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Semi-permanent Shadenet house for reducing the sunburn in pomegranates (*Punica granatum*)

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Abstract
Pomegranate has great economic importance however its major share is damaged due to sunburn. Different techniques like increasing humidity around plant; use of cloth, paper bags to cover fruits; application of reflective materials etc. have been tried to reduce sunburn. Reflective materials and chemicals are preferred due to ease in application; however their use is not desirable in food commodities. Hence, study was conducted to develop semi-permanent shadenet house (SPSH) to reduce sunburn in pomegranates cultivated in hot region. 50% black shadenet was used as shading material. Front height, rear height, length and width of structure were 3.66 m, 3 m, 24.38 m and 6 m, respectively. Shadenet was removed after harvesting to attain tangible plant growth and again installed after fruit setting. Results indicated that installation of SPSH from May to August (or till harvesting) reduced sunburn to 2.9% against 17% sunburn in plants without any shade. SPSH imparted deep red color to peel and arils and increased juice recovery by 20-25%.

Keywords: hot region, pomegranate, semi-permanent, shadenet, sunburn, fruit quality

Introduction

Pomegranate (*Punica granatum*) is one of the most important fruit crops of sub-tropical and tropical regions. In India, pomegranate has great economic importance due to its refreshing juice and medicinal properties. India ranks first in pomegranate production and contributes about 60-70% in international trade of pomegranate (Meena *et al*, 2016) [9]. Due to its ability to withstand water and heat stress, pomegranate crop is successfully cultivated in hot and arid/semi-arid regions in India (Kashyap *et al*, 2012) [6]. Area under pomegranate crop in country is 2,09, 000 ha and total production of country is reported to be 24,42,000 MT (Anonymous, 2017) [1]. Moreover, the finest quality of pomegranates is produced in the country throughout year. Major export market for India's pomegranate is Bangladesh, United Arab Emirates, Nepal, Netherlands, UK, Saudi Arabia and Rassia (APEDA Database, 2011-12).

In India, pomegranate is commercially grown in Maharashtra, Andhra Pradesh, Karnataka and Tamil Nadu. Since last decade, its cultivation is started in Rajasthan, Haryana and Punjab also (Meena *et al*, 2017) [8]. These states are located in tropical region of North-western India where summers are very hot. Maximum temperature during summer touches to 46-49°C in the region. Due to climatic extremities in region, pomegranate crop faces many biotic and abiotic stresses that are responsible for yield loss. Major biotic stress is due to bacterial blight disease caused by *Xanthomonas axonopodis* pv. *punicae*, that brings 30-50 % fruit loss (Raghuwanshi *et al*., 2013) [14]. Another important factor causing yield loss in pomegranate is sunburn (Meena *et al*, 2016) [9]. In hot climates, spring flowering (*Ambe bahar*) is preferred for fruiting. Fruiting period in *Ambe bahar* is from April to August-September which happens to be very hot summer (day temperature ≥40 °C) in the region and faces strong solar radiations resulting in significant amount of sunburn. Pomegranate is a terminal bearing plant due to which fruits are exposed to solar radiations. Moreover, fruits are more susceptible to sunburn as compared to leaves as fruits do not have mechanism of utilizing solar radiation for photosynthesis. Sunburn damage in pomegranate can be as high as high 30% of harvested fruit or even more (Melgarejo *et al*, 2004) [10].

Sunburn negatively affects pomegranate fruit quality. It changes peel color from brown to black; depletes moisture content of fruits and causes drying; and decreases market value of fruits (Yazici *et al*, 2005) [19]. Peel colour is the most important quality trait as consumers select fruits on the basis of peel colour. Besides, aril colour, juice colour, juice content, antioxidants etc. are also important quality indicators of pomegranate fruits. Reports indicate that sunburn adversely affects all the quality attributes of fruits causing loss in nutritional and market value of fruits (Melgarejo *et al*, 2004; Meena *et al*, 2016; Lal and Sahu, 2017) [10, 9, 7]. Several techniques have been suggested by various researchers to reduce sunburn damage in pomegranate fruits (Melgarejo *et al*, 2004; Vatandoost *et al*, 2014; Meena *et al*, 2016) [17, 10, 9]. These techniques include increasing humidity near plant canopy, use of anti-transpirants, sunscreens, shading materials, covering fruits with cloth, paper bags, or reflective materials (e.g. kaolin); use of chemicals (sun shield, vitamin E, vapogard) etc. (Yuri *et al*, 2002) [20].

