Response of Strawberry (*Frageria annanasa*) cv. Chandler to Different Mulching Materials

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Abstract: The experiment under discussion was conducted at Fruit Crops Research Programme, of Horticulture Research Institute, National Agricultural Research Center, Islamabad, Pakistan (Latitude: 33.42°N; Longitude: 73.08°E; Elevation: 683 msl) during the years 2006-07. Effects of different mulching materials, such as, wheat straw, rice straw, transparent and black plastic mulch, were studied on the growth and performance of strawberry cultivar 'Chandler'. Maximum plant height (17.70 cm) was observed in rice straw mulch treatment. Whereas, black plastic mulch increased root length (14.73 cm), soil moisture (39.45), soil temperature (22.33), vegetative growth (Leaf area index 17.81, crown diameter 7.76 cm), leaf chlorophyll (43.53), fruit yield (210.0) and total soluble solids (8.06). The rice and wheat straw mulch significantly ameliorated the fruit weight loss and spoilage percentage.

Key words: Moisture conservation, mulching, yield

INTRODUCTION

Mulching is the most important agricultural practice in strawberry crop, being exercised world-over. In addition to moisture conservation and temperature regulation, it avoids the contact of berries with soil and thus minimizes the chances of fruit rot, which adversely affects post-harvest life of the berries. Use of proper mulch is, thus, equally important for increasing shelf life (Sharma, 2002). Singh *et al.* (2005b) reported that, in northern plains of India, to get an early and high yield of the best quality strawberry could be planted in mid-September, if mulched with black polyethylene. Lareau and Lamarre (1993) compared straw mulch with black plastic mulch and concluded that black plastic mulch increased the yield, number and weight of crowns but decreased the fruit-size of tribute and tri-star strawberries.

Strawberry is known as the most delicious and refreshing fruit with high nutritive value (Cordenunsi *et al.*, 2003) and high hexose/sucrose ratio (Nishizawa *et al.*, 2005) to millions of people of the world. It is one of the most perishable fruits with short shelf life due to the susceptibility of berries to mechanical injury, water loss, decay and physiological deterioration (Nunes *et al.*, 1995). Much research has been conducted and there were efforts of manipulating pre-harvest (Mukkun *et al.*, 2001) and post harvest factors (Cordenunsi *et al.*, 2005) that affect fruit quality in order

to enhance strawberry shelf life. Its cultural practices are highly variable (Sharma, 2002). Superficial colour of berries determines the time of harvest, while fruit firmness is associated with shelf life. Recently, the determination of ascorbic acid has been of major interest (Aaby *et al.*, 2005; Scalzo *et al.*, 2005).

This study was conducted to measure the effect of mulching materials on yield, quality and shelf life of strawberry.

MATERIALS AND METHODS

Experiment was carried out during 2006-2007, at Fruit Crops Research Program, National Agricultural Research Center, Islamabad, Pakistan (Latitude: 33.42°N; Longitude: 73.08°E; Elevation: 683 msl). The present investigation was undertaken to determine the response of strawberry cultivar 'Chandler' to different mulching materials, such as wheat straw, rice straw, transparent plastic and black plastic mulch. Strawberry plants were grown in open field conditions, using different mulching materials as pre-harvest treatments. Field was ploughed up three times with disc harrow and leveled for better drainage. Farmyard manure was applied @ 20 t ha⁻¹, ammonium sulfate @ 500 kg ha⁻¹, super phosphate @ 300 kg ha⁻¹ and potassium sulfate @ 150 kg ha⁻¹, prior to plough the soil. Raised beds of width 70 cm with height of 30 cm were prepared.

Following treatments were applied during spring 2006 and 2007, under the field condition:

- T₀ = Bare ground
- T₁ = Wheat straw
- T₂ = Rice straw
- T₃ = Transparent plastic mulch
- T₄ = Black plastic mulch

Periodic measurements of soil moisture from the same plot each day were taken from randomly selected plots for all treatments of a replication on an observation day. For soil moisture status, soil samples were taken in aluminum cans from 15-30 cm depth for each treatment and moisture percentage was determined by gravimetric method (Yasin *et al.*, 1996). Root zone temperature was measured, using a bimetal thermometer (REOTEMP Instruments, San Diego, CA), that produced a direct measurement of soil temperature. Leaf area index was calculated, using the Leaf canopy analyzer 2000, LI-COR, Inc., 4421 (Welles and Norman, 1991). Leaf chlorophyll concentration was recorded by Spad-502 chlorophyll meter (Minolta Camera Co. Ltd., Osaka, Japan (Arenas *et al.*, 2002).

