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Effect of Different Shade Net Structures on Reference Crop Evapotranspiration

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ABSTRACT

Shade net structures provide favorable environment for the crop growth there by for achieving greater yield and high quality produce. Accurate irrigation scheduling in protected cultivation structures is one of the important factors in achieving higher yields and avoiding loss of quality. Stevenson's screens were installed to monitor the different climatological parameters i.e. maximum and minimum temperature, relative humidity, vapor pressure in shade net houses as well as open field. An investigation was carried out to evaluate the effect of red and green (35, 50 and 75% shade) shade net houses as well as open field cultivation condition (control) on reference crop evapotranspiration (ETr) during kharif, rabi and summer season using Hargreaves-Samani method. Study showed that the ETr at different structures was reduced by about 11.47, 15.84, 22.61 and 24.31% in red and green with 35, 50 and 75% shades, respectively in comparison to control. The ETr values during the study period were varied from 5.41 to 7.3 mm for red, 4.69 to 7.30 mm for green (35%), 4.20 to 6.85 mm for green (50%) shade and 4.11 to 7.05 mm for green (75%) shade net house, while the same was 6.03 to 7.67mm for the control plot.

Key words: *Temperature, Relative humidity, Shade net house, Reference crop evapotranspiration, Hargreaves-Samani method*

Highlights

Estimation of reference crop evapotranspiration using Hargreave-Samani equation for the red, green (35, 50 and 75% shade) shade net houses and for control plot.

INTRODUCTION

India is a leading country in area and production after china in many fruits and vegetables in the world accounting roughly 10% and 15% respectively, of total global production. India produced 93.70 million metric tonnes of fruits and 176.17 million metric tonnes of vegetables[11]. However, India is lagging far behind while considering the total agricultural production. The reason is predominantly use of years back technology and cultivation practices is also traditional leading to low productivity. There are different ways to revive from this situation.

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Bringing additional area under vegetable cultivation, use of hybrid seeds and use of improved agro-techniques are some of the important ways to increase the vegetable production[15]. Another approach is cultivation under protected environment. Uncontrolled avail of harsh climate like high wind, hot and humid climate, an extreme cool to extreme hot forces to the farmer and scientist to develop a technology for cultivation of crops under prevailing adverse climatic conditions. Research results have shown that by adopting protected cultivation, productivity of vegetable crops can be increased by 3 to 5 times as compared to open environment[14].

Crops grown in open fields of a semi-dry climate were subjected to the direct sunlight, high temperature and wind resulting in high crop evapotranspiration (ETc), therefore, demanding large amount of water. In contrast, shade net houses favour plant growth by avoiding the former conditions.

Farmers in arid/ semi-arid regions of the world use shade nets in protective cultivation on a large scale. The role of shed net in achieving higher productivity through modified micro climate, protection against the adverse climatic condition, insects and pest attacks has been quoted by many scientists. However, very limited research is available on the effect of colored nets and its shading on its water requirement.

Shade net house is a framed structure made of materials such as GI pipes, angle iron, wood or bamboo. It is covered with plastics net which are made of 100% polyethylene thread with specialized UV treatment having different shading percentages. It provides partially controlled atmosphere and environment by reducing light intensity and effective heat during day time to crops grown under it. It promotes seasonal and off-seasonal cultivation round the year. Shading nets are used in tropical and subtropical countries for vegetable production[3,7]. The need of protected cultivation since last 10 years has been dramatically increased. The various cause are reduced weed pressure, moisture conservation, reduction of certain insect pests, higher crop yields, and more efficient use of soil nutrients[10].

Crops need water in particular quantities for their optimum growth. Excessive or deficit amounts of water could retard crop growth and ultimately lower the crop yields. Conditions influencing the rate of water use by crops include the type of the crop, its growth stage, climatic parameters *viz.* temperature, wind velocity, humidity *etc*., available water supply and soil characteristics[13,9].

