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EFFICACY OF MULCHES ON SOIL MODIFICATIONS, GROWTH, PRODUCTION AND QUALITY OF STRAWBERRY (*Fragaria x ananassa* Duch.)

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ABSTRACT

A field experiment using different kinds of mulch materials viz. No mulch (M_0), Rice husk (M_1), White polythene (M_2) and Black polythene (M_3) was conducted on medium to deep black soil at Jhalawar Rajasthan to observe their effect on the soil physicochemical changes and on growth, production and quality of strawberry. Highest increase in soil temperature to the tune of 1 to 6° C was recorded under black polythene mulch. Black as well as white polythene mulch was almost equally effective in conserving soil moisture which was higher by 1 to 3.5 % as compared to no mulch. Rice husk mulch were effective in increasing soil organic matter, available nitrogen and water holding capacity as maximum value of OC (0.59%), Available N (424.5 kg/ha),) and WHC (46.4%) was observed under rice husk mulch. Maximum plant E-W spread (45.4cm) and N-S spread (45.6cm), biomass (55.1 g), total chlorophyll content (3.3 mgg^{-1}), root biomass (7.3 g) root volume (45.6 cc), root length (28.2 cm), fruit length (54.0 mm), fruit width (42.6 mm), average fresh fruit weight (36.7 g) number of fruits/plant (33.6), yield/plant (536.6 g), juice percentage (96.1 %), total sugar (5.2 %), reducing sugar (4.1 %) sugar, vitamin C (52.5 $mg100g^{-1}$), anthocyanin content (38.9 $mg100g^{-1}$) and minimum titratibility acidity (1.66 %) was observed in black polythene mulch. Maximum number of leaves (97.4) and highest chlorophyll (3.3 mg g^{-1}) content at the time of harvest was observed in case of white polythene mulch. The use of black polythene mulch is therefore recommended as improved practices in strawberry cultivation on soil and climatic condition similar to jhalawar district Rajasthan.

KEY WORDS: Strawberry, Polythene mulch**,** Rice husk Mulch, Soil temperature, Soil moisture.

INTRODUCTION

Strawberry (*Fragaria x ananassa* Duch.) is one of the most tempting and refreshing fruits of the world, which was introduced in India during the early sixties, but could not become choice of grower initially due to several reasons (Sharma and Sharma, 2004). However, during last decade, it has become favourite fruit among growers because of its remunerative prices and higher profitability. Further, availability of day-neutral and high yielding varieties and standarization of plasticultural techniques have resulted in phenomenal increase in its area and production particularly near towns and cities (Sharma and Sharma, 2004; Paramanick et al., 2005). Among various production practices, mulching is considered as an important cultural practice. Mulching plays an important role in soil moisture conservation, weed control, regulation of soil-hydrothermal regime, besides keeping the delicate fruit neat and cleans (Gupta and Acharya, 1993; Hancock, 1999; Tarara, 2000). In strawberry, mulching has been found to improve plant growth, berry weight, fruit yield and quality. (Hassan *et al.*, 2000; Sharma and Sharma, 2003; Moor *et al.*, 2004; Singh and Asrey, 2005; Singh *et al.*, 2006). The advantage of mulching lies in its effect on soil environment modification. Different materials are used in different parts of the world, but black polyethylene is the most widely used (Sharma and Sharma, 2004; Singh and Asrey, 2005; Singh *et al.*, 2006). The greatest benefit from plastic mulch is that the soil temperature in the planting bed is raised, promoting faster crop development and earlier harvest. Black plastic mulch can give a harvest earlier by some 7-14 days. Plant growth can be doubled due to mulching under specific conditions. Mulching reduces evaporation losses by reducing thermal gradient and exchange of vapour between soil and atmosphere as it acts as barrier thereby promoting downward movement of water. Under mulched conditions, more uniform soil moisture is maintained and irrigation frequency can be reduced. Voth, (1972) observed 70% increase in berry yield of winter plantations with clear plastic mulch which is primarily due to rise in soil temperature and better plant growth and health. An increase in strawberry (*Tioga*) yield by 68 percent and 33 percent when plants were mulched with clear plastic and pine needles over control has been reported by Badiyala and Aggrawal, (1981). Fertilizer loss by leaching is less beneath the mulch, so that fertilizers are optimally used and not wasted. The soil under plastic mulch remains loose and friable and roots access to adequate oxygen in not compromised, and microbial activity is enhanced (Parmar *et al* 2013). Considering advantages of mulch reported from various researches mainly conducted in traditional areas, systematic studies were conducted in 'Winter Dawn' strawberry, which is a newly emerging day neutral cultivar in the Indian climate to determine the efficacy of different mulches in modifying soil parameters, properties, time of harvest, yield and quality of fruit from a nontraditional but potential area for strawberry cultivation in India.

