



Coloured plastic mulching influences post-harvest quality of tomato (*Solanum lycopersicum*) fruits under polyhouse conditions

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Tomato fruit (*Solanum lycopersicum* Lam.) is a rich source of vitamin C, lycopene and carotenoids along with some minerals. Vitamins and phytochemicals which neutralize free radicals, and other bioactive and dietary substances are also abundantly found in tomato fruits. A significant quantity of carotenoids (lycopene) were found in tomatoes, may help to prevent human degenerative disorders (Abir *et al.* 2023). Tomato crop can be successfully grown in almost all the parts of India including north-western states, like Punjab and Haryana. The south-western area of Punjab is typically a semi-arid and dry-farming region, having average annual rainfall ranging between 300–350 mm. Increasing water use efficiency and crop productivity in such semi-arid regions by use of mulching for production may be a feasible and realistic approach.

Tomato crops are mostly cultivated on raised beds covered with plastic mulch in peri-urban areas which gives higher marketable yield. The soil micro-environment is modified artificially by mulching, which could have a significant influence on the constitutional, compositional, and various functional attributes of various soil microorganisms (Kannaujia *et al.* 2023). In earlier studies, our study have showed that the mulched tomato plants exhibited a comparatively higher growth, ultimately demanded higher uptake of mineral nutrients to meet the various physiological and cellular processes as compared with the plants in control (Dukare *et al.* 2020). The majority of earlier studies used field research to mainly investigate how mulching affects soil humidity, temperature, structure,

plant growth parameters and crop yield under open field conditions. However, meagre research has been done on how it affects the accumulation of bioactive compounds in fruits and the availability of functional parameters under mulched tomato in the polyhouse conditions. Therefore, in present study, we addressed how crop mulching affects important post-harvest quality traits under polyhouse condition. In polyhouse conditions, the consequences of various mulching on postharvest quality measures have not yet been evaluated in a comparative manner. Hence, the primary research's major goal was to determine the effects of various coloured plastic films and organic mulching on the physical and biochemical compounds found in tomato fruits grown using standard agricultural practices.

The study was carried out during 2019–2020 at ICAR-Central Institute of Post Harvest Engineering and Technology, Abohar, Punjab. Tomato crop was grown with different types of mulching under polyhouse condition. A total six types of mulching treatments, viz. organic, black, red, yellow, white, silver and no mulch were used for study. The evenly chopped wheat straw were used as organic mulch treatment @0.4 kg/m² of bed. The seeds of tomato (var. Heem Sohna, Syngenta), having intermediate growth feature were sown during fourth week of August 2019 and One-month old tomato seedlings were transplanted in raised beds (25 m long, 0.5 m wide and 20 cm high) with plant to plant spacing of 50 cm having drip irrigation facility. The width between the centres of two consecutive beds was maintained as 0.7 m. Plastic mulch (0.5 m wide and 0.003 cm thick) was placed over the raised beds before the week of tomato planting. Total six picking were done to accomplish the total harvesting of physiological mature fruits from different mulching conditions. Tomato fruits were harvested from 3rd picking and analyzed for various physical and biochemical parameters viz. fruit dimensions (sphericity), ascorbic acid, lycopene content, total soluble solids (TSS), total phenolics and total antioxidant capacity.

To estimate the sphericity of tomato fruit, 5-tomato fruits were taken from each mulching treatment and different

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dimensions such as length, breadth and pericarp thickness were measured in mm by a digital vernier caliper. From the different measured dimensions, sphericity of fruits was calculated using the following formula.

$$\text{Sphericity} = \frac{\text{Geometric mean diameter}}{\text{Longest dimension (L)}}$$

Where,

$$\text{Geometric mean diameter} = (L \times B \times T)^{1/3}$$

Total soluble solids was estimated by using a hand refractometer and results were represented as °Brix. Ascorbic acid was estimated by using 2, 6-dichlorophenol indophenols dye method and expressed in mg/100 g as per the method of AOAC (2000). Total phenolic content was determined by Singleton *et al.* (1999) with some modifications and expressed in µg GAE/100g. Total antioxidant capacity were estimated by “CUPRAC” methods as reported by Apak *et al.* (2004) and results expressed in µmol TE/g. The lycopene content was calculated as described by Brandt *et al.* (2003), and findings were presented in mg/100 g.

