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# Suitability of Protected Structures for Round the Year Vegetables Cultivation

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## ABSTRACT

The fully and partially controlled protected structures can be constructed for providing suitable microclimates for cultivation of vegetables. The fixed and operating cost of protected structures affects the profitability of cultivated vegetables. In this study protected structures i.e. shade net structure, insect proof net structure and polyhouse were constructed to study its suitability for round the year vegetables i.e. tomato and capsicum cultivation. Based on minimum and maximum temperature, it is found that shade net structure can be used only during summer season, insect proof net can be used during winter season and polyhouse can be used during winter and rainy season. Due to variation of open field micro climate round the year and different working principle of protected structures, not a single structure is found suitable for round the year cultivation of tomato and capsicum.

**Keywords** Protected structures, Temperature, Cultivation, Microclimates, Profitability.

## INTRODUCTION

Protected cultivation is an agro technology wherein the microclimate around the plant is controlled fully, partially or modified to protect the crop from adverse microclimate parameters. The productivity and quality of any produce is influenced by the genetic characteristics of the cultivar, agronomical and microclimate management. Under open field cultivation, we can best manage agronomical management and there is no control on microclimate around the plant (Rai 2020). The important microclimate parameters are temperature (air temperature (minimum and maximum) and soil temperature), light (intensity, quality and duration), relative humidity, carbon dioxide and air velocity (Rai 2021).

The protected cultivation structures allows regulation of macro and micro environments and facilitate optimal plant growth, extension of growing period, production of early/off-season crop, reduction in use of pesticides and weedicide, efficient uses of resources (water and fertilizer), obtaining higher and better quality yields (Gruda and Tanny 2015).

The protected structures are used for vegetables cultivation predominantly for tomato and capsicum (Sabir and Singh 2013). The desired temperature, light

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intensity and relative humidity required for tomato cultivation is varies between 10-28$^0$C, 40-60 klux and 55-65% respectively however for capsicum it varies between 12-25$^0$C, 40-60 klux and 65-70% (Iyenger *et al.* 2011). The environment condition required for cultivation of tomato and capsicum are almost similar in nature. The environment condition required for tomato and capsicum cultivation also varies with growth stages and requirement varies during day and night time. It has been reported that based on open field microclimate, for cultivation of tomato and capsicum, the light intensity is in desirable range but there is need to increase the minimum temperature during winter season. During summer season there is need to reduce the maximum temperature and light intensity but during rainy season temperature and broadly light intensity is in desirable range required for cultivation of tomato and capsicum (Rai 2018).

The various protected structures used for protected cultivation are polyhouse and net structure (shade net structure and insect proof net structure) (Rai 2020).The primary reason for using polyhouse is protection from low temperature in addition to other secondary benefits such as providing suitable relative humidity, higher carbon dioxide, protection from wind speed, rainfall, hailstorm and insects and diseases (Sánchez-Hermosilla *et al.* 2013, Manonmani *et al.* 2018, Gurav *et al.* 2022, He *et al.* 2023). There are different types of polyhouse structures are available such as low cost/technology, medium cost/technology and high cost/technology that can be utilized as per the requirement.

The shade net structure reduces the light intensity to mitigate the adverse effects of high temperatures (Serra *et al.* 2020) and increases total marketable yield during summer season (Kittas *et al.* 2012). Insect proof net structure are designed to protect crops from various types of insects by means of physical exclusion by adjusting the size of screen holes to the size of the targeted pest (physical exclusion) or by optical exclusion by blocking their vision i.e. blocking/absorbing specific ultraviolet visible radiation spectra (Ben-Yakir *et al.* 2012).

Each protected structures consists of structural material, cladding material and gadgets used for climate control. The available microclimate inside the polyhouse and net structure (shade net structure and insect proof net structure) depends upon open field microclimate condition, cladding material and gadgets used for climate control. Due to different cladding material used for each protected structures, the available microclimate condition under each protected structures varies throughout the year (Rai 2020). The fixed cost and operating cost, profitable crop cycle and utilization period affects the profitability of selected protected structure.