MATERIALS & METHODS

The experiment was conducted in the Protected Cultivation Unit**,** College of Horticulture and Forestry, Jhalrapatan, Jhalawar, Rajasthan during the year 2013-14. The experimental site was situated at 24°32' N latitude and 76 °10' E longitude in south-eastern part of Rajasthan on deep black soils moderate in fertility. Soil pH was in the rage of 7.2-7.5, Electrical conductivity (EC) in the rage of 0.33-0.39 dSm^{-1} with organic carbon in the range of 0.50-0.60 %. Agro-climatically, the district falls in Zone V, known as Humid South Eastern Plain. About 84.2 per cent population of the district is rural whose main occupation is agriculture. The average rainfall in the region is 954.7 mm, and daily maximum temperature range in the summer is 43- 48°C and minimum to 1.0-2.6°C. The experiment was laid out to evaluate 4 numbers of treatments with 5 replications; in the strawberry cv. Winter Dawn planted under raised bed planting system at 60 cm × 30 cm spacing. Different kinds of mulches *i.e*., Control (No Mulch) (M_0), Rice Husk (5cm thick) (M_1), White Polythene (25 micron) (M_2) and Black Polythene (25 micron) (M_3) were four treatments. In order to assess the effect of various treatments more precisely, all the experimental plots were subjected to uniform cultural practices including fertilizer application and plant protection measures.

Surface soil moisture (0-15cm) was monitored using gravimetric method at 30 days intervals where as soil temperature at the depth of 5cm was monitored using mercury in glass thermometer calibrated with standard thermometer at each 15 days interval. The soil samples were analysed both before and after experiment. To assess the fertility status of soil, representative soil samples (0-30 cm depth) from three spots from each plot of experimental site was collected, composited and air dried. The samples were powdered using a wooden mortar and pastle and passed through 2 mm plastic sieve and were analyzed for available pH and EC in soil: water suspension (1:2) using glass electrode and conductivity meter. Organic carbon was determined by the Walkley and Black's method as described by Black (1965). Available nitrogen was determined by using alkaline potassium permanganate method (Subbiah and Asija, 1956) using auto nitrogen analyzer. Available phosphorus was determined by Olsen *et al.*, (1954) method using 0.5 M $NaHCO_3$ solution adjusted at pH 8.5 using spectrophotometer as described by Black. (1965). Available Potassium was determined using 1N neutral ammonium acetate method (Meston 1956)) using flame photometer as described by Black (1965) Water holding capacity of disturbed soil samples was determined by using a circular brass box having perforated bottom.

Plant parameters: Three plants were selected randomly in each replication for taking observations on growth and physico-chemical parameter of fruits. Numbers of leaves (per plant) were counted from tagged plants in each replication after completion of harvesting period. East-west and north-south spread (cm) of the plants was recorded with the help of a meter scale. After completion of harvesting, chlorophyll from leaves of tagged plants were estimated using method suggested by Sadasivam and Manickam (1997). Tagged plants were uprooted and cleaned, weighed for fresh weight thereafter dried in oven at 70°C till constant weight, dry biomass was recorded. Fresh weight of the roots was taken by excavation of the plants. The root volume was measured by water displacement method where as root length of the plants was measured with the help of meter scale. The dry weight of the roots was taken after drying the roots in oven at 70 °C till the weight was constant. The number of fruits/plant was recorded by counting the fruits reaching harvesTable maturity. The yield/plant (g) was recorded by adding yield of all the harvests obtained from selected plant. Fruit length and width (mm) of 10 fruits from each treatment was taken with the help of digital vernier caliper. The weight of fruits (g) from each tagged plants was taken on each date of harvest. Dry weight (g) of the fruit was recorded after drying the fruits in oven at 70°C till the constant weight was achieved. Total soluble solids (TSS) (°Brix) were recorded with the help of hand refractometer. The titrable acidity (%) was determined by titrating the juice against standard alkali solution (0.1 N NaOH). Total and reducing sugars were estimated by Lane and Eynon method (1923) as described in AOAC (1984). Juice percentage of ripe fruits was estimated after crushing and squeezing with muslin cloth. Ascorbic acid content was determined by titration with 2, 6-dichlorophenolindo phenol (AOAC 1984). Total anthocyanin content was determined using methods suggested by Fuleki and Francis (1968). The data was subjected to statistical analysis for RBD as described by Gomez and Gomez (1984) using probability values (P=0.05) to test significance of observed differences and LSD for mean separation.

RESULTS & DISCUSSION

Effect on physico-chemical properties of soil:

Soil Temperature: Soil temperature at the depth of 5cm was higher under plastic mulch and highest under black plastic and was relatively lower under rice husk mulch on most of the days of observation. The warming under plastic mulch is attributed to entrapment of long wave radiation from soil, reduction in conduction loss and cutoff of convection loss under plastic mulch. Plastic mulch was more effective in reducing thermal loss than cutting incoming solar energy. Temperature on a typical day under black polythene mulch was higher by 1 to 6°C and under white polythene was in the range of 0-5°C as compared to control (Fig.1). Rice husk shows varied effect in terms of cooling as well as warming on different days. The net effect is actually tradeoff between mulch led reduction in incoming solar energy and reduction in heat loss from the soil which may vary on different day depending on prevailing weather conditions. Increased soil temperature due to mulch has been recorded under several studies (Ramakrishna et al., 2006; Singh and Kamal 2012).

Soil moisture: Similar to the temperature, surface soil moisture (0-15cm) was higher under plastic mulches and both type of plastic mulch show similar effect in terms of soil moisture. The higher moisture under plastic mulches may be due to reduced exposed surface area resulting to reduced evaporation. High surface soil moisture and reduced evaporation under plastic mulches have been reported under several studies (Ramakrishna *et al.,* 2006; Liu *et al.,* 2014, Bakshi *et al.,* 2015). Surface soil moisture under rice husk mulch was intermediate between control and plastic mulches on almost each day of observations. This may be due to some evaporation loss through porous mulch and moisture absorption by mulch itself and/or, subsequent evaporation.

