Environment and Ecology 42 (1A) : 198—206, January—March 2024
Article DOI: https://doi.org/10.60151/envec/VQEG3728
ISSN 0970-0420

# Study the Feasibility of Round the Year Utilization of Permanent Shade Net Structure

**Amit Raj Topno, Pramod Rai**

Received 20 July 2023, Accepted 5 December 2023, Published on 6 March 2024

## ABSTRACT

A study was conducted to assess the feasibility of permanent shade net structure in comparison to open field condition for round the year cultivation. Experiment was conducted during 2016-2017 for winter, summer and rainy season. The microclimate parameters recorded were maximum and minimum temperature, light intensity and dry bulb and wet bulb temperature. The results showed that shade net lowered the temperature, light intensity and increased the relative humidity during winter, summer and rainy season in comparison to open field condition. The crops taken during round the year were i.e. winter season (pea, cabbage, cauliflower, and potato), summer season (tomato) and rainy season (spinach and coriander). During winter season under shade net structure only cabbage yield was better than open field and tomato yield during summer season under shade net structure was substantial higher than open field.

**Keywords** Light intensity, Microclimate, Open field, Permanent shade net, Temperature, Yield.

## INTRODUCTION

It is possible to cultivate any crops in any region of the world by providing suitable microclimate conditions and it can be done by proper selection of protected cultivation system. The crop cultivated in the protected cultivation system affects its economic viability. In the view of current global climate change, shortage of water resources, increasing food supply demand, prevalence of pests and diseases in crops can be mitigated by adoption of protected cultivation with more sustainability (Pachiyappan *et al.* 2022).

The productivity and quality of crops is influenced by the genetic characteristics of the cultivar, agronomical practices and microclimate conditions. Among the aforementioned factors environment is most influential which is getting unstable with climate change scenarios.

There are many challenges in maintaining the environmental condition in open field as per crop requirement. The other challenges of open field conditions are productivity and quality of produce, efficiency of resource utilization in surface irrigation

Amit Raj Topno[1], Pramod Rai[2]*

[1]Senior Research Fellow, [2]Junior Scientist Cum Assistant Professor
[1,2]Department of Agricultural Engineering, Birsa Agricultural University, Kanke, Ranchi, Jharkhand 834006, India

Email: pramod_kgp@yahoo.co.uk
*Corresponding author

(water and fertilizer), glut during production season which leads to profitability of cultivated crop.

The protected cultivation technologies address the challenges faced in open field condition and if it is planned properly the farming enterprise can be profitable and sustainable. The commonly used protected cultivation technologies are greenhouse structure, shade net structure, insect proof net structure and plastic mulching (Gowtham and Mohanalakshmi 2018). The protected cultivation system can provide suitable environmental condition such as air and soil temperature (maximum and minimum), light (quantity and quality), relative humidity.

The two basic approach followed in protected cultivation system 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).

The selection of right crop as per market requirement is most important factor for profitable farming thereafter selection of right protected cultivation system is essential which can provide suitable micro-environment. The other concerning issue is proper utilization of protected cultivation system round the year and selection of crop cycle as per available micro-environment in selected structure.

The shade net structure is normally used to reduce the light intensity and modify the light quality and it also reduces the temperature apart from other usual benefit (Wani *et al.* 2011, Mira-García *et al*. 2020). The usual vegetables taken under protected cultivation system are tomato and capsicum. During summer season in open field high temperature (air and soil) and light intensity is major challenge for cultivation of tomato and capsicum, so the permanent shade net structure can be successfully utilized for cultivation of tomato and capsicum. But the open field environment changes throughout the year, so environment inside the permanent shade net structure also changes round the year.

The Government of India promoting permanent shade structure through its scheme Mission for Integrated Development of Horticulture (MIDH) by providing subsidy to the farmers. The farmers by their own and government support constructing permanent shade net structure for cultivation of crops. As discussed above though approach one is right in selection of protected cultivation system (Baudoin *et al.* 2013) but if permanent shade net structure already constructed, it is very essential to select proper crop cycle so that already constructed permanent shade net structure can be utilized round the year to make it profitable.