The microclimates parameters especially temperature required for vegetables i.e. tomato and capsicum cultivation are considered to study the suitability of protected structures for round the year cultivation. Among the various microclimate parameters, the suitable temperature inside the protected structure plays a very important role in selecting the appropriate protected structure. Keeping the above facts into consideration this study was conducted to find out the suitability of protected structures for round the year vegetables cultivation.

## MATERIALS AND METHODS

The experiment was conducted at research farm (longitude: 85.318° E, latitude: 23.448° N) of the AICRP on Plastic Engineering in Agriculture Structure and Environment Management (PEASEM), Department of Agricultural Engineering, Birsa Agricultural University, Kanke, Ranchi, Jharkhand. For experiment protected structures i.e. shade net structure, insect proof net structure and natural ventilated polyhouse (NVP) were constructed and different materials used were i.e. bamboo, GI wire, coal tar, waste plastic, nail, cladding materials [shade net material (color: Green, nominal shade rating: 50%, UV stabilized insect net proof material (40 mesh) and UV stabilized clear film (200 micron)]. The specification of protected structures are, length: 12 m, width: 4.5 m, side height: 1.5 m, central height: 2.25 m and door width: 1 m and height: 1.5 m.The minimum and maximum temperature in open field and protected structures were measured using minimum and maximum thermometer (ZEAL: UK, range: -40 °C to 50 °C, least count: 1 °C).

## RESULTS AND DISCUSSION

### Temperature during winter season

The range and mean of min$^m$ and max$^m$ temperature during winter season for meteorological week (1$^{st}$ to 9$^{th}$ and 44$^{th}$ to 52$^{nd}$) under open field and protected structures is given in Table 1. The mean of minimum temperature for open field, shade net, insect proof net and polyhouse are respectively 14.6°C, 12.9°C, 14.8°C and 16.2°C. It is clear that there is 1.7°C decrease in minimum temperature under shade net structure in comparison to open field. The decrease in minimum temperature may be due to non availability of solar radiation during night period (Stamps 1994, Möller *et al.* 2010). There is 0.2°C increase in minimum temperature under insect proof net in comparison to open field temperature. It has been reported that due to dense mesh configurations of insect proof net, it reduces the air exchange rate with the open field and the mean air velocity inside insect proof net, resulting in higher temperature (Mahmood *et al.* 2018).

The increase in minimum temperature under polyhouse is 1.6°C in comparison to open field temperature. It has been reported that the increase in minimum temperature under polyhouse is between 1 to 3°C due to higher heat loss (Rai 2018).

It is clear from Table 1 that there is 1.9°C decrease in maximum temperature under shade net structure in comparison to open field. Depending upon the shade net material used for cladding material, it reduces the light intensity/solar energy and hence reduction in temperature under shade net structure. The increase in maximum temperature under insect proof net is around 1.2°C in comparison to open field and similar trends have been reported by other researcher (Guo *et al*. 2015). The increase in maximum temperature under polyhouse is 7.1°C in comparison to open field and it is widely reported that the increase in maximum temperature under polyhouse is between 5 to 10°C (Yadav *et al.* 2014, Badji *et al.* 2022). Due to green-house effect, the temperature inside the polyhouse is always more than the open field. The greenhouse effect in polyhouse is due to two different effects i.e. (i) a confinement effect, resulting from the decrease in the air exchanges with the outside environment

**Table 1.** Mean of min$^m$ and max$^m$ temperature during winter season for meteorological week (1$^{st}$ to 9$^{th}$ and 44$^{th}$ to 52$^{nd}$) under open field and protected structures.

| Conditions | Minimum temp (°C) | | | Maximum temp (°C) | | |
|---|---|---|---|---|---|---|
| | Range | | Mean | Range | | Mean |
| Open field | 4.8 | 21.2 | 14.6 | 29.3 | 42.4 | 36.6 |
| Shade net | 4.2 | 18.8 | 12.9 | 28.5 | 40.1 | 34.7 |
| Insect proof net | 4.8 | 23.5 | 14.8 | 32.8 | 43.4 | 37.8 |
| Polyhouse | 6.0 | 22.5 | 16.2 | 38.9 | 49.8 | 43.7 |

