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# Effect of Cladding Materials on Greenhouse Microclimate and Biometric Growth of Gerbera (*Gerbera Jamesonii L.*) in Subhumid Subtropics

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**ABSTRACT**

The use of new cladding films as greenhouse covering is spreading out in protected cultivation. The selection of suitable cladding has tremendous influence on crop production capability. Although, their effects on vegetable production received much attention, few studies focus on floricultural crops. In the present study, the efficacy of two cladding materials (UV stabilized and Diffused) of greenhouse on the microclimate and biometric growth of Gerbera was investigated during winter and summer seasons of the year 2009. The effect of greenhouse cladding on the microclimate and crop growth was considerable. Diffused film maintained 3°C and 1.5°C less temperatures during winter and summer respectively against commonly used UV stabilized film. The reduction of incoming solar energy in the UV stabilized and diffused films were 60 and 50% in winter and 80 and 70% in summer with internal shading and fogging. The biometric performance of gerbera was superior in the diffused film to the UV stabilized film in terms of plant height, leaf area index and flower yield. Although, reduction of greenhouse temperatures in the diffused film is less in summer (1.5°C), but its effect was prominent in getting sustained flower yield (7 flowers/$m^2$) during summer as compared to the UV stabilized film (4 flowers/$m^2$). The statistical analysis on Gerbera growth inferred that Yanara was superior both in terms of leaf area index (3.42) and flower yield (8 flowers/$m^2$) as compared to others and thus evolved as most suitable techno-economic cultivar in subhumid subtropics.

**Key words :** Biometric growth, Cladding material, Diffused film, Floriculture, Gerbera, Microclimate.

The diversity of cladding materials for the greenhouse and other plant production structures increased dramatically during the past four decades (Geocomelli *et al*. 1990). The cladding material of the greenhouse influences the amount and type of solar radiation at the canopy which directly affects the plant growth. In addition, the microclimatic factors such as relative humidity and carbon dioxide concentration are also get affected by the type of glazing material. The economic viability of using energy-efficient cladding materials depends not only on their cost and energy saving potential but also on the conducive microclimate that affects crop biometric growth (Hemming *et al*., 2006). Hence, a careful thought is necessary in the selection of suitable cladding materials based on their capabilities and shortfalls in general and development of a relationship within overall greenhouse crop production system in particular.

Summer cooling by fan and pad system in subtropics presents some limitations such as increased humidity, lack of environmental uniformity and high inputs of energy and water (Kacira, 2007). Adjustable shading and high pressure fogging to reduce the direct effect of heat load in the greenhouse has limitations such as reflecting back essential photo-synthetically active radiation (PAR) and affecting the flower quality (Cerney *et al*., 1999; Zanon, 2000; Glacer *et al*., 2000). Hence, the use of new cladding films by reflecting back the unwanted near infrared radiation and to create favorable microclimate for crop growth is necessary for floricultural production in subtropics (Kumar *et al*., 2009).

Earlier research in subtropics conducted by Zhang *et al*., (1996) and Garcia *et al*., (2001) on the extensive energy and microclimate assessment of different greenhouse covering materials inferred that new cool plastic films (films that block a part of near infrared radiation) are suitable for maintaining good biometric growth in terms of height, vegetative growth and commercial yield of vegetable crops as compared to that of standard UV stabilized film. Arcidiacono *et al*. (2001) compared the effect of different greenhouse covering materials (Polythene film, Insect-proof net and a Photo-selective red colored film) on the microclimate of greenhouse tomato cultivation during summer. The greenhouse covered with the insect-proof net maintained temperatures similar to those recorded outside while the photo selective film was not effective in controlling the temperature rise during summer.

Cemek *et al*. (2006) studied the effects of different covering films like UV stabilized, IR absorbed, single layered and double layer polyethylene on aubergine growth and productivity. The final yield of plants grown in double layer polythene cover were higher among others and where as light transmission was highest in single layer polythene, intermediate in UV stabilized and IR absorbed and the lowest in double layer poly houses. The plants in double layer greenhouse grew faster (more leaves and flowers) than other type of greenhouses. Kittas *et al.* (2006) evaluated the effect of two UV absorbing cladding materials on the eggplant (soil less) and concluded that UV absorbing film with 0% transmission to UV light are about are about 21% taller and have about 17% higher leaf product (leaf length × width) than the plants grown in the greenhouse with 5% transmission to UV light.

