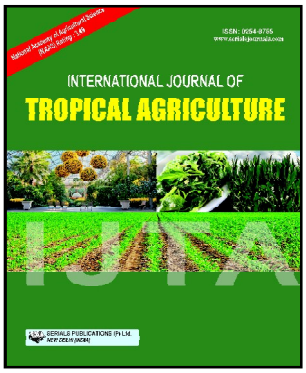

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Effect of shape of polyhouse and variety in the growth and yield of Chilli under humid tropical climate

P. Suseela*

Professor, Hi-TechResearch and Training Unit, Instructional Farm, Kerala Agricultural University, Vellanikkara Thrissur, Kerala, India, Pin: 680 656, E-mail: suseela1963palazhy@gmail.com, suseela_palazhy@yahoo.co.in

Abstract: In order to study the effect of shape of polyhouse in growth and yield of chilli, three different shaped naturally ventilated polyhouses (namely gable, quonset and mansard/aerodynamic shapes) having same floor area (150 m^2), eave height, ridge height and roof & side ventilation were designed and constructed in north – south direction at HTR&TU, KAU, Vellanikkara, Thrissur, Kerala. Study was conducted by observing the temperature, CO_2 concentration and relative humidity inside the polyhouses. The temperature inside gable shaped greenhouse was found to be lesser than Quonset and Mansard shaped greenhouses. During peak hours of the day (12 pm to 2.30 pm), temperature inside gable shaped greenhouse was 1.5 to 2^0C lesser than other two greenhouses. Relative humidity inside gable shaped greenhouse was found to be lesser during night time and more in peak hours of the day. There was no significant difference in the CO_2 concentration inside the structures.

In all the three polyhouses and open field, six varieties of chilli were cultivated to select high yielding varieties of chilli for humid tropical climate under the polyhouse. Statistical analysis of the yield data revealed that all the varieties of chillies gave maximum yield in gable shaped structure and maximum yield was obtained for seirra variety inside gable shaped greenhouse (4.36 kg) and the minimum yield for Ujwala variety in the open field (0.221kg). It was also found that in all the polyhouses, maximum yield was obtained for the seirra variety and minimum yield for Ujwala variety. The yield of sierra, NS 230 and NS 1701 was on par in all the greenhouses. The yield of all other varieties was found to be significantly lesser than the sierra variety. The yield under gable shaped polyhouse was about 12 to 15 times more than that of open field and a benefit - cost ratio of 3.07 could be attained. The study revealed that optimal greenhouse design suitable for Kerala homesteads for cultivating chilli is gable shaped structure oriented in north – south direction and sierra variety is more remunerative.

Key words: polyhouse, shape, temperature, RH, chilly, Variety, yield

INTRODUCTION

Full potential yield from the crop can be attained only at favorable climatic condition. Polyhouse can provide controlled environmental condition by providing a barrier between the plant microclimate and ambient climate. As Kerala is having humid tropical climate, pest and disease attack is comparatively more. Because of the uncertainty in the climatic conditions, high labour wages and severe pest and disease attack, people are not coming forward for cultivating the vegetables. Polyhouse is the most practical method of achieving the objectives of protected agriculture, where natural environment is modified by using the sound engineering principles to achieve the optimum plant growth and yield and also to provide protection from pest and disease attack. In order to develop a cheap and economical greenhouse technology suitable for Kerala, which falls under humid tropical climatic condition, a detailed study of the greenhouse environment of this condition is needed. Reduction of temperature in the interior of the greenhouses located in the warm regions is fundamental to obtain good control of the climate. Polyhouse structure that having facility to provide natural ventilation is most suitable to Kerala conditions since it is the cheapest method of lowering the temperature & humidity and replacement of carbon dioxide deficiency and hence study was concentrated on naturally ventilated polyhouses.