Soil pH: Soil pH is measurement of hydrogen ion activities in soil solution. Though there was no significant difference among treatments, the lowest pH (6.76) was recorded under black polythene mulch (Table 1) which may be attributed to the high rate of mineralization, generation of organic acid due to increased temperature and entrapment of released CO_2 under mulched conditions. More intensive mineralization and generation of large amount of organic acid and CO_2 led formation of carbonic acid was explained as reason by Cabilovoski *et al.* (2014) which perhaps resulted in lowering the soil pH. The effect may be temporary/transit state and may return to original conditions if put to similar management.

Electrical conductivity: There was increase in EC across the treatment and more increase under control and rice husk mulch. Authors are unable to find exact reason however probably this difference may be attributed to seasonal EC cycle as tradeoff between mineralization-immobilization, fixation and release of ions. In control condition the ions released would have been less utilized by plants as compared to polythene mulches due to higher root activities under elevated temperature as indicated by higher biomass produced (discussed in later section). The reduced EC in soil under black polythene may also be due to the generation of organic acid and CO_2 (Cabilovoski *et al.,* 2014).

TABLE 1: Effect of mulches on physico-chemical properties of soil after experiment

Treatment	pH	EC (dS/m)	OC (%)	Available N (kg/ha)	Available P_2O_5 (kg/ha)	Available K_2O (kg/ha)	WHC (%)
	Initial value						
	7.3	0.36	0.54	363.7	21.9	266.2	40.9
	Post experiment value						
Control	6.76	0.53	0.52	392.1	28.5	440.4	41.6
Rice husk	7.28	0.45	0.62	424.5	34.5	444.2	46.4
White polythene	6.97	0.39	0.55	421.0	33.9	450.4	38.5
Black polythene	7.49	0.38	0.57	375.5	37.4	473.3	43.2
CD at 5%	NS	0.07	0.07	59.04	4.16	42.42	3.76
SEm±	0.21	0.02	0.02	20.34	1.43	14.61	1.29

Soil organic matter: Highest soil organic matter was observed under rice husk mulch (Table 1.) which may be attributed to the decomposition and mixing of mulch materials. Rice husk mulch of 5cm thickness is equivalent to all most 100 t/ha of organic matter. Though the time span for full decomposition was less but the portion in direct contact of soil might have decomposed and become part of soil resulting to increased organic matter content of surface soil. An increase in the total content of soil organic carbon in organic mulch has been reported by Marinari *et al.* (2010). Break down of organic mulches and becoming part of the soil and source of plant nutrients has been reported in several studies (Sharma *et al.,* (1998); Bond and Grundry (2001); Gruber *et al.,* (2008).

Available N and P: The highesr available N (473.3 kg/ha) and P (37.4 kg/ha) was recorded under rice husk mulch. The increased soil organic matter is also the probable reason behind increased available nitrogen and phosphorous in the soil.

Available K: There was increase in available potassium across all treatments with highest (473.3kg/ha) under black polythene mulch (Table 1). Authors are unable to find exact explanation but increased K may be attributed to release of K from the native soil which has significant amount of K-rich Illite clay. The increased temperature led clay surface expansion might have helped more release of K under black polythene mulch. The role of mulches in conservation of nutrients has been narrated by Gruber *et al.* (2008).

Water holding capacity: Water holding capacity though considered as conservative soil physical properties was highest (46.4 %) under rice husk mulch. This may be attributed to increased soil organic matter. Ramesh *et al.* (2008) reported increased water holding capacity of the soil with corresponding increase in the level of organic carbon and clay. Organic mulches are known to influence the physical properties of soil by increase in the soil organic matter, porosity and cation exchange capacity (Merwin and Brown, 2009) in addition to aggregate stability and structure of soil (Smets *et al.,* 2008).

Effect on plant growth

Plant growth parameters like number of leaves per plant, plant E-W spread and N-S spread (cm), plant fresh weight and dry weight (g), total chlorophyll content of leaves, root length, root weight (fresh and dry) and root volume were found influenced by different type of mulches.

Higher number of leaves per plant was recorded from strawberry plants under plastic mulch, highest under white polythene mulch (97.4) statistically at par with number of leaves under white polythene mulch (94.1) whereas minimum (73.3) was recorded in control. Maximum number of leaves in the white polythene might be related to better exploration of nutrients and water (Sturm *et al.* 2003) in late stage of crop under modified radiation condition due to higher reflection from white polythene mulch as compared to other treatments.

The Higher E-W spread (45.4 cm) and N-S spread (45.6 cm) of plant were recorded in plants under polythene mulch highest under black polythene (not significantly higher than white polythene mulch) whereas, lowest E-W spread (38.5 cm) and N-S spread (39.3 cm) were recorded from control (Table 2). Similar results have been reported by Pires *et al.* (2006) and Bakshi *et al.* (2014). Favorable environment, better moisture conservation vis-à-vis suppression of weeds under polythene mulch has been reported as reason behind better plant growth parameters (Qureshi *et al.*, 2012). Favorable modification of hydrothermal regime and physico-chemical properties as discussed in previous section may also be attributed for better growth as similar observation was reported by Dwivedi *et al.*,(2000) and Hira *et al.*, (2003). Better growths of strawberry plant under plastic mulch have been reported in several studies (Fear and Nonnecke, (1989); Gupta and Acharya, (1994); Mohamed, 2002).