An overview of the above pertinent literature revealed the fact that although there is a considerable progress in the evaluation of new cladding materials in terms of microclimate and crop growth for vegetables, studies related to floricultural crops for Indian climate are limited. Hence, there is a need to carry out in-depth investigation concerning the effects of cladding material on microclimate and behavior of floricultural crop under subtropical climate. The present study addresses the problem of controlling summer temperatures favorable for gerbera cultivation by evaluating two cladding films suitable for subhumid subtropics of India.

## MATERIAL AND METHODS

### Greenhouse Facilities, Crop Cultivation and Irrigation System

The experiment has been performed in two similar East-West oriented Sawtooth shapes of greenhouses covered with UV stabilized and Diffused films located at Agricultural and Food Engineering Department, Indian Institute of Technology, Kharagpur, India, during winter and summer seasons of the year 2009 (Fig.1). The dimensions of greenhouses are as follows: eaves height of 3 m, ridge height of 4.5 m, floor area of 84 m$^2$ with length and width as 14 m and 6 m respectively. The greenhouses were equipped with ridge and side ventilation equal to 60% of the floor area and covered with insect proof net of 20-mm size to eliminate the risk of high temperatures (Harmanto *et al.*, 2006). In addition, shade net (50% perforation) was placed from inner side of the greenhouses covering 50% and 100% of the gutter area in winter and summer months to avoid scorching effect to the crop.

Soil, farmyard manure, rice husk and fine sand were mixed in the proportion of 3:3:3:1 to improve soil aeration and better drainage ((NCPAH, 2000). Optimum soil pH ranging from 5.5 to 6.5 was maintained by adding lime at a rate of 2 kg m$^{-2}$. Disinfection of the soil was done by spraying Formalin at a rate of 450 ml per square meter and the soil was covered with a plastic film for 6 to 8 weeks to get rid of the fungus Phytophthora, which is a menace to the gerbera culture**.** Single super phosphate (0:20:0) @ 2.5 kg per 100 ft$^2$ and $MgSO_4$ @ 0.5 kg per 100 ft$^2$ was added for better root establishment and to take care of the magnesium deficiency. Plenty of organic matter in the form of well rotted farmyard manure was added to improve soil's physical health. Raised beds of size 60 cm wide 45 cm height were prepared in the greenhouses and two rows of Gerbera were planted in the greenhouse with spacing of 37.5 cm 30 cm and plant density of 8 to 10 plants per square meter. A pathway of 30 cm was maintained in between the beds to facilitate easy movement for cultural operations. Initial irrigation for crop establishment was applied using overhead micro sprinklers for four weeks to ensure uniform root development. Later, irrigation water was quantified as per the requirement of the crop and supplied through inline drippers of 2 lph capacity.

### Experimental design and treatments

Four varieties of gerbera such as Esmara, Yanara, Osiris and Popov were planted on the raised beds of the greenhouses as shown in Fig.2. The statistical design used in the experimentation was split-plot completely randomized block design consisting of greenhouse covers as main plots and cultivar rows as subplots comprising four replications (4R) of each distributed randomly among the greenhouse subplots. Plant height, number of leaves, leaf area index (LAI), stalk length, flower diameter and yield per meter square area were used to describe the crop biometric performance.

### Measurements

#### Climate

The following microclimatic data were recorded outside and inside the greenhouses.

- Air temperature (T,°C), Vapor pressure deficit (e, kPa) by means of combined sensor of the model HMP 45 C installed at 1.25 m above the ground level.
- Global radiation ( $R_g$, in Wm$^{-2}$) and PAR ($R_p$ in Wm$^{-2}$) by means of pyranometers of

the model (SPLITE) and PARLITE of Kipp and Zonen with quantum sensitivity of 5.42 $\mu$ v/$\mu$ m by installing them at the diagonal centre of the greenhouse at a height of 1.5 m above the floor.