Keeping the above discussion in view this study was planned to select the suitable crop during rainy and winter season based on low light intensity available inside the permanent shade net structure so that it can be utilized round the year.

## 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 during 2016-2017 for winter, summer and rainy season. For experiment different crops were taken as shown in (Table 1) and in-line drip irrigation was used for precise irrigation and fertigation with proper RDF. The low cost permanent shade net structure was constructed using bamboo, GI wire, coal tar, waste plastic, nail and cladding material. The dried bamboo of 25 cm diameter was used for constructing shade net structure. The 4 mm diameter GI wires were used to fasten the bamboo poles with the main structure. The cladding material used was shade net material (color (green)

**Table 1.** Crops taken for round the year cultivation.

| Season | Crop | Variety | RDF (kg/ha) |
|---|---|---|---|
| Winter | Peas | Arkel | 40:80:40 |
| | Cabbage | BC 76, Syngenta | 76:46:83 |
| | Cauliflower | Amazing, Sainio | 76:46:83 |
| | Potato | Lal gulab | 150:60:90 |
| Summer | Tomato | Lakshmi | 111:67:133 |
| Rainy | Spinach | All green, Euro Seed | 100:90:60 |
| | Coriander | Jyoti, Pan Seed | 50:40:30 |

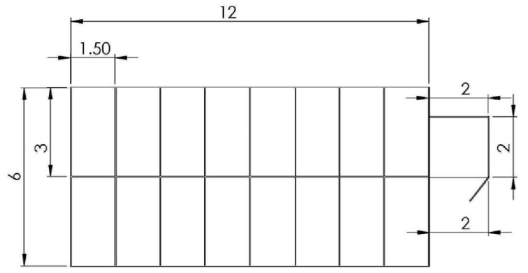


**Fig. 1.** Top view of low cost shade net structure.

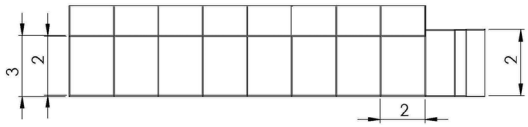


**Fig. 2.** Front view of low cost shade net structure.

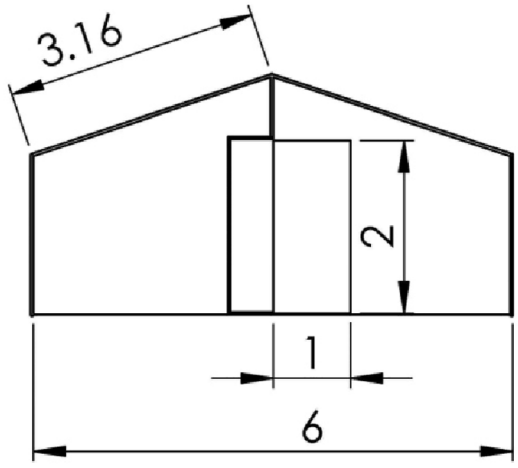


**Fig. 3.** Side view of low cost shade net structure.

and nominal shade rating (50%)). The specification of developed permanent shade net structure is, length: 12 m, width: 6 m, side height: 2 m and central height: 3 m and door: width: 1 m, height: 2 m. The top, front, side and isometric view of permanent shade net structure are shown in (Figs. 1–4).

The site used for construction of low cost permanent shade net structure was research farm of AICRP

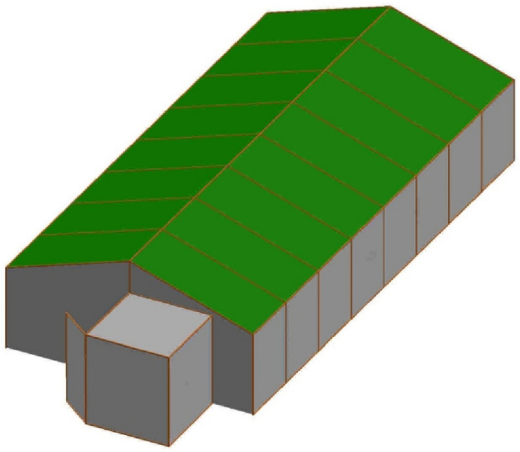

**Fig. 4.** Isometric view of low cost shade net structure.

on PEASEM and it was free from natural shades, buildings and trees. The single span gable type shade net structure was constructed with orientation of East-West. The marking the four corners as rectangle (12 m × 6 m) act as floor area and diagonal was measured for accuracy of floor area. The mark point was done at every 1.5 m distance along the length parallel sides and holes of diameter 30 cm up to 50 cm depth was done at mark points. The wrapping of sharp edges was done with waste plastic film to prevent the film from damages.

