Defence Life Science Journal, Vol. 9, No. 4, OCTOBER 2024, pp. 335-342, DOI : 10.14429/dlsj.9.19723

Effect of Coloured Plastic Mulches on Yield and Quality of Tomato (Solanum lycopersicum) in Central Himalayan Region

Ankur Agarwal*, Pradeep Kumar Yadav, Devi Sahay, Om Prakash, Sanjay Mohan Gupta & Madhu Bala
DRDO-Defence Institute of Bio Energy Research (DIBER), Goraparao, Haldwani-263 139, Uttarakhand, India
Email: ankur.diber@gov.in

ABSTRACT

Plastic mulches are used nowadays to significantly increase crop yield due to ease of use, transportation, and storability. The main objective and aim of this investigation is to examine the role of colored plastic mulch on growth, quality, and yield attributing traits of tomato (*Solanum lycopersicum*) in the central Himalayan region. The field experiment contained mulches in red, black, yellow, silver, and a no mulch control from Oct 2019 to Feb 2020. Red plastic mulch improved growth, yield, and quality attributing characters compared to other mulches and control. Red mulched treatment maintained better soil moisture and better soil temperature (up to 6 °C) compared to control and other colored mulches. The yield of tomatoes ranged from 13.49 to 20.27 kg.m-2 with the maximum under red plastic mulch. A yield increase of 29.72 to 50.25 % was achieved using mulch as compared to control. The plant growth, quality, and flowering attributing traits also exhibited superiority under mulching over control with red mulch showing the best effect. Tomato fruits harvested from red mulch treatment exhibited the highest value of quality parameters such as TSS (5.20 °B), lycopene content (5.59 mg/100g), ascorbic acid content (16.86 mg/100g), and carotenoid content (3.51 mg/g FW).

Keywords: *Solanum lycopersicum*; Inorganic mulch; Productivity; Quality; Biochemical

1. INTRODUCTION

Mulching causes an increase in soil water retention, minimises weed issues, improves soil temperature, reduction in disease-pest attacks better nutrient use efficiency, and many more that significantly improve various crop productivity[1,2]. Now these days, the use of this technique is very common due to the ease of its application, transportation, and storage. The effect of various organic and inorganic mulching have been recently successfully demonstrated in many crops including tomato[3,4].

Mulching decreases soil moisture losses by minimising the soil temperature and evaporations, promoting favorable microbial activities, reducing the hardiness of soil[5], and lesser incidence of some diseases[3]. Plastic mulches are widely used in crop production and significantly reduce losses related to weed competition[4,6] and more efficient use of soil nutrients[7] by directly affecting the micro-climates near plant soil by modifying radiation budget[8].

Tomato (*Solanum lycopersicum*) is considered as second most used-up vegetable worldwide after potato that is consumed as fresh, cooked, and in a multiple processed form[9]. Among the various factors responsible for tomato fruit yield, supply of nutrients, and availability of moisture, weed competition and variation in diurnal temperature play vital roles. Tomato is considered an important cash crop in Uttarakhand[10] and is usually grown on an area of approximately 9.2 thousand hectares. Unfortunately, its productivity is quite less (11.29 t/ha) as compared to the national average of 25.04 t/ha. This region is characterised by steep slopes, which often face problems of soil erosion and loss of top soil layer due to rains and irrigation. Mulching has been a good strategy to reduce soil erosion. As the effectiveness of mulch depends on mulch applied, soil type, micro-climatic conditions, and other related factors, a need was felt to generate scientific data on the performance of various colored mulches on the performance of tomatoes.

2. MATERIALS AND METHODS

A field pilot experiment was carried out to observe the role of various color mulches on the yield and quality of tomatoes (F1-Hybrid Arka Rakshak) over the control (without mulch). This experiment was

