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RESPONSE OF NETTING AND PROTECTIVE SPRAY APPLICATION ON FRUIT QUALITY OF APPLE CV. RED VELOX

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ABSTRACT

The present study was conducted to evaluate the effectiveness of various particle films and netting in reducing the quality losses caused by sun damage in apple cv. Red Velox. Three types of particle films viz., Kaolin (4, 6 and 8%), Silica Gel (0.25, 0.75 and 1.25%) and Calcium carbonate (1, 2 and 3%), were applied as foliar spray at three different intervals. The first application was done during second week of June, followed by the second application during second week of July while the third spray was applied one month before the expected harvest. The Black and White net were installed once on second week of June and maintained till harvest. The experiment was laid out in Randomized Complete Block Design with three replications. Fruit quality was evaluated based on various physical and biochemical attributes, including fruit weight, fruit length, fruit diameter, fruit volume, fruit firmness, SSC, total sugar and titratable acidity. The results revealed that particle film treatment and netting significantly influenced the physical and biochemical characteristics of fruits compared to the control. Among the various treatments, Kaolin @ 8% and Black net proved to be most effective in enhancing the fruit quality attributes, therefore, these can be effectively utilized to improve fruit quality under high solar radiation and temperature conditions.

Keywords **:** Apple, red velox, particle film, netting, fruit quality, climatic change

Introduction

Apple (*Malus* × *domestica* Borkh.) belonging to the Rosaceae family, is one of the oldest and most economically important temperate fruit crops cultivated worldwide. Since ancient times, it has been the most widely grown and consumed fruits due to its nutritional and health benefits. Apples are rich sources of antioxidants, sugars, organic acids and several other biologically active compounds, making them an essential component of the human diet (Wu *et al.*, 2007). In India, apple cultivation is mainly confined to the north-western Himalayan states such as Jammu & Kashmir, Himachal Pradesh and Uttarakhand, along with limited cultivation in Arunachal Pradesh, Sikkim and Nagaland. Among these areas, Jammu & Kashmir is the largest producer of apples in the country due to its highly favourable climatic conditions and apple cultivation is an important source of income for the region.

Fruit growers work intensely to implement production methods that yield large quantities of high-quality fruit that can be sold for the highest possible

prices. Fruit of high quality that is provided for fresh market is often assessed based on its appearance. Studies on consumer preferences for apples have shown that colour matters for market value and that red is linked to sweetness (Saure, 1990; Matsuoka, 2020). The two most important characteristics of a high-quality apple are its size and visual appearance (Hirst and Flower, 1998). Climate change causes a lot of challenges for the apple industry, due to the global warming and stratospheric ozone layers depletion, UV-B radiation reaching the surface of the earth continues to rise (Kerr and McElroy, 1993). This causes physiological disorders like sunburn in apples, which are known to lower the fruit's market value. Sunburn has become increasingly common, and there is a greater chance that it will take place at greater rate in future under similar circumstances.

Several kinds of photoprotective compounds found in plant tissues decrease the adverse effects caused by excessive light. These include components of the xanthophyll cycle, antioxidants of the ascorbate-glutathione pathway, pigments like anthocyanins and carotenoids and secondary polyphenolic chemicals like flavonoids and chlorogenic acid. Prevalent exposure to light has a significant impact on the biosynthesis and expression of these compounds and related enzymes (Awad *et al*., 2001; Merzlyak *et al.,* 2002; Solovchenko and Schmitz Eiberger, 2003; Ma and Cheng, 2003).

Different techniques have been developed to mitigate quality losses (Musacchi and Serra, 2018) caused by sun damage such as use of shade nets (Manja and Aoun, 2019), chemical substances that reflect or filter out UV radiation (Gindaba and Wand, 2005), antitranspirants (Racsko and Schrader, 2012) etc. According to McCaskill *et al.* (2016), fruit temperature drop of up to 2 °C can be achieved under nets that allow enough transfer of heat from the fruit surface to the surrounding air while simultaneously reducing the intensity of the solar radiation through interception and dispersion. In addition to netting, it has been suggested to use particle film sprays such as kaolin, silica gel, calcium carbonate, etc. to lower the fruit temperature, which can lessen sunburn and enhance the colour and quality of red fruit (Glenn and Erez, 2002; Heacox, 1999). According to Glenn *et al.* (2001), particle film sprays improved fruit size and yield, enhanced CO_2 assimilation, decreased heat stress and occasionally enhanced red fruit color.