The maximum and minimum temperature in open field and shade net structure was measured using maximum and minimum thermometer (ZEAL: UK, range: -40°C to 50°C, least count: 1°C). The dry bulb and wet bulb temperature in open field and permanent shade net structure was recorded using dry bulb (db) and wet bulb (wb) hygrometer (ZEAL: UK, range: -5 °C to 50 °C, least count: 1°C), and data was recorded at 7 AM and 2 PM daily. The relative humidity (RH) was calculated from psychometric chart using dry bulb (db) and wet bulb (wb) temperature for temperature recorded at 7 AM and 2 PM The light intensity in open field and permanent shade net structure was recorded using lux meter (Lutron: Tiwan, range: 0-200 klux, least count: 0.01 lux, accuracy: ±3%) and data was recorded at 7 AM and 2 PM daily for the entire cropping period. The geometry of low cost permanent shade net structure in 2D and 3D is designed using Solidworks 2016.

**Table 2.** Environmental conditions under permanent shade net structure and open field.

| Sl. No. | Cultivation season | Environmental condition | | | | | |
|---|---|---|---|---|---|---|---|
| | | Open field | | | Shade net | | |
| | | Temperature (°C) | Light intensity (klux) | Relative humidity (%) | Temperature (°C) | Light intensity (klux) | Relative humidity (%) |
| 1 | Winter (November-February) | 3-33 | 1.01-73.56 | 24-81 | 1.5-31 | 0.5-29.42 | 26-86 |
| 2 | Summer (March-June) | 19.6-43.2 | 14.35-78.3 | 13-56 | 18-41.2 | 6.31-39.15 | 18-81 |
| 3 | Rainy (July-October) | 9-38 | 2.3-55.4 | 39-90 | 8.5-36.5 | 1.06-26.59 | 43-93 |

## RESULTS AND DISCUSSION

### Environmental conditions under permanent shade net structure

The environmental condition under open field and permanent shade net structure during winter season (November-February), summer season (March-June) and rainy season (July-October) is shown in (Table 2). The environmental condition both for open field and permanent shade net structure are range of weekly mean for minimum and maximum temperature, range of weekly mean for light intensity measured at 7 AM and 2 PM and range of weekly mean for relative humidity measured at 7 AM and 2 PM. The decrease in minimum and maximum temperature is respectively 1.5°C and 2°C. The decrease in minimum temperature may be due to non availability of solar radiation during night period as reported by (Stamps 1994, Möller *et al*. 2010) and decrease in maximum temperature is due to reduction in light intensity/ solar energy and hence reduction in temperature. The reduction in maximum temperature under shade net is affected by many factors i.e. shade factor, weaving type, color (Ilić *et al.* 2012). Similar results are reported by Rai (2020) and Shahak *et al.* (2004). Despite the fact that the basic purpose of shade net is to reduce radiation and air velocity, its effect on temperature is much more complicated. The air temperature inside the permanent shade net structure is a combined outcome of several simultaneous energy transfer processes, which include radiation exchange, convection and evapotranspiration. The shading effect certainly reduces the amount of incoming radiant energy, and thus has the potential to reduce air temperature. However, these circumstances are not always same and other effects has also crucial role (Tanny 2013).

It is clear from (Table 2) that the reduction in light intensity under permanent shade net structure is between 39%-49% in comparison to light intensity recorded for open field. The reduction in light intensity is due to shade net material (color (green) and nominal shade rating (50%)) and it is affected by shade factor, weaving type, color (Appling 2012, Mditshwa *et al*. 2019).