One of the most debated issues in irrigation science is to estimate the ETo using weather data[5]. Reliable estimation of evapotranspiration (ET) is of great importance for the computation of irrigation water requirements, water resources management and determination of water budget[4]. Reference evapotranspiration (ETr) is the amount of evapotranspiration that is expected at a location with specified reference conditions under the actual weather conditions. The ETr is multiplied by a crop coefficient (Kc) to determine actual ET from ETr. The crop coefficient is obtained with respect to type of the plant, maturity of the plant and local factors such as soil type[8]. The evapotranspiration rate is normally expressed in millimeter (mm) per unit time. The rate expresses the amount of water lost from a cropped surface in units of water depth. The time unit can be an hour, day, week, month or even an entire growing period or year.

The different methods for estimation reference crop evapotranspiration includes Thornthwaite method[17], Blaney and Criddle method[2], Pristly-Taylor Method[12], FAO Radiation method and FAO-24 pan evaporation Method[5], Hargreaves-Samani Method[6], Penman-Monteith Method[1] *etc*. FAO have recommended Penman- Monteith method for estimating ETr. The Modified Penman-Monteith model, which has solid physical principles, could be used to estimate the water requirements for greenhouses and shad net houses. This model requires input atmospheric condition measurements inside the structure. The recent study showed that the Penman-Monteith method provides more consistently accurate ETr estimates in open field condition. But this method needs many climatological parameters, which may not be always available particularly in a shade net house therefore it is necessary to adopt other methods that need data less climatological parameters and give estimate as close as possible to ETr given by Penman-Monteith method. The Hargreaves-Samani method (HSM) is preferably used for estimation of ETr in the shade net houses. It only needs daily maximum and minimum temperature, hence same was selected. In present study an attempt was made to estimate the reference evapotranspiration under different shade net structures.

MATERIAL AND METHODS

The study was carried out at Department of Irrigation and Drainage Engineering, Dr.ASCAE, MPKV, Rahuri, Dist - Ahmednagar, Maharashtra State. The Mahatma Phule Krishi Vidyapeeth, Rahuri is located within $19^0$20' N latitude and $74^0$38' E longitude and at altitude of 532m above the mean sea level.

Meteorological instruments

Different meteorological instruments/devices were used to monitor the climatological parameters that influence evapotranspiration. It includes anemometer, solar radiation sensor, rain gauge sensor, relative humidity sensor, air temperature sensor, Stevenson's screen etc.

The Stevenson's screen or instrument shelter is an enclosure to shield meteorological instruments against precipitation and direct heat radiation from outside sources, while still allowing air to circulate freely around them. It forms a part of standard weather station. The Stevenson's screen holds instrument that may include maximum, minimum, dry bulb and wet bulb thermometer etc. Its purpose is to provide a standardized environment to measure temperature, humidity, dew point and atmospheric pressure.

Meteorological data

The daily meteorological data was recorded for the period of one year (1^{st} January to 31^{st} December 2014) from ET monitoring station, installed in the open field at the Instructional farm of department of Irrigation and Drainage Engineering, Dr. ASCAE, MPKV Rahuri. The different climatological parameters monitored by ET station include maximum and minimum temperature, relative humidity, vapor pressure, bright sunshine hours, wind speed and rainfall. Similarly, separate Stevenson's screens were installed to monitor the different climatological parameters in shade net houses as well as open field, respectively. Figure 1 shows the installation of Stevenson's screen in the experimental area.

(a) open field (b) red shade net (c) green shade net (35% shade)

(d) green shade net (50% shade) (e) green shade net (75% shade) (f) Experimental area

Fig. 1: Installation of Stevenson's screen in the experimental area

Methods for estimation of reference crop evapotranspiration

Various methods are available in literature to compute reference crop evapotranspiration (ETr). However, the selection of a particular method depends on availability of data, accuracy of data, accuracy needed in estimation and suitability of data to climatic condition. Hargreaves-Samani method was used to calculate ETr.

