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Study on change in microenvironment under different colour shade nets and its impact on yield of spinach (*Spinacia oleracea* L.)

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ABSTRACT

Field experiment was undertaken at research farm of IARI, New Delhi to study the effect of change in the microenvironment under different colour shade nets during summer and rainy season, of 2012 on yield of spinach. Spinach crop was sown under different colour shade nets such as red, green, black, white along with control (without shade net) during summer and rainy season. Crop duration from sowing to harvesting was 62 days in summer and 58 days in rainy season. Different weather parameters were measured at regular interval in each treatment. Results showed that the light intensity, incoming radiation, canopy temperature, air temperature, soil temperature were found to be lower under different colour shade nets compared to the control. However the relative humidity, soil moisture were found to be higher under colour shade nets compared to control.

Key words: Spinach, light intensity, radiation, percentage reflectance

Spinach (*Spinacia oleracea* L.) is vegetable crop, grown in winter season. During summer season (off season) crop encounters various stresses such as extreme temperature, high light intensity, humidity, wind speed etc. Crop grown in open condition also gets affected from various pests and diseases. Nets are commonly used to protect agricultural crops from excessive solar radiation, extreme temperature and pests. In recent period, nets are used for reducing thermal load, improving microenvironment, and providing physical protection. Colour nets represent new agro-technological concept, which aims combining physical protection with different filtration of solar radiation, promoting desired physiological response. The utilization of solar radiation by vegetable crops is based on selective filtration of light by different colour shade nets with special optical properties that modify the quality of natural radiation. Use of shade nets aims to optimize desirable physiological responses, in addition to providing physical protection and the substantial effect on shoot elongation, branching and flowering in ornamentals crops (Oren-Shamir *et al.*, 2001). The colour shade nets approach was evaluated in ornamentals (Nissim-Leval., 2008), vegetables (Fallik *et al.*, 2009) and fruit trees (Shahak *et al.*, 2004). Coloured shade nets not only exhibit special optical properties that allow the control of light, but also have the advantage of influencing the microclimate to which the plant is exposed and offer physical protection against excessive radiation, insect pests and environmental changes (Shahak *et al.*, 2004). Shade nets are frequently used to protect agricultural crops from excessive solar radiation, improving the thermal climate (Kittas *et al.*, 2009). The air temperature was lower than that of ambient air, depending on the shading intensity. Shade net not only decrease light quantity but also alters light quality to a varying extent and might also change other environmental conditions (Smith *et al.*, 1984).

Relative humidities are often higher under nets than outside as a result of water vapour being transpired by the crop and reduced mixing with drier air outside the netted area (Elad *et al.*, 2007). Nettings, regardless of colour, reduce radiation reaching crops underneath. Obviously, the higher the shade factor, the more radiation will be blocked. Reductions in radiation resulting from netting will affect temperatures (air, plant, soil) and relative humidities (Stamps, 1994). Nets also reduce wind speeds, which can affect temperatures, relative humidities,

Table 1: Spectral indices measured under different colour shade nets.

Spectral indices	Control(without Shade nets)	White shade net	Black shade net	Red shade net	Green shade net
NDVI	0.37	0.42	0.67	0.73	0.77
RVI	1.74	2.17	5.06	6.48	7.59

Table 2: Yield (kg ha^{-1}) under different colour shade nets.

Season	Control	White	Black	Red	Green
Summer	8950 ±256	10931 ±146	11078 ±183	14232 ±256	14893 ±330
Rainy	2525±64	1530±34	1465±30	2605±96	3580±94

and gas concentrations resulting from reductions in air mixing. These changes can affect transpiration, photosynthesis, respiration, and other processes (Rosenberg *et al.*, 1983). Shade nets not only decrease light quantity but also alters light quality, might also change other environmental conditions which determine the commercial value of crop, including yield, product quality, and rate of maturation (Shahak *et al.*, 2004).