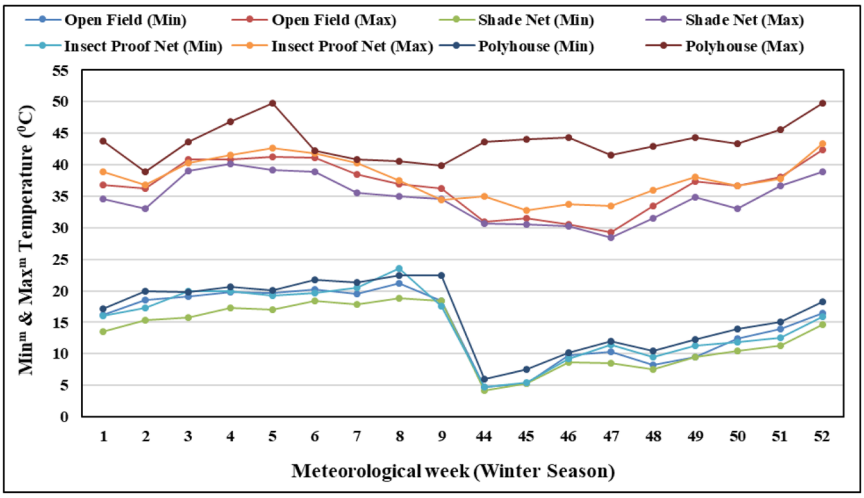


**Fig. 1.** Variation for mean of min$^m$ and max$^m$ temperature during winter season for meteorological week (1$^{st}$ to 9$^{th}$ and 44$^{th}$ to 52$^{nd}$) under open field and protected structures.

and (ii) an effect caused by the existence of a cover characterized by its low transparency to far infrared radiation (emitted by the crop, the soil and the inner greenhouse elements), but its high transparency to sunlight (Baudoin *et al*. 2013).

It is clear from Table 1 that the minimum temperature in open field varies between 4.8°C to 21.2°C with mean of 14.6°C, so depending upon actual open field temperature, there is need of protection from low temperature when it is less than 10°C. It is very clear that polyhouse is more efficient in increasing the temperature followed by insect proof net structure but shade net structure reduces the temperature. The shade net structure apart from reducing the temperature during winter season, it reduces the light intensity inside the structure, which is not at all desirable because during winter season because light intensity is in desirable range in open field. The variation for mean of min$^{m}$ and max$^{m}$ temperature during winter season for meteorological week (1$^{st}$ to 9$^{th}$ and 44$^{th}$ to 52$^{nd}$) under open field and protected structures is given in Fig. 1.

**Temperature during summer season**

The range and mean of min$^{m}$ and max$^{m}$ temperature during summer season for meteorological week (10$^{th}$ to 26$^{th}$) under open field and protected structures is given in Table 2. The mean of minimum temperature for open field, shade net, insect proof net and polyhouse are 21.3°C, 20.3°C, 23.0°C and 23.6°C respectively. The decrease in minimum temperature under shade net structure is 1.0°C and increase in minimum temperature under insect proof net and polyhouse are 1.7°C and 2.3°C respectively in comparison to open field.

**Table 2.** Mean of min$^{m}$ and max$^{m}$ temperature during summer season for meteorological week (10$^{th}$ to 26$^{th}$) under open field and protected structures.

| Conditions | Minimum temp (°C) | | | Maximum temp (°C) | | |
|---|---|---|---|---|---|---|
| | Range | | Mean | Range | | Mean |
| Open field | 20.2 | 22.3 | 21.3 | 29.3 | 42.5 | 34.6 |
| Shade net | 18.3 | 21.3 | 20.3 | 28.5 | 41.0 | 33.5 |
| Insect proof net | 21.3 | 24.5 | 23.0 | 32.5 | 45.5 | 37.8 |
| Polyhouse | 18.3 | 25.4 | 23.6 | 35.5 | 50.0 | 42.0 |

The decrease in maximum temperature under shade net structure is 1.1°C and increase in minimum temperature under insect proof net and polyhouse are 3.3°C and 7.4°C respectively in comparison to open field. Similar observations are reported during winter season for the decrease and increase in minimum and maximum temperature respectively under shade net structure and insect proof net structure and polyhouse in comparison to open field.