TABLE 2: Effect of mulches on growth attributes of strawberry

Treatment	No.of leaves/ plant	Plant spread (cm)		Plant weight (g)		TCC* of leaves (mg/g)	Root volume (cc)	Root length (cm)	Root weight (g)	
		E-W	N-S	F W	D W				FW	DW
No mulch	73.3	38.5	39.3	90.0	30.9	1.84	20.0	20.6	18.5	4.0
Rice husk	82.4	39.2	40.0	121.2	33.8	2.02	40.7	22.2	32.8	5.4
White polythene	97.4	45.1	42.7	126.2	45.8	3.26	35.4	24.3	21.6	4.7
Black polythene	94.1	45.4	45.6	187.3	55.1	2.58	45.6	28.2	37.8	7.3
CD at 5%	9.25	5.63	5.06	9.88	2.72	0.12	1.79	1.95	1.43	0.48
SEm±	3.18	1.94	1.75	3.40	0.93	0.01	0.62	0.67	0.49	0.16

Note: TCC: Total Chlorophyll, E-W: east –west, N-S: north south, FW: fresh weight, DW: dry weight

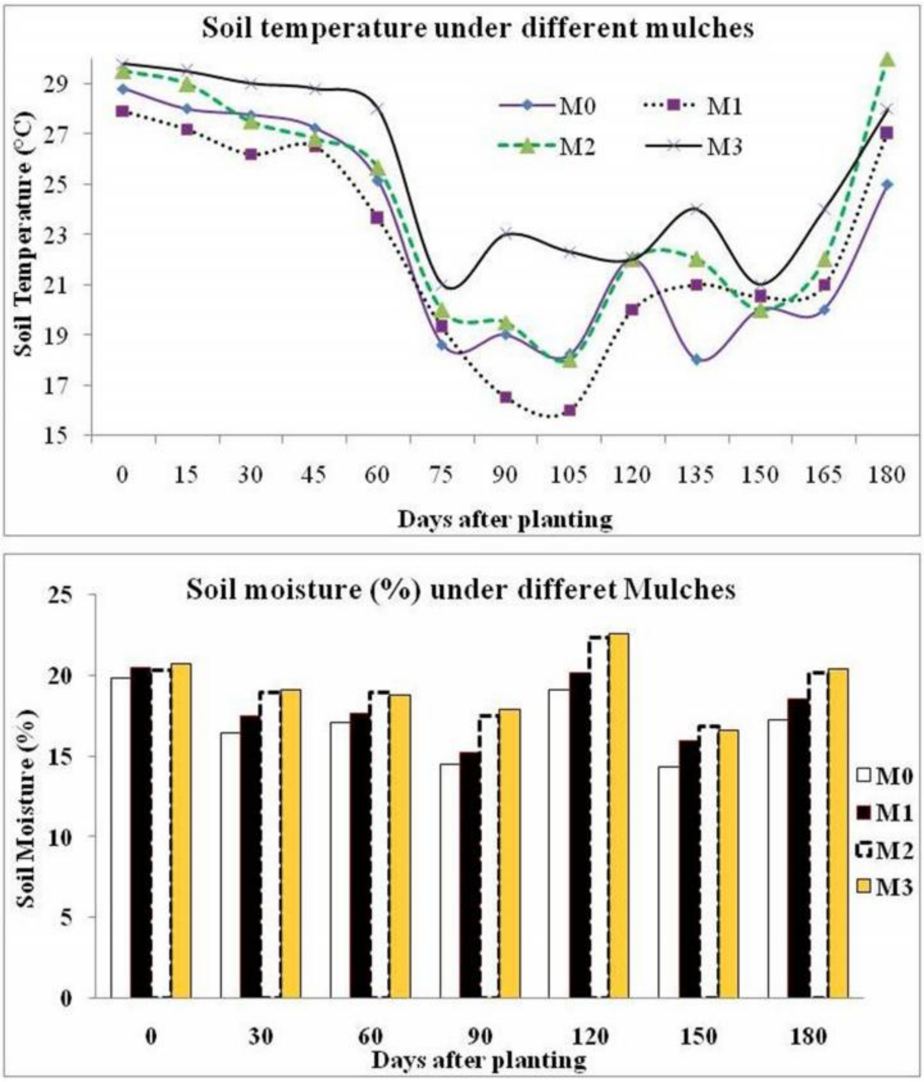

Fig.1. Soil temperature at the depth of 5cm at 15 days interval and surface soil moisture (0-15cm) at 30 days intervals under different mulch treatments (M0: Control (No mulch), M1: Rice husk, M2: White polythene, M3: Black polythene)