Hargreaves - Samani method

The equation developed for solar radiation as a function of extraterrestrial solar radiation as well as maximum and minimum temperature difference by Hargreaves-Samani method (HSM) represented by equation (1).

$$ETr = 0.0023 \times Ra \times (Tmean+17.8) \times (Tmax-Tmin)^{0.5} \quad (1)$$

Where,

ETr = Average potential evapotranspiration (mm day^{-1})

Ra = Extraterrestrial radiation (mm day^{-1})

Tmax= maximum temperature (^{0}C)

Tmin= minimum temperature (^{0}C)

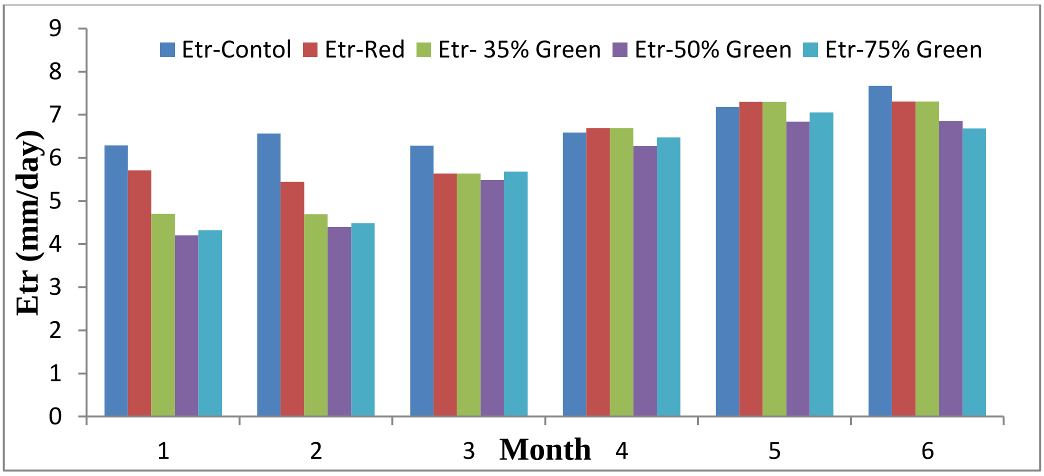
Tmean= mean temperature (^{0}C)

Statistical analysis

The study carried out to observe the effect of two factors *viz.* different types of shade net houses and time of the year. Factorial experiment with Randomized Block design (RBD) was used and analysis was carried out using SAS 9.3 software. Each experiment was replicated three times. Tukey test was applied for the multiple pair-wise comparisons of the data according to Snedecor and Cochran[16].

RESULTS AND DISCUSSION

The values of reference crop evapotranspiration **(**ETr) for open field, red shade net house and green shade net house (35, 50 and 75% shaded) were estimated by using Hargreaves-Samani method (HSM) using the daily data recorded from the Stevenson's screen.



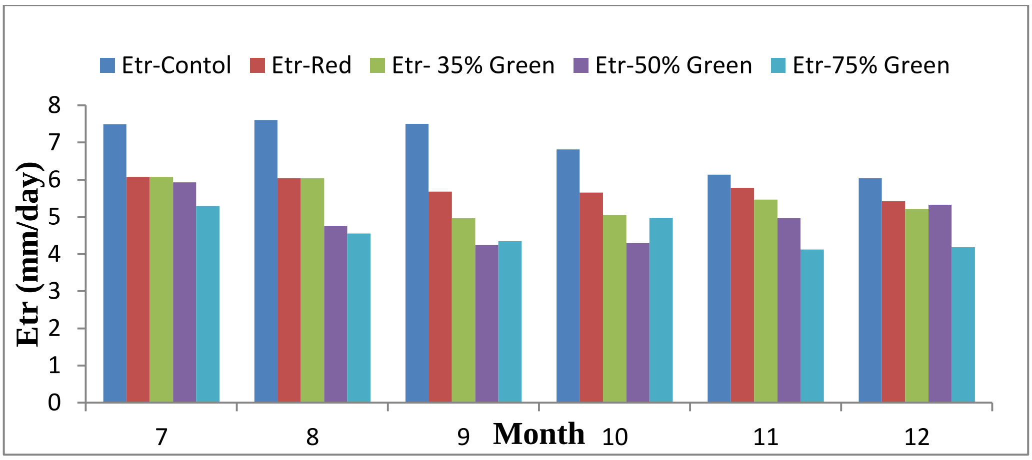


Fig. 2: ETr variation in different shade net and control condition by using Hargreaves-Samani method