Shade nets are often deployed over crops to reduce heat stress (Elad *et al.*, 2007) however, in enclosed net shade houses, temperatures during the day are typically higher than outside (Perez *et al.*, 2006; Stamps, 1994) and may be lower at night, at least during radiation freezes (Stamps, 1994). Diffuse light has been shown to increase radiation use efficiency, yields (both at the plant and ecosystem level), and even be a factor affecting plant flowering timing and amounts (Guenter *et al.*, 2008). Any shade nets can scatter radiation, especially ultraviolet because nets are usually made using ultraviolet-resistant plastic (Wong, 1994). Shade nets that increases light scattering but does not affect the light spectrum that has been shown to increase branching, plant compactness, and the number of flowers per plant (Nissim-Levi *et al.*, 2008). Keeping the above point in view the present study was done to investigate the change in the microenvironment under different colour shade nets.

MATERIALS AND METHODS

A field experiment was conducted on the sandy loam soil of research farm of IARI, New Delhi during 2012 with spinach crop. The crop (varity Pusa Bharti) was grown during summer and rainy season with drip irrigation under different colour shade nets for generating different microenvironment along with control (without shade nets). These colour shade nets (white, black, red, green) having distinct transmittance spectra in the visible range, and no modification under control (without shade net) condition. The knitting density of each net was designed to provide 40% shading in the photosynthetically active radiation region. The microenvironment and production under these colour shade were compared with the open field microenvironment and production. Color shade nets were obtained from Polysack Plastics Industries (Nir-Yitzhak, Israel) under the trade mark ChromatiNet. The shading nets were mounted on a structure about 1.5 m height over the plants. Crop duration from sowing to harvesting is sixty two days in summer and fifty eight days in rainy season. Plot size for each treatment was 27 m^2 .Total water supply in each treatment for whole growing season in summer was 3378 liter with help of drip irrigation. Soil texture of experimental sites was sandy loam. Ph was 8.0, organic matter content was 0.25%, and EC was 0.81, rich in average phosphorus and potassium.

Weather parameter like temperature and relative humidity were measured under different colour shade along with control (without shade nets) by pocket weather tracker at 11 A.M. Light measurements were carried out periodically under the shade nets, to monitor the actual light conditions to which the plants were exposed. All measurements were done on clear days at noon. The light intensity was measured by the digital light meter. The photosynthetically active radiation as well as reflected radiation by plant under different colour shade nets was measured by the line quantum sensor around 11A.M. Percentage reflectance under different colour shade along with control (without shade net) was measured using spectroradiometer in the wavelength range of 350-2500 nm. Various spectral indices like normalized difference vegetation index (NDVI), ratio vegetation index were calculated using reflectance at different wavelength as

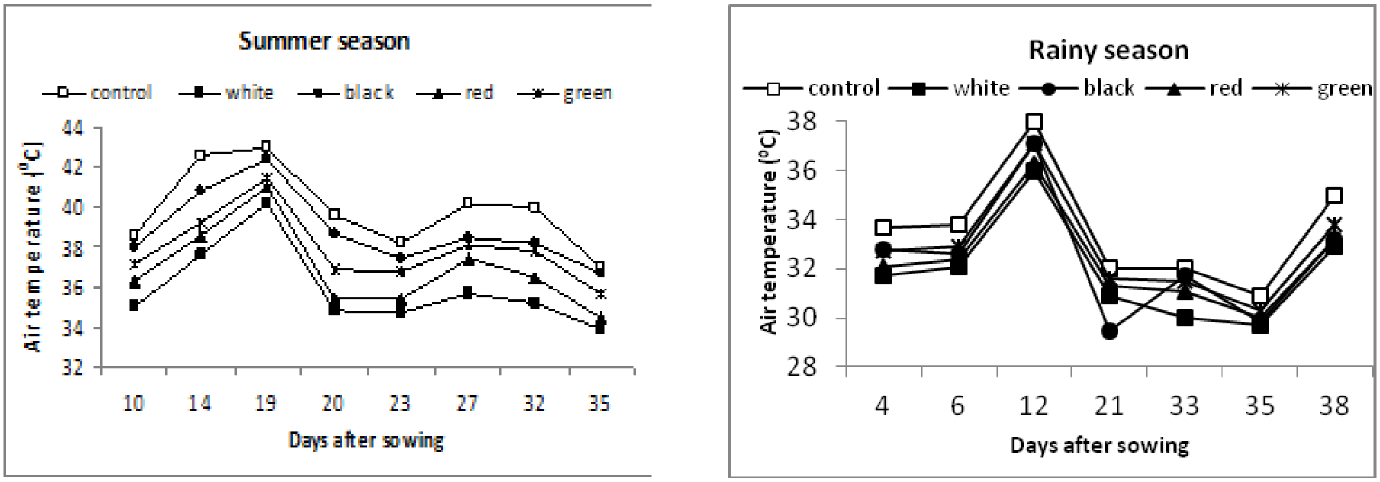

Fig.1: Air temperature under different colour shade nets along with control during summer and rainy season.