Maximum fresh fruit weight (187.3g) as well as dry weight (55.1g) was recorded under black polythene mulch followed by under white polythene mulch and minimum under control (Table 1). Similar findings were reported by Singh and Dwivedi, (2011) and Pop *et al.* (2013). The better growth and biomass may be attributed to higher photosynthetic activities under favorably modified soil hydrothermal conditions and better water and nutrient availability as discussed in previous section (Fig.1). Increased vegetative growth in black polythene has also been highlighted by Garg *et al.* (2007) and Taparauskiene and Miseckaite, (2014) in strawberry. Maximum chlorophyll content (3.26 mg g^{-1}) was recorded in plants grown under white polythene mulch, followed by 2.58 mg g^{-1}in plants grown under black polythene and minimum (1.84 mg g^{-1}) was recorded in control. The exact reason is beyond the comprehension of authors however possibly the higher chlorophyll content in plant grown on white mulch may be attributed to differential of synthesis and degradation of chlorophyll on white polythene. Further, the high activity of enzyme chlorophyllase may also be attributed to less chlorophyll content in the leaves under control. The differential values of the cholorophyl may be due to differences in degree of light reflection by the mulches. Decoteau *et al.* (1988) affirmed that plants grown on different types of plastic mulches respond to even the small changes in ambient light induced by mulch colour.

Root growth of the strawberry plant also responds differently with different types of mulches. The maximum fresh (37.8g), dry (7.3g) weight of roots, root volume (45.55cc) and root length (28.2 cm) was observed on black polythene mulch and the minimum fresh weight (18.5 g), dry weight (4.0 g), root volume (20.0 cc) and root length (20.6 cm) was recorded in control (Table 2). Similar results have been observed by Verma *et al.* (2005). Black polythene mulch resulted in overall better root growth parameters. Effect of black polythene mulch in favourably modifying the soil environment might be the reason for improved root length, root weight and root volume as described by Verma *et al.* (2005).

Effect on yield and quality**:**

The maximum fruit length (54.0 mm), fruit width (42.6 mm), fresh (36.7 g) and dry (2.9 g) weight of fruit, number of fruits/plant (33.6) and yield/plant (536.6g) was recorded on black polythene when used as mulch and the minimum variables on fruit length (47.72mm), fruit width (37.6 mm), fresh (26.9 g) and dry (2.1 g) weight of fruit, number of fruits/plant (25.3) and yield/plant (218.9 g) was recorded in control. The yields under polythene mulches were more than double as compare to no mulch. Higher yield under black polythene mulch has been reported by Singh and Ahmed, (2008) and Kher *et al.* (2010). Fruit width, length: diameter ratio and number of fruits per plant under white polythene mulch was not significantly different from the same under black polythene mulch. Length: diameter ratio was recorded maximum (1.27) on black polythene mulch and minimum (1.18) on white polythene mulch but was statistically similar across different treatments.

Favourably modified hydrothermal condition, improved nutrients availability supported better plant growth under black polythene mulch was well translated in form of highest fruit yields per plant. Increase in availability of nutrients and highly suppressed weeds as a reason for improved yield has been reported by Sharma and Khokhar, (2006) and Munguia *et al.* (1998). More favourable modification of soil temperature and moisture under black polythene may be attributed for better fruit growth parameter. In this treatment, the temperature was recorded in the range of 21-24°C which was in the range of 16-22°C in all other treatments over almost entire productive period *i.e.*, 18th December, 2013 to 20th March, 2014. Observations regarding larger fruits in black polythene mulch have also been reported by Mathad and Jholgiker (2005) and Kumar *et al.* (2012b). Dry weight is the net result of balancing of respiration by photosynthesis which was favourable in case of black mulch as compared to other treatment. Higher number of fruits/plant under mulched conditions has also been reported by Nagalakshmi *et al.* (2002).

Quality parameters: Effect of different type of mulches was also observed in terms of quality parameter. Though the maximum TSS (7.3°B) was observed in M_3 (Black polythene) and the minimum TSS (6.3°B) on rice husk, but it was statistically at par across all treatments (Table 3). Similarly titrable acidity was statistically similar across different treatments. Total sugars (5.15 %), reducing sugar (4.10 %), TSS: acid ratio (4.40), Vitamic C (52.5 %), Juice percentage (96.1 %) and anthocyanin content (38.9 %) were highest in case of black polythene mulch which was significantly higher than rest of the treatments except TSS: acid ratio which was statistically at par with control. Total sugar (2.9%), reducing sugar (2.0%) and anthocyanin content (29.5%) was observed lowest in case of white polythene mulch where as lowest Vitamin C and juice percentage was recorded in case of rice husk mulch.

Difference in quality parameters and in general improved quality under black polythene much may be explained in terms of higher moisture and nutrient availability, higher root activities including higher uptake of water and nutrients, high photosynthesis and other enzymatic activities. Higher TSS, lower acidity in fruit mulched with black polythene has been reported by Gupta and Acharya, (1993); Hassan *et al.* (2000) and Sharma *et al.,* (2004). These results are also in conformity with the findings of Mathad and Jholgiker, (2005) and Singh *et al.* (2007).

