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Mulching improves strawberry fruit growth and yield by regulating soil temperature and soil moisture in humid tropical India

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ABSTRACT

Production and quality of strawberry (Fragaria × ananassa, Duch.) fruits are significantly reduced in conventional farming methods in humid tropical India. Little information exists on the effect of mulching and its mechanisms regulating environmental factors, physiological processes as well as biochemical constituents to improve its yield and quality. Here, the effects of different coloured plastic mulches (black, transparent, and red) and organic mulches (paddy straw, banana leaves and weeds) were tested on the yield and quality of strawberries. Black plastic mulches had a large impact on fruit weight, size, and phytochemical content. The mean fruit yield with black plastic mulching was 68% greater than the control. Black polythene mulching adjusted environmental factors and physiological processes to boost productivity and quality of strawberry fruits and hence could be recommended in humid tropical regions.

Key words: Strawberry; Mulching; Phenolic compounds

INTRODUCTION

Inappropriate soil conditions, such as poor water and nutrient availability, non-optimal temperature, and weed infestation, hinder crop growth and yield, posing a worldwide food crisis due to the fast growing human population. To deal with them, soil mulching has been widely employed as an effective approach for improving soil qualities and, as a result, crop development (Qin *et al.* 2016). In a humid tropical environment, growing strawberries might be difficult because of a strong weed infestation, poor establishment, root damage, etc. Farmers need new methods to control weeds, enhance plant germination, and boost yields in the future. The delicate fruits of strawberry rest on the ground in direct contact with soil surface which makes the fruits unclean and susceptible to soil-borne pathogen infections, resulting in a reduced fruit quality. Accomplishing this would offset or possibly even reduce the costs associated with growing strawberry.

Mulching is used to improve growth and harvest conditions, as well as total productivity, for a variety of reason. Plastic mulches are created from a number of materials and applied to a range of crops, soil types, and climatic conditions in a variety of thicknesses, mulching configurations, and time periods. The plastic film's optical characteristics and impermeability (physical barrier) impact heat transmission and obstruct gas and mass exchange between the soil surface and its surroundings. Organic mulches, such as straw, husks, hay, sawdust, compost, wood chips, and other animal and plant materials, are effective in improving soil physical properties, reducing nitrate leaching, supplying organic matter, regulating temperature and water retention, preventing erosion, participating in the nutrient cycle, improving nitrogen balance, and increasing biological activity(Sarolia *et al.* 2012). Mulching with synthetic materials and plant wastes is a well-established strategy for increasing the profitability of horticultural crops in this regard. In humid tropical regions of India, crops are exposed to high temperature, heavy rainfall and diseases. Plastic mulching can curb this problem and is thus commonly used for premium and seasonal products like strawberries.However, information on the impact of mulching on soil temperature and moisture contentsare rare. The objective of this study was to understand the mechanisms through which plastic and organic mulching impact environmental and biochemical process to achieve better strawberry fruit yield with higher quality, under humid cultivation conditions. Finding out the most important parameters determining growth parameters under different

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mulching in humid tropical condition and factors governing these parameters were also an important task in these regions.

MATERIALS AND METHODS

The field investigation was carried out for two years during 2018-2020, at Horticultural farm, university of Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, West Bengal. Summers are warm and dryer, while winters are chilly and rainy.Mean annual rainfall is 1400 mm.Before planting the crops, composite soil samples from all of the experimental plots were collected and examined. The soils are mostly sandy to sandy loam in texture, porous and grayish black in color. The soil was moderately acidic (pH = 6.25), low in organic carbon (0.42%), nitrogen (210 kg ha^{-1}), and potassium (120 kg ha^{-1}) and high in phosphorus (21 kg ha^{-1}). Both organic and inorganic mulches were employed; paddy straw (T3), weed (T5), and banana trash (T6) were used as organic mulches, while black polythene (T1), red polythene (T4), and transparent polythene (T2) were used as inorganic mulches. Hence, six mulching materials were evaluated against a control. They were replicated thrice and distributed in a randomised block design. Length and breadth of bed was 2 meter and 1 meter respectively. Planting was done during first week of November.

