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Growth and yield of strawberry (*Fragaria* x *ananassa* Duch) under different mulches in vertisols of Madhya Pradesh

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Abstract
Using plastic mulch in conjunction with drip irrigation enables the successful development of strawberries in hot and humid areas. This study examined the effects of several mulches on strawberry growth and yield at the ICAR Central Institute of Agricultural Engineering, Bhopal. Here, randomized block design with five treatments were taken and each treatment was replicated four times. Of these, three involved the application of mulch in the colours silver, black, and white; the other two involved the use of organic mulch and no mulch at all. Results show that while no mulching treatment resulted in significantly lower values of growth parameters, yield (15.11 t/ha), and BC ratio (1.25), treatments with black colour plastic mulching produced superior values of growth parameters, yield (28.09 t/ha), net returns, and BC ratio (2.28). When selecting strawberry plants for growing in non-intrusive environments, particularly the semi-arid tropics, plastic mulching must be used overall.

Keywords: Mulching, sub tropical, soil moisture, climate, nutrients

1. Introduction
Strawberries (*Fragaria* x *ananassa* Duch) are a popular and delicious fruit known for their vibrant color, sweet taste, and versatile uses and belongs to family rosaceae (Kumar *et al*., 2019) [9]. The modern cultivated strawberry, *Fragaria* x *ananassa* Duch., is a hybrid of two octoploid species, primarily dioecious, *Fragaria cheloensis* Duch. and *Fragaria varginiana* Duch (Kumar *et al*, 2012) [7]. Chromosome number for strawberries is 2n=2x=56. It comes up with many fianancial benefits as it starts fruiting within 50 days after transplanting. They are rich in natural antioxidants, phenolic compounds, anthocyanins, and phenolic acids, making them a highly nutritious fruit choice (Lal *et al*., 2013) [9]. The vitamin and mineral content in strawberries further adds to their health benefits and nutritional value. Strawberries are particularly rich in vitamin C, which is essential for boosting the immune system and promoting healthy skin (Chung and Ouyang, 2020) [4]. A single serving of strawberries can provide more than the recommended daily intake of vitamin C, making it an excellent source of this important nutrient (Wei *et al*., 2022) [17].
In addition to vitamin C, strawberries also contain significant amounts of other vitamins and minerals. They are a good source of manganese, which plays a role in bone health and metabolism. Strawberries also contain folate, which is important for cell growth and development, especially during pregnancy (Newerli-Guz *et al*., 2023) [10]. Furthermore, strawberries are a great source of potassium, which is essential for maintaining normal blood pressure and heart health. The mineral content in strawberries also includes magnesium, which is necessary for various bodily functions, including muscle and nerve function (Galvão *et al*., 2014) [5].
Not only do strawberries offer an array of vitamins and minerals, but they are also low in calories and high in fiber, making them an excellent choice for those looking to maintain a healthy weight and promote digestive health (Kim *et al*., 2016) [6].
The cultivation of strawberries in India has seen a remarkable increase in recent years, with farmers from Punjab, Haryana, Delhi, Uttarakhand, and Jammu and Kashmir and Madhya Pradesh states showing great interest in this fruit crop (Saima *et al*., 2014) [15]. The subtropical varieties of strawberries being cultivated in India have their own unique characteristics and advantages (Rathod *et al*., 2020) [14].

One of the key benefits of these subtropical varieties is their ability to withstand higher temperatures and humidity levels compared to traditional strawberry cultivars. This means that farmers can cultivate strawberries throughout the year, even in the summer months when the weather is hot and humid (Brym *et al*., 2022) [2]. This extended growing season is advantageous for both farmers and consumers, as it provides a steady supply of fresh strawberries and reduces dependence on imported strawberries during off-seasons.

Therefore, the efforts need to be done to grow strawberry crop in different part of Madhya Pradesh. The present study is based on the performance of strawberry under black cotton soil of Madhya Pradesh under different colored plastic mulching.