Among all techniques, reflective materials are preferred more due to ease in their application and tolerable cost. Reports suggest that spraying kaolin on pomegranate fruits reduced sunburn from 21.9% in untreated fruits to 9.4% in treated fruits (Melgarejo *et al*, 2004) [10]. The most important characteristic of reflective materials is their white colour and ability to reflect sunlight (Glenn *et al*, 1999) [5]. Besides, spray of GA_3, boron or other micro-nutrients is also recommended to reduce fruit cracking (Sepahi, 1986) [15]. However, all these techniques are costly and require expertise during their application. Moreover, in present days of health consciousness, use of chemicals is not advisable in food commodities. Hence, non-chemical techniques may be identified to manage sunburn problem in pomegranate fruits. One such technique is shadenet house in combination with evaporative cooling of fruits. Report indicates that creating shade over plant and appropriate RH around it can reduce sunburn damage significantly.

Extent of solar radiations falling on fruit surface may be significantly reduced by installing shadenets over plants during fruit development. Color shadenets represent one of the modern agro-technological approaches aiming at combining physical protection to plants together with differential filtration of solar radiations (Meena *et al*, 2016) [9]. Several studies demonstrated that crops grown under coloured shadenets of 50-80% shading intensity produced higher yield as compared to open field conditions (Shahak *et al*, 2004) [16]. Colour shadenets improve photosynthesis, canopy vitality, fruit set and fruit sizing, and extend harvest season. Effectiveness of colour shadenets in cultivating vegetables, ornamentals and fruit trees has been confirmed by previous studies (Shahak *et al*, 2004; Nissim-Levi, 2008; Fallik *et al*, 2009) [16, 11, 3]. These shadenets exhibit unusual optical properties that allow control of solar radiations and modifying microclimate around crop. They offer protection against insects, excessive solar radiations and improve thermal climate near crop (Shahak *et al*, 2004) [16].

Therefore, keeping in view the potentiality of colour shadenets in reducing heat stress caused by solar radiations, study was conducted in hot and semi-arid region of Punjab (India) to develop a semi-permanent shadenet house (SPSH) over pomegranate plants and evaluate its efficacy in reducing sunburn.

Materials and Methods

Experimental site

Experimental site was located in hot and semi-arid region of Northwestern India. Study was carried out for two consecutive seasons (year 2015 and 2016) on eight year old commercial orchard at ICAR-CIPHET, Abohar, Punjab. Site is located at 30.17°N latitude, 74.18° E longitude and 390 m above mean sea level. Average annual rainfall at site is 328 mm and monthly averaged insolation is 5.07 kWh/m^2/day.

Pomegranate plants cv. *Mridula* spaced at 3×4 m were used in study. Orchard was managed using recommended package of practices. In 2015 season, different treatments comprising of colour shadenets, kaolin, borax and evaporative cooling system (fogger) were applied to plants and the best treatment on the basis of fruit quality was determined. In 2016 season, the best treatment determined during season 2015 was used to develop SPSH over plants. Subsequently, efficacy of developed SPSH in reducing sunburn was evaluated. Mean daytime temperature during both seasons was recorded between 33-41 °C whereas mean daytime RH was found to be 15-50%.

Treatments

Different treatments applied to plants were aimed at reducing sunburn and improving fruit quality. Description of the treatments is given in Table 1. All treatments were applied to single plant and replicated thrice. Front height of shadenet cover was 3.65 m whereas rear height was 3.00 m. Nets were such installed that no fruits were exposed to sunlight.