Climatic change in traditional fruit growing regions has intensified environmental stresses such as elevated temperatures and increased solar radiation, which significantly effect the productivity and fruit quality of temperate fruit crops. Apple being one of the most economically important temperate fruit crop worldwide, its cultivation is highly sensitive to climatic variations. The objective of this work was to evaluate the effect of application of different particle films as well as white and black net on quality of Red Velox cultivar of apple.

Materials and Methods

The experiment was conducted in the experimental fields of Division of Fruit Science, Sher-e-Kashmir University of Agricultural Science & Technology of Kashmir, Shalimar, Srinagar Jammu & Kashmir during the year 2024. Eight year old trees of apple cv. Red Velox were selected with a spacing of 3×1.5 meters. The experiment consisted of 12 treatments replicated thrice in Randomized complete block design (RCBD).

Treatments and their time of application

The experiment comprised of 12 treatments including two hail net treatments and three particle films treatments applied at different concentrations. The treatments were: T_1: Control, T_2: White net (mesh size 3 × 3 mm), T_3: Black net (mesh size 3 × 3 mm), T_4: Kaolin @ 4.00%, T_5: Kaolin @ 6.00%, T_6: Kaolin @ 8.00%, T_7: Silica Gel @ 0.25%, T_8: Silica Gel @ 0.75%, T_9: Silica Gel @ 1.25%, T_{10}: Calcium carbonate @ 1.00%, T_{11}: Calcium carbonate @ 2.00% and T_{12}: Calcium carbonate @ 3.00%. The hail nets were installed on 2nd week of June and maintained until harvest. The particle film treatments were applied at three different intervals: first application was made during second week of June, the second during the second week of July and the third one month before expected harvest.

Kaolin, Silica Gel and Calcium carbonate ($CaCO_3$) was prepared by dissolving requisite quantities directly in water using Tween -20 (1%) as a surfactant.

Fruit quality assessment

Fruit weight (g) was measured using a digital weighing balance on ten randomly selected fruits from each treatment. Fruit length (mm) and diameter (mm) of ten randomly selected fruits from each treatment were recorded with the help of a digital vernier calliper. Fruit volume (cm^3) was determined using the water displacement method. However, Fruit firmness was determined with the help of penetrometer (Effigi, 11 mm Prob.) and expressed in Newton (N). Soluble solids content (SSC) was measured using a digital Hand Refractometer (0–32% range; Erma, Japan) and expressed in ^{o}Brix. Total sugars were estimated by using the Lane and Eynon method as discussed by

Ranganna (1986) in his study. Titratable acidity (%) was calculated by titrating 10 mL of the sample with 0.1 N NaOH using phenolphthalein as indicator (Ranganna (1997).

The data was analysed using R statistical software following the analysis of variance procedure described by (Fisher, 1950). Treatment effects were compared using critical difference (CD) at 5% level of significance.