RESULTS AND DISCUSSION

Available soil moisture: All mulched plots maintained higher soil moisture content at 30 cm depth from the top of the soil surface. Among the mulches used, the black plastic mulch had higher average soil moisture content, followed by transparent plastic mulch and wheat straw mulch had the least increase even that of the bare ground (Table 1). This occurs due to the fact that in the mulched soil, the evaporating soil moisture condenses on the mulch which serves as insulating substances and drips down again to the soil surface. Improvement of water infiltration and higher water retention resulting from

mulches has also been reported by Swenson *et al.* (2004), Miller *et al.* (2002), Arriaga and Lowery (2003) and Hedau and Kumar (2002).

Soil temperature: Black plastic mulch treatment retained maximum (22.3°C) soil temperature followed by transparent plastic mulch (21.37°C). The potential of organic mulches (wheat and rice straw mulch) to retain soil temperature were lower than black plastic mulch (Table 1). Similar increase in soil temperature under black plastic mulch has been reported previously by Diaz-Perez *et al.* (2004). Minimum soil temperature was observed under rice straw mulch. These results are in agreement with those of Diaz-Perez *et al.* (2004), they found that mean soil temperature under black mulch was 9°C higher than that under organic mulch. Both wheat straw mulch and rice straw mulch resulted in significantly less soil moisture % as compared to the bare ground.

Vegetative growth of plants: Mulching improved plant growth and development. Rice straw mulch produced the tallest plants. The highest leaf area index and crown size were recorded in black plastic mulch, followed by rice straw mulch. Root length was markedly higher in rice straw mulch and transparent mulch, followed by wheat straw mulch (Table 2 and 3). Increase in growth characteristics by mulching has also been reported by Agele *et al.* (2000), Singh *et al.* (2005a) in tomato and Dobbelaere *et al.* (2000), for strawberry. The present investigation established the fact that mulching improves the vegetative growth in strawberry. Similar results have also been reported by Moor *et al.* (2004).

Mulching increased the leaf chlorophyll content as recorded in black plastic mulch and rice straw mulch, followed by wheat straw mulch. This could be due to the fact that mulching also improved the Leaf Area Index (LAI) and retained by available soil moisture. The

Table 1: DMRT of treatment means showing the effect of mulching on soil temperature and moisture contents, (Data on soil temperature and moisture were collected weekly (Transplanting to final harvest). Each mean represents three replications and twenty observations recorded for each mean)

Treatments	Soil temperature (°C)			Soil moisture (%)		
	2006	2007	Mean	2006	2007	Mean
Bare ground	18.02	19.52	18.77 ^c	29.63 ⁱ	31.60 ^h	30.61 ^e
Wheat straw mulch	15.7	16.3	16.00 ^d	34.33 ^g	35.33 ^f	34.83 ^d
Rice straw mulch	15.8	16.17	15.99 ^d	35.79 ^e	36.80 ^d	36.30 ^c
Transparent plastic mulch	21.57	21.17	21.37 ^b	36.45 ^d	37.42 ^c	36.94 ^b
Black plastic mulch	22.33	22.33	22.33 ^a	38.71 ^b	39.45 ^a	39.08 ^a
LSD	0.939		0.664		0.4402	0.3113
Mean of years	18.68 ^b	19.1 ^a		34.98 ^b	36.12 ^a	
Source	F value			F value		
Years	6.5901*			27.5395*		
Treatments	168.0611**			879.1486**		
Interaction	2.4725 ^{NS}			5.0932**		

Figures followed by different letters are significantly different at (p>0.05), according to Duncan's multiple range tests, NS : Non significant, *p>0.05, **p>0.01

Table 2: DMRT of treatment means showing the effect of mulching on vegetative growth of strawberry cv. Chandler. (Data on plant height, LAI and crown size were collected at final harvest. Each mean represents three replications and ten samples, collected for each mean.)