It is clear from (Table 2) that there is 2-5% increase in relative humidity inside the permanent shade net structure in comparison to open field condition. The increase in relative humidity inside the permanent shade net structure is due to result of water vapor being transpired by the crop and reduced mixing with drier air outside (Elad *et al.* 2007, Mditshwa *et al.* 2019). Similar observations were obtained during summer season and winter season.

Normally for successful cultivation of any vegetables the desired temperature range required is 10-30°C (Meena and Verma 2018). The desired environmental conditions i.e. temperature, light intensity and relative humidity required for cultivation of tomato and capsicum are respectively 10-28°C, 40-60 klux and 55-60% and 12-25°C, 40-60 klux and 65-70% (lyenger *et al.* 2011). It is clear from (Table 2) that there is a decrease in temperature during winter season; however it was desirable that minimum temperature should increase to make the micro climate suitable for cultivation of tomato and capsicum. Similarly there is reduction in light intensity under permanent shade net structure during winter season which is not desirable at all for culti-

**Table 3.** Growth parameters and yield of pea.

| Sl. No. | Parameters | Open | Shade net |
|---|---|---|---|
| 1 | Green pod/plant | 18-39 | 3-6 |
| 2 | Green pod wt (g)/ plant | 97-168 | 19.5-36 |
| 3 | Green pod length (mm) (range) | 38.75-95 | 43.33-95 |
| 4 | Seed yield/plant (g) | 46.5-76.5 | 12-17.5 |
| 5 | Yield (t/ha) | 20.2 | 4.3 |

vation of tomato and capsicum. Similar observation was recorded for light intensity during rainy season. Due to low light intensity during June-February in permanent shade net structure, vegetative growth is favored over reproductive growth and the fruit set are reduced for tomato and capsicum due to lack of photo assimilates affecting the productivity severely. During these months the Photosynthetic Photon Flux Density (PPFD) level is far from adequate and as light being the energy source promoting photosynthesis and growth in plants it follows that under low PPFD the other environmental factors cannot be utilized efficiently (Adegoroye and Jolliffe 1987, Schrader 2011, Collado and Hernández 2022).

## Crop performance under permanent shade net structure

### *Winter season*

During winter season the major challenge in open field is low minimum temperature but the available light intensity is in desirable range for crop cultivation. As a result, the required sunlight for optimum growth of crops is reduced under permanent shade net structure and inhibiting its biological processes. During winter season four crops were transplanted i.e. Pea, Cabbage, Cauliflower and Potato. Numbers of observations were done for its growth and physical parameters.

**Table 4.** Physical parameters and yield of cabbage.

| Sl. No. | Parameters | | Open | Shade net |
|---|---|---|---|---|
| 1 | Head size (Height) (cm) | With leaf | 12-21.5 | 21-25 |
| | | Without leaf | 9-14 | 12-18 |
| 2 | Head size (Width) (cm) | With leaf | 28.5-33 | 39-49 |
| | | Without leaf | 8-12 | 12-16 |
| 3 | Head weight (g) | With roots and leafs | 523-1141 | - |
| | | Without roots and leafs | 252-712 | - |
| | | With leaf | - | 947-1470 |
| | | Without leaf | - | 520-1044 |
| 4 | Yield (t/ha) | | 31.2 | 47.1 |

**Table 5.** Physical parameters and yield of cauliflower.

| Sl. No. | Parameters | Open | Shade net |
|---|---|---|---|
| 1 | Good | 4228 (63.67%) | 4082(73.91%) |
| | Damage | 2413 (36.33%) | 1441(26.09%) |
| 2 | Leaf (g) | 3360 | 3508 |
| 3 | Head size (cm) | 41.5-52.5 | 49-63 |
| 4 | Yield (t/ha) | 5.31 | 4.42 |

It is clear from (Table 3) that yield for pea in open field and permanent shade net structure is respectively 20.2 t/ha and 4.3 t/ha. It is clear from the yield that open field has significantly higher yield which is 64.59% more than compared to shade net structure. The number of pods in open field condition was more which ranges between 97-168 grams per plant.