Received : 5 Feburery 2024, Revised : 18 July 2024
Accepted : 25 July 2024, Online published : 26 September 2024

conducted during the winter season of the year 2019-2020 at the field test facility, DIBER-DRDO, Goraparao, Haldwani, Uttarakhand. The average monthly mean minimum and maximum temperature and humidity ranged from 0OC to 22 OC & 23 OC to 45 OC; and 22 to 48 % & 63 to 92 %, respectively. The experimental soil site contains alluvial soil and falls under the warm moist sub-humid zone. The plots of 12 m x 6 m were prepared for the transplantation of tomato seedlings. The distance of plants was kept at 60 cm (row to row) and 45 cm (plant to plant). The thickness of different colored mulches was 25-micron. The experiment comprised five treatments viz., T1 (Red mulch), T2 (Black mulch), T3 (Yellow mulch) T4 (Silver mulch) T5 (no mulch, control) with four replications. The different color plastic mulches have been laid before transplanting plant materials. Also, the small transplanting holes were made on the plastic mulch for planting each tomato plant. The Trellis-type structure was prepared and made up of wooden poles with separate hanging metal wires for giving support to each plant. The average soil moisture content was recorded before irrigation during the growth phase. Soil temperature was recorded twice during the growth phase, i.e., 30 and 45 days after transplanting at a depth of 10 cm using a soil thermometer. The average was worked out of three readings.

All the required essential standard agricultural practices were followed for raising healthy crops. The experimental data were recorded on 10 randomly selected plants in each replication. Various agronomic data were recorded viz. plant height, number of primary branches, days to first flowering, days to 50 % flowering, number of flowers per cluster, number of fruits per cluster, fruit length and diameter, pericarp thickness, number of locules, average fruit weight, fruit yield per plants, fruit yield per square meter area, chlorophyll 'a' and 'b' content, total chlorophyll and carotenoids content, SPAD reading.

Total Soluble Solids (TSS), beta-carotene content, lycopene content, and ascorbic acid content were also estimated after harvesting of fresh fruits. The TSS of red ripened fruit of tomato was recorded by Digital Refracto meter at the time of harvesting as per methods suggested by Akusu[11] *et al.,* Nutritional quality of freshly harvested tomato fruits such as ascorbic acid content, lycopene content, and B-carotene content were estimated as prescribed by Sadasivam and Manickam[12]. Chlorophyll 'a', chlorophyll 'b', total chlorophyll content, and carotenoid content were also estimated to visualise the green color appearance of the tomato leaves as an indicator of physical quality[13]. SPAD readings were also measured using the SPAD meter-502 (Konica Minolta) during growth phage 60 days after transplanting of crop[14]. Data were analysed by following standard statistical procedure[15].

3. RESULTS AND DISCUSSION

3.1 ANOVA

Analysis of variance (ANOVA) revealed that most of the traits varied significantly due to treatments (Table 1a,b,c) exhibiting the importance of choosing suitable colored mulch for tomato crops. The average soil moisture content was recorded before irrigation during the growth phase. The average values of soil moisture content revealed better retention under mulch treatments. The average values of soil moisture content were found 39.12, 34.78, 31.91, 31.11, and 20.87 % in red, black, yellow, and silver plastic mulch and control, respectively.

3.2 Effect on Soil Temperature

The effect of plastic-coloured mulches on soil temperature regulation was significantly prominent (Table 2). All mulches helped in retaining higher soil temperature as compared to control. The temperature at 1300 hrs (daytime) showed improvement up to 6 °C under red-colored mulches 45 Days After Transplanting (DAT) whereas improvement in temperature at 1730 hrs (evening time) was up to 3.8 °C under red mulch again at 45 DAT. It was also found that red mulch maintained the soil temperature more uniformly during the growth phase. Black mulch treatment also showed an insignificant response with red-colored mulch towards the lower side. Soil temperature under no mulch (control with weeds) and bare soil could not retain soil temperature and showed loss of heat with diurnal variation. Diaz-Perez[16] also recorded that dark-colored mulches (blue, black, red, and gray) resulted in the highest mean root zone temperature and degree day accumulation in the soil and the lowest in light-colored mulches (silver and white). Nair and Havlovik[17] also reported a significant effect of colored mulches on root zone temperature, however the effect on tomato yield was non-significant.

Table 1(a). Analysis of variance (ANOVA) for the effect of mulching on growth and flowering traits of tomato.

Source of variation	df	Mean Squares						
		Plant height (cm)	No. of primary branches	Days to first flowering	Days to 50 % flowering	No. of flowers per cluster	No. of fruits per cluster	SPAD meter reading
Replication	3	12.75	0.002	0.106	0.312	0.052	0.292	73.02
Treatment	4	308.36**	5.67**	61.40**	199.19**	11.72**	6.25**	281.60 NS
Error	12	3.35	0.01	0.75	1.94	0.36	0.80	142.18

NS, *, ** denotes non-significant or significant at P< 0.05 and 0.01, respectively.