Treatments	Plant height (cm)			Leaf area index (LAI)			Crown size (cm)		
	2006	2007	Mean	2006	2007	Mean	2006	2007	Mean
Bare ground	16.70 ^d	16.02 ^e	16.36 ^e	10.68 ^e	11.50 ^f	11.09 ^e	0.97 ^f	0.97 ^f	0.97 ^e
Wheat straw mulch	17.80 ^{ab}	17.60 ^b	17.70 ^b	15.43 ^d	13.75 ^e	14.59 ^c	1.43 ^c	1.05 ^{ef}	1.24 ^c
Rice straw mulch	17.98 ^a	17.95 ^a	17.96 ^a	17.08 ^b	16.25 ^c	16.66 ^b	1.75 ^b	1.30 ^d	1.52 ^b
Transparent plastic mulch	17.58 ^b	16.88 ^{cd}	17.23 ^d	13.93 ^e	11.65 ^f	12.79 ^d	0.99 ^f	1.15 ^e	1.07 ^d
Black plastic mulch	17.92 ^a	17.10 ^c	17.51 ^c	18.17 ^a	17.45 ^{ab}	17.81 ^a	1.87 ^a	1.65 ^b	1.76 ^a
LSD	0.2485		0.1757	0.7667		0.5421	0.113		0.07993
Mean of years	17.6 ^a	17.11 ^b		15.06 ^a	14.12 ^b		1.40 ^a	1.22 ^b	
Source	F value			F value			F value		
Years	425746**			23.6230**			52.0548**		
Treatments	104.4698**			218.7743**			153.0590**		
Interaction	8.4612**			9.9435**			23.0590**		

Figures followed by different letters are significantly different at ($p > 0.05$), according to Duncan's multiple range tests, NS: Non significant * $p > 0.05$ ** $p > 0.01$

Table 3: DMRT of treatment means showing the effect of mulching on leaf chlorophyll contents, root length and fruit yield of strawberry cv. Chandler. (Data on leaf chlorophyll and fruit yield were collected periodically. Root length was collected at final harvest. Each mean represents three replications and ten observations, recorded for each mean)

Treatments	Leaf chlorophyll			Root length (cm)			Fruit yield plant ⁻¹ (g)		
	2006	2007	Mean	2006	2007	Mean	2006	2007	Mean
Bare ground	39.22 ^e	41.00 ^c	40.11 ^d	5.58	4.81	5.19 ^d	180.3 ^e	169.8 ^f	175.0 ^e
Wheat straw mulch	41.33 ^c	42.08 ^b	41.70 ^b	12.01	13.68	12.84 ^b	200.5 ^b	203.0 ^b	201.8 ^b
Rice straw mulch	42.33 ^b	44.38 ^a	43.35 ^a	11.8	10.15	10.97 ^c	190.5 ^c	185.0 ^d	187.8 ^c
Transparent plastic mulch	40.10 ^d	41.15 ^c	40.63 ^c	13.77	13.2	13.48 ^{ab}	183.5 ^{de}	180.3 ^e	181.9 ^d
Black plastic mulch	42.58 ^b	44.47 ^a	43.53 ^a	15.36	14.1	14.73 ^a	210.5 ^a	209.5 ^a	210.0 ^a
LSD	0.5538	0.3916	NS	1.606	3.732	2.639			
Mean of years	41.11 ^b	42.62 ^a		11.7	11.19		193.05 ^a	189.5 ^b	
Source	F value			F value			F value		
Years	43.9597**			1.3083 ^{NS}			22.0131**		
Treatments	133.4830**			46.4058**			252.6998**		
Interaction	4.5309**			1.3745 ^{NS}			7.2887**		

Figures followed by different letters are significantly different at ($p > 0.05$), according to Duncan's multiple range tests, NS: Non significant * $p > 0.05$ ** $p > 0.01$

increased vegetative growth and Leaf Area Index (LAI) promote the solar radiation intercepted by the canopy and thus increase leaf chlorophyll contents as stated earlier by Kirnak *et al.* (2001). The leaf area index was significantly and positively correlated with chlorophyll content ($r = 0.721^{**}$) and fruit weight ($r = 0.712^{**}$) and available soil moisture contents.