It is clear from (Table 4) that yield of cabbage under open field and permanent shade net structure are respectively 31.3 t/ha and 47.1 t/ha. The yield obtained under permanent shade net structure is more than 50.5% in comparison to open field condition. Similar observation was reported for cabbage cultivation under permanent shade net structure and it produced good yield and quality (Santosh *et al.* 2017). In contrary the yield for cauliflower in open field and permanent shade net structure are respectively 5.31 t/ha and 4.42 t/ha and there is 16.8% reduction in yield of cauliflower (Table 5). The reduction in yield of cauliflower is because open field provides adequate environment for its growth. Hence, there is no need of shade net during winter season for cultivation of cauliflower. Yasoda *et al.* (2018) reported that shade net is more profitable with higher yield for off-season cultivation of cauliflower however it was cultivated during summer season.

The total yield of potato in open field is 11.8 t/

**Table 6.** Growth parameters and yield of potato.

| Sl. No. | Parameters | | Open | Shade net |
|---|---|---|---|---|
| 1 | Plant height (cm) | | 43-52 | 95-157 |
| 2 | Stem diameter (mm) | | 30-50 | 29-45 |
| 3 | Number of shoots | | 1-4 | 2-3 |
| 4 | Number of branches | | - | 0-3 |
| 5 | Leaf weight (kg) per bed ($m^2$) | | 4.8 | 10.81 |
| 6 | Tuber weight (kg) per bed ($m^2$) | | 14.2 | 9.72 |
| | Weight of 5 potato (790 g) | Length (cm) | 11-12 | - |
| | | Diameter (cm) | 5.09-5.25 | - |
| 7 | Weight of 5 potato (660 g) | Length (cm) | - | 9-10 |
| | | Diameter (cm) | - | 4.77-6.05 |
| 8 | Distribution of tuber | Big and medium | (12.59) 88.66% | (6.9) 70.99% |
| | | Small | (1.61) 11.34% | (2.82) 29.01% |
| 9 | Yield (t/ha) | | 11.8 | 8.1 |

ha whereas in permanent shade net structure it is 8.1 t/ha. The yield of potato is 37.18% higher in open field in comparison to shade net structure. Schulz *et al.* (2019) reported that shading has no influence on the emergence of potato. There are number of factors affecting potato tuber yield such as nitrogen, cultivar, planting density, spacing of tubers and climatic conditions of the region (Putz 1989). The (Table 6) shows the size distribution for big and medium size of potato in open field and permanent shade net structure is respectively 88.66% and 70.99%. The tuber size is primarily influenced by the size of the seed tubers and the conditions under which they are grown (Schulz *et al.* 2019).

The environmental conditions under permanent shade net structure during winter season are discussed in details in section 3.1. Due to permanent nature of structure the light intensity also reduced during winter season which is not desirable for cultivation of tomato and capsicum. The selection of crops i.e. pea, cabbage, cauliflower and potato were done during winter season keeping above facts into consideration. The selected crops i.e. pea, cabbage, cauliflower and potato is successfully and profitably cultivated in open field condition without any protection from environmental condition. It is very clear from the results obtained for pea, cauliflower and potato that the yield under permanent shade net structure is reduced in comparison to open field condition except for cabbage.

**Table 7.** Plant growth parameters of tomato.

| Sl. No. | Parameters | Open | Shade net |
|---|---|---|---|
| 1 | Plant height (cm) | 33-41 | 61-148 |
| 2 | Stem height (cm) | 0.5-3 | 2-7.5 |
| 3 | Stem girth (mm) | 7.53-13.59 | 6.35-9.21 |
| 4 | Internodal length (cm) $I^{st}$ and $III^{rd}$ | 0.5-3 and 1-3 | 1-4 and 2-4.5 |
| 5 | No. of nodes/plant | 29-66 | 14-81 |
| 6 | Yield (t/ha) | 35.6 | 74.8 |

***Summer season***

In general light intensity and maximum temperature is high during summer season and these are more than the desired range for cultivation in open field. The summer is among the most challenging season for cultivation because the intensity of sunlight influences the evaporation, high water requirement, transpiration, wilting conditions to plants. During the summer season plant height of tomato in permanent shade net structure is found higher as compared to open field condition as shown in (Table 7). According to Singh *et al.* (1994) and Tehlan and Malik (2010) reported that shade net affected the height of plants. The thickness of stem girth is more in open field in comparison to shade net structure. It is observed that internodal length is higher in permanent shade net structure with less number of nodes per plant. Similar results were also reported by Chitwood *et al.* (2012).