Polyhouse cultivation in humid tropical climate is a technical area on which only little information is available. Design of a polyhouse for proper control in the environmental conditions requires an accurate prediction of the polyhouse microclimate based on the dynamic environmental condition coupled with the knowledge of the response of the plants to environment. To take the advantage of these opportunities, a better understanding of the physical processes, which create the polyhouse environment, is required. Knowledge of the effect of shape on the temperature and relative humidity inside the polyhouse will help to adopt proper design of the polyhouse for a particular locality. But there is no generic model of the naturally ventilated structure, which can be applied for a polyhouse with differing physical characteristics. This information could then be used together with the improved understanding of the plant response to the environment to define the best combination of conditions for cost effective plant production. In order to develop a cheap and economical polyhouse technology suitable for Kerala, which falls under humid tropical climatic condition, a detailed study of the polyhouse environment of this condition is needed.

Since chilli is an important crop for Kerala on economical point of view and it found to perform well under polyhouse, selection of suitable variety of chilli for polyhouse farming in Kerala has great value. With this in mind, an attempt was made to study the effect of shape of polyhouse on CO_2 concentration, temperature and RH inside the polyhouse and its influence on growth & yield of chilli. Study was also made to select most suitable varieties of chilli under polyhouse farming.

MATERIALS AND METHODS

The study was conducted at Hi-Tech Research and Training Unit, Instructional Farm, KAU, Vellanikkara, Thrissur. Design of a structure is most important factor because desirable environmental conditions can be obtained only through the selection of optimal shape, orientation and proper arrangement of ventilation of a polyhouse. The orientation of the structure was selected so as to achieve good environmental condition inside the polyhouse. Polyhouses located at latitudes less than 35^0 should be oriented with roof ridges parallel to the north – south line (Albright, 1995; Suay, et al; 2006)). Since the study area is having a latitude of $10^0 13'$, polyhouses were constructed with their longer axis parallel to the N-S direction. Moreover,

reduction of loss of production due to shadows of structural components can be eliminated in the N-S orientation since shadows move during the day and therefore, the production in specific area does not suffer (Kariyanna, 1998). In order to avoid shading effect from one polyhouse to another, all the polyhouses were arranged in north – south line. Hence, all the three polyhouses were constructed with their longer axis parallel to the N-S direction in three agro ecological stations . FAO (1999) specified that, polyhouses has to be placed next to each other at a distance of 2m, so that proper ventilation efficiency can be ensured. Hence a distance of 3m was maintained between the sides of the polyhouses. Hence, in order to study the influence of shape of naturally ventilated polyhouse on inside CO_2 concentration, temperature, RH and growth & yield of chilli, three naturally ventilated polyhouses having different shapes (gable shape, Quonset shape and mansard shape) oriented in north –south direction were constructed. All the polyhouses were constructed with same floor area of 150m^2, same ridge height, side height and roof and side ventilations (in case of quonset and mansard shaped greenhouse roof ventilation was provided only on western side as during summer season, most of the time wind is blowing towards western side. In gable shaped greenhouse, roof ventilation was provided on both sides). Albright (1997) specified that to get maximum benefit of natural ventilation, the side and roof ventilators are to be provided in such a way that the distance between the centers of the roof and side ventilators is maximum. Hence, in all sides of the greenhouses, apron was restricted only to a height of 40 cm above the floor level & 40cm below the soil and remaining portion of all sides were fully covered with insect proof net (40 mesh). Roof ventilation in quonset and mansard shaped structures were provided at the ridge level on leeward side (western side). In the case of gable shaped polyhouse, roof ventilation was provided on both sides (western and eastern sides) at ridge level. The details of dimensions are given in table.1. Insect proof net was provided at the roof ventilators. This will help to prevent the entry of the insects and pests. The roof of all the polyhouses were covered with 200 micron 5 layered UV stabilized polyethylene sheets having a combination of antidust- diffused- UV stabilized- IR cooling- anti dust/anti mist.

The details of dimension of the polyhouses are given in Table.1 and the schematic representation of different shaped polyhouses are shown in Fig.1, 2 and 3.

