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Effect of coloured shade nets on yield and quality of pomegranate (*Punica granatum*) cv. Mridula in semi-arid region of Punjab

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ABSTRACT

The productivity of pomegranate (*Punica granatum* L.) cv. Mridula was examined under shade nets of different colours (Red, Black and Green) with shade intensities (Red 50% PAR, Black 50% PAR, Green 35% PAR and 50% PAR) in Abohar, Punjab over two growing seasons. To overcome the evaporation losses, use of fogger and micro-sprinkler was done along with Kaolin 4% and Borax 0.4% to prevent sunburn and cracking problem. An insect net (50 mesh) was also used to prevent the damage from insects especially pomegranate fruit fly. The experimental results clearly showed that photoselective nets influenced photosynthetically active radiation (PAR) transmitted through the canopy which caused variation in average monthly temperature and humidity. The quality of the fruits was affected under the open field conditions as compared to other treatments. Maximum acidity (0.412%), Vitamin C (13.52 mg/100 g), total sugars (13%) and highest antioxidant activity (40.1%) were recorded under open field conditions. Whereas minimum acidity (0.206%), minimum vitamin C (5.80mg/100g), total sugars (6.8%), and total phenols (7.5%) were recorded in the fruits grown under black shade net (50%). On the other hand, the application of shade net had significant impact on the quantitative characteristics. Shading with the net (Red 50%) resulted in the significant increase in the length of the fruits (83.39 mm) along with higher fruit weight (310 g) and highest yield of 6.70 kg/plant as compared to the open field condition (3.14 kg/plant). The results, therefore, demonstrate the potency of photoselective netting (Red colour) for improving the agro-economic performance of horticultural crops especially in harsh climates and arid zones. Placing the red nets over mature plants at intermediate shade levels (35% PAR and 50% PAR) provides higher yield without any detrimental effects on fruit quality.

Key words: Biochemical, Pomegranate, Shade net, Sun burn, Yield

Pomegranate (*Punica granatum* L.) belonging to the family punicaceae, is one of the favourite table fruits in the world for its refreshing juice with nutritional and medicinal properties. This fruit crop has wide adaptability and grows well in tropical, sub-tropical and even temperate regions. Pomegranate can tolerate water stress and thus can be grown successfully in arid and semi-arid regions (Poonam *et. al*. 2012). India ranks first in pomegranate production (11.4 lakh tonnes) in world, contributing 60-70% to the international trade by exporting 1% of total fruit production (Jhadav and Sharma 2007). Covering of the fruits with special cloth, paper bags or use of nets is also in use to protect agricultural crops from excessive solar radiation and improving the thermal climate (Kittas *et al.* 2009, Shahak 2004). Colour nets represent a new agro-technological concept, which aims at combining the physical protection together with differential filtration of the solar radiation. Studies of several crops grown under various coloured shade nets of the 50-80% shade, yielded high as compared to open field conditions (Shahak *et al.* 2004). Many scientists reported that coloured nets helps in improving canopy vitality, photosynthesis, improved fruit set, fruit size and extended harvest season (Arthurs *et al*. 2013). Whereas, kaolin is reported as one of the most important cultural practices globally in many fruits as it helps in reducing the transpiration, suppresses weed growth, improves the plant productivity (Farazmand 2013). At present, many cooling systems are also available in India to bring down the temperature of growing environment during summer season (Leyva *et al*. 2014). Some of research carried out in India revealed that foggers are highly effective during extreme summer conditions for cooling of fruit crops. Some studies under different types of shade net house have been carried out for growing of nursery as well as for production of some important medicinal plants and cut flower in hilly regions of India. But scanty information is available on sun burn and cracking of pomegranate fruits in semi-arid regions. Use of reflective material (Kaolin) is mostly preferred due to both application facility and tolerable cost with reduction of

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sunburn damage on fruit (Parchomlochuk and Meheriuk 1996). Besides growth regulators, micronutrients are also known to impart beneficial effects as evident in various fruit crops (Kassem *et al.* 2011). Among micronutrients, boron plays a significant role in improving fruit set, retention of fruit to maturity, fruit weight, quality and yield. Boron is associated in translocation and transformation of sugars, cell division, uptake of calcium by plant and K/Ca ratio (Zende 1998).