Table 1(b). Analysis of variance (ANOVA) for the effect of mulching of yield and attributing traits of tomato.

Source of variation	df	Mean Squares							
		No.of locules per fruit	Fruit length (cm)	Fruit diameter (cm)	Pericarp thickness (cm)	Average fruit wt. (g)	Fruit yield per plant (kg)	Fruit yield per Sqm (kg)	TSS (°B)
Replication	3	0.183	0.167	0.101	0.000	2.439	0.007	0.027	0.000
Treatment	4	0.45 ^{NS}	0.050^{NS}	0.015^{NS}	0.023**	96.04**	11.75**	28.59**	1.04**
Error	12	0.18	0.019	0.009	0.000	0.884	0.088	0.073	0.015

^{NS},*,** denotes non-significant or significant at P< 0.05 and 0.01, respectively.

Table 1(c). Analysis of variance (ANOVA) for the effect of mulching on quality traits of tomato.

Source of variation	df	Mean Squares						
		B-carotene content (mg/100g)	Lycopene content (mg/100g)	Ascorbic acid content (mg/100g)	Chlor 'a' content (mg/100g)	Chlor 'b' content (mg/100g)	Total Chlor content (mg/100g)	Carotenoid content (mg/100g)
Replication	3	0.007	0.011	0.052	0.004	0.009	0.021	0.063
Treatment	4	5.88**	5.07**	27.00**	0.091**	0.086 ^{NS}	0.330 ^{NS}	0.212 ^{NS}
Error	12	0.029	0.012	0.036	0.014	0.056	0.119	0.068

^{NS},*,** denotes non-significant or significant at P< 0.05 and 0.01, respectively.

Table 2. Average soil temprature (n=3) at 10 cm depth during the crop cycle under various treatments.

Treatments	Soil temperature 30 DAT		Soil temperature 45 DAT	
	1300 hrs	1730 hrs	1300 hrs	1730 hrs
(T1) Red	34.0	26.0	33.0	26.0
(T2) Black	33.0	26.0	31.2	26.2
(T3) Yellow	33.0	25.2	31.0	23.0
(T4) Silver	31.2	25.0	29.0	23.2
(T5) Control	28.0	24.0	28.2	23.0
Bare soil	29.2	23.0	27.0	22.2
CD value (P=0.05)	0.210	0.246	0.660	0.712

3.3 Effect on Growth and Flowering Traits

The results presented in Tables 3 a,b, and c revealed that the vegetative growth attributes like tomato plant height (115.77 cm), presence of primary branches in number (7.63), number of flowers per cluster (11.81) were recorded highest in red mulch treatment (T1)and lowest in the control treatment. Mulching has exhibited earliness in flowering compared to control. Red mulch exhibited earliness in flowering by 17 days compared to the control whereas the effect of yellow and silver mulch was less prominent. The effect of black mulch was statistically at par with red mulch for plant growth and days to flowering. The number of flowers per cluster and fruits per cluster also improved significantly under mulch treatments ranging from 24.8 to 57.6 % and 33.7 to 64.3 % over control, respectively. This increase in tomato growth under mulch treatments may be attributed to better temperature and moisture retention as compared to control.

It has been reported that mulching decreases the fluctuations of soil temperature up to the first 20-30 cm depth and promotes root growth and development, cuts down fertiliser leaching and soil compaction with cleaner vegetable production[18], and results in to increase in soil temperature, promoting faster crop development and earlier harvest[19].

Various previous studies have successfully proven that tomatoes grown under red mulch plastic contain more numbers of flowers, fruit fresh weight, number of fruits, and earlier flowering rate as compared to other color mulches including black and white mulches[20,21]. Usually, red and black plastic mulch produce the same temperature trends, however, red plastic mulches showed around 0.2 °C less cool hourly average temperature differences as compared to black plastic mulch. Mulching has been reported to preserve soil moisture by controlling evaporation from the soil surface1 and regulating condensation of soil water at night due to temperature reversals[22].