Table 1
Details of dimensions of different polyhouses

Shape of polyhouse	*Length (m)*	*Breadth (m)*	*Orientation*	*Eave height (m)*	*Ridge height (m)*	*Roof ventilation*	*Side Ventilation (%)*	*Remarks*
Gable shaped	20	7.5	N-S	3.5	6	10%(ie.,78.5 cm on W & E sides)	50	Side vertical, triangular shaped roof, roof extended from sides (60cm)
Quonset shaped	20	7.5	N-S	3.5	6	10% (ie., 1.57m on W side)	50	Side vertical, arch shaped roof, roof extended from sides (60cm)
Mansard shaped	20	7.5	N-S	3.5	6	10% (ie., 1.57m on W side)	50	Side curved arch shaped roof

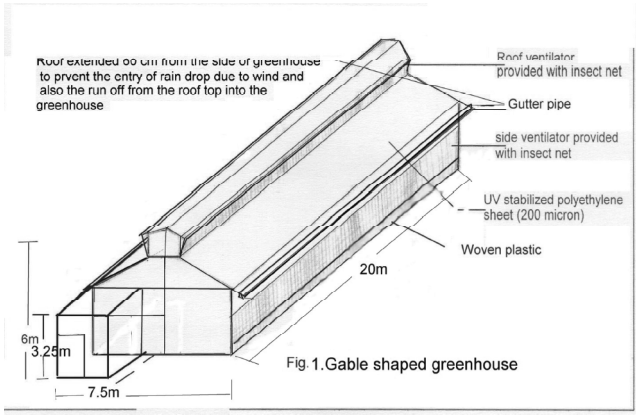

Fig.1.Gable shaped greenhouse

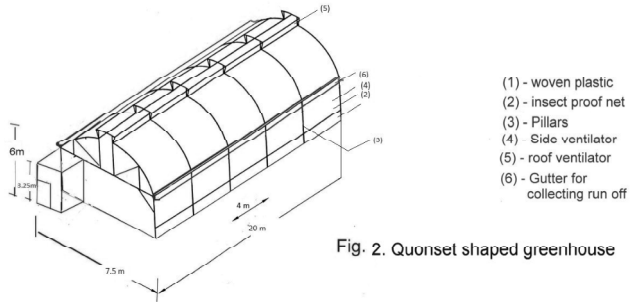

Fig. 2. Quonset shaped greenhouse

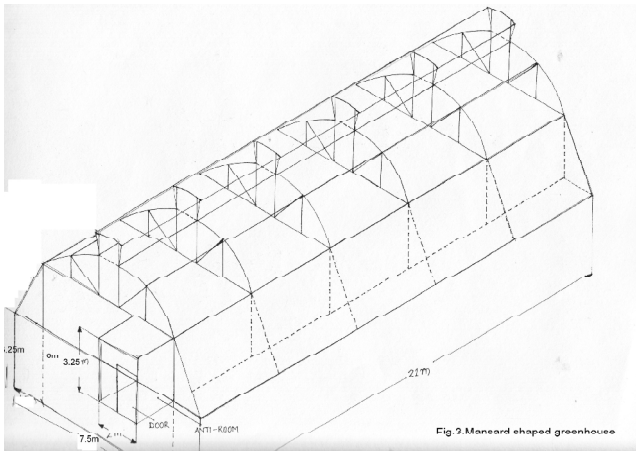

Fig.3.Mansard shaped greenhouse

Temperature, relative humidity and concentration of CO_2 measurements in all the polyhouses and in the open field were automatically recorded throughout the cropping period at 30 min. interval both during day and night by using sensors and computerized greenhouse monitor. In all the greenhouses, the temperature at a height of 0.75 m, 1.5m, 2.25m, 3m, 4m and 5 m from the floor level was noted at five points. Temperature at a particular level and at a particular time inside the polyhouse was taken as the mean of these five observed values. Relative humidity inside the polyhouses was noted at the centre and at four corners of the polyhouse and average of these readings was taken as the corresponding observation at a particular time. Outside the greenhouse, readings of these climatic parameters were taken at 3 different points and averaged out to get the respective values.