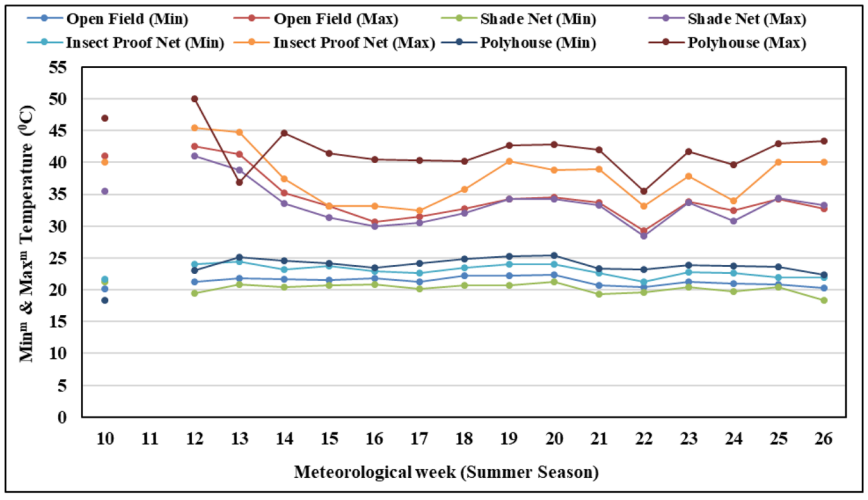


**Fig. 2.** Variation for mean of min$^{m}$ and max$^{m}$ temperature during summer season for meteorological week (10$^{th}$ to 26$^{th}$) under open field and protected structures.

It is clear from Table 2 that the minimum temperature in open field varies between 20.2°C to 22.3°C with mean of 21.3°C, So depending upon actual open field temperature, there is no need for protection from minimum temperature when it is more than 10°C. It is very clear that both the insect proof net structure and polyhouse increases the minimum and maximum temperature, which is not desirable during summer season because the open field temperature is more than required desirable temperature for cultivation of tomato and capsicum. During summer season, the shade net structure reduces both the temperature and light intensity and performs better than insect proof net structure and polyhouse. The variation for mean of $min^m$ and $max^m$ temperature during summer season for meteorological week ($10^{th}$ to $26^{th}$) under open field and protected structures is given in Fig. 2.

**Temperature during rainy season**

The range and mean of $min^m$ and $max^m$ temperature during rainy season for meteorological week ($27^{th}$ to $43^{rd}$) under open field and protected structures is given in Table 3. The mean of minimum temperature for open field, shade net, insect proof net and polyhouse are 9.4°C, 9.1°C, 10.5°C and 11.6°C respectively. The decrease in minimum temperature under shade net structure is 0.3°C and increase in minimum temperature under insect proof net and polyhouse are 1.1°C and 2.2°C respectively in comparison to open field.

**Table 3.** Mean of $min^m$ and $max^m$ temperature during rainy season for meteorological week ($27^{th}$ to $43^{rd}$) under open field and protected structures.

| Conditions | Minimum temp (°C) | | | Maximum temp (°C) | | |
|---|---|---|---|---|---|---|
| | Range | | Mean | Range | | Mean |
| Open field | 4.2 | 16.7 | 9.4 | 23.5 | 35.5 | 29.9 |
| Shade net | 3.7 | 18.0 | 9.1 | 23.8 | 35.0 | 28.6 |
| Insect proof net | 4.8 | 17.5 | 10.5 | 27.5 | 36.5 | 32.3 |
| Polyhouse | 5.2 | 19.0 | 11.6 | 32.0 | 42.5 | 37.1 |

The decrease in maximum temperature under shade net structure is 1.3°C and increase in minimum temperature under insect proof net structure and polyhouse are 2.4°C and 7.2°C respectively in comparison to open field. Similar trends have been reported during winter and summer season for the decrease and increase in minimum and maximum temperature respectively under shade net structure and insect proof net structure and polyhouse in comparison to open field.