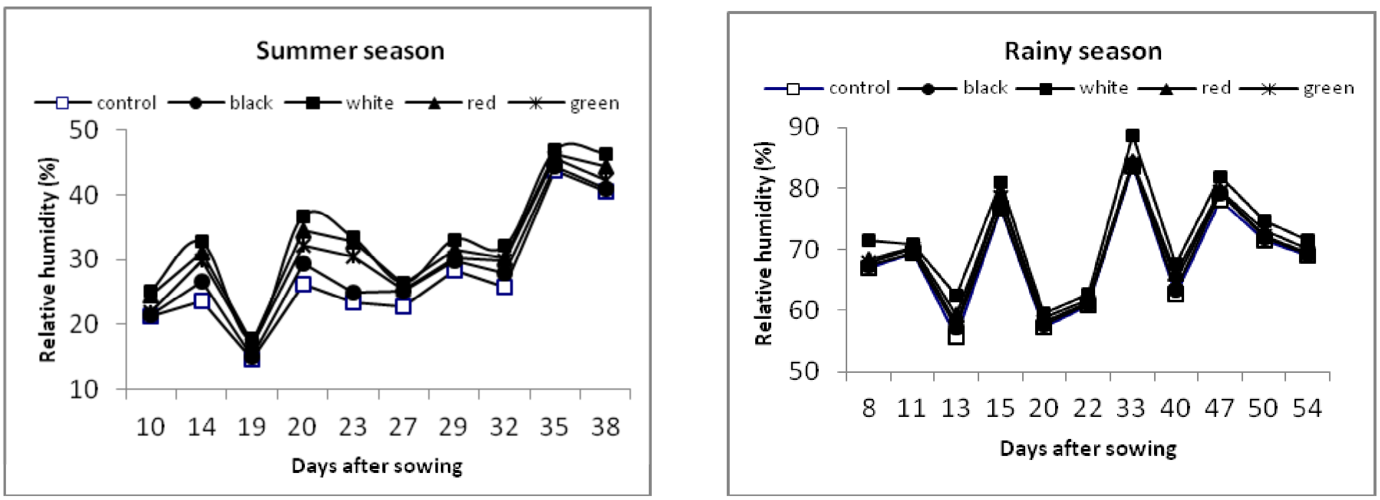

Fig.2: Relative humidity under different colour shade nets along with control during summer and rainy season