In order to study the effect of shape of polyhouse on growth & yield characteristics of chilli, 6 varieties of chilli namely Sierra, NS1101, NS1701, NS 230, Bond, Ujwala were cultivated in three different shaped poyhouses namely quonset shape, gable shape and mansard shape at Hi-Tech Research and Training Unit, Vellanikkara. Observations on growth and yield characteristics were taken during 2013 to 2017 and statistical analysis of the same was made.

RESULTS AND DISCUSSION

Statistical analysis of the climatological observed data at half an hour interval during day and night time throughout the study period (2013-17) revealed that microclimate inside the greenhouse changes with shape of the greenhouse. In order to study the variation of temperature at different height, temperature sensors have installed at different height. Fig. 4 to Fig. 6 shows variation of temperature with time at different height inside the three shaped greenhouses under study. At all positions, temperature inside Gable shaped greenhouse was lesser than other greenhouses. At a height of 0.75m from floor level, the peak temperature in gable shaped greenhouse was 34.25^{0}C, in Quonset shaped greenhouse 37^{0}C and in mansard shaped greenhouse 38^{0}C. This is due to difference in incident solar radiation and also due to accelerated movement of hot air through the roof ventilation in the case of gable shaped greenhouse. In the case of gable shaped greenhouse, due to accelerated movement of hot air, the difference in temperature at 0.75m and 5m

from the floor level comes around 9^0C. Whereas in the case of Quonset shaped greenhouse, it is 7.5^0C and in Mansard shaped greenhouse it is 7^0C only.

The possible reason for the reduction of temperature in Gable shaped greenhouse compared to other two may be as follows. If the transparent covering is at right angles to the sun's rays, there will be maximum transmission of solar radiation into the greenhouse. The curved or semicircular roof provides the maximum light/solar radiation transmission. The most efficient transmitting surface is a hemisphere of 1m radius (Manbeck and Aldrich, 1967). The mansard type, originally proposed for the reason that the roof design allows the sun to penetrate at right angles for many months of the winter under British conditions (Smith, 1967), was later withdrawn from consideration since the proposed advantage was not sufficient to outweigh the increased cost of a complicated structure. Quonset shaped greenhouse design also allows maximum solar radiation to penetrate at right angles as roof is circular/semicircular in shape. Since the transmission of solar radiation is more in mansard and Quonset shaped greenhouse than Gable shaped greenhouse, temperature inside Quonset shaped greenhouse is more than gable shaped polyhouse. In the case of gable shaped poly house, roof is very steep and triangular in shape. Hence in the Gable shaped greenhouse, during the peak hours of the day (from 12.30 pm to 2.30pm) only cosine component of the solar radiation will enter the greenhouse. This helps to reduce the temperature inside the greenhouse especially during peak hours of the day. In the case mansard shaped greenhouse, not only the roof, but also the sides are curved. Hence transmission of solar radiation inside mansard shaped greenhouse will be more than Quonset shaped greenhouse. Under Kerala condition, our prime requirement is to reduce the temperature to make the environment favourable to plant growth. Hence gable shaped greenhouse provided with roof and side ventilation is suitable to Kerala. In other states of India, as there is prominent winter season, they have to increase the temperature during this period. Hence, they are following Quonset shaped polyhouse to get favorable climatic conditions throughout the year. In many cases, farmers are constructing polyhouses in barren land. Hence to protect the polyhouse from strong wind, farmers are following the mansard/aerodynamic design. But in Kerala, due to lack of land and there are trees and buildings within the required limit, protecting the structure from wind is not a great problem. If farmer is using 2mm thick GI pipes of correct specification, there won't be any problem. Moreover in Kerala, there is no prominent winter season. Our prime requirement is to reduce temperature and to maintain medium RH. Hence gable shaped greenhouse with roof ventilation on both sides oriented in north south direction are found to be more suitable.

In this study, arrangement have also been provided to study the effect of shape of polyhouse on growth attributes and yield of chilli and to determine the most suitable variety of chilli for cultivating inside the polyhouse. In order to screen/ evaluate most suitable variety of chilli, six varieties (Sierra, NS1101, NS1701, NS 230, Bond, Ujwala) of chilli were raised in all the three polyhouses namely gable shape, quonset shape and mansard shape or aerodynamic design and in the open field at HTR&TU, IF, Vellanikkara. The growth attributes and yield of each varieties were observed. Statistical analysis of the observations was made and the results of the same are given in table 3.