Yield: Black plastic, transparent plastic and rice straw mulches produced higher weight of single fruit. However, the maximum fruit length was found in wheat straw mulch followed by black plastic mulch. The fruit width was not significantly affected by mulching. It was observed that mulching influenced yield significantly in strawberry, maximum yield (210.0 g) was obtained by the use of black plastic mulch, followed by wheat (201.8 g) and rice straw (187.8 g) mulch, respectively (Table 3), whereas, Table 4 describes the DMRT of treatment mean and shows the effect of mulching on fruit

size and fruit weight of strawberry. Similar studies have been reported by Moor *et al.* (2004), that mulches had significant influence on yield and quality of strawberry.

Fruit quality: Rice straw mulch and transparent plastic mulch have no significant effect on ascorbic acid contents of strawberry fruit, in contrast wheat straw mulch and black plastic mulch showed decrease in ascorbic acid content. Ascorbic acid contents were lower in black plastic mulch treatment as compared to bare ground treatment. The relatively low content of ascorbic acid could be the causes of high temperature during ripening of the fruit. This is in line with studies conducted by Lee and Kadir (2000). Total Soluble Solids (TSS) were considerably affected by the mulching treatments. All types of mulches showed increase in TSS (Table 5). Moor *et al.* (2004) have described that application of organic mulch is better than plastic mulch as for production of better quality of strawberry.

Table 4: DMRT of treatment mean, showing the effect of mulching on fruit size and single fruit weight of strawberry cv. Chandler. (Data on fruit size were collected periodically. Each mean represents three replications and ten observations, recorded for each mean)

Treatments	Single fruit weight (g)			Fruit length (cm)			Fruit width (cm)		
	2006	2007	Mean	2006	2007	Mean	2006	2007	Mean
Bare ground	12.95 ^c	13.02 ^c	12.99 ^c	3.24 ^d	3.08 ^e	3.16 ^d	2.83	2.81	2.82 ^{ab}
Wheat straw mulch	15.02 ^b	14.85 ^b	14.94 ^b	3.45 ^b	3.55 ^a	3.50 ^a	2.75	2.83	2.79 ^b
Rice straw mulch	15.82 ^a	15.73 ^a	15.77 ^a	3.08 ^e	3.06 ^e	3.07 ^e	2.84	2.91	2.87 ^a
Transparent plastic mulch	15.80 ^a	15.27 ^{ab}	15.54 ^a	3.26 ^d	3.21 ^d	3.23 ^c	2.74	2.78	2.76 ^b
Black plastic mulch	15.93 ^a	15.95 ^a	15.94 ^a	3.36 ^c	3.48 ^b	3.42 ^b	2.78	2.78	2.78 ^b
LSD	0.6157	0.4354	0.06527	0.04615	NS	0.07297			
Mean of years	15.11	14.97		3.28	3.28		2.79	2.82	
Source	F value			F value			F value		
Years	0.8382 ^{NS}			0.0000 ^{NS}			1.4895 ^{NS}		
Treatments	65.3526 ^{**}			108.5471 ^{**}			3.4561 [*]		
Interaction	0.6306 ^{NS}			10.7039 ^{**}			0.6652 ^{NS}		

Figures followed by different letters are significantly different at ($p > 0.05$), according to Duncan's multiple range tests, NS : Non significant * $p > 0.05$, ** $p > 0.01$

Table 5: DMRT of treatment means showing the effect of mulching on quality attributes of strawberry cv. Chandler. (Data on quality aspects were collected periodically after harvest. Each mean represents three replications and ten samples, collected for each mean)

Treatments	Ascorbic acid (mg 100 g ⁻¹)			Fruit firmness (lbs)			TSS (° Brix)		
	2006	2007	Mean	2006	2007	Mean	2006	2007	Mean
Bare ground	66.75 ^a	66.50 ^a	66.63 ^a	4.890 ^{ab}	4.900 ^a	4.9	7.33 ^c	6.70 ^d	7.02 ^c
Wheat straw mulch	54.00 ^c	50.50 ^c	52.25 ^b	4.900 ^a	4.860 ^{ab}	4.88	7.58 ^{bc}	7.63 ^{abc}	7.60 ^b
Rice straw mulch	62.25 ^b	69.00 ^a	65.63 ^a	4.905 ^a	4.920 ^a	4.91	7.65 ^{abc}	8.28 ^a	7.96 ^{ab}
Transparent plastic mulch	67.25 ^a	66.25 ^a	66.75 ^a	4.825 ^b	4.915 ^a	4.87	7.73 ^{abc}	8.23 ^{ab}	7.98 ^{ab}
Black plastic mulch	53.50 ^c	53.75 ^c	53.63 ^b	4.903 ^a	4.892 ^{ab}	4.9	7.90 ^{abc}	8.23 ^{ab}	8.06 ^a
LSD	3.32	2.348	0.06527	NS	0.6	0.4242			
Mean of years	60.75	61.2		4.88	4.9		7.64	7.81	
Source	F value			F value			F value		
Years	1.4211 ^{NS}			0.6747 ^{NS}			1.5685 ^{NS}		
Treatments	83.8816 ^{**}			1.4425 ^{NS}			8.9585 ^{**}		
Interaction	5.5966 ^{**}			3.0915 [*]			2.9215 [*]		