Three replications of each mulching treatments were used in research experiment by following the completely randomized statistical design (CRD). Analysis of variance (ANOVA) statistical techniques were used to analyse the study's findings, and duncan's multiple range test (DMRT) was used to compare the average values at a significance level of 5% ($p < 0.05$). The MINITAB 17 software was used to perform principal component analysis (PCA) in order to determine the correlations between the characteristics of tomato fruits and their associations with various mulching treatments.

Fruit dimensions and sphericity: It is evident from Table 1 that the highest fruit sphericity was observed under organic mulch and white plastic mulch, while the least was observed in silver mulch treatment. Kannaujia *et al.* (2023) reported that yellow plastic mulch had highest fruit sphericity and red plastic mulch had lowest value but difference were non-significant among the treatments under open field conditions. Similarly, Awasthi *et al.* (2006) also reported that the maximum fruit length and diameter in brinjal fruit occurs under black mulch over white plastic

mulch and no-mulch.

TSS: The maximum TSS content was noted in white mulch preceded by organic mulch and the least was observed under no-mulch treatment (Table 1). Similar results have been reported by Mendonca *et al.* (2021), where they reported that maximum TSS content was noted in the tomato fruits (var. Cordillera, Feltrin, Farroupilha, Brazil) produced under white mulch (4.58°Brix) followed by organic mulch (4.55°Brix). Solar radiation and temperature affects the accumulation of sugar in fruits, however, higher temperatures ($>30.3^{\circ}\text{C}$) negatively affects the tomato development (Mendonça *et al.* 2021). White mulch and organic mulch have tendency to keep the plant environment cooler than other mulches, hence these treatments produced tomato fruits with higher TSS contents.

Ascorbic acid: As evidenced in Table 1, maximum ascorbic acid content was found under white mulch, followed by black mulch, and lowest under no-mulch. The stimulating effect of application of plastic mulching on plant development and metabolism, which enhanced chemical composition of fruit, probably the reason for increase in ascorbic acid in tomato fruits (Helaly *et al.* 2017, Mohammed and Saeid 2020). According to Gad EL-Moula *et al.* (2018), ascorbic acid concentration of tomato fruits was considerably influenced by different coloured mulching. The content was highest under green plastic mulch (28.30–28.88 mg/100 g) followed by red plastic mulch (28.01–28.58 mg/100 g).

Total phenolics: The highest values of total phenolics were found in silver mulch followed by black mulch while yellow coloured mulch had the lowest value (Table 1). In comparison to no-mulch, soil temperatures under plastic mulching were substantially higher. An increase in temperature under the mulch accelerate the antioxidant enzymes, which increased production of antioxidant compounds in cowpea pods. Variation in soil temperature and barrier properties of mulching is key factors for increased phenolic content in tomato fruits (Kannaujia *et al.* 2023).

Total antioxidant capacity: Presented results in Table 1 showed that highest CUPRAC capacity was found in red coloured mulch proceeded by silver mulch and lowest was recorded in no-mulch. The higher amount of phenolic compounds may be explained by increased soil temperature

Table 1 Effect of different mulching treatments on physical and biochemical parameters of tomato fruits produced under polyhouse