The variation in ETr from January to December in different shade net and control condition is shown in Fig.2 (a & b). Table 1 shows average value of ETr, best fit polynomial equation of reference crop evapotranspiration. The Monthly ETr values estimated by using HSM method were showed that higher ETr was observed in month of April, May and June while minimum in January and February month. Summary of polynomial equation for monthly ETr estimated by HSM method in each of five structures. Based on these results, the 50% green shade net polynomial ranked first with highest coefficient of determination (R^2=0.99) followed by 35% green (R^2=0.96), open field (R^2=0.94), 75% green (R^2=0.93) and Red shade(R^2=0.91).

Table 1. Average value of ETr, best fit polynomial equation

Field	**Mean ETr**	**Best fit polynomial equation**	**R^2**
Open field	6.846	$y = -4E\text{-}05x^6 + 0.0021x^5 - 0.0374x^4 + 0.2973x^3 - 1.061x^2 + 1.6921x + 5.4335$	0.94
Red shade	6.060	$y = -4E\text{-}05x^6 + 0.0004x^5 + 0.0187x^4 - 0.3669x^3 + 2.2947x^2 - 5.1255x + 8.9367$	0.91
35% green	5.761	$y = -8E\text{-}05x^6 + 0.0016x^5 + 0.003x^4 - 0.2656x^3 + 1.9091x^2 - 3.9918x + 7.0504$	0.96
50% green	5.291	$y = -0.0002x^6 + 0.0051x^5 - 0.0511x^4 + 0.135x^3 + 0.3887x^2 - 1.2413x + 4.9619$	0.99
75% green	5.181	$y = 0.0001x^6 - 0.0073x^5 + 0.1394x^4 - 1.2586x^3 + 5.3801x^2 - 9.2239x + 9.3374$	0.93

Note: Y= Observation values of climatological parameters, x= Meteorological days

Table 2. ANOVA for effect of shade net colour and month on Etr throughout year

Source	**Model**	**Replication**	**Shade-net**	**Month**	**Shade-net × Month**
F value	11.70^{**}	0.10^{NS}	60.81^{**}	32.55^{**}	2.55^{**}

R^2 = 0.8580, CV = 8.84, Mean evapotranspiration = 5.8295, ** = Significant at 1% level of significance, ^{NS} = Non-significant.

Table 3. Tukey comparison for least squares means in each shade net

Shade net	Open	Red	35% Green	50% Green	75% Green
Mean	6.846^a	6.060^b	5.7614^b	5.291^c	5.181^c

Means with the same letter are not significantly different

From analysis of variance (ANOVA) Table.2, it was observed that the effect of shade-net structures was significantly different at 1% level of significance, with coefficient of determination of 0.8580, coefficient of variance 8.84 and the mean ETr 5.8295. Tukey test showed that the effect of different shade net and month differed significantly at 1% level of significance. From analysis it was observed that there is significant difference between open and red shade net. However the red and green shade net (35% shade) were at par with each other while latter differed significantly from green shade net (50% shade). There was no significant difference between 50% and 75% green shade nets.

CONCLUSION

Hargreaves-Samani methods (HSM) were used for estimation of reference evapotranspiration (ETr) using climate data for one year. From the above data we can conclude that, evapotranspiration in open field is higher comparing to red and green shade net. It also showed that the ETr at different shade net structure was reduced by about 11.47%, 15.84%, 22.61% and 24.31% respectively in Red, Green 35%, Green 50% and Green 75% comparison to open field cultivation. The polynomial line equation in six degree was found to be the best fit for all shade net structures on monthly basis. Hargreaves – Samani method can be adopted for estimation ETr in shade net house. The ETr values during the study period varies from 5.41 mm to 7.3 mm for red shade net house, 4.69 mm to 7.30 mm for 35 % green shade net house, 4.20 mm to 6.85 mm 50% green shade net house and 4.11 mm to 7.05 mm for 75% green shade net house and 6.03 mm to 7.67mm for open field .

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