3.4 Effect on Yield and Yield Attributing Traits

Results presented in Tables 3 a,b, and c exhibited that mulching resulted in better-sized fruits with good pericarp thickness. The highest fruit weight was recorded under red mulch (95.69 g) followed by black (93.07 g), yellow (92.64 g), silver (92.45 g) mulch, and control (82.90 g). Results showed that the tomato grown under red mulch

had the highest fruit yield (20.27 kg) per square meter area followed by grown over black, yellow, and silver mulch. The lowest yield was recorded on without mulch (13.49 kg) per square meter area. Mulches of all colors exhibited significantly higher yields compared to the control (without mulch). The percent yield increase observed under red mulch was 50.25 % over control followed by black mulch (41.88 %), yellow mulch (34.39 %), and silver mulch (29.72 %). This increase in the yield of tomatoes over control may be attributed to the better retention of soil moisture and temperature and, thereby better plant growth under the red mulch treatment as already discussed. Higher early yields have been reported from plants grown on black and red mulch than plants grown on other color mulches like white, green, and brown mulch[23].

According to Decoteau[24], tomato plants grown under red mulch gave the greatest marketable yield compared to black and silver mulch. The mulch surface can induce change in the microclimate (e.g., spectral balance and quality of light, root zone temperature) that can act through natural regulatory systems within the plant growth and fruit production[8] and better nitrogen use efficiency[2]. Diaz-Perez[3] in their study on tomatoes has reported that plastic mulches maintained the root zone temperature at 26.1 °C, which is optimal for tomato growth and yield. In our experiments, red and black mulches maintained this temperature, which may be attributed to the better performance of these mulches. In addition to this, the positive effect of reflected light on plant growth and yield has been well documented[25]. It has been reported that red mulch transmits comparatively more red and near-infrared energy than white mulch film (as much as 64 % as compared to 13-40 %). Photosynthetically Active Radiation (PAR) is being utilised by plants with considerable reflectance at 550 nm[26].

Table 3(a). Mulching effect of on growth and flowering characters of tomato.

Treatments / Mulch	Plant height (cm)	Number of primary branches	Days to first flowering	Days to 50 % flowering	Number of flowers per cluster	No. of fruits per cluster	SPAD Meter Reading
(T1) Red	115.77	7.63	27.34	35.72	11.81	9.73	79.46
(T2) Black	107.04	6.84	30.07	38.67	10.22	8.31	73.13
(T3) Yellow	99.28	5.81	31.81	46.75	9.44	7.92	68.63
(T4) Silver	98.77	5.79	31.92	47.19	9.35	7.97	69.89
(T5) Control	93.13	4.49	38.00	53.23	7.49	5.92	56.53
SEm	0.91	0.05	0.43	0.69	0.91	0.30	5.96
CV (5%)	1.78	1.67	2.71	3.14	9.88	7.38	7.14

Table 3(b).Mulching effect on yield and yield attributing characters of tomato.

Treatments/ Mulch	Number of locules	Fruit length (cm)	Fruit diameter (cm)	Pericarp thickness (cm)	Average fruit wt. (g)	Fruit yield per plant (kg)	Fruit yield per Sqm (kg)	Increase in yield (%) over controlled
(T1) Red	2.75	2.68	2.23	0.57	95.69	5.53	20.27	50.25
(T2) Black	2.50	2.60	2.18	0.49	93.07	5.18	19.14	41.88
(T3) Yellow	2.50	2.51	2.14	0.46	92.64	4.90	18.13	34.39
(T4) Silver	2.00	2.45	2.12	0.44	92.45	4.85	17.50	29.72
(T5) Control	2.00	2.41	2.06	0.36	82.90	3.71	13.49	-
SEm	0.21	0.07	0.04	0.01	0.47	0.06	0.45	-
CV (5%)	8.22	5.49	4.42	2.62	1.02	5.19	3.79	-

Table 3(c). Mulching effect on quality attributing characters of tomato.

Treatments/ Mulch	TSS (°B)	B-carotene content (mg/100g)	Lycopene content (mg/100g)	Ascorbic acid content (mg/100g)	Chlorophyll "a" content (mg/gFW)	Chlorophyll "b" content (mg/gFW)	Total chlorophyll content (mg/gFW)	Carotenoid (mg/gFW)
(T1) Red	5.20	7.78	5.59	16.86	2.89	1.54	4.36	3.51
(T2) Black	4.36	6.13	4.92	14.72	2.86	1.47	4.43	3.32
(T3) Yellow	4.30	5.93	3.52	10.93	2.86	1.44	4.50	3.25
(T4) Silver	4.20	5.15	3.24	13.72	2.80	1.30	4.10	3.24
(T5) Control	3.80	4.57	3.04	10.76	2.52	1.18	3.80	2.88
SEm	0.06	0.08	0.05	0.09	0.06	0.12	0.17	0.13
CV (5%)	2.84	2.86	2.70	1.41	4.29	7.06	8.14	8.06