Fruit quality

Fruit quality was evaluated in terms of sunburn (%), peel colour, aril colour, aril weight and juice content. Sunburn (%) was calculated as ratio of sunburn affected fruits to total fruits on plant. Peel and aril colour was determined using Hunter color Lab (Model No. LX16244, Hunter associates Laboratory, Virginia) in terms of Commission Internationale de L' Eclairage 'L' (lightness), 'a' (redness) and 'b' (yellowness). Colour values were replicated five times. Aril weight (g) and juice content (ml) were determined by measuring the arils and juice of samples.

Development of semi-permanent shadenet house

SPSH was developed on the basis of data obtained from first season. Structure was termed as semi-permanent because net was installed during fruit development till harvesting (April to August-mid September) and was removed after harvesting in order to attain tangible plant growth and subsequent flowering and fruiting. If net is not removed, it would negatively affect reproductive growth.

SPSH was developed using black net (50% shading intensity) for a cluster of 8 plants (Fig.1a-b). Length, width, front height and rear height of structure were 25, 6, 3.65 and 3 m respectively. MS pipes of 6 cm diameter were used as columns whereas wire rope of 9 mm diameter was used as horizontal members. Structure was equipped with fogger system having total discharge of 16 litres per h.

Statistical analysis

Measurements on sunburn (%), peel colour, aril colour, aril weight and juice content were replicated five times and means were reported. Duncan's multiple range test (DMRT) was performed to test statistical differences in these quality parameters. SPSS statistical software version 16.0 (SPSS, INC., Chicago, USA) was used to conduct DMRT tests. Significance was accepted at 5% level of significance (α=0.05).

Results and Discussion

Effect of different treatments on fruit quality

It is evident from results that all treatments significantly (α=0.05) affected fruit quality parameters. Control treatment had the highest value (18.3%) of sunburn affected fruits followed by F (11.1%) and GS (9.2%) treatments (Fig.2). BSF was found to be the most efficient treatment in reducing sunburn. Reduction in sunburn in pomegranate fruits due to shadenet has also been reported by Meena *et al* (2016) [9]. Among different net colours, black net was better in reducing sunburn. Sunburn values under GS, RS and BS were 9.2, 8.4 and 5.3%, respectively.

Solar radiations when fall on a surface, they are absorbed, reflected and transmitted. Perfect black surface absorbs all solar radiations without reflection and transmission whereas white surface reflects all radiations without absorption and transmission. All three phenomenon are present in a surface having colours other than black and white. Therefore, by virtue of its absorption property, black shadenet absorbed most of the radiations whereas green and red nets absorbed-reflected some portion and transmitted remaining radiations to the plants beneath. In case of red and green nets, solar radiations passed through holes as well as transmitted through netting material. On the contrary, in case of black net, solar radiations passed through holes only without transmission through netting material that might have contributed to lower air temperature below black net as compared to green and red nets. Results indicated that temperature below black net was lower by 2-3 °C than that under green and red nets.

Results (Table 2 and Fig.3a-b) indicate that aril weight, juice content, peel colour and aril colour were significantly (α=0.05) affected by different treatments applied to pomegranate plants. Aril weight and juice content were highest in fruits grown under BSF treatment whereas values of these parameters were least in fruits grown under control treatment. Fruits grown under control treatment were exposed to high intensity solar radiations causing partial drying of the fruits. Moisture removal from fruits might be the reason behind low aril weight and juice content under control treatment. BSF treatment prevented the fruits from solar radiations and hence produced fruits having higher aril weight and juice content.

Colour coordinates "L, a and b" indicate the intensity of darkness, redness and yellowness, respectively. Peel and arils of '*Mridula*' variety are of deep red colour. Hence 'a' values were used for comparing the treatments. Results indicated that fruits produced under BSF treatment had highest 'a' values of peel (46.6) and aril (41.44). Visual observations indicated that arils of fruits produced under BSF treatment had deep red colour. On the contrary, arils of fruits produced under control treatment were of light red colour.