Mulching treatments	Fruit sphericity	TSS (°Brix)	Ascorbic acid (mg/100 g)	Total phenolics (µg GAE/100 g)	Total antioxidant capacity (µmol TE/g)	Lycopene content (mg/100 g)
Control	0.93±0.01 ^{abc}	4.81±0.13 ^a	31.5±0.10 ^a	75.25±3.96 ^b	21.84±1.84 ^a	1.50±0.13 ^a
Black	0.94±0.00 ^{bc}	4.86±0.10 ^a	37.4±0.13 ^b	178.25±11.01 ^d	22.04±2.84 ^a	1.30±0.10 ^a
Red	0.93±0.01 ^{bc}	4.83±0.25 ^a	36.6±0.13 ^b	122.25±5.99 ^c	22.95±1.17 ^a	2.22±0.12 ^b
Yellow	0.92±0.02 ^{ab}	4.93±0.09 ^a	36.6±0.12 ^b	58.75±4.76 ^a	22.64±2.03 ^a	2.76±0.20 ^c
Organic	0.95±0.00 ^{bc}	5.01±0.37 ^a	35.7±0.10 ^b	66.25±5.75 ^{ab}	22.83±0.53 ^a	1.39±0.07 ^a
White	0.95±0.02 ^c	5.06±0.16 ^a	40.8±0.13 ^c	70.00±2.71 ^{ab}	22.58±0.24 ^a	2.38±0.03 ^b
Silver	0.91±0.01 ^a	4.85±0.21 ^a	36.6±0.15 ^b	182.50±9.72 ^d	22.94±0.94 ^a	1.52±0.09 ^a

Means values with at least one similar superscript letter in a column are not significantly different according to DMRT test ($p < 0.05$).