It is clear from Table 3 that the minimum temperature in open field varies between 4.2°C to 16.7°C with mean of 9.4°C, so depending upon actual open field temperature, there is need for protection from low temperature when it is less than 10°C. Apart from

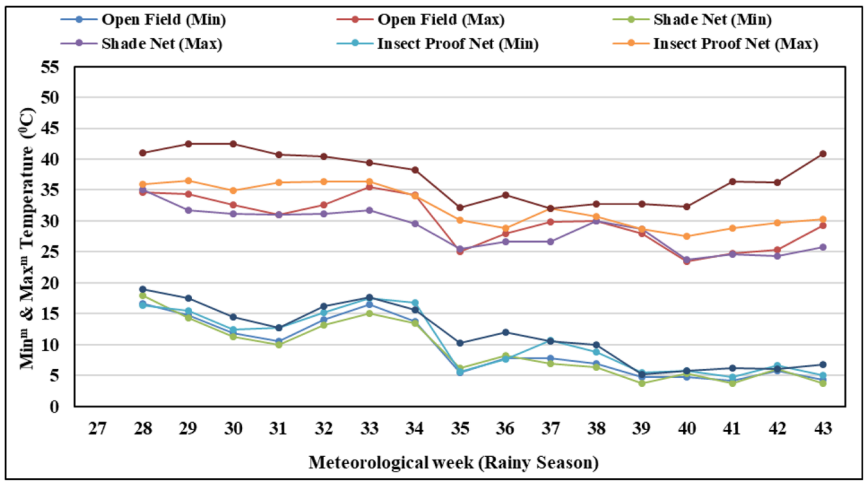


**Fig. 3.** Variation for mean of $min^m$ and $max^m$ temperature during rainy season for meteorological week ($27^{th}$ to $43^{rd}$) under open field and protected structures.

temperature, the high rainfall during rainy season is major challenge for cultivation of tomato and capsicum and polyhouse works efficiently in protecting from rainfall. Due to porous nature of net structure, the shade net and insect proof net structure do not protect from high rainfall during rainy season. The shade net structure has additional challenge during rainy season because light intensity in open field is already low and shade net material further reduces the light intensity inside the structure, which is not desirable for cultivation of tomato and capsicum.The variation for mean of $min^m$ and $max^m$ temperature during rainy season for meteorological week ($27^{th}$ to $43^{rd}$) under open field and protected structures is given in Fig. 3.

**Suitability of protected structures**

It is clear from above discussion that each protected structures i.e. shade net structure, insect proof net structure and polyhouse has certain challenges in cultivation of vegetables i.e. tomato and capsicum round the year i.e. winter season, summer season and rainy season.

The shade net structure works efficiently during summer season by reducing the temperature and light intensity but it faces challenges during winter and rainy season for cultivation of tomato and capsicum. The insect proof net structure is effective during winter season when open field temperature is not very severe but it faces challenge during summer and rainy season. The polyhouse can be utilized for cultivation of tomato and capsicum during winter and rainy season but it faces major challenge during summer season when even open field temperature and light intensity is not suitable for cultivation of tomato and capsicum and due to greenhouse effect it further increase the air temperature inside the polyhouse.

Depending upon type of protected structures i.e. shade net structure, insect proof net structure and polyhouse, the fixed cost for constructing the structure and operating cost for running the structure varies vary widely. The fixed and operating cost of constructed structure is very vital component which affects the profitability of cultivated crops, so it is very essential to minimize the fixed and operating cost. It is very essential that the constructed structure should provide suitable microclimate for round the year so that early/off-season tomato and capsicum production cycle can be followed and the constructed structure is profitable with lower carbon foot print.

It is possible to cultivate any crops in any region of the world, provided that the protected structure is properly designed and equipped to provide suitable microclimate. The two basic approach followed in protected cultivation are (i) choose a species for its high economic potential and develop the most suitable protection, growing systems and technology (ii) choose a crop suitable for existing structures within the farm and capitalize on those (Baudoin *et al.* 2013).