The morphological parameters of each plants were observed. Weight of fruit (Khalid*et al*,2013), specific gravity, length and breadth of fruit, no of fruits per plant fruit (Tariq *et al.* 2013), yield per ha (Tariq *et al.* 2013), days to flowering, and no of flowers per plant(Khalid *et al.* 2013) were observed. Soil temperature of each replication was measured during December to March for both yearsdaily and expressed as mean monthly temperature. Soil moisture was measured gravimetrically for each plot in once in a week during December to March and expressed as average moisture content during the period. The data from the field and laboratory were statistically evaluated, and the treatment variability was tested for significance using the F test (Gomez K A and Gomez,1984). All of the tables show the standard error of the mean and the crucial difference at the 5% level. Fisher and Yates table were used to determine crucial differences at a 5% level of significance.The effects of mulching on strawberry growth, yield and quality parameters were reckoned using a one-way analysis of variance.

RESULTS AND DISCUSSION

Effect of mulching on fruiting and flowering pattern

Number of days required to flowering was significantly impacted by mulching. The minimum number of days (31.83 days) were required to flower in black polythene mulched plot (T_1) followed by red polyethylene (T_4) and transparent polythene (T_2) (Table 1). For organic mulching, plants with paddy straw mulching (T_3) required lower days (36.34 days) to flower than that with weed and banana trash mulching (Table 1). Similarly, mulching had profound impact on number of flowers per plant. In comparison to plants without mulching, the number of blooms in plants with black polythene mulch (T_1) was 91% greater, followed by red polythene (T_4) and transparent polythene (T_2) mulching, respectively (Table 1). Among the organic mulching practices, number of flowers in plants with paddy straw mulch (T_3) were ~15 and 30% greater than dry weed (T_5), banana leaf mulched (T_6) plots, respectively (Table 1). Evidently plants with polythene mulching had ~41% greater number of flowers than plants with organic mulching. However, there was no significant effect of by organic and inorganic mulching practices on flowering to fruiting duration (Table 1). Interestingly, fruit set percentage was significantly impacted by mulching. The highest fruit set was seen in plants with black polythene mulching (83.82 %) (T_1) followed by plants with red polythene (T_4) and transparent polythene (T_2). In case of organic mulching fruit set was higher than control. Among these, plants with paddy straw mulch (79.56%) recorded highest fruit set percentage followed by plants with weed and banana trash mulching and the lowest fruit set percentage was recorded under control (68.79%) (T_7). Effect of inorganic and organic mulch was substantially visible on number of fruits per plant. Among the inorganic mulching,plants with black polythene (T_1) mulch had higher number of fruits followed by plants with red polyethylene and

transparent polyethylene (Table 1). The use of paddy straw mulch (T_3) had ~12 and 32% greater number of fruits per plant than dry weed (T_5) and banana trash mulched (T_6), respectively. Generally, plants with polythene mulching had ~51% greater number of fruits than plants with organic mulching (Table 1).

Table 1: Effect of different polythene and organic mulching on number of flowers per plant, number of fruits per plant, days to flowering, flowering to fruiting and fruiting duration of strawberry in humid tropical India. LSD is the Least Significant Difference among treatments calculated from Duncan Multiple Range test (DMRT; p<0.05)

Treatments	Number of flowers per plant	Number of fruits per plant	Days to flowering (day)	Flowering to fruiting (day)	Fruiting duration (day)
T_1	42.33	35.50	31.83	4.50	94.84
T_2	36.50	29.33	34.67	4.67	87.00
T_3	34.00	26.83	36.34	6.00	84.50
T_4	39.50	32.66	34.08	4.67	92.17
T_5	29.64	23.17	37.83	5.67	80.83
T_6	26.00	20.04	39.84	6.00	78.34
T_7	22.05	15.33	43.06	6.67	75.17
LSD (P<0.05)	2.41	2.81	5.31	0.97	2.38