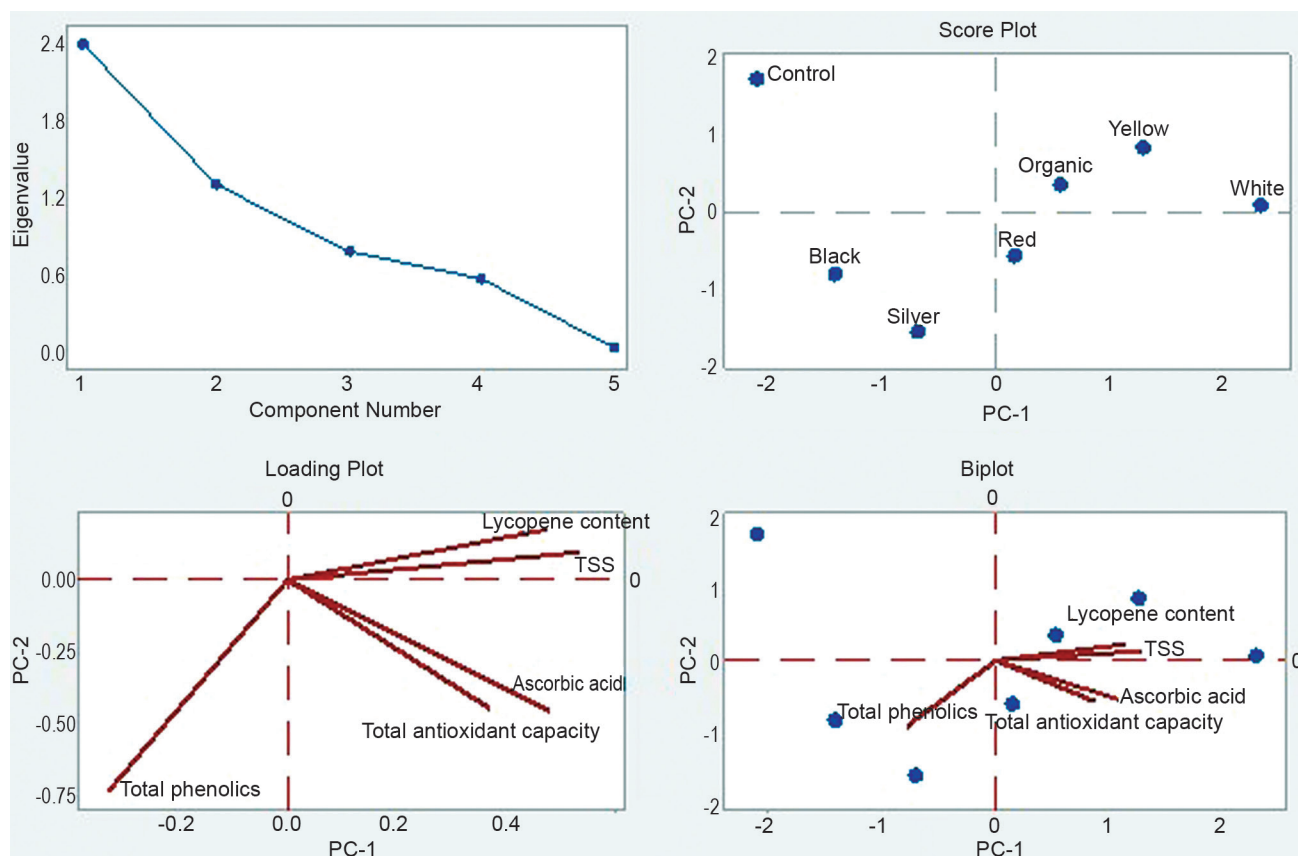


Fig. 1 Depiction of the results of Bi-plots of first two PCA obtained for TSS (Total soluble solids), ascorbic acid, total phenolics, antioxidant capacity and lycopene content.

and various photo-period conditions under various coloured mulch (Wang and Zheng 2001, Kannaujia *et al.* 2023). The antioxidant capacity shows a positive correlation with phenolics compounds (Chaieb *et al.* 2011). During the temperature stress, accumulation of phenolic compounds increased that led to increase the ability to biosynthesis of antioxidants activity as described by Rivero *et al.* (2001).

Lycopene content: The highest amount of lycopene was obtained in yellow-coloured plastic mulch followed by white mulch treatment while least values were observed under black plastic mulch treatment under polyhouse condition (Table 1). Polyethylene mulch increased the amount of lycopene in mature tomato fruits because they have a growth-promoting effect on the plant's metabolism, which is reflected in the chemical composition of the tomato fruit (Helaly *et al.* 2017, Mohammed and Saeid 2020). Tomato plants grown under silver mulching showed better nutrients uptake as compared to organic and no mulch. On plastic mulching, desired root-zone temperature is achieved which further enhances soil biotic-functions and roots' physiological processes associated with uptake of moisture as well as nutrients from soil solution (Dukare *et al.* 2020).

Principal component analysis (PCA) and principal component (PC) biplot: PCA analysis was applied to recognize the relationships between the post-harvest quality traits of mature ripe tomato fruits and their association with different mulching treatments and results are presented in

Fig. 1. First principal component (PC-1) explained 47.80% of the variance in polyhouse condition, while second principal component (PC-2) accounted for 25.80%. Fig. 1 indicated that most of the analyzed parameters are intimately related to white-coloured mulch preceded by organic, yellow and red mulches, although total phenolics were closely linked with silver and black coloured mulches. It is also evident from Fig. 1 that the control treatment did not showed any association with the biochemical parameters estimated in the study. PCA has been applied by various researchers to establish the association among the various post-harvest quality parameters of cherry tomatoes (Kannaujia *et al.* 2019, Kannaujia *et al.* 2023).

SUMMARY

The study was carried out during 2019 and 2020 at ICAR-Central Institute of Post Harvest Engineering and Technology, Abohar, Punjab to find out how different coloured plastic mulch treatments affected the physical and biochemical post-harvest quality traits of tomato fruits under polyhouse. Tomato crop was grown with different types of mulching treatments, viz. organic, black, red, yellow, white, silver and no mulch. The highest fruit sphericity (0.95) was observed under the organic mulch and white mulch while the least (0.91) was observed in silver mulch. The highest total soluble solids (TSS) values (5.06 °Brix) and ascorbic acid (40.8 mg/100 g) were observed under

white mulch. The highest phenolic content (182.50 µg GAE/100 g) was found in silver mulch followed by black mulch (178.25 µg GAE/100 g). Red mulch had the highest CUPRAC antioxidant capacity (22.95 µmol TE/g), while yellow mulch had the highest lycopene concentration (2.76 mg/100g). In conclusion, white plastic mulch delivers better results regarding greater tomato fruit quality traits than other mulches.

The outcomes of the present study's findings demonstrated the positive effects of different types of coloured plastic mulch on physical and biochemical characteristics of tomato fruits. Results showed that under polyhouse condition, white plastic mulch treatment followed by organic mulching treatment is strongly related to almost every biochemical indicator (viz. antioxidants and phenolic content). The build up of bioactive substances in mature tomato fruits is positively impacted by the mulching treatment.

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