Normally it has been reported that in India second approach is followed i.e. first protected structures (shade net structure, insect proof net structure and natural ventilated polyhouse) are constructed then cultivation are done. But we need to follow the first approach i.e. there is need to first identify a suitable crop for its high economic potential, find out the challenges in growing the selected crop in open field and based on the challenges, there is need to identify suitable protected structure which can provide suitable microclimate such as multipurpose greenhouse (Rai 2019), temporary shade net structure (Rai 2020), plastic low tunnel (Rai 2020), rain shelter and shade net structure, protected structure with peripheral insect proof net (Rao *et al.* 2018, Rai 2021).

The polyhouse can be used for round the year cultivation but there is need to find out suitable passive cooling system for summer season with lower fixed and operating cost. Rai (2018) has developed a passive cooled detachable roof greenhouse which reduces the light intensity and decreases the inside polyhouse temperature by 2 to 3°C. Rai (2022) has used IR reflective polyhouse film to passively reduce the polyhouse temperature during summer season and it has been reported that mean temperature during summer season under IR reflective film polyhouse is 5°C lower than temperature under clear film polyhouse, which is same as open field temperature. Rai (2024) has evaluated the performance of detachable roof polyhouse with fogger and the reduction in temperature is between 2.5-7.5°C with average drop

of 6.5°C in comparison to open field.

## CONCLUSION

The open field micro climate is not very suitable for round the year cultivation of vegetables i.e. tomato and capsicum. The fully and partially controlled protected structures i.e. shade net structure, insect proof net structure and polyhouse can be constructed for providing suitable microclimates for cultivation of vegetables. The minimum and maximum temperature is recorded both under open field and protected structures and it is found that the shade net structure works efficiently during summer season by reducing the temperature and light intensity but it faces challenges during winter and rainy season due to reduction in temperature and light intensity. The insect proof net structure is effective during winter season when open field temperature is not very severe but it faces challenge during summer and rainy season. The polyhouse can be utilized for cultivation during winter and rainy season but it faces major challenge during summer season. The fixed and operating cost of protected structures affects the profitability of cultivated vegetables. There is need to develop suitable protected structure which can work round the year and if passively cooled polyhouse can provide suitable microclimate during summer season it can be utilized for round the year cultivation or otherwise based on challenges faced during cultivation of tomato and capsicum other suitable structure can be utilized.

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### REFERENCES

Badji A, Benseddik A, Bensaha H, Boukhelifa A , Hasrane I (2022) Design, technology, and management of greenhouse: A review. *Journal of Cleaner Production* 373 (12): 133753 https://doi.org/10.1016/j.jclepro.2022.133753

Baudoin W, Nono-Womdim R, Lutaladio N, Hodder A, Castilla N, Leonardi C, Pascale SD, Qaryouti M, Duffy R (2013) Good Agricultural Practices for greenhouse vegetable crops: Principles for Mediterranean climate areas. FAO, Rome. pp 616.

Ben-Yakir D, Antignus Y, Offir Y, Shahak Y (2012) Optical manipulations of insect pests for protecting agricultural crops. *Acta Horticulturae* 956: 609-615. https://doi.org/10.17660/*Acta Hortic* 2012.956.72

Gruda N, Tanny J (2015) Protected crops – recent advances, innovative technologies and future challenges. *Acta Horticulture* 1107: 271-278. https://doi.org/10.17660/ActaHortic.2015.1107.37

Guo Z, Liu H, Yuan H, Yang G, Zheng J, Chen L (2015) Insect-proof nets affect paddy field microclimate parameters and grain quality of different japonica rice varieties. *J Crop Sci Biotech* 18 (2): 73–81. http://dx.doi.org/10.1007/s12892-014-0018-0

Gurav A, Jain SK, Mhade R, Pawar A, Chavan M (2022) Comprehensive review on naturally ventilated greenhouse. *The Pharma Innovation Journal* 11 (12S): 1042-1048.