The shade net material reduce the maximum temperature and light intensity during summer season. Normally during summer season average light intensity in open field is around two times of light intensity available in during winter season. The light intensity available in open field during winter season is in desirable range required for cultivation of tomato. So cultivation of tomato under permanent shade net structure during summer provides more suitable micro climate condition than micro climate available in open field. Due to high light intensity

**Table 8.** Crop yield of spinach and coriander during rainy season.

| Sl. No. | Condition | Spinach | | Coriander | |
|---|---|---|---|---|---|
| | | First crop (yield) t/ha | Second crop (yield) t/ha | First crop (yield) t/ha | Second crop (yield) t/ha |
| 1 | Open | 68.4 | 74.1 | 10.3 | 69.6 |
| 2 | Shade net | 42.1 | - | 13.5 | - |

sun burn is major challenge for tomato cultivation during summer season which reduces the marketable yield of cultivated tomato Rai (2020). The shade net material not only increases the yield of tomato but it also increases the marketable yield of tomato. Ilić *et al.* (2017) reported the significant increase in the total fruit yield of tomato during summer season under colored shading nets. Kittas *et al.* (2012) reported that increasing the intensity of shading >40% decreased flowering and fruit yield of tomato.

***Rainy season***

For rainy season, two crops spinach and coriander were taken for study. In rainy season light intensity in open field is already low due to cloudy day which obscures the incoming solar radiation. The yield recorded for spinach for open field and under permanent shade net structure is found to be respectively 68.4 t/ha and 42.1 t/ha as shown in (Table 8). It is observed that spinach yield in open field is 47.60% higher than permanent shade net structure. However, excess rainwater during rainy season exceeds the saturation capacity of the soil and high humidity creates numerous challenges for cultivation. Due to above reason low yield for spinach was also reported by Meena and Vashisth (2014). The weight distribution of spinach crop in open and shade net is found to be 76.04% and 57.48% respectively. Though no irrigation water was given to spinach under permanent shade net structure during cultivation period but it has excess moisture due to high rainfall. However during dry spell open field spinach was irrigated two times. Soil moisture in shade net is more as compared to open field thus farmers can take advantage of it by allow using less irrigation water on their crops and contribute to water conservation across the globe during winter and summer season (Tezcan *et al.* 2023).

**Table 9.** Physical parameters of crops in open vs shade net during rainy season.

| Sl. No. | Condition | Crop | | | |
|---|---|---|---|---|---|
| | | Spinach | | Coriander | |
| | | Plant height (cm) | Weight distribution (%) | Plant height (cm) | Weight distribution (%) |
| 1 | Open | 6-10 | 76.04 | 15 | 33.33 |
| 2 | Shade net | 6.5-8 | 57.48 | 18 | 87.78 |

The yield recorded for coriander in open field and under permanent shade net structure is found to be 10.3 t/ha and 13.5 t/ha respectively. The shade net provides better microclimate as compared to open field thus influences the performance of coriander with higher yield (Rajasekar *et al.* 2013, Ashok 2021). The plant height and weight distribution of spinach and coriander are given in (Table 9). The plant growth was more vigours under permanent shade net structure in comparison to open field.

There is reduction in yield of spinach for first crop under permanent shade net structure in comparison to open field but the second crop could not cultivated successfully under shade net structure. In contrary the yield of coriander for first crop was higher under permanent shade net structure in comparison to open field but the second crop of coriander could not cultivated successfully under shade net structure. So it is very difficult to cultivate even coriander leaf during rainy season. The high relative humidity inside the permanent shade net structure and no protection from rainfall is major challenge which needs to be addressed for successful cultivation of crops. Keeping plant height of spinach and coriander into consideration, there is no need to cultivate these crops under permanent shade net structure during rainy season. The plastic low tunnel technology with application of suitable cladding materials i.e. UV stabilized film (50 micron), shade net material (color (green) and nominal shading rate (50%)) and insect net proof material (40 mesh) can be utilized for providing suitable micro climate condition for cultivation of spinach and coriander. The plastic low tunnel technology will be more economical than permanent shade net structure for cultivation of these crops (Rai 2020).