Effect of SPSH on fruit quality

Overall, treatment BSF was better in reducing the sunburn and producing fruits of better quality. Hence, this treatment was used for developing SPSH. SPSH was installed over a cluster of eight plants in 2016 season. Results indicated that 2.9% fruits produced under SPSH were affected from sunburn whereas almost 17% fruits produced under control treatment were affected from sunburn. Thus, SPSH reduced the sunburn damage by almost 14%. Results also showed that SPSH imparted redness to peel and arils of the fruits and increased juice recovery by 20-25%. Higher juice recovery under SPSH than control treatment might be due to partial drying of fruits under control treatment.

Conclusions

Pomegranate fruits are mainly grown in tropical and sub-tropical regions where temperature during fruiting period exceeds 40 °C. Therefore, fruits grown in region are damaged by sunburn. Sunburn reduces market value of fruits. Various techniques have been suggested to prevent fruits from sunburn damage. Shadenets of different colours may be used to prevent fruits from direct exposure of solar radiations that cause sunburn. In present study, ten different treatments involving coloured shadenets, evaporative cooling and chemical sprays were applied to plants. Results indicated that among all treatments, BSF was found to be the best treatment in reducing sunburn and producing fruits of deep red colour. Hence, in season 2016, SPSH of black shdenet (50% shading intensity) was installed over plants and found that structure reduced sunburn damage by almost 14%. SPSH imparted redness to peel and arils and increased juice recovery. Observations also indicated that net of SPSH should be removed after harvesting to attain tangible plant growth and subsequent flowering and fruiting.

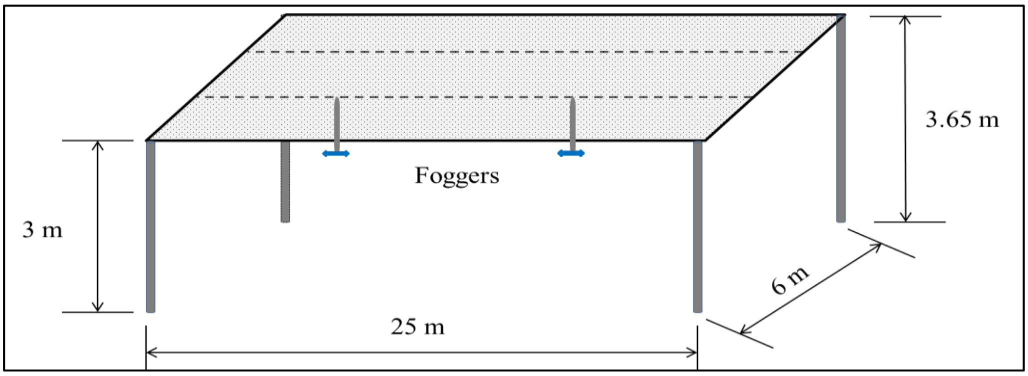
Table 1: Treatment codes and their description

Treatment	Description	Treatment code
Green shadenet	50% shading intensity	GS
Red shadenet	50% shading intensity	RS
Black shadenet	50% shading intensity	BS
Green shadenet + fogger	50% shading intensity	GSF
Red shadenet + fogger	50% shading intensity	RSF
Black shadenet + fogger	50% shading intensity	BSF
Fogger	Installed at 2.5 m high over plant	F
Kaolin	4% solution, thrice a day	K
Borax	0.4% solution, thrice a day	B
Control	No any treatment	C