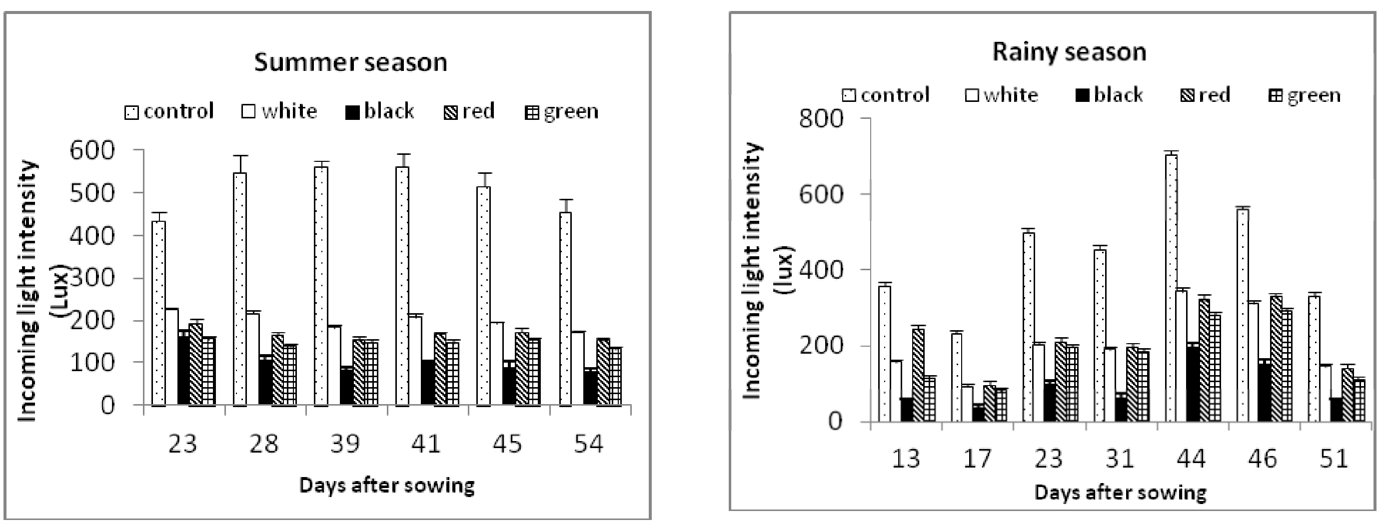

Fig.3: Light intensity measured at 11 A.M. under different colour shade nets along with control during summer and rainy season

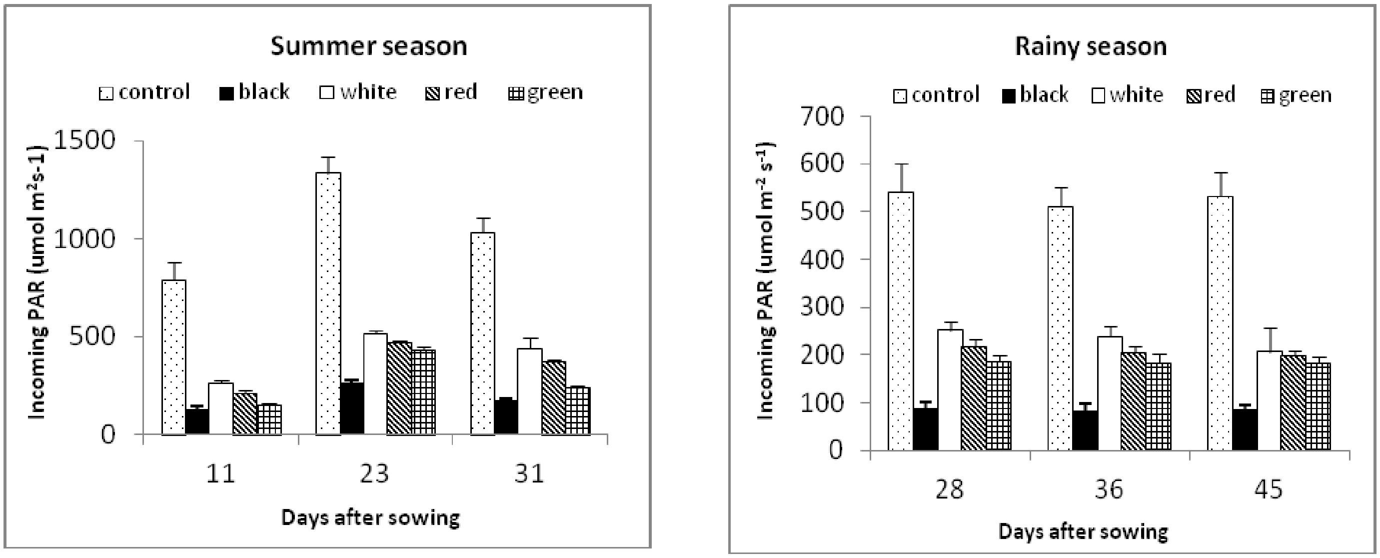

Fig.4: Incoming photosynthetically active radiation under different colour shade nets along with control during summer and rainy season