## CONCLUSION

The study investigated the feasibility of permanent shade net structure compared with open field for round the year cultivation. The microclimate parameters (maximum and minimum temperature, light intensity and dry bulb and wet bulb temperature) were recorded and crops were cultivated i.e. winter season (pea, cabbage, cauliflower, potato), summer season (tomato) and rainy season (spinach and coriander) to study the feasibility of permanent shade net structure for round the year cultivation. The shade net lowered the temperature and light intensity and increased the relative humidity during winter, summer and rainy season in comparison to open field condition due to permanent nature of shade net material. It is very essential to first select the profitable crop cycle for round the year cultivation before constructing the permanent shade net structure. Based on the microclimate requirement for selected crops, the protected cultivation system should be selected and its utilization for round the year is very important parameter before selecting the protected cultivation system.

## ACKNOWLEDGMENT

The author expresses his sincere gratitude to the Indian Council of Agricultural Research, New Delhi for providing financial facilities through the AICRP on PEASEM (earlier PET), BAU, Ranchi to carry out the research work.

### REFERENCES

Adegoroye AS, Jolliffe PA (1987) Some inhibitory effects of radiation stress on tomato fruit ripening. *J Sci Food Agric* 39 (4) : 297—302. https://doi.org/10.1002/jsfa.2740390404.

Appling S (2012) Colored shade cloth affects the growth of basil, cilantro, and parsley (Doctoral dissertation, Virginia Tech).

Ashok AD (2021) Performance of Coriander (*Coriandrum sativum* L.) var. CO (CR) 4 under different growing environment and seasons. *Int Res J Adv Sci Hub* 3 (Special Issue 7S) : 87—90.

Baudoin W, Nono-Womdim R, Lutaladio N, Hodder A, Castilla N, Leonardi C, Pascale S De, Qaryouti M (2013) Good Agricultural Practices for greenhouse vegetable crops-Principles for Mediterranean climate areas. Food and Agriculture Organization of the United Nations. Rome, Italy.

Chitwood DH, Headland LR, Filiault DL, Kumar R, Jiménez-Gómez JM, Schrager AV, Maloof JN (2012) Native environment modulates leaf size and response to simulated foliar shade across wild tomato species. *PLoS One* 7 (1) : e29570. https://doi.org/10.1371/journal.pone.0029570. s

Collado CE, Hernández R (2022) Effects of light intensity, spectral composition, and paclobutrazol on the morphology, physiology, and growth of petunia, geranium, pansy, and dianthus ornamental transplants. *J Pl Growth Regulation,* pp 1—18. https://doi.org/10.1007/s00344-021-10306-5.

Elad Y, Messika Y, Brand M, David DR,Sztejnberg A (2007) Effect of colored shade nets on pepper powdery mildew (Leveillulataurica). *Phytoparasitica* 35 : 285—299. https://doi.org/10.1007/BF02981163.

Gowtham T, Mohanalakshmi M (2018) Influence of growing environment on growth and yield parameters of coriander under shade net and open field condition. *Madras Agric J* 105 (7/9): 332—335. https://doi.org/10.29321/ MAJ. 2018.000155.

Ilić ZS, Milenković L, Stanojević L, Cvetković D, Fallik E (2012) Effects of the modification of light intensity by color shade nets on yield and quality of tomato fruits. *Scientia Horticulturae* 139 : 90—95. https://doi.org/10.1016/j.scienta.2012.03.009.

Ilić ZS, Milenković L, Šunić L, Barać S, Mastilović J, Kevrešan Ž,Fallik E (2017) Effect of shading by colored nets on yield and fruit quality of sweet pepper. *Zemdirbyste-Agriculture* 104(1) : 53—62. https://doi.org/10.13080/ z-a.2017. 104.008.

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 J Horticult Sci Biotech* 87(1) : 7—12. https://doi.org/10.1080/14620316.2012.11512822.