Various degree of light exposure under different mulch conditions might have influenced plant growth yield and most importantly quality parameters. Assuming incoming solar radiation is same for all treatments, reflection might have played role in modifying micro site conditions. Absorption of solar radiation, conduction of heat to the soil and vice versa, heat loss through evaporation, heat loss from mulch itself as radiation and conduction resulted in differential soil thermal regime. Kasperbauer *et al.* (2001) reported that black polythene reflects less than 5 percent of incident radiation irrespective to growing environments. Thus, it may be assumed that the response of black polythene mulch in terms of improvement of fruit qualities (TSS, titraTable acidity, TSS/acid ratio, vitamin C, total sugar, reducing sugar and anthocyanin content) as found in the present experiment may be due to changes in substrate temperature more than to the reflected light. In case of white polythene mulch it appears that plant was still in vegetative active phase as evidenced in terms of higher chlorophyll content (tabl 2) and lower anthocyanin content (3 b). Higher reflectance light and modified soil thermal regime may be linked to this observation which needs further study for affirmation.

TABLE 3(a) Effect of mulches on yield attributes of strawberry

Treatment	Fruit length (mm)	Fruit width (mm)	Length: dia ratio	Fruit weight (g)		No. of fruits /plant	Fruit yield/plant (g)
				FW	DW		
No mulch	47.7	37.6	1.26	26.9	2.1	25.3	218.9
Rice husk	48.0	38.5	1.24	28.2	2.2	29.3	302.2
White polythene	48.2	40.7	1.18	31.7	2.1	32.8	478.1
Black polythene	54.0	42.6	1.27	36.7	2.9	33.6	536.6
CD at 5%	4.12	4.04	0.12	4.55	0.40	4.36	35.00
SEm±	1.42	1.39	0.04	1.57	0.14	1.50	12.06

TABLE 3(b) Effect of mulches on quality attributes of strawberry

Treatment	TSS (°B)	Tit. Acidity (%)	TSS/ acid ratio	Total sugars (%)	Reducing sugars (%)	Vitamin C (mg/100g)	Juice (%)	Anthocyanin (mg/100g)
No mulch	7.2	1.66	4.34	3.22	2.33	45.3	82.4	30.2
Rice husk	6.3	1.71	3.70	3.11	2.27	39.2	65.1	36.0
White polythene	6.9	1.83	3.77	2.88	2.02	40.4	90.5	29.5
Black polythene	7.3	1.66	4.40	5.15	4.06	52.5	96.1	38.9
CD at 5%	NS	NS	0.24	0.50	0.44	3.84	7.62	4.76
SEm±	0.52	0.10	0.08	0.17	0.15	1.32	2.62	1.64

CONCLUSIONS

Strawberry can be successfully grown on medium to deep black soil of Jhalawar district Rajasthan. Different type of mulch has differential effect soil parameters and properties. However all mulches (rice husk, white polythene and black polythene) were superior to no much in terms of plant growth, yield and quality. Black polythene mulch was most effective in raising soil temperature as soil temperature was higher to the tune of 1 to 6°C where as equally effective to white polythene mulch in soil moisture conservation against evaporation. Highest plant spread, biomass, fruit size, fruit yield, total sugar, vitamin C and anthocyanine content observed under black polythene mulch indicates higher role of elevated soil temperature as catalyst for root activities including uptake of water and nutrients which was ultimately reflected in terms of high biomass and yield. Therefore black polythene mulch of thickness 25 micron can be recommended as improves practice for resource conservation, higher growth, yield and better quality of strawberry grown under similar soil and climatic conditions.

REFERENCES

AOAC (1984) *Official Methods of Analysis, 14th edn. Association of Official Analytical Chemists*, Washington DC.

Badiyala, S.D. and Aggrawal, G.C. (1981) Note on the effect of mulches strawberry production. *Indian Journal of Agricultural Research,* 51(11): 832-834.

Bakshi, P., Bhat, D.J., Wali V.K., Sharma, A. and Iqbal, M. (2014) Growth, yield and quality of strawberry (*Fragaria* x *ananassa* Duch.) cv. Chandler as influenced by various mulching materials. *Afr. J. Agri. Res.* 9(7):701-706.

Bakshi, P., Wali, V.K., Iqbal, M., Jasrotia, A., Kour, K., Ahmed, R. and Bakshi, M. (2015) Sustainable fruit production by soil moisture conservation with different mulches: A review. *African J Agric Res.,* 10(52): 4718-4729.

Black, C.A. (1965) Methods of Soil Analysis, Vol 1. American Society of Agronomy, Madison, Wisconsin, USA.

Bond, W. and Grundy, A.C. (2001) Non-chemical weed management in organic farming systems. *Weed Research,* 41: 383-405.

Cabilovski, R., Manojlovic, M., Bogdanovic, D., Magazin, N., Keserovic, Z., Sitaula, B.K. (2014) Mulch type and application of manure and composts in strawberry (*Fragaria* × *ananassa* Duch.) production: impact on soil fertility and yield. *Zemdirbyste-Agriculture,* 101(1): 67–74.

Decoteau, D.R., Kasperbauer, M.J., Daniles, D.D. and Hunt, P.G. (1988) Plastic mulch colour effects on reflected light and tomato plant growth. *Scientist Hort.,* 34: 169-175.

Dwivedi, S.K., Singh, B. and Elipaljor (2000) effect of mulch on establishment and growth of apple sapling in cold arid conditions of Ladakh. *Progressive Horticulturae,* 32(1): 42-45.

Fear, C.D. and Nonnecke, G.R. (1989) Soil mulches influence reproductive and vegetative growth of ‘Fern’ and ‘Tristar’ day-neutral strawberries. *HortScience,* 24(6): 912-913.