Keeping in mind all the things, an investigation was undertaken by applying shade nets and spray of reflective materials like kaolin and borax and use of foggers and sprinklers to see the effect on yield and quality of pomegranate cultivar Mridula in semi-arid of region of Punjab (Abohar).

MATERIALS AND METHODS

During 2012-13, to study the effect of different cultural management practises on yield and quality of pomegranate cv. Mridula under the climatic condition of Punjab, a field trial was conducted at Central Institute of Post harvest Engineering and Technology (CIPHET), Abohar (Punjab) located at 30°4'N and 74°12' longitude on an average elevation of 221.7 meters above mean sea level. The experimental soil was 1 m deep, well drained sandy loam in texture with average pH 8.1. Three years old plants of pomegranate cv. Mridula spaced at 10 × 12 m were used for the experimental studies. The plants were grown under recommended horticultural package and practices with integrated weed management. Drip irrigation system was used for application of irrigation and fertilizers. The treatments comprised of evaporative cooling by micro sprinkler (T1), evaporative cooling by over tree fogger (T2), colour shade nets viz., Green 35% (T3), Red 50% (T4), Black 50% (T5), Green 50% (T6), insect net 50 mesh (T7), foliar spray of kaolin 4% (T8) and borax 0.4% (T9) beside a control (open field without any treatment), T10 were applied during the fruit development stage . The experiment was laid out in factorial randomized block design with 10 treatments each having five replications (Table 1). The shade nets were applied at the start of warm weather in early june. The temporary houses like structures were built with the help of bamboos at 3 m height and were covered with different coloured shade nets during hot summer. Overhead cooling of plants was done with foggers and micro sprinklers having the discharge capacity of water @ 4 l/hr, done periodically for at least 1h/day during hot summer days. Sun burn affected deformed and discoloured fruits were discarded manually during the fruit development to maturation stage. Fruits were collected after attaining maturity for recording observations on fruit length, fruit weight, aril weight, aril per cent, juice per cent, TSS, acidity, ascorbic acid, total sugars, total antioxidants, phenols and colour value. Physical parameters like fruit length (cm) and width (cm) was measured by digital vernier calliper. The average weight (g) of five fruits was recorded by digital balance. The total soluble solids (^{o} Brix) was recorded by digital hand refractometer. The total acidity (%) was determined according to the methods of AOAC, 1970 while the total sugars and ascorbic acid were estimated by the method given by Ranganna (1986). The total phenolic content was analysed using the Singelton and Rossi method (1965). Antioxidant activity was assessed according to the method suggested by Williams *et al*. (1985). Colour value was estimated through the use of calorimeter. The experiment data was analysed for analysis of variance (ANOVA) using RBD to test the significance of observed differences. The differences in quantified concentrations were evaluated using F test at $P < 0.05$.

Table 1 Details of treatments used in the study

T1	Over tree micro sprinkler with 2.5 metre height
T2	Over tree fogger with 2.5 metre height
T3	Green shade net 35% with 3.0 metre height
T4	Red Shade net house 50% with 3.0 metre height
T5	Black Shade net 50% with 3.0 metre height
T6	Green Shade net 50% with 3.0 metre height
T7	Insect proof net 50 mesh with 3.0 metre height
T8	Kaolin spray 4%
T9	Borax spray 0.4%
T10	Control (Open field without any treatment)

RESULTS AND DISCUSSION

The results obtained in the study showed that the use of shade nets of different colours exerted a significant impact on qualitative and quantitative traits of pomegranate fruits. Data depicted in Table 2 revealed that treatment T-4 (50% Red shade net) significantly increased the average fruit weight (310 g), length (83.3 mm), aril weight (28 g), juice percentage (69.8%) and yield (6.7 kg). Average fruit weight (302 g) and yield (4.8 kg) were significantly increased by

Table 2 Comparative changes in physical parametres and yield of pomegrante as influenced by differernt treatments (Expressed in mean)