The results of the study indicate that all the varieties of chilli gave maximum yield in gable shaped structure. In all the polyhouses, sierra variety gave maximum yield and Ujwalla variety gave minimum yield. Statistical analysis of the yield data revealed that maximum yield was obtained for Sierra variety inside gable shaped polyhouse (4.36 kg) and the minimum yield for Ujwalla variety in open field (0.22kg). In all the three polyhouses, the yield

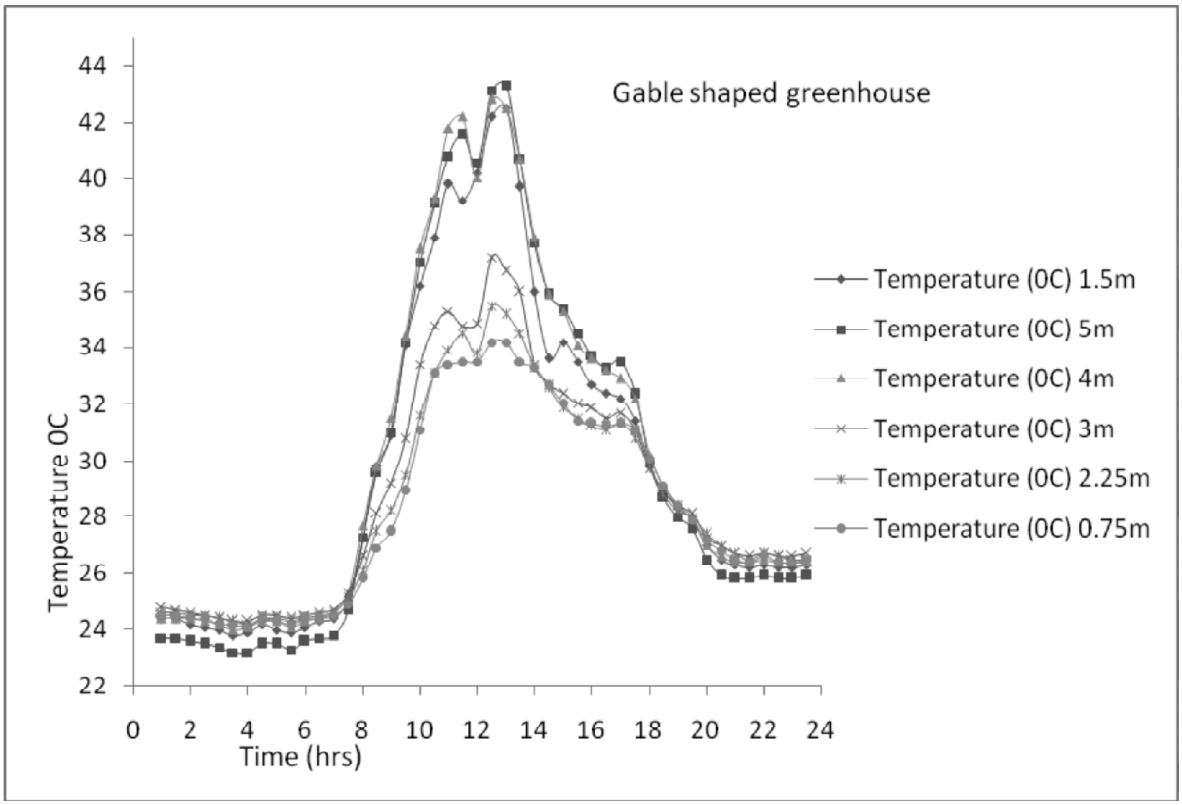

Figure 4. Variation of temperature with time at different height inside gable shaped greenhouse