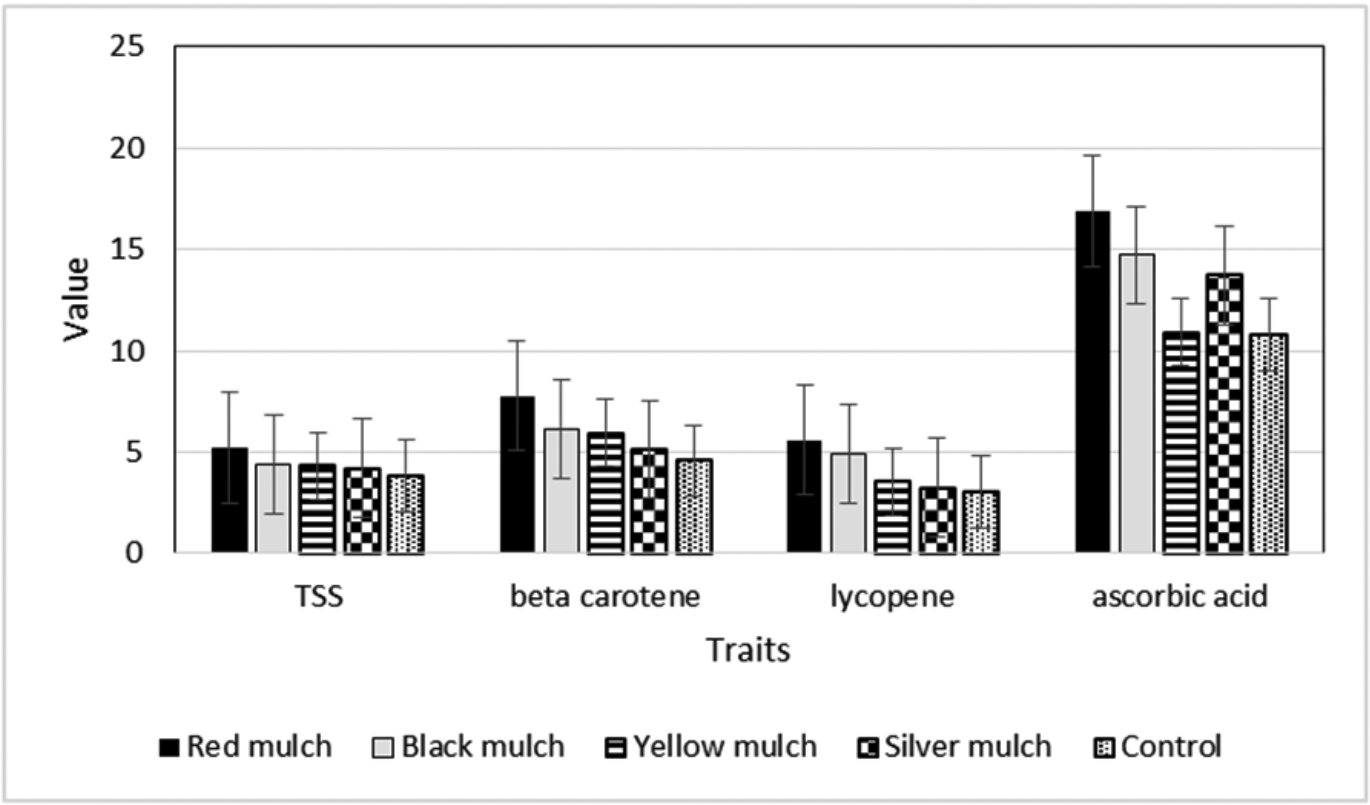

Figure 1. Effect of coloured mulching on quality traits [TSS, Beta Carotene (mg/100 g), Lycopene (mg/100 g) & Ascorbic acid (mg/100 g)] of tomato.