All the above measurements were logged at an interval of 30 minutes by means of a data logger (CR1000), Campbell Scientific, Canada. However, in the present study, the measurements of three times of the day i.e., 8:30 AM, 12:30 PM and 4 PM are taken for analysis and to show the trends by considering them as the effective lag timings. In addition, the temperatures of greenhouse components such as cover, canopy, soil and shade net were monitored three times a day as above by infrared thermometer manually to get inference on the performance covering materials.

**Spectral properties**

Measurement of the spectral transmittance of two cladding materials were made in the laboratory using a portable spectrometer equipped with glass halogen lamp and an external integrating sphere internally coated with barium sulphate. Measurements were carried out on samples taken before the installation of the films ion the greenhouses. These laboratory measurements were shown in Table 1.

**Crop Biometric Growth**

A series of non-destructive measurements were made in twelve replications of each greenhouse four times during the experimental period i.e., 30 DAT, 60 DAT and 90 DAT and 180 DAT. However, in the present study, the performance of varieties in terms of growth parameters (plant height, leaf area index and flower yield) was assessed at two stages, i.e., after 90 and 180 days after plantation coinciding winter and summer months of the year 2009. The results were statistically interpreted for the plant height, leaf area index and flower yield. All the data collected from the greenhouses during field experiments were analyzed using the statistical tool of M-Stat C.

## RESULTS AND DISCUSSION

### Greenhouse microclimate

### Effect on temperature and vapor pressure deficit

Fig 3(a) shows effect of two cladding films on the temperature of greenhouses at 8:30 AM during winter. It is apparent from the figure that weekly average temperatures in the greenhouse covered with UV stabilized film varied from 21 to 29°C, against outside condition (22 to 29°C). On the contrary, air temperature in the greenhouse covered with diffused film varied from 20 to 29°C with less marginal difference (1°C). On the other hand, the temperature variation during summer in UV stabilized and diffused films are 30 to 38°C and 30 and 36°C, respectively against ambient condition (29 to 37°C) with a temperature difference of 2°C between the films. Marginal temperature difference of 1 to 2°C was observed between the greenhouses at 8:30 AM in both winter and summer seasons. However, during the effective heating period, i.e., from fifth week of the experiment (DAT 30 to DAT 48) remarkable decrease (2 to 3 °C) in the temperature was observed in both the covers. From seventh week onwards (DAT 49) an increasing trend in the temperature was observed in general and less diffused film temperatures in particular due to inbuilt property of the film.

The temperature variations in cladding films at 12:30 PM are shown in Fig3 (b). Maximum temperature difference (3°C) was observed in diffused film at 12:30 PM than that of UV stabilized film (1°C) during winter. In summer, no temperature difference was observed between the covers of the greenhouses due to intermittent fogging. On the other hand, the variation of temperature at 4:00 PM in winter also followed similar trend of 12:30 PM, where as in summer, it is less (1°C) except in fifth week (34 DAT).

Overall, the temperature variation in the UV and diffused covers during winter and summer seasons indicated that the UV stabilized film maintained slightly higher temperature than the temperature desirable for gerbera production during summer. In contrast, the diffused film maintained 2°C less temperature than the UV stabilized film during summer months which was found beneficial for gerbera production. The combined results on seasonal variation of temperature between the two greenhouse covers indicated that the effect of cover properties was more prominent in the winter season than in the summer season. On an average, the diffused film maintained 3°C less temperature than the UV stabilized film during winter and in summer, it was less in summer (2°C) due to the effect of intermittent fogging.

No vapor pressure differences were observed between the two covers of greenhouses irrespective of the seasons during three times of the day because of the effect of more ventilation area provided from ridge and sides. However, slightly less vapor pressure deficit was observed during 12:30 PM in the diffused film due to less internal temperatures and more crop canopy.