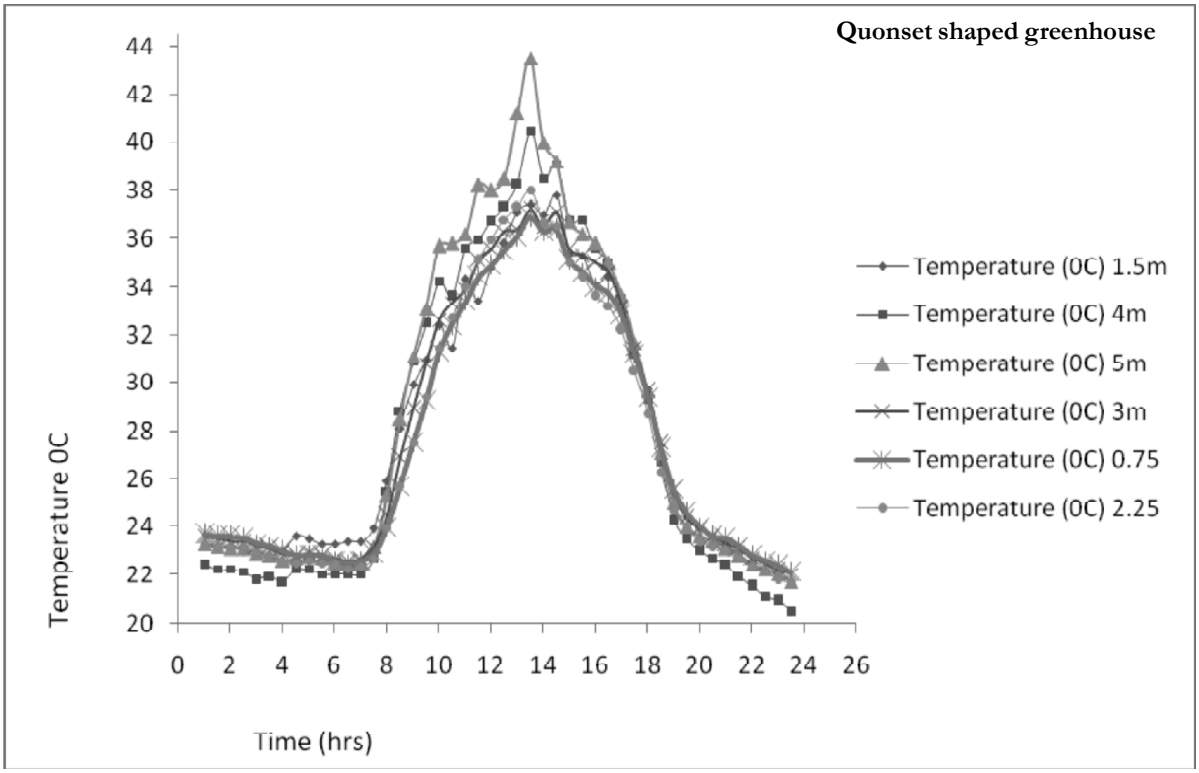

Figure 5: Variation of temperature with time at different height inside quonset shaped greenhouse

