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Effect of mulch type on physico-chemical quality of tomato (*Solanum lycopersicum*) in semi-arid region of India

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Tomato (*Solanum lycopersicum* L.) is a well-known source of vitamin C, lycopene, carotenoids along with various minerals and other bioactive and dietary substances. Lycopene is a main carotenoid present in tomatoes that have received attention for its potential role in preventing various diseases (Kannaujia *et al*. 2019). Tomato is grown in almost all regions of India. The south-western area of Punjab state is a typical semi-arid and dry-farming region, with average annual rainfall ranging between 300–350 mm. Hence, crop mulching can be an appropriate and effective method for increasing crop yield and water-use efficacy in semi-arid and dry farming environments. Reports indicate that crop mulching with plastic film is preferably used to modify the soil temperature, preserve soil moisture and reduce weed problems. Organic mulches can provide multiple benefits and have the ability to suppress weed growth, controlling soil surface temperatures and soil moisture. Organic mulch also improves soil biological health by increasing organic matter, porosity and water holding capacity. Moreover, crop mulching augments the synthesis of bioactive compounds which lead to improved post-harvest fruit quality (Kannaujia *et al*. 2021).

In most of the previous studies, field research was mainly focused on impacts of plastic mulch and organic mulch on soil moisture, soil temperature, crop growth, yield etc. But, the impact of coloured-plastic mulching on the availability of functional parameters and bioactive compound accumulation has been barely studied. So far, the effects of coloured-plastic and organic mulch on post-harvest functional tomato fruit quality characteristics have not been evaluated by using a comparison methodology. With these backgrounds, the present study was done to determine the impact of coloured-plastic mulching and organic mulching on physical properties and biochemical compounds present in tomato fruits cultivated under open-field conditions with the use of standard agro-inputs.

The research was conducted at All India Coordinated Research Project on Plastic Engineering in Agriculture Structure and Environment Management (AICRP-PEASEM) field at ICAR-Central Institute of Post Harvest Engineering and Technology (CIPHET), Abohar, Punjab during 2019–20. During the study, tomato crop was cultivated with different types of colored plastic film mulching (black, red, yellow, white and silver), organic mulching and no-mulch in open-field conditions. The finely chopped (3–5 mm size approximately) straw of wheat, was used as organic mulch treatment and were applied @0.4 kg straw/m^2 of bed. Tomato variety (var. Heem Sohna, Syngenta, India), with features of intermediate growth, long duration and high yielding potential was obtained from the local seeds and fertilizer market. The seeds of tomato were sown during last week of August (2019) and one month seedlings were transplanted during the last week of September. Raised beds (25 m long, 0.5 m wide and 20 cm high) with drip irrigation setup for each plant were prepared in each treatment. Plastic film mulch (0.5 m wide and 0.03 cm thick) was placed over the raised beds before the week of tomato planting. Total 10 pickings were done to accomplish the total harvesting of physiological mature fruits from different mulching conditions.

To measure the average fruit weight, 10 mature red fruits from each mulched plant were harvested and then weight of each fruit was measured using an electronic weighing balance. The sphericity of fruits was calculated by measuring the dimensions of length, breadth and thickness by using digital vernier calipers.

Total soluble sugar (TSS) was estimated by using a hand refractometer and the results were represented in °Brix.

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Ascorbic acid was estimated by using the 2,6-dichlorophenol indophenols dye method and expressed in mg/100 g. Lycopene content from extracts of freshly crushed tomato was estimated by method of Brandt *et al*. (2003) and expressed in mg/100 g. Total phenolics were estimated by the method suggested by Singleton *et al*. (1999) and expressed in mg GAE/100 g. Total antioxidant capacity was determined by "CUPRAC (Cupric Reducing Antioxidant Capacity)" method, as reported by Apak *et al*. (2004) and expressed in µmol TE/g.

Three replications of each mulching treatment were used in this experiment by following the completely randomized design. The data were statistically analysed using analysis of variance (ANOVA), and Duncan's multiple range test was used to compare the mean values at the significance level of 5%. The MINITAB 17 programme was used to conduct principal component analysis (PCA) in order to determine the correlations between fruit quality traits and their associations with various mulching treatments.