Treatment	Five fruit weight (g)	Fruit length (mm)	Aril weight (100 arils)	Juice (%)	Fruit yield (Number of fruits)	Yield (kg)	Sun burn (%)
T1	302	83.1	22.9	66.4	47.04	4.8	4
T2	200.6	74.04	24.6	63.4	30.24	3.3	3.6
T3	197	71.98	20.3	63.8	24.48	3.712	4.4
T4	310	83.39	28	69.8	29.76	6.704	3.8
T5	240.4	77.78	22	63.2	38.16	3.52	3.2
T6	275.8	81.8	21.8	68.8	31.44	4.08	4.6
T7	266	79.98	24	67.6	33.12	3.36	5.2
T8	240	82.18	20.8	69.6	51.84	3.34	3.4
T9	217	72.42	21.2	67.6	46.56	4.28	3.2
T10	248.8	75.8	20.6	62.4	27.64	3.14	8.4
Sem	13.66	2.185	NS	NS	5.404	1.077	0.733
CD (P=0.05)	39.18	6.27			15.50	1.523	2.10

the use of micro sprinklers. Evaporative cooling increased the dry matter partitioning to fruit and hence resulted in increased fruit weight and yield. The results are in conformity with Parchomchuk and Meheriuk (1996) who have also reported the similar results in apple after using shade nets of different colours. In India, the commercial plantation of pomegranate exists in Maharashtra, Gujarat, Rajasthan, Karnataka and to a limited extent in Andhra Pradesh, Madhya Pradesh, Uttar Pradesh, Punjab, Haryana and Tamil Nadu owing to its preference for arid climate (Kashyap *et al.* 2012). It suggests that that the tested photo selective shade nets modify light quality leading to lower temperature as compared to the open fields. It also helped in promoting fruit-set and fruit retention. This might be due to higher content of scattered/diffused light. Similarly, El-Gizawy *et al.* (1992) showed that the increase in shading intensity in tomato crop resulted in increased fruit production. Another possible reason could be due to the fact that with the use of shade nets, various metabolic processes gets altered which improved fruit bud differentiation, flowering intensity, higher ratio of fruit set resulting in improved yield. Furthermore, highest yield of 6.70 kg in T4 (Table 2) was significantly attributed to highest value of individual fruit weight, i.e. 310 g and larger size of fruits. Possible increase in pomegranate yield could be due to mixture of natural, unmodified light passing through the holes of the shade net, together with the diffused, spectrally modified light creates an environment that increase plant canopy and its vitality as observed by Shahak *et al.* (2004). Moreover, open field grown plants were exposed to rainfall and periods of high temperature, which favoured the development of the bacteria Xanthomonas *axonopodis* cv. *Punicae* causing bacterial blight. This pathogen reduced the leaf area of plant which exposed the fruits to direct sunlight and ultimately reduced the yield of control being 3.14 kg. Among all coloured shade nets, the highest yield was recorded from red colour (6.7 kg). The possible reason could be that the spectral manipulation intends to specifically promote desired physiological responses, while the scattering improves the penetration of the spectrally modified light into the inner plant canopy. The effects of the red nets might be attributed to their relatively reducing of far-red spectral bands in the filtered light, and might further be related to similar effects reported for photoselective films. Shahak *et al.* (2004) obtained similar results in pepper where positive effects of the red net were recorded on pepper productivity. Besides effects on the pomegranate yield, fruit acidity was also affected. Open field, control (T10) produced fruits were more acidic (0.412%) than fruits produced in a protected environment. Table 3 shows that over tree cooling treatment either through sprinkler or fogger, viz. T1 and T2 has also reduced the acidity of fruits (0.24 and 0.23%), respectively. The lower acidity of fruits grown in the protected environment may be the result of lower photosynthetic activity of plant (shading in protected environment) and lower carbohydrate accumulation in the fruits as organic acids are supposed to produce from the stored carbohydrates (Sakiyama and Stevens 1976). The TSS has slightly declined due to shading (T3, T4 and T5) as compared to control, i.e. T10 (Table 3). These results are in conformity with the findings of Seeley *et al*. (1980) who have reported that shading reduces the soluble solid contents of fruits. Another important basis of fruit quality, i.e. sugar contents was also affected. The fruits produced in the open field (T10) had higher total sugars (13%) than fruits produced in the protected environment, viz. T3, T4, T5 and T6 (9.6, 10.8, 6.8 and 9.2%), respectively, (Table 3). On application of different coloured nets, the sugar content increased under red colored shade netting (Table 3). Positive effects of the red coloured net on pepper productivity were also reported by Shahak *et al.* (2004). The lower sugar content of fruits produced in the protected shade environment may be related to lower light intensity, which reduced to approximately 42 to 45% lower than in the open field, provided it is within the limits which does not hampers photosynthetic system significantly. Higher luminosity enhances the photosynthetic activity of the plants. Thus, the high sugar content of the fruits produced in the open field (T10) may be attributed to the greater light intensity in this crop environment and greater photosynthetic plant activity. Similar results were also reported by Martins *et al.* (1999). Alike sugar, ascorbic acid, i.e. vitamin C content also showed variation under different treatments (Table 3). In control (T10), fruits showed higher content of