He A, Wu X, Jiang X, Maimaitituxun R, Entemark A, Xu H (2023) A study on the impact of different cooling methods on the indoor environment of greenhouses used for lentinula edodes during summer. *Agriculture* 13(8): 1560. https://doi.org/10.3390/agriculture13081560

Iyenger KS, Gahrotra A, Mishra A, Kaushal KK, Dutt M (2011) Greenhouse: A reference manual. National committee on Plasticulture Applications in Horticulture. New Delhi.

Kittas C, Katsoulas N, Rigakis V, Bartzanas T, Kitta E (2012) Effects on microclimate, crop production and quality of a tomato crop grown under shade nets. *The Journal of Horticultural Science and Biotechnology* 87(1): 7-12. https://doi.org/10.1080/14620316.2012.11512822

Mahmood A, Hu Y, Tanny J, Asante EA (2018) Effects of shading and insect-proof screens on crop microclimate and production: A review of recent advances. *Scientia Horticulturae* 241: 241-251. https://doi.org/10.1016/j.scienta.2018.06.078

Manonmani A, Thyagarajan T, Elango M, Sutha S (2018) Modelling and control of greenhouse system using neural networks. *Transactions of the Institute of Measurement and Control* 40(3): 918-929. https://doi.org/10.1177/014233121667023

Möller M, Cohen S, Pirkner M, Israeli Y, Tanny J (2010) Transmission of short-wave radiation by agricultural screens. *Biosystems Engineering* 107(4): 317-327. https://doi.org/10.1016/j.biosystemseng.2010.09.005

Rai P (2018) Development of low-cost detachable roof greenhouse for round the year cultivation of Tomato and capsicum. *Journal of Agricultural Engineering* 55(3): 66-72. https://doi.org/10.52151/jae2018551.1663

Rai P (2019) Development of low-cost multipurpose greenhouse (MGH) for round the year utilization. *HortFlora Research Spectrum* 8 (1–2): 16-20.

Rai P (2020) Application of Plasticulture Technologies in Jharkhand. Lap Lambert Academic Publishing ISBN: 978-620-2-81699-1.

Rai P (2021) Economic analysis of greenhouse cultivation. SlideShare, Retrieved on April 22, 2024, pp 1–37. from https://www.slideshare.net/pramodrai30/economic-analy sis-of-greenhouse-cultivation.

Rai P (2022) Annual Progress Report (2022-23). AICRP on PEASEM (ICAR), Ranchi Center, BAU, Kanke, Ranchi, pp 1-162.

Rai P (2024) Annual Progress Report (2023-24). AICRP on PEASEM (ICAR), Ranchi Center, BAU, Kanke, Ranchi, pp 1-131.

Rao KV, Gumasta V, Saxena CK, Patel GP, Babu VB (2018) Performance of tomato (*Solanum lycopersicum* L.) under drip irrigation with peripheral insect proof net. *Agricultural Engineering Today* 42(1): 1-5. https://doi.org/10.52151/jae2018552.1655

Sabir N, Singh B (2013) Protected cultivation of vegetables in global arena: A review. *The Indian Journal of Agricultural Sciences* 83(2): 123-135.

Sánchez-Hermosilla J, Páez F, Rincón VJ, Callejón ÁJ (2013) Evaluation of a fog cooling system for applying plant-protection products in a greenhouse tomato crop. *Crop Protection* 48: 76-81. https://doi.org/10.1016/j.cropro.2013.02.018

Serra S, Borghi S, Mupambi G, Camargo-Alvarez H, Layne D, Schmidt T, Kalcsits L, Musacchi S (2020) Photoselective protective netting improves "Honeycrisp" fruit quality. *Plants* 9(12): 1708. https://doi.org/10.3390/plants9121708

Stamps RH (1994) Evapotranspiration and nitrogen leaching during leather leaf fern production in shadehouses. SJRWMD Spec. Publ. SJ94- SP10. St. Johns River Water Management District, Palatka, FL.

Yadav RK, Kalia P, Choudhary H, Husainand Z, Dev B (2014) Low-cost greenhouse technologies for higher income and nutritional security. *International Journal of Agricultural Science and Food Technology* 5(3): 191-196.