2. Material and Method

2.1 Experimental Site

The Present study was conducted at Precision Farming Development Centre in ICAR Central Institute of Agricultural Engineering, Bhopal (MP) during *Rabi* season 2019-20 and 2020-21. The field was located between latitude 23°18´56.44´´N and 77°24´12.84´´E longitude on an altitude of 510 ft above mean sea level. The field was uniform. The experimental site's soil was composed of vertisols with a high clay percentage that ranged from 49.7 to 53.7%, silt content of 28–34%, and sand content of 12–18% (Chandel *et al*., 2022) [3]. Field capacity of the soil varied from 28.5 to 31 % (Rao *et al* 2023) [13]. The soil's pH is between 6.5 and 8.0 (neutral), and its EC is less than 1.0 (normal) ds/m. The area has a humid subtropical climate, meaning it experiences scorching summers, chilly, dry winters, and a humid monsoon season.

2.2 Experimental Design

This experiment was laid down in Randomized block design with 5 treatments were taken each was replicated 4 times in different experimental units. Each experimental plot measured 10 m x 6.5 m. Different colored plastic mulches were used in three treatments and in rest two treatments straw mulching and no mulching was practiced. For plastic mulching three layered of 30 micron was used. The crop was irrigated by drip irrigation method for which inline drip of emitter spacing at 25 cm was used which was capacity of 2 lph. Different treatments details along with cultivation practices is given in Table 1.

Table 1: Details of different treatments

Treatment	Mulch Colour	Material	Plant Spacing (cm)	Irrigation Method	Irrigation Level	Method of Planting
T_1	Silver	Plastic	45×30	Drip	100% ETc	Raised Bed
T_2	Black	Plastic				
T_3	White	Plastic				
T_4	Organic	Straw				
T_5	Control	No Mulch				

2.3 Data Collection

Five plants from each plot were selected randomly for observing the growth and yield parameters of plants. In growth parameters crown height (cm), crown spread (cm), number of leaves per crown and SPAD value of leaves were taken. The crown height was taken from the above mulch portion to the top leaf of a crown. The plant spread was firstly measured from the north to south from the central axis of a crown then east to west in the same way and the mean values of them are presented in the Table 2. SPAD value which suggest an indirect criterion for chlorophyll content of plant were taken with the help of SPAD meter (Konika, Minolta) by selecting the upper, middle and lower leaves from each selected plant and means of which are presented in the Table 2. There were almost 12-16 harvest were observed throughout the growth period in different treatments. Each time after harvest number of fruits are counted and their weight(gm/plant) were taken and the mean values of them are presented in the Table 3. In the yield parameter yield and water productivity (Kg/M^3) were worked out. After the senescence stage that means after the final harvest during peak summer season the mean values of all the harvest were summed up and the final yield was computed. Water productivity was carried out to know the quantity of water used in the unit amount of production. Water productivity was worked out from the following formula

$$\text{Water productivity (kg/m}^3\text{)} = \frac{\text{Economic Yield (kg/ha)}}{\text{Water applied (m3/ha)}}$$

Every treatment has an irrigation schedule designed to fulfil the crop's water requirements in order to meet the research area's crop evapotranspiration demand.

5 t/ha of vermicompost was applied to the field during final tillage and as a basal dose 23:58:0 N:P:K was given. Rest of the crop fertilizer demand was fulfilled through water soluble fertilizers, which were applied on the basis of fertilizers scheduling.

2.4 Economic Analysis

Firstly, the cost of cultivation of each treatment was worked out. The Cost of cultivation includes the price of planting material (tissue culture seedling), primary and secondary tillage field preparation, vermicompost manure, raised bed formation, fumigation of raised beds, drip irrigation and mulch cost along with their laying on raised beds, water soluble fertilizers, pesticides, fixed capital cost, labour charge. After all the benefit cost ratio was computed on the basis of gross return and cost of cultivation to know the monetary efficiency of various treatments (Table 4).

2.5 Statistical Analysis

IBM SPSS Statistics 20 was used to analyze the data using an F-test and an analysis of variance to assess the relevance of the treatments.