Results and Discussion

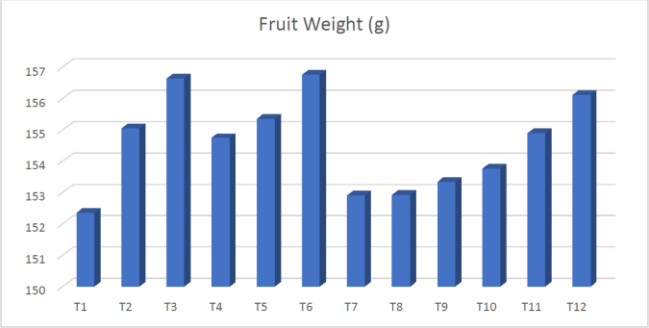

Fig. 1 : Response of Fruit weight (g) to different particle film treatments and netting in apple cv. Red Velox ($\mathbf{T_1}$: Control, $\mathbf{T_2}$: White net, $\mathbf{T_3}$: Black net, $\mathbf{T_4}$: Kaolin @ 4%, $\mathbf{T_5}$: Kaolin @ 6%, $\mathbf{T_6}$: Kaolin @ 8%, $\mathbf{T_7}$: Silica Gel @ 0.25%, $\mathbf{T_8}$: Silica Gel @ 0.75%, $\mathbf{T_9}$: Silica Gel @ 1.25%, $\mathbf{T_{10}}$: Calcium Carbonate @ 1%, $\mathbf{T_{11}}$: Calcium Carbonate @ 2%, $\mathbf{T_{12}}$: Calcium Carbonate @ 3%)

The application of various particle film and netting treatments significantly influenced the Fruit weight (Fig. 1). The highest fruit weight (156.76 g) among the treatments was recorded from Kaolin @ 8%, which was statistically at par to Black net (156.64 g) and Calcium Carbonate @ 3% (156.11 g). However, the lowest fruit weight was recorded in control (T_1; 152.36 g), followed by Silica Gel @ 0.25% and 0.75% (152.90 and 152.92 g), respectively. The increase in fruit weight under such treatments may be explained by the fact reflective particle films, such as calcium carbonate and kaolin, have been shown to promote fruit growth and development by lowering fruit and canopy temperatures, improving overall canopy carbon assimilation rate, increasing water-use efficiency and reducing solar damage (Glenn, 2009). Glenn *et al*. (2003) found that particle films based on kaolin and calcium carbonate improved carbon assimilation and fruit size in apples, whereas Glenn and Erez (2002) reported lower fruit temperature and sunburn incidence following kaolin application. Our results are also in accordance with (Gindaba and Wand, 2005) and (Weerakkody *et al*., 2010) who also reported an increase of fresh weight of fruit by application of Kaolin. Similarly, the highest fruit weight under black net can be due to the lower fruit surface temperatures and decreased incident solar radiation inside the canopy. It has been reported that protective netting can lower fruit surface temperatures by 1.5-4.0°C, reducing heat damage and enhancing fruit growth conditions (McCaskill *et al*., 2016).

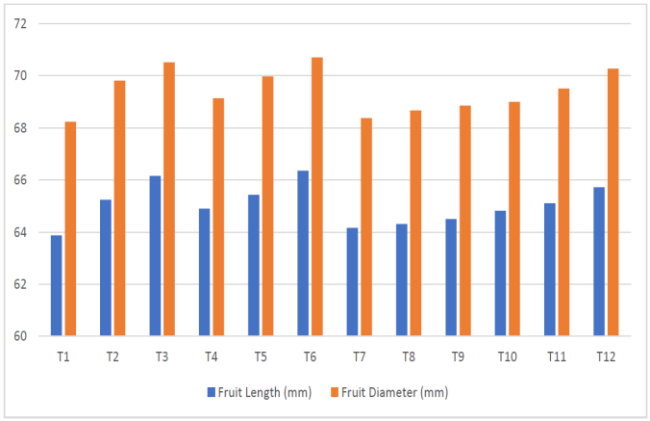

Fig. 2 : Response of Fruit length and diameter (mm) to different particle film treatments and netting in apple cv. Red Velox ($\mathbf{T_1}$: Control, $\mathbf{T_2}$: White net, $\mathbf{T_3}$: Black net, $\mathbf{T_4}$: Kaolin @ 4%, $\mathbf{T_5}$: Kaolin @ 6%, $\mathbf{T_6}$: Kaolin @ 8%, $\mathbf{T_7}$: Silica Gel @ 0.25%, $\mathbf{T_8}$: Silica Gel @ 0.75%, $\mathbf{T_9}$: Silica Gel @ 1.25%, $\mathbf{T_{10}}$: Calcium Carbonate @ 1%, $\mathbf{T_{11}}$: Calcium Carbonate @ 2%, $\mathbf{T_{12}}$: Calcium Carbonate @ 3%)