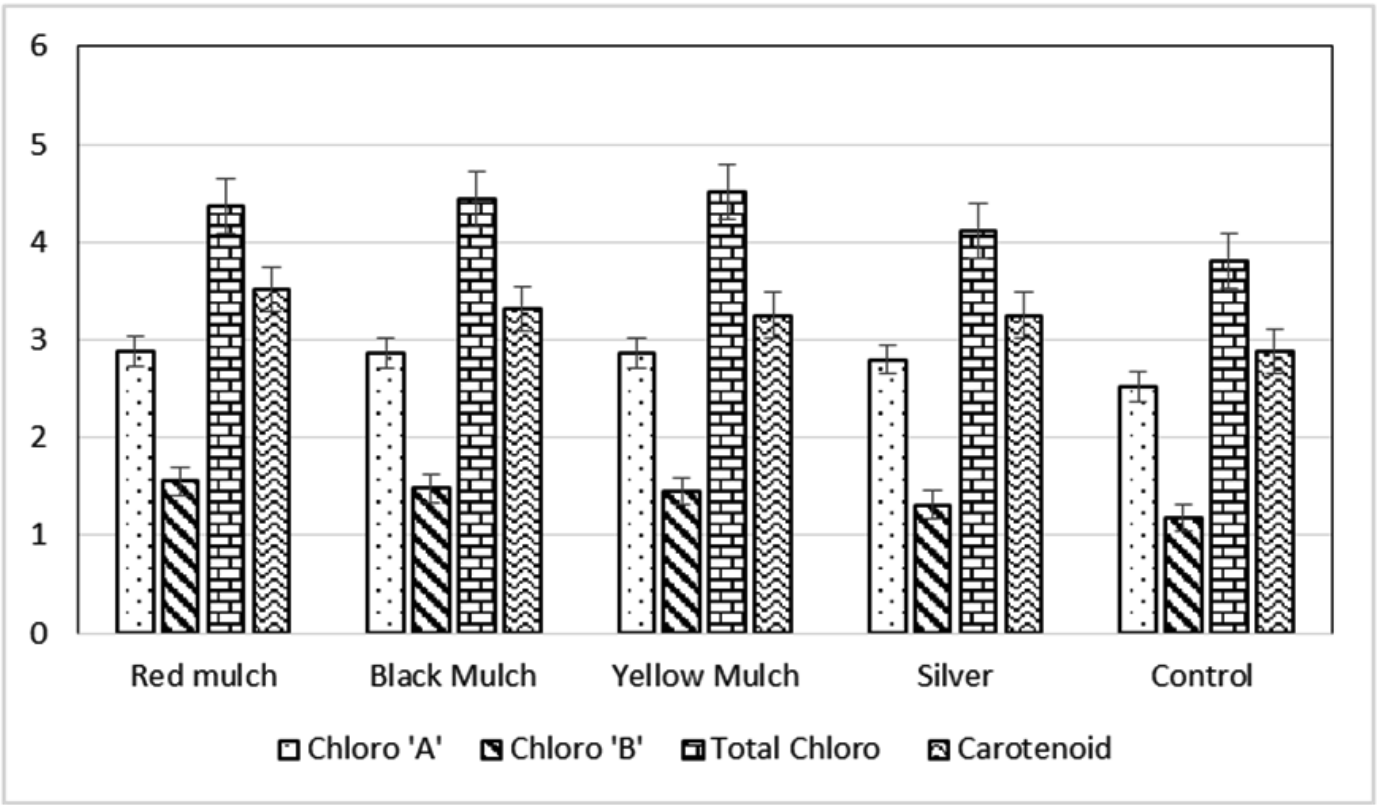

Figure 2. Effect of coloured mulching on quality traits [Chl A (mg/100 g), Chl B (mg/100 g), Total Chl (mg/100 g) & carotenoid content (mg/100 g] of tomato.

3.5 Effect on Quality Traits

The results exhibited that the quality parameters of tomatoes improved under the influence of mulch (Table 3 a,b,c; Figure 1 and Figure 2). Tomato fruits harvested from red mulch treatment exhibited the highest value of quality parameters such as TSS (5.20 °B), lycopene content (5.59 mg/100g), ascorbic acid content (16.86 mg/100g), and carotenoid content (3.51 mg/GFW). Whereas, the lowest values of these traits were observed under control. Previous studies have also reported improvement in the quality characters of tomatoes under red plastic mulch[20,27].