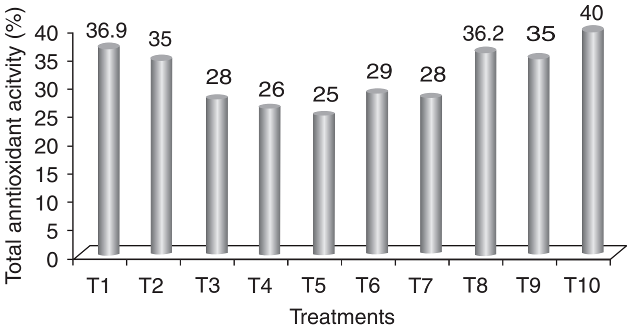

Fig 1 Comparative changes in total antioxidant activity under the influenceof various treatments applied in the study.

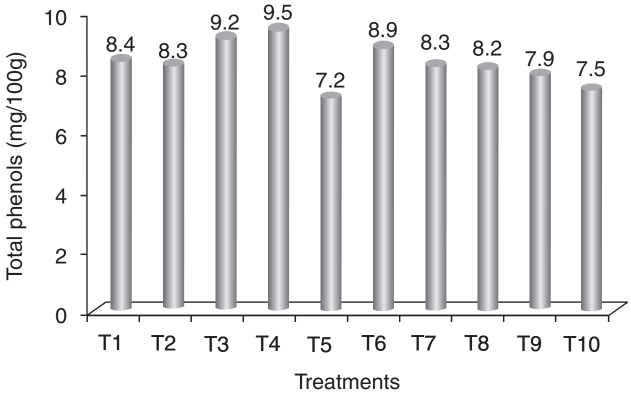

Fig 2 Comparative changes in total phenol concentrations under the influence of various treatments applied in the study.

Table 3 Comparative changes in physico-chemical attributes of pomegranate as influenced by different treatments

Treatment	TSS (° Brix)	Acidity (%)	Ascorbic acid (mg/ 100g)	Colour value -L	Total sugars (%)
T1	15.3	0.242	8.3	45.5	9.6
T2	16.1	0.236	7.3	43.92	9.2
T3	14.9	0.206	7.08	44.50	9.6
T4	14.6	0.23	6.04	46.38	10.8
T5	14.7	0.232	5.80	43.4	6.8
T6	15.2	0.24	8.68	45.96	9.2
T7	15	0.212	9.28	42.92	8.8
T8	15.5	0.246	10.44	42.98	9.2
T9	15	0.228	11.92	42.8	10.2
T10	15	0.412	13.52	39.3	13
Sem		0.018	0.577	1.16	0.461
CD (P=0.05)	NS	0.074	1.655	3.33	1.323