(Black polythene = T_1, Red polythene =T_4, Transparent polythene =T_2, Paddy straw =T_3, Weed =T_5 and Banana trash =T_6, T_7 = Control)

The highest fruiting duration was observed for plants with black polythene mulching (94.84 days) (T_1) followed by plants with red and transparent polythene mulching (Table 1). Among the organic mulching practices highest duration was observed for plants with paddy straw mulching (84.50) (T_3) followed by plants with weed and banana thrash mulching (Table 1).

Effect of mulching on fruit yield and weight

Fruit weight in plants with inorganic mulch such as, black polythene mulch (T_1) was ~75, 3 and 14% higher than plants with no mulch (control) (T7), red polyethylene (T4),and transparent polythene mulch (T_2), respectively (Table 2). However, fruits in plants with organic mulch, such as paddy straw mulch (T_3) was~4 and 22% heavier than plants with dry weed mulch (T_5), banana leaf mulched plots (T_6), respectively (Table 2). However, plants with polythene mulching had heavier fruits than plants with organic mulching plots. Plants with black polythene mulching (T^1) had greater fruit weight than plants with organic mulching. During first and second year of investigation, black polythene (T_1) mulching significantly improved the fruit length over control (T_7). Use of organic mulch like paddy straw (T_3), weed (T_5), and banana trash (T_6) significantly improved fruit length over control. However polyethylene mulching significantly improved the fruit length over organic mulching practices (Table 2). During first year, breadth of fruits in plants withblack polythene (T_1) mulch was ~23% higher than control. Breadth of fruits in plants with paddy straw mulch was ~8% higher than control. However, plants with paddy straw and banana leaf thrash mulching had almost similar breadth. Specifically polythene mulching enhanced fruit breadth ~10% over organic mulching (Table 2).

Among the inorganic mulching practices black polyethylene mulch produced higher leaf area followed by transparent and red polyethylene mulch. Plants with black polyethylene mulch (T_1) had the highest number of runners per plant (9.17) followed by plants with red polyethylene (T_4) and transparent polyethylene mulch (T_2) (Table 2). Among the organic mulching practices, plants with paddy straw mulch (T_3) had greater number of runners per plant (6.17) followed by plants with dry weed mulch (T_5) and banana trash mulching (Table2).Strawberry fruit yield in plants with black polythene mulch (T_1) was ~68, 14, and 22% higher than plants with control (T_7), red (T_4), and transparent polythene mulching (T_2), respectively (Table 2). Organic mulch practices, paddy straw mulch (T_3) resulted in ~4 and 11% higher fruit yieldthan dry weed (T_5) and banana leaf mulching (T_6), respectively. Mulching has no significant variable impact on specific gravity of fruits (Table 2).

Table 2: Effect of different polythene and organic mulching on fruit weight, fruit length and fruit breadth, number of runners per plant, fruit yield, specific gravity and leaf area of strawberry in humid tropical India. LSD is the Least Significant Difference among treatments calculated from Duncan Multiple Range test (DMRT; $p<0.05$)

Treatments	Fruit weight (g)	Fruit length (cm)	Fruit breadth (cm)	Number of runners per plant	Fruit yield (kg ha^{-1})	Specific gravity
T_1	26.53	5.13	3.23	9.17	10965.73	0.89
T_2	23.77	4.72	3.06	7.50	9027.44	0.89
T_3	21.72	4.63	2.86	6.17	8601.13	0.88
T_4	25.37	4.88	3.14	8.00	9610.22	0.90
T_5	20.39	4.53	2.86	6.00	8231.48	0.90
T_6	17.48	4.31	2.78	5.17	7693.33	0.90
T_7	15.20	4.15	2.60	4.67	6587.11	0.90
LSD (P<0.05)	4.84	0.36	0.29	0.93	323.67	0.08