The various particle film and netting treatments had a significant impact on fruit length and diameter (Fig. 2). Among the treatments, Kaolin @ 8%, Black net and Calcium carbonate @ 3% recorded the maximum fruit length (66.35, 66.16 and 65.72 mm, respectively). However, control showed the lowest fruit length (63.88 mm). Similarly, the fruit diameter under Kaolin @ 8% (70.70 mm) was the largest, followed by Black net (70.51 mm) and Calcium Carbonate @ 3% (70.27 mm), whileas control reported the lowest fruit diameter (68.23 mm). The observed increase in fruit length and diameter under Kaolin and calcium carbonate treatments may be attributed to their ability to decrease the radiation and heat load on leaves exposed to sun thereby allowing them to better regulate leaf temperature and improve light distribution inside the canopy, improve photosynthetic efficiency and promote greater carbon assimilation at the whole plant level contributing to enhanced fruit growth (Glenn and Puterka, 2007; Rosati *et al.*, 2007). The results were in agreements with those obtained by Abd El-Naby *et al.*, (2020). Similarly, greater fruit size under black netting can be due to the improved conditions of canopy enhancing the light interception and promoting carbohydrate partitioning in developing fruits. Such improvement in microclimate of canopy supports the fruit growth (Bosco *et al*., 2018).

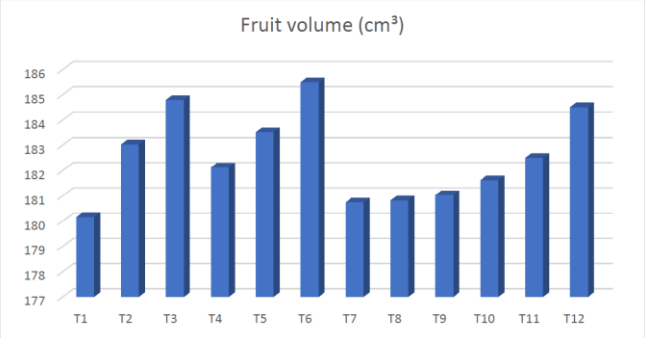

Fig. 3 : Response of Fruit volume (cm^3) to different particle film treatments and netting in apple cv. Red Velox ($\mathbf{T_1}$: Control, $\mathbf{T_2}$: White net, $\mathbf{T_3}$: Black net, $\mathbf{T_4}$: Kaolin @ 4%, $\mathbf{T_5}$: Kaolin @ 6%, $\mathbf{T_6}$: Kaolin @ 8%, $\mathbf{T_7}$: Silica Gel @ 0.25%, $\mathbf{T_8}$: Silica Gel @ 0.75%, $\mathbf{T_9}$: Silica Gel @ 1.25%, $\mathbf{T_{10}}$: Calcium Carbonate @ 1%, $\mathbf{T_{11}}$: Calcium Carbonate @ 2%, $\mathbf{T_{12}}$: Calcium Carbonate @ 3%)

The various applied treatments had significant effect on Fruit volume (Fig. 3). The treatments Kaolin @ 8% showed the highest fruit volume (185.51 cm^3) followed by Black net (184.80 cm^3) and Calcium Carbonate @ 3% (184.52 cm^3). However, control recorded the lowest fruit volume (180.17 cm^3). The current results are consistent with those of Glenn *et al.* (2003), who found that kaolin particle films decrease fruit temperature and improved apple fruit quality attributes. Our findings are also consistent with those of Al-Saif *et al.* (2022), who also noted that applying a spray containing calcium and kaolin increased volume of pomegranate fruits. Moreover, higher fruit volume by black netting may be associated with favourable microclimate that maximizes light utilization within the canopy and encourages greater accumulation of assimilates (Bosco *et al*., 2018).

