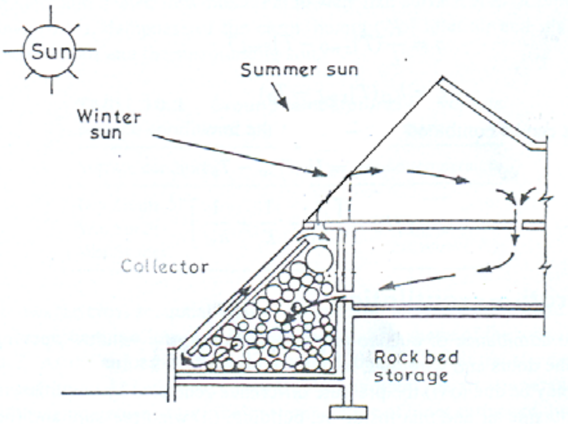

Fig. 2. The rock bed-passive solar system

In addition, earth-air tunnel can be exploited for heating and cooling of the green house using the constant ground temperature few meters below the ground surface, where it remains constant throughout the year (Table 1) (Tiwari, 2002).

Table 1. Ground temperature for various surface conditions at depth of 4m

Surface condition	Ground temperature
Dry Sunlit	27.5^{0}C
Wet Sunlit	21.5^{0}C
Wet Shaded	21.0^{0}C

The air passing through a tunnel or a buried pipe gets cooled in summer and heated in winters. Parameters like surface area of pipe, length and depth of the tunnel below ground, dampness of the earth, humidity of inlet air and it's velocity affect the exchange of heat between air and surrounding soil. Fig 3. shows the cross sectional view of an earth tunnel below the ground at 4m depth where air available from atmosphere is allowed to pass through it. The shape of the tunnel is cylindrical with radius r and length L. As the air passes through the tunnel there is a heat transfer from inner surface of the tunnel to the flowing air by forced convection. Depending upon the air temperature, the air either heated or cooled. If the temperature of air is below than temperature of inner surface of the tunnel, heat is transferred from surface to air for heating. This occurs in the winter season. For summer it is vice versa.

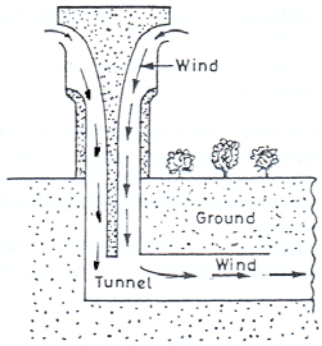

Fig. 3. The cross sectional view of an earth tunnel and wind tower

Referring to Fig 4. the energy balance for an elemental length dx can be written as:

$$\dot{m}_a C_a \frac{dt(x)}{dx} dx = 2\pi r h_c \left(T_o - T(x)\right) dx$$

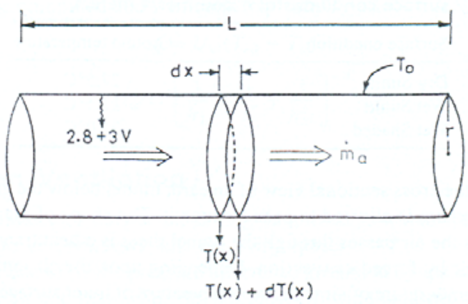

Fig. 4. Flow direction through an earth-air tunnel

Where h_c is convective heat transfer obtained as $h_c = 2.8 + 3V$ (Duffie and Beckman, 1991), V is the speed of air flowing through the tunnel, $\dot{m}_a = \pi r^2 \rho V$

ρ , C_a and $\dot{m}_a$ are density, specific heat capacity and mass flow rate of air, respectively.
T_0 is underground surface temperature.
T(x) is the temperature of air as a function of x.
The solution of above equation with $T(x=0)=T_{fi}$ can be written as:

$$T(x) = T_o\left(1 - e^{-\frac{2\pi r h_c}{m_a C_a}x}\right) + T_{fi} e^{-\frac{2\pi h_c}{m_a C_a}x}$$

Assume $T_{fo}=T(x=L)$, The rate of thermal energy carried away by the flowing air is

$$\dot{Q}_u = \dot{m}_a C_a \left(T_{fo} - T_{fi}\right)$$

$$\dot{Q}_u = \dot{m}_a C_a \left(T_o - T_{fi}\right)\left[1 - e^{-\frac{2\pi r h_c}{m_a C_a}L}\right]$$

The variation of $\dot{Q}_u$ with L for winter and summer conditions for typical set of parameters has been plotted in Fig 5. This figure indicates that the value of $\dot{Q}_u$ will be positive for winter condition due to lower value of ambient air temperature ($T_a=T_{fi}$) than underground surface temperature (T_o). Further, the value of $\dot{Q}_u$ becomes negative due to higher value of ambient air. The length of tunnel should be optimized for given volume of green house space. A combination of wind tower and air tunnel is effective in increasing the draft of air in the earth air tunnel for the cooling rate of greenhouse (Fig 3).