**Effect on solar radiation**

Laboratory measurements of film spectral transmittance conducted with the spectroradiometer indicated that they have equal transmittance in PAR (400-700 nm), blue (400-500 nm) and green to red (500-700 nm). However, transmittances in the blue region are lower than those from green to red. The radiation levels in the greenhouse during three times of the day in winter shows that similar trend i.e. the effect is much pronounced in winter season than that of summer. The variation at 8:30 AM in winter ranged from 15 to 35 and 17 to 43 W $m^{-2}$ in the UV stabilized and diffused covers, respectively against the summer (12 to 26 and 20 to 35 W $m^{-2}$). On the other hand, the effect of cladding films at 12:30 PM ranged from 24 to 48 W $m^{-2}$ and 38 to 75 W $m^{-2}$ in the UV stabilized and diffused covers in winter season against summer (14 to 40 W $m^{-2}$ and 24 to 42 W $m^{-2}$). The effect at 4.00 PM in winter and summer seasons varied from 8 to 24 W $m^{-2}$ and 10 to 32 W $m^{-2}$ and 4 to 7 W $m^{-2}$ and 4 to 10 W $m^{-2}$, respectively in UV and diffused films.

It is apparent from Fig. 4(a-c) that the solar radiation between the films during different times of the day is comparable in winter season than that of summer. The amount of incoming radiation in the diffused film was always more than the UV stabilized film in both the seasons except at 4:00 PM. Change in the radiation level is due to typical climatic conditions prevalent in the eastern region which is generally associated with cloudiness in summer. On the whole, it was observed that the reduction of solar radiation in the UV stabilized and diffused films were 60% and 50% in winter and 80% and 70% in summer throughout the experimental period and it was favorable for gerbera production (Fig.5).

**Effects on crop biometric growth**

**Effects on height and leaf area index**

The effects of cladding films on the gerbera plant height and leaf area index is presented in Figs. Plant height in the UV stabilized and diffused films are almost same at the establishment stage and the initial dates of sampling. It gradually differ only after 60 DAT (Days after transplantation) and continued up to the time of flowering. Leaf area index increased from UV stabilized cover to diffused cover right from establishment stage to the flowering stage in both seasons of the year. Moreover, the plants in the greenhouse covered with diffused film were relatively healthy (less attack of mites) compared to the UV stabilized greenhouse during summer season. The value of the plant height and leaf area index in the UV film is 14% and 2% lower than the Diffused film greenhouse at the end of the experiment (120 DAT).

At the experimental stage, the attack of spider mite was greater in the summer season in the UV stabilized covered greenhouse, which adversely affected plant growth parameters such as height and leaf area index. Another reason could be a change in the external climate (from winter to summer) and the effect of fogging operation, which created a congenial atmosphere for the attack of pests in the greenhouse covered with UV film. In general, leaf area index in the greenhouse covered with diffused film was more in the summer season than in the winter season due to less attack of pests and diseases (Fig.6).

**Stalk length and flower diameter**

The effect of cladding materials on stalk length and flower diameter is presented in Figs. As flowering of gerbera starts after two months of planting, observations on stalk length and flower diameter were recorded after two months. It is observed that the stalk length and flower diameter followed similar trend in both the covers of greenhouse with greater values in the diffused cover, especially flower diameter. The average flower diameter in the diffused cover reduced from 13 cm to 8 cm and 9 cm to 6 cm in the UV stabilized cover during summer. The less flower diameter in both the covers of greenhouse during peak summer could be attributed to fogging operation performed to equalize or to reduce the greenhouse temperatures.

**Flower yield**

Marketable monthly flower yield recorded from the experimental greenhouses is shown in Figs. It is apparent that both greenhouse covers have similar trend of yield commenced after two months of planting, but the flower maturity under diffused cover occurred 10 days earlier than that of UV stabilized covered greenhouse. At commencement of flowering season, the yield tremendously increased (11 flowers/$m^2$) in the diffused cover. However, the yield trend was reverse in the UV stabilized cover (4 flowers/$m^2$) at the initial flowering. After that, both the greenhouse covers maintained an increasing trend of flower yield (Fig.7)