ascorbic acid (13.52 mg/100g) as compared to evaporative cooling treatments T1 and T2 (8.3 and 7.3 mg/100g), respectively. Whereas all colour shading, viz. T3 (7.08 mg/ 100g), T4 (6.04 mg/100g), T5 (5.08 mg/100g), respectively, had significantly reduced the ascorbic acid content. The ascorbic acid content was slightly lower in treatments of foliar application of kaolin (T-9) and borax (T-8). Similar results were reported by Venter (1977) in tomato. This might be due to the fact that ascorbic acid biosynthesis can be strongly influenced by environmental conditions with light intensity affecting the content of ascorbic acid in pomegranate fruits. Sunburn is key problem in pomegranate fruit. In the present investigation, results obtained clearly indicated that the incidence of sunburn was significantly reduced by black shade netting (3.2%) and over tree evaporative cooling by foggers (3.2%) followed by kaolin treatments (3.4%). Control produced fruits (T10) were severally infested by sun burn (8.4%, Table 2). The increased total fruit yield of shaded plants was probably due to reduction of high heat stress during summer months while the fruits produced under open field condition (T10) were exposed to direct sunlight and hence had to face higher and hot temperature during extreme summers which resulted in the lower yield. A 50% shading of pomegranate (T3, T4 and T5) resulted in lower rind temperature, soil surface temperature and leaf temperature (Fig 3) and may be an option to reduce heat stress under extended summer season scenario towards September. The possible cause of reduction of sunburn/cracked fruits by shading is due to decrease in fruit temperature by the shading treatments. Sunburn/Fruit cracking disorder not only reduces fruit appeal and marketing, but also increases fruit susceptibility to decay resulting in shortened shelf-life. The fruits exposed to direct sunlight in the open (T10) developed a poor colour (39.3 L) mainly because of the exposure to high temperature resulting in low anthocyanin content (Table 3). Similar findings were also reported by Helyes *et al.* (2006) in tomato.

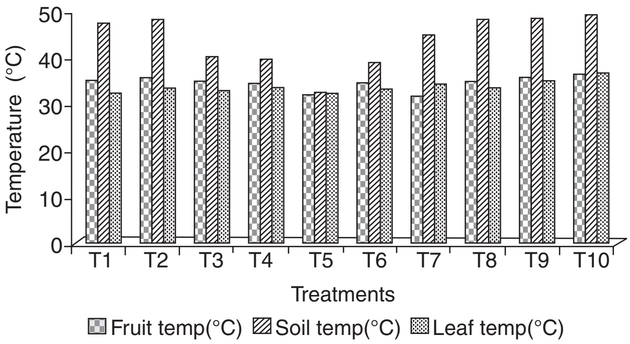

Fig 3 Comparative changes in fruit, leaf and soil temperature due to various treatments under study.

Result depicted in Fig 1 shows that total antioxidant activity was higher in fruits produced in open conditions (40%) compared to pomegranate grown under shade net, viz. T3 (28%), T4 (26%) and T5 (25%), respectively. The higher total antioxidant activity in open field control (T10) might be explained by the fact that plants use several protective measures to avoid sunburn, e.g. induction of antioxidants (Ma and Cheng 2003, Solovchenko and Schmitz-Eiberger 2003). The probable reason is that shade can mitigate the damage of photo inhibition in pomegranate plant with consideration of its photosynthetic characteristics. Similar findings were reported by Mohotti and Lawlor (2002) in tea crop. Interestingly, the total phenols concentration in shaded fruits, viz. T3 (9.2%) and T4 (9.5%), respectively, was notably increased compared to that of sunlight-exposed control fruits (7.5%) (Fig 2). It could be possible because phenolic acids and other flavonoid compounds are synthesized in the same branch of the upstream pathway which may compete for the same substrate under different illumination conditions in leaves. Further investigations are required to better understand the relationship between phenolic acid and other flavonoid compounds reported by Herrmann (1995) and Kulkarni and Aradhya (2005) that the phenolic compounds in pomegranate juice are used up in biosynthesis of flavylium ring during anthocyanin pigment formation leading to reduction in their content.

The results of the present study provide useful data for detecting differences among environment, yield, sunburn and biochemical variations in open field and shaded conditions. Though fruits produced in the open field presented better quality in term of vitamins and sugars content compared to the protected environment but the attack of sunburn disorder in open field produced pomegranate fruits was higher which ultimately reduced their marketing due to colour deterioration and caused loss up to 50%. Therefore, cultivation of pomegranate by shade protection/evaporative cooling can rescue pomegranate grower from sunburn disorder which ultimately reduce the attack of bacterial blight disease attack which is another serious problem of the region. The photo selective light dispersive shade net appears to be interesting tool that can be further implemented within protected cultivation practices. However, the data are preliminary and more research is required for understanding the physiological mechanisms behind the plant responses and for testing results with other crops and environmental conditions.

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