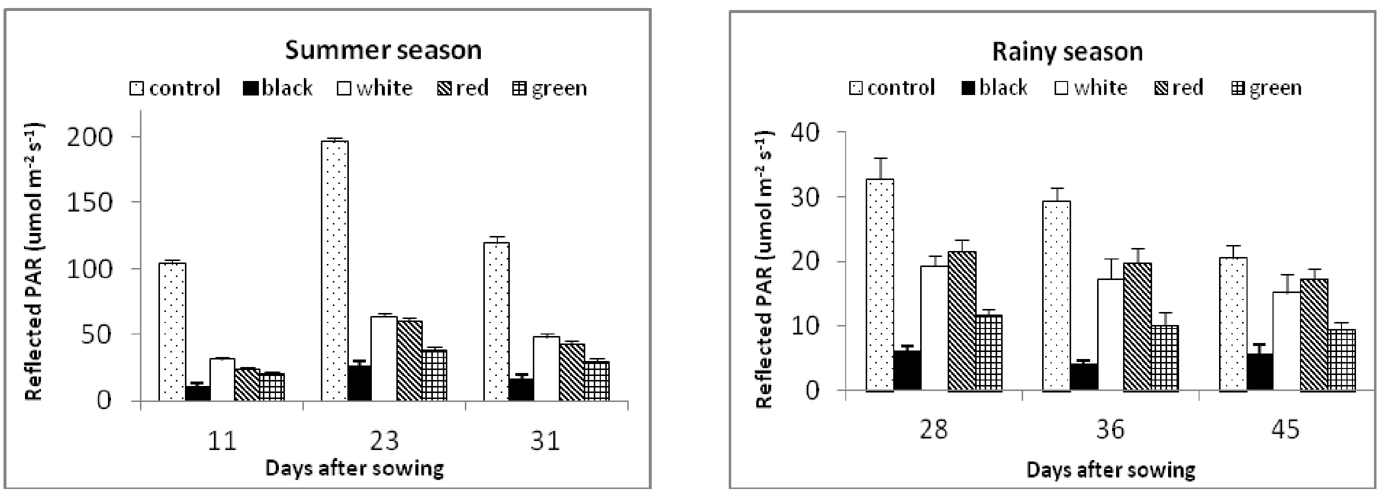

Fig.5: Reflected photosynthetically active radiation under different colour shade nets along with control during summer and rainy season

given in following formulas:

$$\text{Normalized difference vegetation index (NDVI)} = \frac{(NIR_{800} - R_{670})}{(NIR_{800} + R_{670})}$$

$$\text{Ratio Vegetation Index (RVI)} = \frac{NIR_{800}}{R_{670}}$$

Canopy temperature was measured using infrared thermometer. The data for each colour shade nets was mean of three reading. Soil temperature at different depth measured at 2 P.M.

RESULT AND DISSCUSION

Microenvironment under different colour shade nets

Due to different colour shade nets, light intensity varies under net, which play significant role in modify microclimate under nets. Under shade the temperatures were less than the control, the reduction was 1.6-5°C under white shade net, 1.3-3.6°C under red, 1.2-3.4°C under green, 0.4-1.9°C under black shade net. Maximum temperature difference with respect to control was found in white, followed by red, green and black. Temperature was found to be higher in control followed by black, green, red and white shade nets. In rainy season temperature difference under colour shade and control was lower than summer. The reduction was 1.1-3.6°C under white, 0.9-2.5°C under red, 0.4-1.3°C under green, 0.1-1.1°C under black shade net. Temperature was lower than control, followed by red, green and black. Similar to summer