**Statistical Analysis**

The effect of two greenhouse cladding materials on the growth of four cultivars of gerbera (Esmara, Osiris, Popov and Yanara) at two critical stages is shown in Tables 2-6. It is evident that the plant growth parameters varied significantly among the four cultivars at two stages of crop growth, i.e., at flowering (90 days after planting) and at maturity (180 days after planting). The statistical analysis revealed that the plant height of gerbera is significantly influenced by variety at flowering and maturity stages (Table 2). However, the interaction effect is not significant among the four cultivars (Esmara, Osiris, Popov and Yanara). Among the cultivars, plant height at flowering stage was highest in Popov (35.6 cm) which was significantly superior to that of Esmara and Yanara as the extent of increase was higher than that of Least Significant Difference (LSD) value (3.05). However, it is on a par with that of Osiris as the extent of increase was lower than the LSD value. On the other hand, at the maturity stage, the highest plant height was recorded with Osiris (38.5 cm) which is found to be significant to Popov, but on a par with that of Yanara and Esmara. Diffused cover greenhouse resulted in significantly superior plant height (35 cm) at the flowering stage, whereas its superiority was non-significant (NS) at the maturity stage. There is no significant difference with respect to interaction effect of these treatments.

The leaf area index (LAI) varied significantly between the films at both flowering and maturity stages (Table 3). The diffused cover resulted in significantly superior LAI compared to the Quonset shape at flowering stage, but the trend is reverse at the maturity stage. Among the four cultivars, Yanara maintained its superiority in leaf area index both at flowering and maturity stages, with LAI values of 3.42 and 4.51, respectively. The lowest LAI was recorded with Popov and Esmara at flowering and maturity stages respectively. The LAI of three varieties viz., Esmara, Osiris and Popov did not show any significant difference as their extent of superiority was lesser than corresponding LSD value at both flowering and maturity stages. The interaction effect revealed that the popov variety under diffused cover resulted in highest LAI which was found to be significantly superior to that of all the varieties grown under UV stabilized cover (Table:4).

Flower yield is significantly influenced by the greenhouse shape at flowering stage but not at the maturity stage (Table 5) Sawtooth shape resulted in superior flower yield (6.62 flowers/$m^2$) compared to the Quonset (5.75 flowers/$m^2$) at flowering stage. However, the superiority of the Sawtooth greenhouse over Quonset greenhouse in terms of flower yield is not statistically significant at the maturity stage. With respect to the varieties, Yanara recorded significantly superior flower yield (8.87 flowers/$m^2$) at flowering stage which was significantly superior to all the three varieties. However, there was no significant difference among the varieties in terms of flower yield at the maturity stage. In general, the flower yield exhibited an increasing trend from the flowering stage to maturity stage for all the varieties except Yanara. The interaction effect revealed that the Yanara variety under Diffused cover resulted in highest flower yield, which was significantly superior to that of all other treatments (Table: 6)

Overall, based on the results of the crop performance under two covers of greenhouse, it can be inferred that the effect of greenhouse cover is prominent on the biometric growth of different cultivars of gerbera. Among the cultivars of gerbera, Yanara maintained its superiority both in terms of leaf area index and flower yield as compared to other varieties. Performance of other varieties such as Osiris and Esmara are almost same under greenhouse conditions. Maintaining more leaf area index under greenhouse conditions is directly related the crop yield resulting in enhanced transpirational cooling. The variety which yields high leaf area index and flower yield can be recommended as a suitable cultivar under greenhouse for subhumid subtropics. Thus, Yanara variety emerged as the most suitable cultivar for greenhouse cultivation in subhumid subtropics.

## Conclusions

UVstabilized and Diffused films had considerable influence on the microclimate and biometric growth of gerbera in winter season than in the summer season. Air temperature in the UV stabilized film was always greater than the diffused film in both the seasons. On an average, the diffused film maintained 3°C and 1.5°C less temperatures during winter and summer seasons respectively as compared to the UV stabilized film. Though the reduction of greenhouse temperatures in the diffused film against the UV film is less in summer (1.5°C), its effect is comparable as the flower yield (7 flowers/$m^2$) during summer as compared to the UV stabilized film (4 flowers/$m^2$). It was further observed that the reduction of solar radiation in the UV stabilized and diffused films (60 and 50% in winter and 80 and 70% in summer) proved to be favorable for gerbera production. The statistical analysis on the performance of four varieties of gerbera under greenhouse conditions inferred that cultivar Yanara maintained its superiority both in terms of leaf area index (3.42) and flower yield (8 flowers/$m^2$) as compared to other varieties (Popov, Esmara and Osiris). Maintaining more leaf area index is directly related to the crop yield, and hence the cultivar Yanara is recommended for greenhouse cultivation so as to ensure greater economic benefits.

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