4. CONCLUSIONS

The use of mulches has been an important strategy for the conservation of soil moisture and temperature in modern agriculture either alone or in combination with drip irrigation. The availability of mulching sheets of various colors, sometimes makes it difficult to recommend the right colored mulching sheet to farmers in the absence of comprehensive data. In the present study, Mulches of all colors exhibited significantly higher yields compared to the control (without mulch). The percent yield increase observed under red mulch was 50.25 % over control followed by black mulch (41.88 %), yellow mulch (34.39 %), and silver mulch (29.72 %). This increase in the yield of tomatoes over control may be attributed to the better retention of soil moisture and temperature and thereby better plant growth under the red mulch treatment. In light of the above findings, it is suggested to use red-colored mulch over others for better yield and quality of tomatoes under central Himalayan conditions.

REFERENCES

1. Wang, Y.; Xie, Z.; Malhi, S.; Vera, C. & Zhang, Y. Effects of rainfall harvesting and mulching technologies on water use efficiency and crop yield in the semi-arid Loess Plateau, China. *Agric, Water Manage,* 2009, 96, 374-382. doi: 10.1016/j.agwat.2008.09.012
2. Wang X. & Xing, Y. Effects of mulching and nitrogen on soil nitrate-n distribution, leaching and nitrogen use efficiency of maize. *PLoS One,* 2016, **11**(8). doi: 10.1371/journal.pone.0161612
3. Diaz-Perez, J.C.; Batal, K.D.; Granberry, D.; Bertrand, D.; & Giddings, D. Growth and yield of tomato on plastic film mulches as affected by tomato spotted wilt virus. *Hort. Science,* 2003, **38**(3), 395-399. doi: 10.21273/HORTSCI.38.3.395
4. Agarwal, A.; Prakash, O.; Sahay, D.; & Bala, M. Effect of organic and inorganic mulching on weed density and productivity of tomato (Solanum lycopersicum). *J. Ag. Food Res.,* 2022, **7** (100274). doi: 10.1016/j.jafr.2022.100274
5. Hooda, R.S.; Singh, J. & Malik, V.S. Influence of Direct seeding, transplanting time and mulching on tomato yield. *Vegetable Sci.,* 1999, **26**(2), 140-142.
6. Ngouajio, M.; & Emest, J. Light transmission through colored polyethene mulches affected weed population. *Hort. Science,* 2004, **39**, 1302-1304. doi: 10.21273/HORTSCI.39.6.1302
7. Kasirajan, S.; & Ngouajio, M. Polyethene and biodegradable mulches for agricultural applications. *Agriculture Sustainable Development,* 2012, **32**(2), 501-529. doi: 10.1007/s13593-011-0068-3
8. Liakatas, S.; Clark, J.A. & Monteith, J.L. Measurement of the heat balance under plastic mulches part I, radiation balance and soil heat flux. *Agri. For Meteorology,* 1986, **36**(3), 227-239. doi: 10.1016/0168-1923(86)90037-7
9. Agarwal, A.; Ranjan, R.; & Nasim, M. Characterisation of exotic germplasm of tomato and variability studies at mid-hills of Himalaya. *Vegetable Science,* 2015, **42**, 39-42.
10. Agarwal, A.; Sharma, U.; Ranjan, R. & Nasim, M. Combining ability analysis for yile, quality, earliness and yield attributing traits in Tomato. International *J. Veg Sci.,* 2017, **23**(6), 605-615. doi: 10.1080/19315260.2017.1355864
11. Akusu, O.M.; Kiin-Kabari, D.B.; & Ebere, C.O. Quality characteristics of orange/pineapple fruit juice blends. American *J. Food Sci. Tech.,* 2016, **4**(2),43-47. doi: 10.12691/ajfst-4-2-3
12. Sadasivam, S.; & Manickam, A. Biochemical methods (ISBN 9788122421408). New Age International (P) Ltd., New Delhi, 2007, 284.
13. Kamble, P.N.; Giri, S.P.; Mane, R.S. & Tiwana, A. Estimation of chlorophyll content in young and adult leaves of some selected plants. Universal *J. Environ. Res. Tech.,* 2015, **5**(6), 306-310.
14. Leon, A.P.; Vina, S.Z.; Frezza, D.; Chaves, A. & Chiesa, A. Estimation of chlorophyll contents by correlations between SPAD 502 meter and chroma meter in butterhead lettuce. communications in soil science. *Plant Analysis,* 2007, **38**, 2877-2885. doi: 10.1080/00103620701663115.
15. Singh, S.R.J. Statistical methods for agricultural workers. Oxford Book Co., 2012, 288.
16. Diaz-Perez, J.C. Root zone temperature, plant growth and yield of broccoli as affected by plastic film mulches. *Scientia Horticulturae,* 2009, **123**, 156-163. doi: 10.1016/j.scienta.2009.08.014
17. Nair, A., & Havlovic, B.J. Effect of plastic mulch color on tomato production in high tunnels. Iowa state research farm progress reports-2013, 1869.
18. Ham, J.M.; Kluitenberg, G.J. & Lamont, W.J. Optical properties of plastic mulches affect the