In addition to the mentioned system for controlling the temperature of the greenhouse chamber, A movable insulation over the canopy cover is used in both winter and summer condition. In winter, it is used during night or low intensity period to avoid heat losses from inside greenhouse to outside through roofs/walls and during sunshine hour in summer condition to cut-off solar radiation.

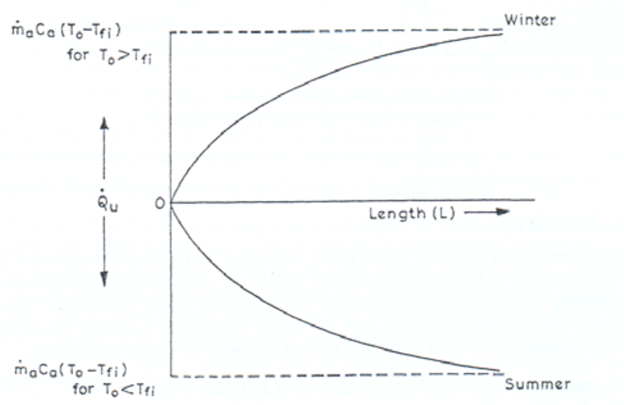

Fig. 5. Variation of $\dot{Q}_u$ with L

Ventilation

Adequate ventilation is a most for successful operation of a green house. In this plan, outside air is introduced into interior through the air tunnel which is at depth of 2.5 to 3 m below the surface of the ground. Therefore the growing area will be warmed in winter and cooled in summer. Exhaust vent to the outside is used in warmer weather.

Misting arrangement

The water from the storage tank is pumped through filter by a water pump to a lateral pipe provided along the length of the greenhouse, at a certain height. The fogger is fitted to provide complete fog inside. The misting system is generally used for creating high relative humidity along with cooling inside the greenhouse.

Solar water still

Surveys show that about 79 percent of water available on the earth is salty, only 1% is fresh and the rest 20% is brackish. Supplying of fresh water is a major problem in deserts and dry land for cultivation and growth of plant. It is notable that there are many saline water resources in deserts and dry land of Iran. Distillation of brackish or saline water is a good method to obtain fresh water. In this plan a continuous passive solar still is proposed for purification of saline water (Fig 6).

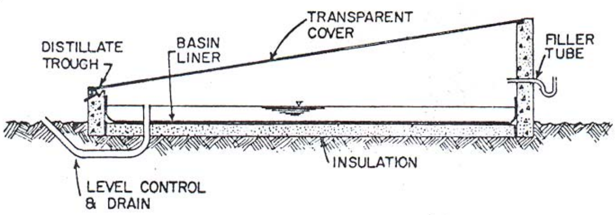

Fig. 6. The continuous passive solar water still

This solar still consist of airtight basin constructed out of concrete/cement, fiber reinforced plastic with two glass cover. The inner surface of the rectangular base is blackened to efficiently absorb the solar radiation incident at the surface. There is a provision to collect the distillate water via distillate trough at lower end of glass cover. The brackish or saline water is fed into the basin for purification. The maximum level of saline water in the basin is controlled using level control and drain. Beside and beneath of the basin is insulated properly to reduce heat losses. The feeding rate of saline water depends on mineral salts of saline water as well as the quality of distillate water required for a specific plant. The facility of still should be installed somewhere to reduce shadowing on it. The long axis of solar still and the orientation of glass cover should be laid along East-West and south, respectively. The variation of distillate production with glass cover inclination has been studied (Cooper, 1996) and identified that the output changes very little with changes of cover slop. To maximize total absorption of solar radiation and avoid falling of distillate water into basin an appropriate cover slop should be chosen. The cover slop less than 10 degree cause the condensed water drop into basin (Dickinson and Cheremisinoff, 1980). It is estimated that the glass cover with angle of 40-45^0 gives good results for desert of Iran. Regarding Iran's deserts climatic condition and number of sunny days in a year which is more than 300 days, it is estimated that the average production of such a solar still is about 4-5 lit/m^2.day.