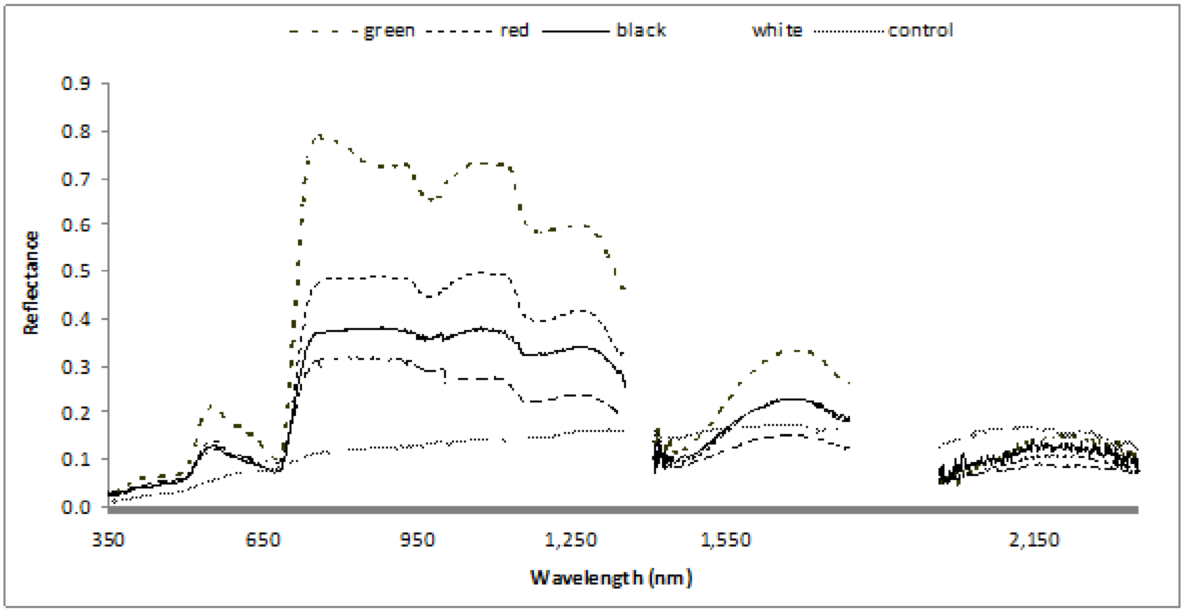

Fig.6: Percentage reflectance under different colour shade nets along with control measured at 45 days after sowing during summer season

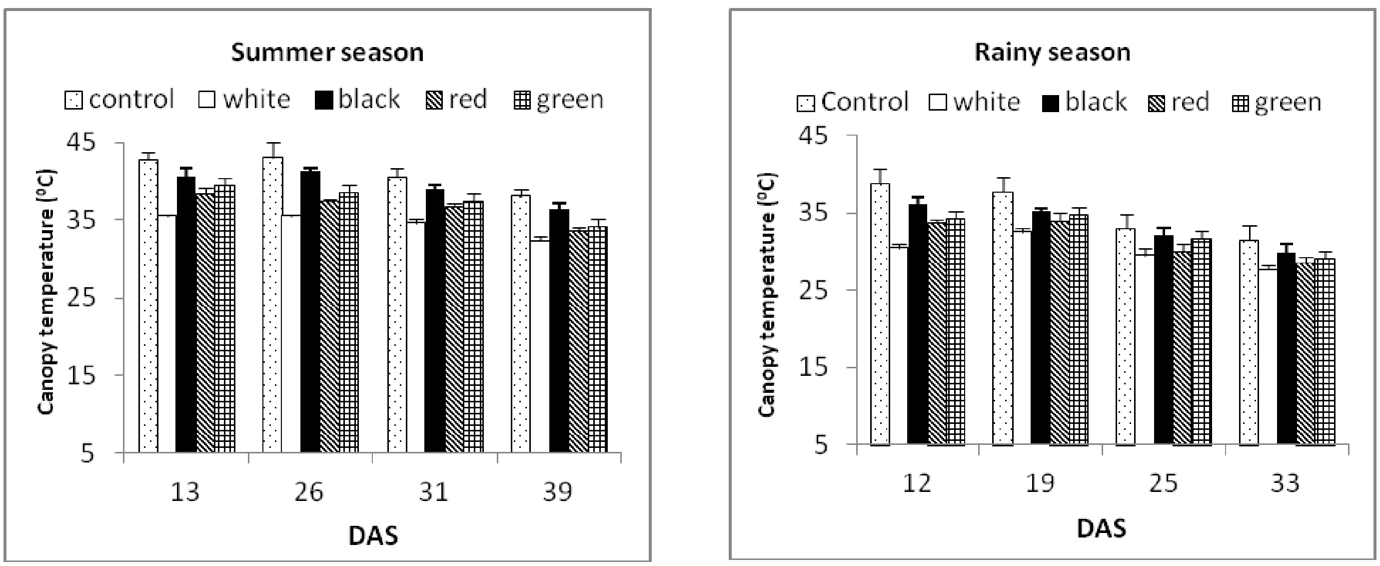

Fig.7: Canopy temperature measured at 11A.M. under different colour shade nets along with control during summer and rainy season

season the temperature was found to be higher in control followed by black, green, red and white shade nets (Fig. 1).

Relative humidity was found to be higher in colour shade nets than control. In summer season relative humidity under white shade net was 3.8-10.4% higher than control followed by under red shade net (2.5-9.5%), under green shade net (0.5-7.2%), under black shade net (0.2-3.1%). In rainy season variation in RH under shades were higher than control (Fig. 2). The air temperature was found to be lower and relative humidity was higher under colour shade nets compared to the control. Shade nets are often deployed over crops to reduce heat stress (Elad *et al*., 2007; Retamales *et al*., 2008; Shahak *et al*., 2004).