Fruit dimensions and sphericity: Better visual appearance is correlated with higher values of sphericity and vice versa. Data (Table 1) demonstrated that the red mulch had the lowest value of sphericity while yellow mulch had the highest sphericity, followed by black mulch. However, the differences among various mulching treatments were not statistically significant (P<0.05). Similar trends have been documented in previous studies. Tesfaye *et al*. (2016) reported that the average length and diameter of tomato fruits were not significantly affected by the mulching treatment. However, Awasthi *et al*. (2006) found that the length and width of brinjal fruits varied significantly, and the values of these parameters were the highest under black mulch as compared to other mulch treatments.

Table 1 Effect of different mulching treatments on physical parameters of tomato fruits

Mulch	Sphericity	Average fruit weight (g)
No-mulch	0.94±0.01^{a}	49.08±1.20^{ab}
Black	0.95±0.01^{a}	47.39±1.32^{ab}
Red	0.87±0.11^{a}	57.59±3.26^{b}
Yellow	0.96±0.01^{a}	43.46±3.28^{a}
White	0.93±0.01^{a}	56.32±3.52^{b}
Silver	0.94±0.02^{a}	40.72±3.23^{a}
Organic	0.93±0.01^{a}	49.69±0.59^{ab}

Means values with same superscript letter in a column are not significantly different according to DMRT test (P<0.05).

Average fruit weight: Polyethylene based plastic film mulch lessen the process of soil infiltration and water absorption, which thereby modifies soil microclimate and the atmosphere and ultimately affects seedlings germination and their metabolic development. Henceforth, the favorable effect of mulching had been demonstrated on improved plants shoot and root growth, physiological development, nutrients uptake, and crop and fruit biomass (Dukare *et al*. 2021). Average fruit weights of the mulching and no-mulch treatments showed significant (P<0.05) differences (Table 1). The tomato grown on silver plastic film had the lowest mean weight, while those grown on red plastic mulch had the highest mean weight, followed by white mulch. Similar results have been reported by Gad EL-Moula *et al*. (2018) that tomato fruits with red-mulch had the highest mean weight.

TSS content: Data (Table 2) indicates that the application of plastic mulches significantly (P<0.05) affected the TSS value of tomato fruits. The highest TSS content was observed under organic mulch followed by silver, whereas the least value was obtained under no mulch. However, the differences in the TSS contents were statistically non-significant (P<0.05). According to Gad EL-Moula (2018), TSS in tomato fruits was considerably impacted by the colour of the mulch. Posada *et al*. (2011) stated that red mulch had increased TSS as compared to other coloured mulches in strawberries.

Ascorbic acid content: The findings (Table 2) demonstrated significant differences (P<0.05) in the amount of ascorbic acid present in tomato fruits grown under various mulching regimens. The ascorbic content was found to be highest in white mulch, followed by organic mulch, and lowest in yellow mulch. The increase in ascorbic acid level in tomato fruits under polythene mulching may be caused by the stimulatory influence on plant development

Table 2 Effect of mulching treatments on biochemical parameters of tomato fruits

Mulch	TSS (˚Brix)	Ascorbic acid (mg/100 g)	Total phenolic content (µg GAE/100 g)	Total antioxidant activity (µmol trolox equiv./g)	Lycopene content (mg/100 g)
No-mulch	4.17±0.12^{a}	29.0±0.06^{d}	45.50±3.29^{bc}	9.03±0.26^{a}	2.50±0.13^{d}
Black	4.62±0.25^{ab}	29.9±0.10^{de}	59.00±3.01^{d}	10.50±0.49^{b}	2.17±0.15^{c}
Red	4.65±0.25^{ab}	25.2±0.02^{c}	45.00±1.72^{bc}	10.40±0.72^{b}	2.99±0.17^{e}
Yellow	4.33±0.25^{a}	21.5±0.08^{a}	47.00±2.39^{c}	9.08±0.76^{a}	1.33±0.07^{a}
White	4.90±37^{b}	32.7±0.04^{f}	57.40±2.06^{d}	8.78±0.16^{a}	1.30±0.02^{a}
Silver	4.50±22^{ab}	23.3±0.12^{b}	41.30±1.97^{b}	8.98±0.65^{a}	1.85±0.02^{b}
Organic	4.97±12^{b}	30.9±0.07^{e}	35.00±1.59^{a}	9.08±0.44^{a}	1.49±0.01^{a}

Means values with same superscript letter in a column are not significantly different according to DMRT test (P<0.05).

and metabolism, which is reflected in increased chemical composition (Moursi 2003). According to Gad EL-Moula (2018), coloured-mulching treatments had a substantial impact on the ascorbic acid concentration of tomato fruits and lettuce heads.