Table 2: Effect of different treatments on quality parameters of fruit

Treatment	Aril weight (g)	Juice content (ml)	Peel color			Aril color		
			L	a	b	L	a	b
GS	160±5c	67±2c	56.8±2.3f	39.9±3.2b	37.4±2.1d	17.84±2.3a	39.37±6.5f	0.11±0.02a
RS	175±3.3d	66±3c	58.5±2.4h	42.3±1.2c	33.7±2.3c	19.26±6.3b	38.83±5.2e	0.82±0.1c
BS	190±7e	68±5d	54.9±2.1e	44.8±5.2e	37.4±3.2d	24.05±1.2f	36.33±5.4c	0.92±0.3c
GSF	187.5±3.4e	68±2d	50.1±3.1c	44.6±1.2e	33.1±3.5c	21.25±3.2c	37.33±4.3d	0.14±0.07a
RSF	211±2.8f	70±3e	49.6±6.2c	44.8±3.2e	39.9±3.6f	31.63±1.2h	35.3±4.2b	1.58±0.6d
BSF	217.8±5.1g	72±1f	52.8±1.3d	46.6±2.3f	38±2.4e	22.45±1.3d	41.44±6.5g	0.12±0.2a
F	170.2±2.5d	70±5e	46±6.2a	39.3±2.6b	31.3±5.2a	30.8±2.3g	35.27±1.2b	1.56±0.3d
K	176±3d	65±3c	55.6±5.3e	43.2±2.8d	38±1.2e	21.89±6.2c	39±6.3f	0.6±0.02b
B	158.5±2.14b	60±2b	57.2±4.2g	39.7±5.1b	38.3±4.5e	23.17±1.2e	39.7±3.2f	0.47±0.03b
C	127.8±3.6a	55±1a	48.5±2.3b	30.2±2.3a	32.9±2.5b	36.2±5.2i	33.33±1.5a	3.34±0.89e

Values followed by same alphabet in a column do not differ significantly (α=0.05).



A.

B.

Fig 1: Semi-permanent shadenet house (a: diagram; b: photo)

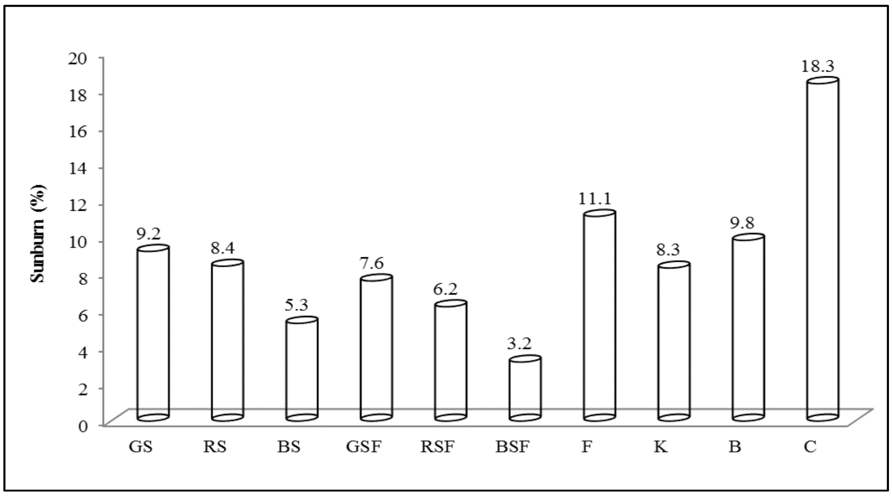


Fig 2: Effect of different treatments on sunburn in pomegranate fruits

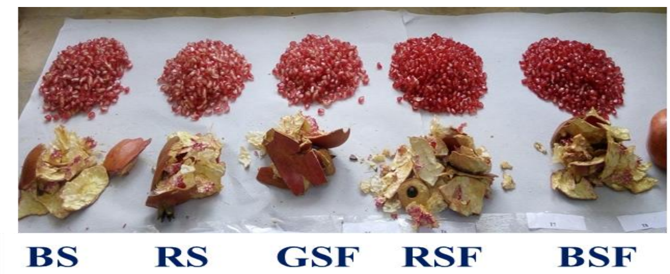


Fig 3: Effect of different treatments on (a) peel and (b) aril color of fruits

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