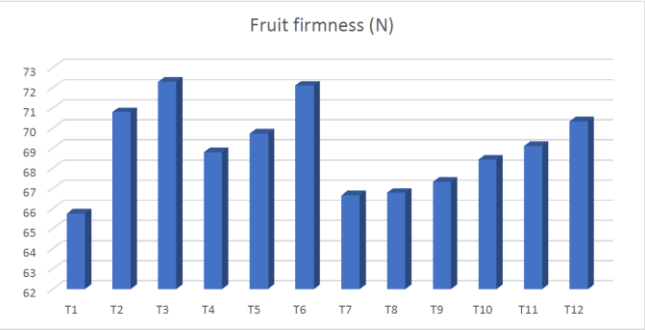

Fig. 4 : Response of Fruit firmness (N) to different particle film treatments and netting in apple cv. Red Velox ($\mathbf{T_1}$: Control, $\mathbf{T_2}$: White net, $\mathbf{T_3}$: Black net, $\mathbf{T_4}$: Kaolin @ 4%, $\mathbf{T_5}$: Kaolin @ 6%, $\mathbf{T_6}$: Kaolin @ 8%, $\mathbf{T_7}$: Silica Gel @ 0.25%, $\mathbf{T_8}$: Silica Gel @ 0.75%, $\mathbf{T_9}$: Silica Gel @ 1.25%, $\mathbf{T_{10}}$: Calcium Carbonate @ 1%, $\mathbf{T_{11}}$: Calcium Carbonate @ 2%, $\mathbf{T_{12}}$: Calcium Carbonate @ 3%)

The different particle film and netting treatments had a significant effect on Fruit firmness (Fig. 4). The highest fruit firmness (72.31 N) was recorded in Black net followed by Kaolin @ 8% (72.11 N) and Calcium carbonate @ 3% (70.33 N). However, control showed the lowest fruit firmness (65.75 N). The highest fruit firmness in the present study under black net may be due to delayed fruit ripening as a result of altered microclimate created by netting. Robinson *et al.* (1983) reported full sunlight exposure is negatively correlated to fruit firmness, indicating that fruit texture may be maintained by lowering solar radiation through netting. Similar findings by Widmer, (1997) showed that apples grown in netted orchards were significantly firmer than those grown in uncovered orchards. These results support the current study's findings, which showed that black netting considerably increased fruit firmness when compared to the control. Moreover, improved fruit firmness by kaolin treatment is because it is well known that lower fruit temperature slow ripening and preserve cell wall integrity for an extended period of time by suppressing respiration and ethylene production rates (Weerakkody *et al.*, 2010 and Pace *et al.*, 2006). As a result, compared to control, fruits treated with kaolin show more firmness and better retention of quality.

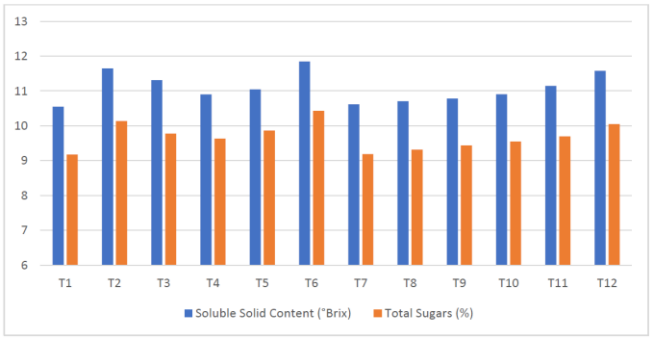

Fig. 5 : Response of Soluble Solid Content (°Brix) and Total Sugars (%) to different particle film treatments and netting in apple cv. Red Velox ($\mathbf{T_1}$: Control, $\mathbf{T_2}$: White net, $\mathbf{T_3}$: Black net, $\mathbf{T_4}$: Kaolin @ 4%, $\mathbf{T_5}$: Kaolin @ 6%, $\mathbf{T_6}$: Kaolin @ 8%, $\mathbf{T_7}$: Silica Gel @ 0.25%, $\mathbf{T_8}$: Silica Gel @ 0.75%, $\mathbf{T_9}$: Silica Gel @ 1.25%, $\mathbf{T_{10}}$: Calcium Carbonate @ 1%, $\mathbf{T_{11}}$: Calcium Carbonate @ 2%, $\mathbf{T_{12}}$: Calcium Carbonate @ 3%)