Total phenolic content: Results of Table 2 show that tomato fruits produced under black mulch had highest total phenolic content followed by white mulch, and least were reported in organic mulched tomato fruits. Differences in soil temperature and the barrier features provided by mulching were identified as the main reason for variations in phenolic content. Comparatively, soil temperatures with plastic mulching were 1–3°C higher than no-mulch condition. Plastic sheets allowed some solar energy to pass through them, trapped and heating the soil. Higher temperature below the plastic mulch increases the antioxidant enzyme which leads to higher synthesis of antioxidant molecules (Kannaujia *et al*. 2021).

Total antioxidant activity: As presented in Table 2, tomato fruits showed the highest values of CUPRAC antioxidant activity in black mulched plots followed by red mulch treatment, and the least was reported under white mulch. The elevated soil temperature and variable light conditions beneath mulch sheets due to variations in colour of mulch could be the possible reason for fluctuation in phenolic compounds and antioxidant activity in tomato fruits (Wang and Zheng 2001). According to Rivero *et al*. (2001) phenol accumulation under thermal stress leads to an increase in its biosynthetic ability.

Lycopene content: According to the results (Table 2) the lycopene concentration was highest in the red plastic mulch treatment, followed by the no-mulch treatment, and the lowest values were found in the white mulch treatment. Lycopene content in ripe tomato fruits increased after polyethylene treatments, which may be attributable to the stimulation of plant development and metabolism that results in an increase in chemical composition (Moursi 2003). Biosynthesis of lycopene is mediated by phytochrome. When solar light falls on coloured plastic mulch, it is absorbed, transmitted or reflected on the plant canopy and fuits. Reflection is governed by the colour of the mulch. For example, red mulch reflects red light, whereas yellow mulch reflects yellow light. Hence, slight variations in red light falling over mature-green fruit could stimulate lycopene accumulation (Alba *et al*. 2000), which may be explained by the highest lycopene content obtained under red plastic mulch.

Principal component analysis and principal component (PC) biplot: The results of PCA on the biochemical and bioactive substances found in tomato fruits produced under various mulching treatments are shown in Fig 1. According to Fig 1, the X-axis is below all of the biochemical parameters that were estimated during the study. In the third and fourth quadrants, the variables red mulch, black