Fuleki, T and Francis, F J. (1968) Quantitative methods for anthocyanins. 2. Determination of total anthocyanin and degradation index for cranberry juice. *Journal of Food Science* **33**:78–83.

Garg, N., Singh, G., Yadav, P., Goel, N. and Soni, M.K. (2007) Effect of mulching on soil microbial population in guava (*Psidiumguajava*) orchard soil. *Indian Journal of Agicultural Sciences,* 77(4): 241-243.

Gomez, K.A. and Gomez, A.A. (1984) *Statistical procedures for agricultural research (*2 ed.). John wiley and sons, NewYork, 680p.

Gruber, S., Acharya, D. and Claupein, W. (2008) Wood chips used for weed control in organic farming. *Journal of Plant Diseases and Protection,* 21: 395-400.

Gupta, R. and Acharya, C.L. (1993) Effect of mulch induced hydrothermal regime on root growth, water use efficiency, yield and quality of strawberry. *Journal of the Indian Society of Soil Science,* 41(1): 17-25.

Gupta, R. and Acharya, C.L. (1994) Use black polythene for higher strawberry fruit yield. *Indian Hort.,* 39(1): 6-7.

Hancock, J.F. (1999) Strawberries.CABI publishing, Wallingford, UK.

Hassan, G.I., Godara, A. K., Kumar, H. and Jitender,A. D. (2000) Effect of different mulches on the yield and quality of 'Oso Grande' strawberry (*Fragaria x ananassa*). *Indian Journal of Agricultural Sciences,* 70(3): 184-185.

Hassan, G.I., Godara, A.K., Kumar, J., Huchehe, A.D. (2000) Effect of different mulches on yield and quality of ‘Oso Grande’ strawberry. *Ind. J. Agric. Sci.* 70, 184–185.

Hira, L., Rao, V.K. and Singh, V.P. (2003) Effect of various mulches on growth and yield of apple cv. Starking Delicious orchard. *Progressive Horticulturae*, 35(1): 25-30.

Kasperbauer, M., Loughrin, J. and Wang, S. (2001) Light reflected from red mulch to ripening strawberries affects aroma, sugar and organic acid concentrations. *Photochem. Photobio. Sci.,* 74(1): 103-107.

Kher, R., Baba, J.A. and Bakshi, P. (2010) Influence of planting time and mulching material on growth and fruit yield of strawberry cv. Chandler. *Indian Journal of Horticulture,* 67(4): 441-444.

Kumar, R., Tondon, V. and Mir, M.M. (2012b) Impact of different mulching material on growth, yield and quality of strawberry (*Fragaria* x *ananassa* Duch.) *Progressive Horticulture,* 44(2): 234-236.

Kuroki, M., Shioi, Y. and Sasa, T. (1981) Purification and properties of soluble chlorophyllase from tea leaf sprouts. *Plant and cell physiol.,* 22: 717-725.

Liu S. Y., Zhang L. F., Li Z. H., Jia J. M., Fan F.C., Shi Y. F. (2014) Effects of plastic mulch on soil moisture and temperature and limiting factors to yield increase for dryland spring maize in the North China, Ying Yong Sheng Tai Xue Bao. 2014 Nov; 25 (11):3197-206. (http://www. ncbi.nlm.nih.gov/pubmed/25898617**)**

Marinari, S., Lagomarsino, A., Moscatelli, M.C., Di Tizio, A. and Campiglia, E. (2010) Soil carbon and nitrogen mineralization kinetics in organic and conventional three-year cropping systems. *Soil and Tillage Research,* 109: 161-168.

Mathad, J.C. and Jholgiker, P. (2005) Effect of synthetic and organic mulches in improving growth, yield and quality of strawberry under subtropical ecosystem. *Acta Horticulturae*, (696): 323-326.

Merwin, I.A. and Brown, M.G. (2009) Apple root growth, turnover, and distribution under different orchard groundcover management systems. *Hortic. Sci*. 44:168-175.

Meston, A. J. (1956) Methods of chemical analysis for soil survey samples.*Department of Science Md. Research Soil Bur.,* pp- 12.

Mohamed, F.H. (2002) Effect of transplant defoliation and mulch colour on the performance of three strawberry cultivars grown under high tunnel. *Acta Horticulturae,* 567: 483-485.

Moor, U., Karp, K., Poldma, P. (2004) Effect of mulching and fertilization on the quality of strawberries. *Agric. Food Sci.* 13 (3), 256–267.

Munguia, L. J., Quezada, R., Zermeno, G. A. and Penna, V. (1998) Plastic mulch effect on the spatial distribution of solutes and water in the soil profile and relationship with growth and yield of muskmelon crop. *Plasticulture,* 116: 27-32.

Nagalakshmi, S., Palanisamy, D., Eswaran, S. and Sreenarayanan, V. V. (2002) Influence of plastic mulching in chilli yield and economics. *South Indian Hort.,* 50(1/6): 262-265.

Olsen, S.R., Cole, C.S., WanTable, F.S. and Dean, C.A. (1954) Estimation of available phosphorus in soils by extraction with sodium bicarbonate USDA, Washington, D.C. Circular, 18: 939.