Figures followed by different letters are significantly different at ($p > 0.05$), according to Duncan's multiple range tests, NS: Non significant * $p > 0.05$, ** $p > 0.01$

Table 6: DMRT of treatment means showing the effect of mulching on shelf life of strawberry cv. Chandler. (Data on shelf life aspects were recorded after harvest (periodically). Each mean represents three replications and five samples, collected for each mean)

Treatments	Weight loss (%)			Spoilage (%)			Shelf life (days)		
	2006	2007	Mean	2006	2007	Mean	2006	2007	Mean
Bare ground	46.25	47.25	46.75 ^a	54.50 ^b	56.25 ^{ab}	55.38 ^a	2.5	2	2.3 ^b
Wheat straw mulch	30.25	33	31.63 ^d	45.00 ^d	50.00 ^c	47.50 ^c	3	2.5	2.8 ^a
Rice straw mulch	31.25	33.25	32.25 ^d	45.00 ^d	43.00 ^d	44.00 ^d	2	2	2.0 ^b
Transparent plastic mulch	40	40.25	40.13 ^b	51.00 ^c	59.25 ^a	55.13 ^{ab}	2	2	2.0 ^b
Black plastic mulch	37	39.5	38.25 ^c	54.50 ^b	56.25 ^{ab}	55.38 ^a	3	2.8	2.9 ^a
LSD	NS	1.138	3.082	2.179	NS	0.3263			
Mean of years	36.95 ^b	38.65 ^a		49.15 ^b	52.85 ^a		2.5 ^a	2.3 ^b	
Source	F value			F value			F value		
Years	27.5238 ^{**}			48.0351 ^{**}			10.7143 [*]		
Treatments	254.2089 ^{**}			45.5332 ^{**}			13.7500 ^{**}		
Interaction	1.8185 ^{NS}			6.9514 ^{**}			1.2500 ^{NS}		

Figures followed by different letters are significantly different at ($p > 0.05$), according to Duncan's multiple range tests. NS: Non significant * $p > 0.05$, ** $p > 0.01$

Shelf life: Organic mulching (wheat and rice straw mulch) reduced weight loss and fruit spoilage in strawberry fruits and improved the shelf life. Minimum fruit spoilage and weight loss was recorded in wheat straw mulch and rice straw mulch, respectively. The black and transparent plastic mulch increased the weight loss in strawberry cultivar 'Chandler'. The increase in weight loss in strawberry fruit produced under plastic mulches could be due to high soil temperature which affects

the growth inhibitory hormone and ethylene stress might be increased under high soil temperature produced by these mulches (Table 6). As per statistical analysis wheat straw and black mulch produced strawberry with maximum shelf life. Sharma and Agrawal (2004) also stated that mulching with black plastic and erection of row covers in winter is very beneficial for better growth and production of strawberry in sub-tropical conditions.

Although, interaction of treatments and year were highly significant regarding pH of fruit, there was not any consistency among treatments in both years.

CONCLUSION

It can be inferred that application of black plastic mulch and rice straw mulch could be highly effective in maintaining soil moisture content in strawberry fields. The black plastic mulch retained higher soil moisture and temperature than the rest of the treatments. Maximum plant height and root length was observed in rice straw mulch treatment, whereas, black plastic mulch resulted in increased Leaf Area Index (LAI), crown size, leaf chlorophyll and total fruit yield. The rice and wheat straw mulch significantly ameliorated the post harvest fruit weight loss and spoilage percentage. Black plastic mulch significantly reduced the ascorbic acid content but increased the Total Soluble Solids (TSS).

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