Light intensity under different colour shade nets

Light intensity under colour shade nets is lower than outside condition. In rainy season light intensity was found to lower as compared to summer season. In summer under white shade net incoming light intensity was 47.8-67.1% lower than that under control followed by red shade net (55.4-72.5%), green shade net (63.7-74.3%)

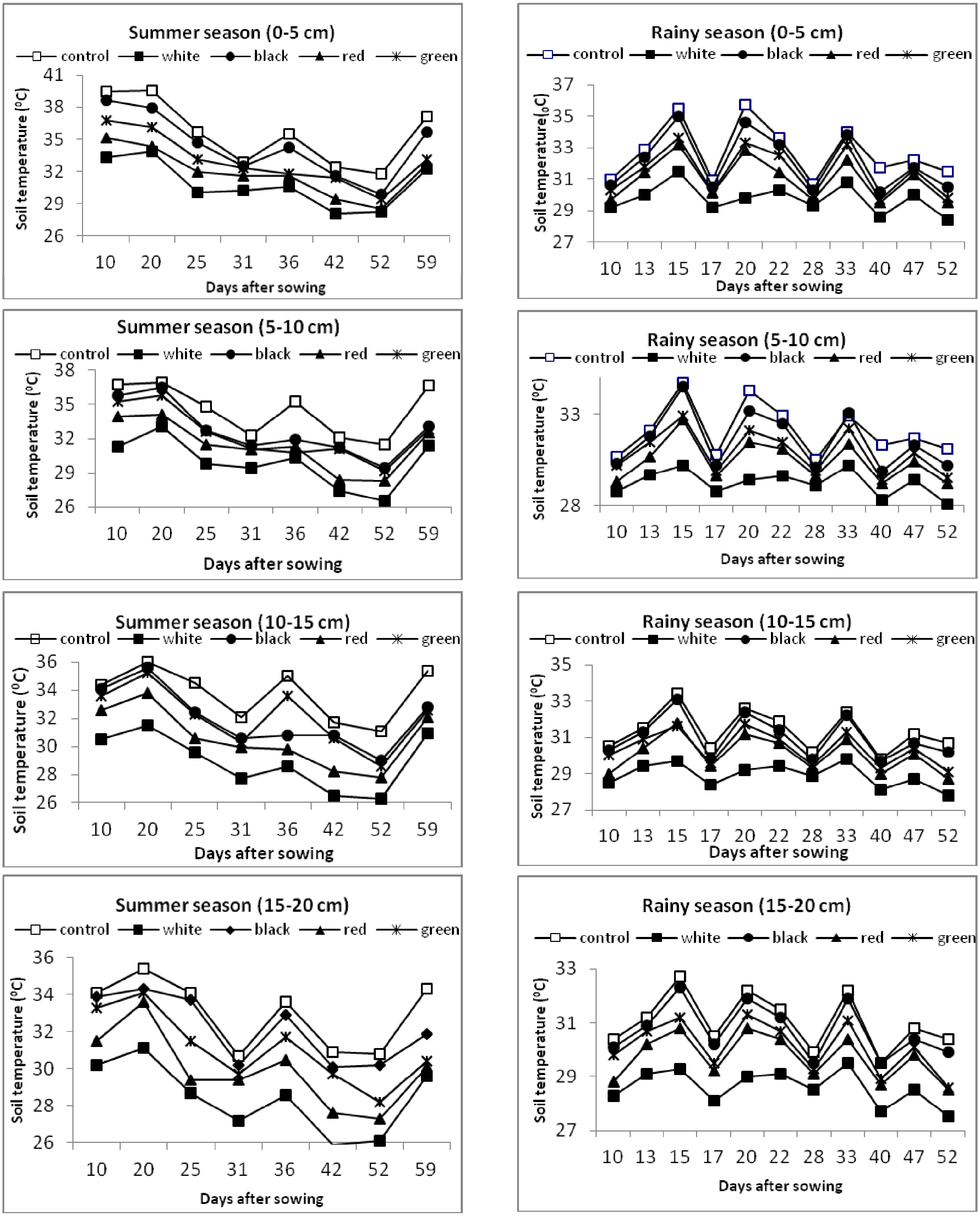

Fig. 8: Soil temperature at different depth under different colour shade nets along with control measured at different days after sowing during summer and rainy season

and black shade net (62-82.7%). In rainy season also similar results were obtained with slight lower value as compared to corresponding value in control (Fig. 3). Shade nets not only decreased light quantity but also alter light quality to a varying extent and might also change other environmental conditions (Smith *et al*., 1984).