Effect of mulching on soil temperature and moisture

The duration of strawberry crop period was from December to March. The soil under black polythene mulch had the highest temperature during these months. In December, the highest temperature was observed in black polythene mulching (27.52^{0}C) followed by red polythene and transparent polythene mulch. Sequentially at middle of January month the highest temperature was seen in T_1 (24.43^{0}C) and the lowest was in T_7 (21.34^{0}C). Same trend was observed in last weeks of January, February and March month also. The soilsunder organic mulching also had greater temperature than control; moreover among organic mulching paddy straw had higher soil temperature, and same pattern was seen during wholestrawberry growth period (Fig 1a). It was observed that in whole cropping duration that lowest soil temperature was observed in no mulch plots (T_7).Soil moisture was also impacted by mulching, the highest moisture content was observed in T_1 (33.26%) followed by red polythene (33.95%) and transparent polythene (33.2%), whereas, the lowest moisture content was in T_7. Invariably, plastic mulches contain more soil moisture than inorganic mulches (Fig 1b).

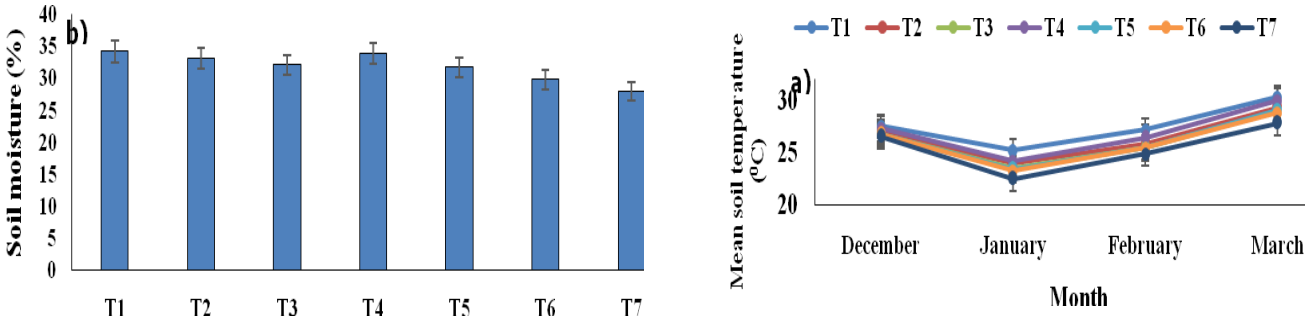

Fig 1: Effect of different polythene and organic mulching on a) soil temperature and b) soil moisture during strawberry cultivation in humid tropical India. Error bars indicate LSD. LSD is the Least Significant Difference among treatments calculated from Duncan Multiple Range test (DMRT; $p<0.05$). (Black polythene = T_1, Red polythene =T_4, Transparent polythene =T_2, Paddy straw =T_3, Weed =T_5 and Banana trash =T_6, T_7 = Control)

Early flowering in plants with polythene mulching than organic mulching might be attributed to an increase in soil moisture with minimal evaporation.Soils under black plastic mulching had different thermal characteristics than control; in colder weather,soil had higher temperatures under mulching than non-mulched soils, while in hotter situation soil had lower temperatures under mulching than non-mulched soil. Early flower blooming is aided by adequate moisture content and soil temperature (Iqbal *et al.* 2009). The same was reflected in humid tropical region of India. There was no significant impact on flowering to fruiting by mulching.

However polythene mulch requires lowest days to set fruit. (Veerpal *et al.* 2020) reported that lesser number of days require from planting to fruit set in the plot with mulching.