Mditshwa A, Magwaza LS, Tesfay SZ (2019) Shade netting on subtropical fruit: Effect on environmental conditions, tree physiology and fruit quality. *Scientia Horticulturae* 256 : 108556. https://doi.org/10.1016/j.scienta.2019.108556.

Meena K, Verma SC (2018) Climate change and vegetable crops cultivation: A review. *Ind J Agricult Sci* 88(2) : 167— 174. https://doi.org/10.56093/ijas.v88i2.79158.

Meena RK,Vashisth A (2014) Effect of microenvironment under different color shade nets on biophysical parameters and radiation use efficiency in spinach (*Spinacia oleracea* L.). *J Agricult Physics* 14 (2) : 181—188.

Mira-García AB, Conejero W, Vera J, Ruiz-Sánchez MC (2020) Leaf water relations in lime trees grown under shade netting and open-air. *Plants* 9 (4) : 510. https://doi.org/10.3390/plants9040510.

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

Pachiyappan P, Kumar P, Reddy KV, Kumar KNR, Konduru S, Paramesh V, Niranjan S (2022) Protected cultivation of horticultural crops as a livelihood opportunity in western India: An economic assessment. *Sustainability* 14 (12) : 7430. https://doi.org/10.3390/su14127430.

Putz B (1989) Kartoffeln: Züchtung, Anbau, Verwertung, Behr's Verlag: Hamburg, Germany.ISBN: 3-925673-45-8.

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

Rajasekar M, Arumugam T, Kumar S (2013) Influence of weather and growing environment on vegetable growth and yield. *J Hortic For* 5(10) : 160—167. https://doi.org/10.5897/JHF 2013.0317.

Santosh DT, Tiwari KN, Singh VK (2017) Influence of different protected cultivation structures on water requirement of winter vegetables. *Int J Agricult Environ Biotechnol* 10 (1) : 93—103. https://doi. org/10.5958/2230-732x.2017. 00004.3.

Schrader LE (2011) Scientific basis of a unique formulation for reducing sunburn of fruits. *Hort Sci* 46(1) : 6—11. https://doi. org/10.21273/HORTSCI.46.1.6.

Schulz VS, Munz S, Stolzenburg K, Hartung J, Weisenburger S, Graeff-Hönninger S (2019) Impact of different shading levels on growth, yield and quality of potato (*Solanum tuberosum* L.). *Agronomy* 9(6) : 330. https://doi.org/10.3390/agronomy9060330.

Shahak Y, Gussakovsky EE, Gal E, Ganelevin R (2004) Color Nets: Crop protection and light-quality manipulation in one technology. In VII International Symposium on Protected Cultivation in Mild Winter Climates: Production, Pest Management and Global Competition 659 pp 143—151).

Singh D, Gill APS, Kumar R (1994) Effect of summer shading on the plant growth and flower production of standard Carnation (*Dianthus caryophyllus* L.) cv Espana under sub-tropical condition of Punjab. *J Ornam Horticult* 2 (1-2): 51—53.

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

Tanny J (2013) Microclimate and evapotranspiration of crops covered by agricultural screens: A review. *Biosystems Engg* 114 (1) : 26—43. https://doi.org/10.1016/j.biosystem seng.2012.10.008.

Tehlan SK, Malik TP (2010) Influence of different shade intensities and varieties on leaf yield of coriander during summer. Abstract Book National Seminar on Recent Trends in Horticulture crops issues and strategies for Research and development. CCS Haryana Agricultural University. Hisar, pp 123.

Tezcan N, Taşpinar H, Korkmaz C (2023) Effects of shade nets on the microclimate and growth of tomato. *J Agricult Sci* 29 (2) : 443—454. https://doi.org/10.15832/ankutbd.1073156.

Wani KP, Singh PK, Narayan N, Khan SH, Amin A (2011) Prospects of vegetable production in cold arid region of Ladakh, Achievement and future strategies. *Int J Curr Res* 33 (6) : 10—17.

Yasoda PGC, Pradheeban L, Nishanthan K, Sivachandiran S (2018) Effect of different shade levels on growth and yield performances of cauliflower. *Int J Environ, Agric Biotechnol* 3(3) : 948—955. https://doi.org/10.22161/ijeab/ 3.3.30.