field temperature regime. *J. American Society of Hort. Sci.,* 1993, **118**(2), 188-193. doi: 10.21273/JASHS.118.2.188

19. Lamont, W.J. Plastic mulches for the production of vegetable crops. *Hort. Tech.,* 1993, **3**(1), 35-39. doi:10.21273/HORTTECH.3.1.35
20. Agrawal, N.; Panigrahi, H.K.; Sharma, D. & Agrawal, R. Effect of different colour mulches on growth and yield of tomato under Chhattisgarh region. *Indian J Hort.,* 2010, **67**, 295-300.
21. Decoteau, R.; Dennis, K.; Hunt, M.J. & Patrick, G. Mulch surface colour affects yield of fresh market tomatoes. *J American Society of Hort. Sci.,* 1989, **102**, 273-275.
22. Tisdall, J.A.; Baverly, R.D & Radcliffe, D.E. Mulch effect on soil properties and tomato growth using micro-irrigation. *Agron. J.,* 1991, **83**, 1028-1034. doi: 10.2134/agronj1991.00021962008300060019x
23. Rao, K.V.R.; Gangwar, S.; Bajpai, A.; Chaurasia, L. & Kumar, S. Effect of different mulches on the growth, yield and economics of tomato (Lycopersicon esculentum). *International J. Agril. Sci.,* 2016, **44**(8), pp. 1885-1887.
24. Decoteau, D.P.; Dennis, D.D. & Hunt, P.G. Mulch surface colour effects on yield of fresh market tomatoes. *Proc. National Agricultural Plastics Congress,* 1986, **19**, 240-248. doi: 10.21273/JASHS.114.2.216
25. Meyer, G.E.; Paparozzi, E.T.; Walter-Shea, E.A.; Blankenship, E.E. & Adams, S.A. An investigation of reflective mulches for use over capillary mat systems for winter-time greenhouse strawberry production. *Appl. Engin. Agr.,* 2012, **28**(2), 271-279.
26. Gates, D.M.; Keegan, H.J.; Schleter, J.C. & Weidner, V.R. Spectral properties of plants. *Applied Optics*, 1965, **4**(1), 11-20.
27. Agarwal, A.; Prakash, O.; Dwivedi, S.K. & Bala, M. Beta carotene rich pure line of tomato with yellow-orange fruit colour. *Veg. Sci.,* 2018, **45**,121-123.

CONTRIBUTORS

Dr Ankur Agarwal is presently working as Scientist 'F' at DRDO-DIBER Haldwani and expert in vegetable science technology.
He has contributed to conceptualise, design and execute experiment in field, Data analysis, writing and proof reading the manuscript.

Mr Pradeep Kumar Yadav is presently working as SRF at DRDO-DIBER Haldwani and did MSc in Agronomy.
He has contributed in care and maintenance of experimental crop and data recording.

Mr Devi Sahay is presently working as SRF at DRDO-DIBER Haldwani and did MSc in Horticulture. He has contributed in care and maintenance of experimental crop and data recording as well as biochemical analysis.

Mr Om Prakash is presently working as Technical Officer-C at DRDO-DIBER Haldwani and did MSc in Botany.
He has contributed in field preparation, layout of experiment, care and maintenance of experimental crop and data recording.

Dr Sanjay Mohan Gupta is presently working as Scientist-F at DRDO-DIBER Haldwani and expert in Plant Biotechnology.
He has contributed in revision, proof reading and editing the manuscript.

Dr Madhu Bala worked as Director at DRDO-DIBER Haldwani.
She has contributed in terms of guidance for designing the study and critical evaluation of the manuscript