Parmar H. N., Polara N. D. and Viradiya R. R. (2013) Effect of Mulching Material on Growth, Yield and Quality of Watermelon (*Citrullus lanatus* Thunb) Cv. Kiran. *Universal Journal of Agricultural Research* 1(2): 30-37.

Pires, R.C.M, Folegatti, M.V., Passos, F.A., Arruda, F.B. and Sakai, E. (2006) Vegetative growth and yield of strawberry under irrigation and soil mulches for different cultivation environments. *Sci.Agric. (Piracicaba, Braz.),* 63(5): 417-425.

Pop, D.F., Mitre, V., Balcau, S.L. and Gocan, T.M. (2013) Correlation between the amount of soluble substance and Vitamin C in ten varieties of strawberries under the influence of mulch and fertilizer. *Bulletin of University of*

Agricultural Sciences and Veterinary Medicine Cluj-Napoca. Horticulture, 70(1): 259-260.

Pramanick, K.K, Kishore, D.K., Sharma, S. K., Das, B.K., Murthy BNS. (2013) Strawberry cultivation under diverse agro-climatic conditions of India. *International Journal of Fruit Science* **13**(1- 2): 36–51.

Qureshi, K. M., Hassan, F., Hassan, Q., Qureshi, U. S., Chaughati, S. and Saleem, A. (2012) Impact of cultivation systems on growth and yield of strawberry *(Fragaria x ananassa)* cv. Chandler. *Pakistan J. Agric. Res.*, 25(2): 129-135.

Ramakrishna, A and Tam, H M and Wani, S P and Long, T D (2006) *Effect of mulch on soil temperature, moisture, weed infestation and yield of groundnut in northern Vietnam.* Field Crops Research, 95 (2-3). pp. 115-125

Ramesh, V., Ballol, S. S., Sharma, K. L., Kausalya, R.., Korwar, G. R. and Ramakrishna, S. (2008) Characterization of soil for physical properties under different land use systems. *Indian Journal of Dryland Agricultural Research and Development*, 23: 102-109.

Sadasivam, S. and Manickam, A. (1997) *Biochemical Methods* (2nd edition). New age International Publishers Limited, New Delhi.

Sharma, C.L. and Khokhar, U.U. (2006) Effect of different mulches and herbicide on growth, yield and quality of strawberry (*Fragaria x ananassa* Duch.) cv. Chandler. In: Temperate horticulture: Current scenario (Eds- Kishore *et al.* New India Publishing Agency, New Delhi), pp: 313-320.

Sharma, R.R., Sharma, V.P. and Pandey, S.N. (2004) Mulching influences plant growth and albinism disorder in strawberry under sub-tropical climate. *Acta Hortic.,* 662: 187-191.

Sharma, R.R., Sharma, V.P. (2003) Mulch influences fruit growth, albinism and fruit quality in strawberry (*Fragaria x ananassa* Duch). *Fruits* 58, 221– 227.

Sharma, S., Rangger, A., von Ltzow, M. and Insam, H. (1998) Functional diversity of soil bacterial communities increases after maize litter amendment. *European Journal of Soil Biology,* 34: 53-60.

.

Sharma, V.P. and Sharma, R.R. (2004) The strawberry. Indian Council of Agricultural Research, New Delhi, pp. 1-162.

Singh, A.K., Kamal, S. (2012) Effect of black plastic mulch on soil temperature and tomato yield in mid hills of Garhwal Himalayas, *Journal of Horticulture and Forestry* Vol. 4(4), pp. 78-80,

Singh, N. and Dwivedi, D.H. (2011) Studies on the different mulches on vegetative growth of strawberry *(Fragaria x ananassa* Duch.) cv. Chandler. *Progressive Horticulture,* 43(1): 134-136.

Singh, R., Asrey, R. (2005) Growth, earliness and fruit yield of microirrigated strawberry as affected by time of planting and mulching. *Ind. J. Hortic.* 62 (2), 148–151.

Singh, R., Asrey, R., Kumar, S. (2006) Effect of plastic tunnel and mulching on growth and yield of strawberry. *Ind. J. Hortic.* 63 (1), 18–20.

Singh, R., Sharma, R.R. and Goyal, R.K. (2007) Interactive effects of planting time and mulching on 'Chandler' strawberry (*Fragaria* x *ananassa* Duch.). *Scientia Horticulturae*, 111(4): 344-351.

Smets, T., Poesen, J. and Knapen, A. (2008) Spatial scale effects on the effectiveness of organic mulches in reducing soil erosion by water. *Earth Sci. Rev.* 89:1-12.

Subbiah, B.V. and Asija, G. L. (1956) A rapid procedure for the estimation of available nitrogen in soils.*Current Science,* 25: 259-260.

Taparauskiene, L. and Miseckaite, O. (2014) Effect of mulch on soil moisture depletion and strawberry yield in sub-humid area. *Pol. J. Environ. Stud.*, 23(2): 475-482.

Tarara, J.M. (2000) Microclimate modification with plastic mulch. HortScience 35, 169–180.

Verma, M.L., Sharma, R.K., Bhandari, A.R. (2005) Effect of soil water conservation practices on root growth, yield, nutrient removal and quality of pea and tomato crop. *Journal of Indian Society of Soil Science,* 53(4): 602-607.

Voth, V. (1972) Plastic in California strawberry. *Hort Science*, 7: 378