The different particle film and netting treatments had a significant effect on Soluble Solid Content and Total Sugar of the fruit (Fig. 5). The highest SSC (11.85 °Brix) and Total sugar (10.43%) was recorded in Kaolin @ 8% followed by White net (11.65 °Brix and 10.14 %, respectively). However, control showed the lowest SSC (10.55 °Brix) and Total Sugar (9.18%). The increase in the SSC and total sugar may be attributed to the enhanced photosynthetic activity in kaolin-treated trees, which leads to greater carbohydrate synthesis and subsequent accumulation of sugar in fruits (Hamdy *et al.*, 2022). The present

findings are in agreement with those of Ergun (2012) and Glenn *et al.* (2001) who reported that kaolin based particle films improve or maintain the fruit quality without any detrimental effect on it. Moreover, the greater values of SSC and Total sugar were found in apples under white nets in comparison to the black nets. According to Robinson *et al.* (1983) sunlight exposure and the accumulation of soluble solids in apple fruits are positively correlated. Increased sugar content and fruit quality have been linked to increased photosynthetically active radiation (PAR), better leaf light interception, and increased synthesis and translocation of photoassimilates under netted conditions (Solomakhin and Blanke, 2008 and Johnson and Lakso, 1986).

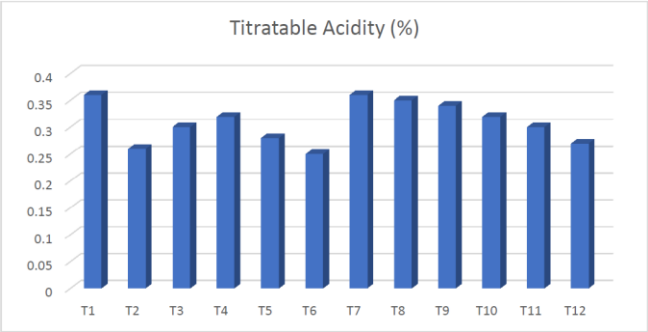

Fig. 6 : Response of Titratable Acidity (%) to different particle film treatments and netting in apple cv. Red Velox (**T_1**: Control, **T_2**: White net, **T_3**: Black net, **T_4**: Kaolin @ 4%, **T_5**: Kaolin @ 6%, **T_6**: Kaolin @ 8%, **T_7**: Silica Gel @ 0.25%, **T_8**: Silica Gel @ 0.75%, **T_9**: Silica Gel @ 1.25%, **T_{10}**: Calcium Carbonate @ 1%, **T_{11}**: Calcium Carbonate @ 2%, **T_{12}**: Calcium Carbonate @ 3%)

The different particle film application and netting had a significant effect on Titratable Acidity of fruit (Fig. 6). The lowest titratable acidity was recorded in Kaolin @ 8% (0.25%), followed by White net (0.26%). In contrast, highest value of titratable acidity was observed in Control and Silica Gel @ 0.25% (0.36%). The lowest acidity in treatment Kaolin @ 8% may be due to the enhanced fruit photosynthetic activity and carbohydrate accumulation resulting from improved micro climatic conditions by application of particle film and netting. Similar results have been obtained by Glenn *et al.* (2003) and Rosati *et al.* (2007) who observed improved fruit quality by application of particle films. However, white net recorded the lower value of titratable acidity than black net. Robinson *et al*. (1983) found a slight negative correlation between sunlight exposure and fruit acidity. The lower acidity observed under white net may be associated with the ability of black net to reduce Photosynthetic Active Radiations (PAR) more than white net.

Conclusion

The findings of present study revealed that the application of particle films and netting significantly improved the fruit quality characteristics such as fruit weight, firmness, SSC, and Total Sugar. However, T_6 (Kaolin @ 8%) and T_3 (Black net) emerged as the most promising treatments for enhancing fruit quality attributes in apple, indicating their potential adoption in regions experiencing high temperature and solar radiation under changing climatic conditions.

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