Photo synthetically active radiation under different colour shade nets

Photo synthetically active radiation in summer season under different colours shades was found to be lower than control. Under white shade net it was 57-66% lower than control, followed by red shade net (61-73%), green shade net (65-76%) and black shade net (79-81%). Similar results were obtained with slightly less reduction as compared to summer season (Fig. 4).

Radiation reflected by canopy under different colour shade net was found to be lower as compared to the control. In summer season the reduction was59.6-70% under white net followed by under red (64.5-77.5%), under green (75.6-80.7%) and under black (86.3-88%). In rainy season similar results were obtained with slightly lower reduction (Fig 5). Similarly Abdel-Ghany & Al-Helal (2010) observed that the shading screens with more shiny colours had raised the levels of reflection, reflecting almost all the incident PAR specterum, in relation to the dark screens, that reflect the incident PAR only in the spectral band of the colour and absorb the incident PAR of the remaining complementary colours of the spectrum.

Percentage reflectance under different colour shade nets

Spectral reflectance of spinach (variety Pusa Bharati) was taken by using spectroradiometer. There was significant difference in reflectance under different colour shade nets. In visible region reflectance peak at 550-560 nm, was found to be more in green shade net and lowest reflectance under white and control shade net. In other colour net there was no significant different in visible region. In 720-1360 nm region reflection was more than visible region. In this region percentage reflectance had higher value under green, followed by red, black, white and control shade net (Fig. 6). In between 1950-2450 nm range there was no significant difference, hence 720-1360 nm range can be used for identification of different colour shade nets. The response of a plant to shading conditions depends on the complex interaction between quality and quantity of the incident light (Lee *et al*., 1997). Percentage reflectance as observed in our study had higher value in colour shade nets than control except in white shade nets.

Spectral indices under different colour shade nets

The different spectral indices viz. NDVI and RVI calculated from spectral data taken in the field from different colour shade nets (Table1) showed that the value of NDVI and RVI was found to be higher in green followed by red, black, white shade net and control.

Canopy temperature under different colour shade nets

Canopy temperature measured under different colour shade nets had lower canopy temperature as compared to corresponding value in control (Fig. 7). In summer season under black shade net canopy temperature was found to be 1.7-2.1^{0}C lower then control, followed by green (3.2 -4.5^{0}C), under red (3.9-5.6^{0}C) and under white (5.6-6.4^{0}C). In rainy season also similar trends were obtained with slightly lower reduction. Our result is also supported by other research, Smith (1995) reported that leaves under the nets were cooler by 1.7-3.9^{o}C on a milder day (11 January 2005) and by 4.3-6.2^{o}C on a hot day (28 Febuarary 2005) than control leaves.

Soil temperature and soil moisture under different colour shade nets

Soil temperature under different colour shade nets measured at different depth and at different crop growth stage had lower value than control in both season. The difference in soil temperature at different depth measured under different colour shade nets during summer had more value than corresponding value in the rainy season. In summer season at 0-5 cm, soil temperatures under different shade net were found to be lower than control by 2- 6^{0}C (Fig. 8). At greater depth the difference between control and shade nets decreased.

Yield under different colour shade nets

Under different colour shade net yield had higher value than control. In summer season result showed that yield under green colour shade net had nearly 66.4% more yield than control, red had 59%, black had 23.8% and white had 22.1% more yield than control condition (Table 2). In rainy season higher humidity inside the shade nets due to sufficient rain, the crop yield was reduced as compared to summer season.

CONCLUSION

The microenvironment was changed using different colour shade nets. The air temperatures, soil temperature at different depth, canopy temperature, light intensity, radiation were found to be lower under different colour shade as compared to the corresponding value under control. Whether the relative humidity had higher value under colour shade nets than corresponding value in control. The percentage reflectance as well as value of different spectral indices such as normalized difference vegetation index and ratio vegetation index was found to be more in green followed by red, black, white and control.

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