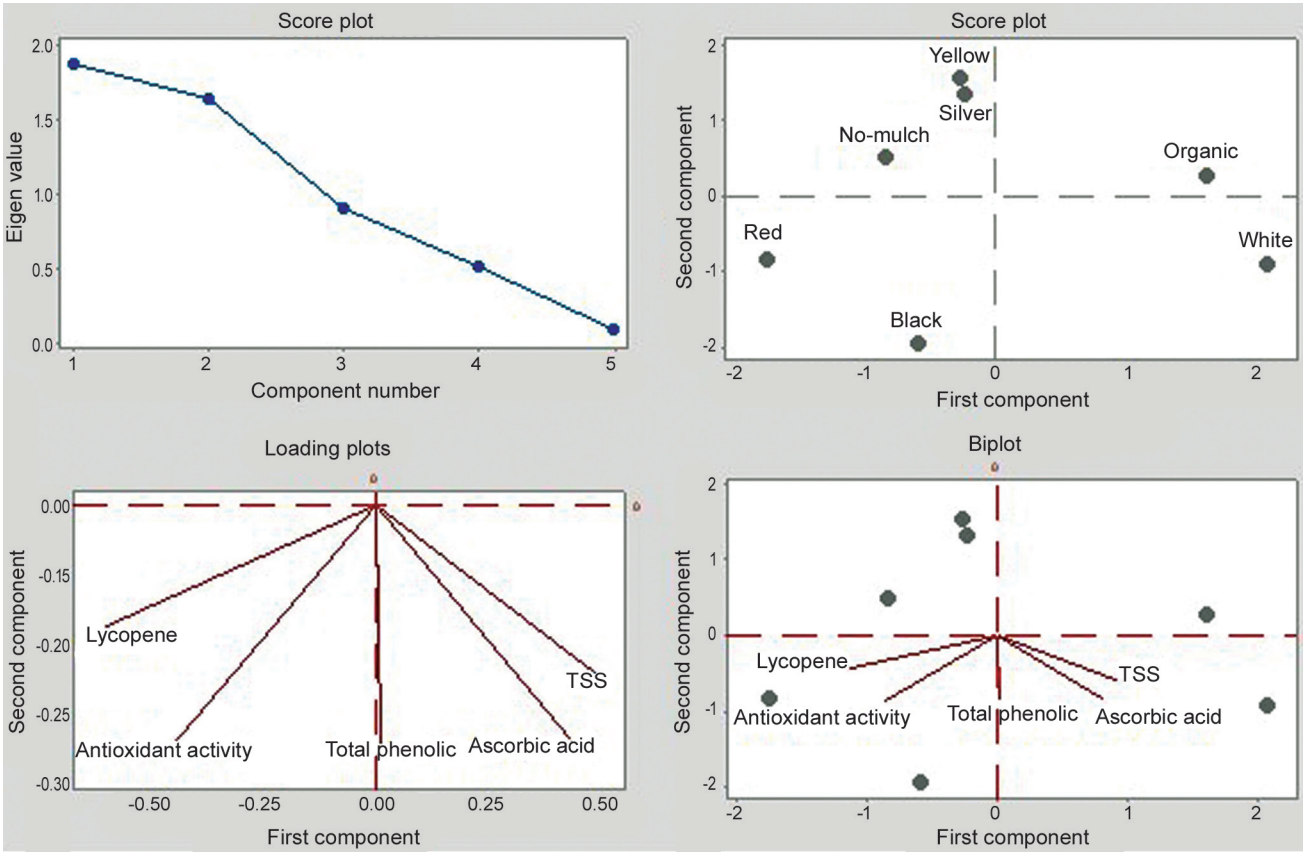

Fig 1 Depiction of the results of PCA conducted for TSS, ascorbic acid, total phenolics, antioxidant activity and lycopene content in tomato fruits.

mulch, and white mulch are similarly loaded. Ascorbic acid and TSS were associated with white mulch, total phenolics were associated with black mulch, and lycopene content and antioxidant activity were closely associated with red mulch. Red mulch was found to be the best mulching among the treatments tested based on the PCA results. Many researchers have used PCA to determine the relationships between the various post-harvest quality characteristics of cherry tomatoes and cowpeas (Coyago-Cruz *et al*. 2018, Kannaujia *et al*. 2021).

The results of the study confirm the beneficial effect of the application of different coloured plastic mulch on physical and biochemical quality traits in tomatoes. Results confirm that almost all the biochemical parameters (antioxidants and total phenolics) are closely connected with black mulch followed by red and white plastic mulching treatments under open field conditions.

SUMMARY

The influence of coloured-plastic mulching on physical and biochemical characteristics of tomato fruits were investigated. During the study, tomato crop was grown in an open field under five coloured-plastic mulching, one organic mulch and a no-mulch treatment. Harvested tomato fruits were analysed for various physico-chemical post-harvest quality parameters. Results evidenced that sphericity of tomatoe fruits was non-significantly ($P<0.05$) affected by mulching treatment. The highest fruit sphericity (0.96) was observed under yellow mulch followed by black (0.95). Likewise, average fruit weight (57.59 g) and lycopene content (2.99 mg/100 g) was found highest under red mulch. The highest TSS content (4.97) were reported in organic mulch followed by silver (4.90), while ascorbic acid content was highest under white mulch (32.7 mg/100 g) followed by organic mulch (30.9 mg/100g). Under black mulch, the highest levels of phenolic content (59.0 µg GAE/100 g) as well as antioxidant activity (10.50 µmol TE/g) were observed. Overall results showed that black mulch performed better, followed by red and white plastic mulch treatments.

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