Photovoltaic and Storage System

Electricity required for illumination, ventilation and irrigation can be provided using silicon photovoltaic cells and associated storage system. Regarding the historical weather data of Iran's desert and dry land, the number of sunny days which is necessary for sustainable electricity generation using photovoltaic is more than 300 days in a year and average solar radiation for stated potential areas varies between 420 and 475 (Cal/cm^2.day). The area of a commercial silicon photovoltaic panel is 0.65 m^2 which generates 45-85 watt depending on solar radiation ranging from 600 to 1000 W/m^2. With regard to climatic condition and total number of sunny days during the year, the number of photovoltaic panels varies. These panels would be connected parallel or series to obtain required electricity for the facilities of the green house. Exceed electricity should be stored in storage batteries for later use at night or cloudy conditions. The stored energy can be delivered as electricity upon discharge. The common lead acid storage batteries, such as those used in automobile, are not ideal for this purpose, but they are probably the best presently available. The power of such batteries ranging from 50-90 A-h with voltage of 12 V or 24V. The number of these batteries which will be connected parallel or series depends on the amount of power used in greenhouse facilities and total of sunny hour during the days of year.

Water Storage and Irrigation System

Distillate water should be accumulated in an enclosed reservoir and capacity of the tank should be large enough to store exceed water in sunny days of the year for later use in cloudy days that water distillation is not possible. An opened basin should also be used near the greenhouse to accumulate the rainfall when it rains. Water should be used efficiently due to water shortage in the desert and dry land. The dripped irrigation system is an appropriate system of irrigation for this plan because of high efficiency of water transfer and low energy consumption.

Automatic control system

By implying an automatic control system the performance and energy use of the facilities can be optimized. Some suitable sensors are used to control ventilation, irrigation, temperature, and relative humidity in the greenhouse chamber. These include temperature, humidity, CO2/O2, and capacitive moisture meter sensors. The places of installation should be representative of green house average conditions. To achieve the best control of the green house condition the same sensors should be used in several places and after averaging the strategies are applied in control unit.

RESULTS AND DISCUSSIONS

The components of the present plan were presented in the material methods in details. An example of such a green house will be presented for cucumber production to give the better picture of this plan.

Based on historical weather data of Iran's desert and dry lands the number of sunny days and average monthly radiation for these areas is suitable for implementation of the plan. Considering row spacing of 80-100 cm and plant spacing of 15-20cm on row for cucumber planting, about 2650 cucumber seeds can be cultivated on 1000 m^2 green house. Water requirement for a plant of cucumber varies between 400ml to 3000 ml during different stage of growth and on average it needs 2 lit/day for one round production (6 months). Therefore 5500 lit of distillate water is required during 6 month-plant growth. For distillation of such amount of water considering 3lit/day.m^2 average production of solar still, 1850m^2 is needed. Based on calculation of electricity required for water pumping of dripped irrigation, ventilation of air via fan and illumination of green house during night, 25m^2 photovoltaic panels and thirty 24V common lead acid storage batteries with capacity of electricity generation of 90 A-h are needed. Using such storage system the green house can work satisfactorily for 3 days without any solar radiation. Based on Iran's historical weather data the probability of this situation is so weak. For better use of electricity generation it is recommended to use DC systems for the green house.

The cost of construction of 1000m^2 of this type of greenhouse with it's associated implements is assessed at 150,000 USD. Each plant in reasonable condition can produce 50kg of cucumber during a round production. For 1000 m^2 green house 130 ton cucumber would be obtained during 6 months and 260 ton for a year. Assuming 40 cent/kg the price of cucumber in Iran after less than 2 years the initial cost of implementing of such green house will be returned.

CONCLUSION

Some advantages of this greenhouse are possibility of plant production in desert with unsuitable condition, independency to other sources of energy except solar energy, being environmental friendly, having high efficiency and being beneficial.

REFERENCES

Cooper, P. I., 1969. Digital simulation of transient solar still processes. Solar Energy, 12, 313.

Dickinson, W. C., P. N. Cheremisinoff, 1980. Solar Energy Technology Handbook, part B. Application, System Design & Economic, New York and Basel London, U.S.A. 560p.

Duffie, J. A. , W. A. Beckman, 1991. Solar Engineering of Thermal Processes. 2nd ed., Jone Wiley & Sons, Inc., New York, U.S.A. 919p.

Rai, G. D., 1994. Non-conventional Source of Energy. Romesh chander khanna for Khanna publishers, Delhi, India. 840p.

Tiwari, G. N., 2002. Solar Energy Fundamentals, Design, Modelling and Applications. Center for Energy Studies, Indian Institute of Technology, Delhi, Alpha Science International Ltd.