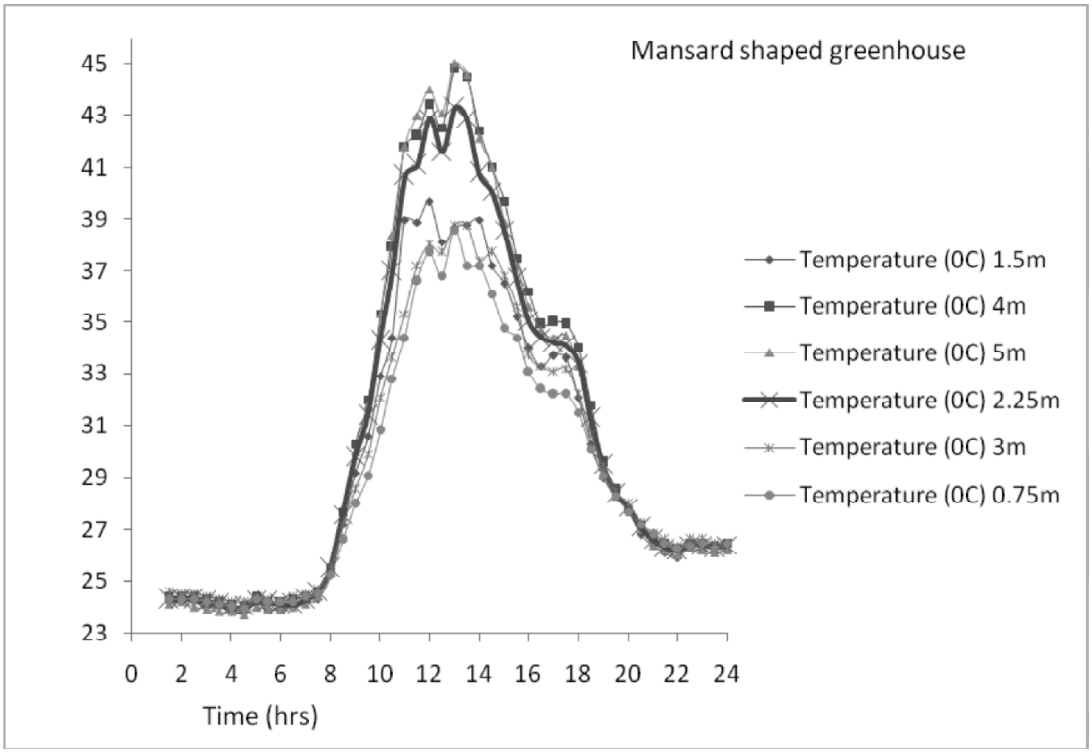

Figure 6: Variation of temperature with time at different height inside mansard shaped greenhouse

Table 3
Effect of shape of greenhouse on growth attributes and yields of different varieties of chilli

Variety	*Gable shape*				*Quonset shape*				*Mansard shape*				*Open field*			
	DT FF (days)	*DT FH (days)*	*Plant ht(m)*	*Yield (Kg)*	*DT FF (days)*	*DT FH (days)*	*Plant ht(m)*	*Yield (Kg)*	*DT FF (days)*	*DT FH (days)*	*Plant ht(m)*	*Yield (Kg)*	*DT FF (days)*	*DT FH (days)*	*Plant ht(m)*	*Yield (Kg)*
Sierra	42	57	4.21	4.36	42	58	4.27	3.99	41	58	4.32	3.51	49	65	58.5	0.34
NS1101	36	52	4.15	2.65	38	53	4.09	2.45	38	54	4.23	2.38	46	62	62.4	0.24
NS230	36	52	4.27	3.84	37	54	4.37	3.38	37	54	4.31	2.95	54	68	52.3	0.27
NS1701	36	52	4.32	3.98	38	53	4.35	3.41	38	53	4.26	3.15	53	69	58	0.29
Bond	38	54	4.25	3.1	38	55	4.34	2.52	39	56	4.3	2.328	49	67	60.5	0.24
Ujwala	48	64	3.35	2.65	49	64	3.25	2.23	49	65	3.52	2.34	54	68	60.2	0.22
Mean	39.33	55.17	44.98	3.43	40.33	56.17	45.18	2.96	40.33	56.67	48.78	2.78	50.83	66.5	58.65	0.253
CD(P<0.05)	0.43	0.48	3.87	0.873												0.06

obtained for the Sierra variety, NS 230 and NS1701 was on par and that of NS1101, bond and Ujwalla in Gable, mansard and Quonset shaped polyhouses was significantly lesser than Sierra variety. The yield of all the chilli varieties in open field was found to be considerably lesser than (10 to 20 times) that obtained in all the polyhouses. Sierra gave the biggest size fruits.

CONCLUSION

The analysis of climatic parameters and yield & growth characteristics of chilli revealed that optimal poyhouse design suitable for cultivation of chilli in Kerala homesteads is gable shaped structure. Among all the variety tested, Sierra variety gave maximum yield in gable shaped greenhouse. The study indicates that all varieties of chillies are giving considerably higher yield in polyhouses than open field and hence cultivation of chilli inside the polyhouses of Kerala is remunerative.

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