Greater fruit weight, length and breadthin plants withmulching (Table 2) may be ascribed with superior hydrothermal regimes of soil, improved moisture conservation, and weed suppression in these plots than bare plot. The reason for higher fruit weight, length, and breadthin black and red plastic mulched plots might be linked to the reflection of red light onto plants from the mulch. Consequently, red and far-red light potentially impart a morpho-genic impact that play major roles in determining fruit quality. Thus, strawberry weight variation under black and red plastic mulching might be endorsed with reflection of light of different wavelengths that proceeded through the native photo-morphogenic coloured pigments (predominantly phytochrome) within the developing plants under black plastic mulching; later the transmitted wavelengths influenced distribution of greater amount of photo-assimilates to the maturing fruit over the far-red reflecting red plastic mulch (Casierra-Posada *et al.* 2011). Moreover according to Kirchhoff's law of thermal radiation, black plastic would potentially emit greater amount of light than red plastic.

In turn, colored plastic mulches may change the microclimate in the field and influence the conditions of light, soil temperature, and air humidity surrounding the plants. Black plastic mulch appeared to heat soil, which is common for cold seasons due to its warming potential, whilst transparent plastic appeared to reflect a significant part of wavelengths and might thus cause cooling of soil body. Red mulch reflected light has a smaller red to far-red (R / FR) ratio than regular sunlight, whilst black plastic doesn't really impact the ratio. Better hydro-thermal conditions of soils under black plastic mulching expedites nutrient diffusion from solution to plant root, higher soil microbial activities, better root growth etc (Shen *et al.* 2016; Bandopadhyay *et al.* 2018). However, organic mulch materials (e.g. paddy straw, weed leaves, banana trash) could potentially absorb greater sunlight, facilities faster evaporation, reduces red to far-red (R / FR) ratio, permits more weed population etc than plastic mulching and resultantly produces fruits of lesser weight (Fan *et al.* 2012). Therefore, it may be pondered that better fruit weight, length, and breadthof strawberry fruits under black plastic mulches than red ones in this research might be due to favorable neighboring hydrothermal microclimate.

Polythene mulching resulted in greater fruit production than organic mulching (Table 2). A propitiously altered hydrothermal regime, accelerated nutrients uptake, and augmented moisture availability espoused superior crop growing under black polythene mulching. Eventually, this was reflected through the highest fruit yields. Accelerated nutrient uptake and exceedingly subdued weed population might be other reasons of higher yield. Greater fruit yield under mulched plots may be ascribed with superior hydrothermal regimes of soil, improved moisture conservation and weed suppression in these plots than bare plot. The reason for higher fruit yield in black plastic mulched plots might also be the reflection of red light onto plants from the mulch.

Mulching conserves soil moisture and, as a result, enhances seedling development (Woods*et al.* 2012), mostly by limiting the soil surface exposed to direct sunlight (Benigno*et al.* 2012). Organic mulching improves plant development by altering the soil environment. The application of organic mulch modifies soil organic carbon (SOC) dynamics by changing the nutrition cycle and energy exchange between the soil and plants (Wang *et al.*2018). Soil temperature under mulches was higher, for both types of mulches (plastic and organic mulch) (Fig 1a). Additionally coloured plastic mulches may change the microclimate in the field and soil temperature surrounding the plants. Black plastic mulch increases soil temperature, which is common for cold seasons due to its warming potential. According to Kirchhoff’s law black material absorbs and emits more radiation, which is converted to heat resulting in higher soil temperature under black polythene mulching.

CONCLUSION

The study evaluated the impact of polythene and organic mulching on yield and quality of strawberry fruits in humid tropical India. In these regions, black polythene mulching significantly improved strawberry fruit

yield. Importantly, Soil temperature and moisture was found to be the most important parameters for maintaining strawberry fruit yield and quality. Black polythene mulching also regulated these two factors to improve sweetness, fruit shape and yield in humid tropical regions.Black polythene mulching adjusted environmental factors and physiological process to boost productivity and quality of strawberry fruits and hence could be recommended to increase productivity and profitability of strawberry cultivators in humid tropical regions.

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