3. Results and Discussion

3.1 Plant Growth Parameters

Statistical Analysis of pooled values of two year data reveals significant difference for crown height under different treatments. Treatment T_1(Silver plastic mulch) produced significantly superior values (22 cm) of crown height than rest

of the treatments, however it was found at par with the values of T_2 (Black plastic mulch). While maximum values of plant spread (24.06 cm) and number of leaves/plant (27.31) were recorded in treatment T_2, although these were found at par with the similar characters of T_1. These higher values in mulch treatments maybe the outcome of change in microclimate beneath the plants due to presence of plastic mulches (Yadav *et al*., 2023) [18]. Values from SPAD meter which considered as non-destructive and indirect method for assessing the chlorophyll content were found significant for different treatments. Higher SPAD values were recorded in T_2 (48) for black colour plastic mulch and these were found statistically at par with similar character of T_1, T_3 and T_4. Our findings are in line with the findings of Ughareja and Pandya, 2023 [16].

Table 2*:* Influence of different mulches on the plant growth parameters of strawberry

Treatments	Crown height(cm)	Plant Spread(cm)	Number of leaves/Plant	SPAD value
T_1	22.00	23.25	25.88	46.24
T_2	20.75	24.06	27.31	48.00
T_3	19.5*0*	21.56	24.21	44.82
T_4	17.75	19.55	20.12	42.9*0*
T_5	15.25	16.92	18.21	41.85
CD (p=0.05)	1.92	2.09	2.33	4.20

3.2 Yield Attributing Characters and Yield

Statistical Analysis of number of fruits, weight of fruit and economical yield states significant difference between different treatments. Treatment T_2(black plastic mulch) produced significantly superior values (32.73 nos, 468 gm and 28.09 t) respectively than rest of the treatments. All these aforesaid values were found at par with the treatment T_1(silver plastic mulch), while lower values for number of fruits, fruit weight and yield (19.67 nos, 252 gm and 15.11 t) respectively were recorded in T_5 (control) treatment. All these out research findings are in agreement with the findings of Bakshi *et al*, 2014 [1]. Water was applied through drip irrigation method on the basis of crop evaporation demand (ETc). Water productivity was carried out, where statistical analysis suggests higher values of water productivity (6.28,6.69 and 5.75) respectively in all the plastic mulch treatments (T_1, T_2 and T_3), while lowest values (2.77) were found in treatment T_5(Control or no mulch). Using a drip irrigation system in conjunction with mulching the soil to improve soil temperature, preserve moisture, decrease erosion, improve soil structure, and raise organic matter content is an efficient way to modify the crop growth environment and boost yield and quality parameters (Rao *et al*, 2016) [12].

Table 3: Effect of different mulches on yield attributing character and yield of strawberry

Treatments	Number of fruits/Plant	Weight of fruits(gm)/Plant	Yield (t/ha)	Water Applied (m3/ha)	Water Productivity (Kg/m^3)
T_1	31.20	439	26.35	4195	6.28
T_2	32.73	468	28.09	4195	6.69
T_3	28.87	402	24.12	4195	5.75
T_4	21.60	289	17.32	5034	3.44
T_5	19.67	252	15.11	5453	2.77
CD (p=0.05)	2.80	39.54	2.37		0.57

3.3 Economics of different treatments

The cost of cultivating subtropical strawberries is typically greater since transplanting is done using tissue culture plants, which are far healthier than the actual runners. With the exception of the treatments that mulched straw and those that did not, all of the fixed and variable costs were estimated to be almost identical, with the exception of the cost of the plastic mulch. Treatment T_2 (black plastic mulch) had higher values of gross return (28.64 lakhs/ha), net return (16.06 lakhs/ha) and benefit cost ratio (2.28). All of the above values were recorded at the lowest levels in treatment T_5 (no mulching), which produced a gross return of 15.41 lakhs/ha and the lowest values of net return (3.13 lakhs/ha) and BC ratio (1.25).

Table 4: Economics of strawberry as influenced by the different mulches

Treatments	Cost of Cultivation 10^5 ₹/ha	Gross return 10^5 ₹/ha	Net Return 10^5₹/ha	BC ratio
T_1	12.586	26.873	14.287	2.14
T_2	12.586	28.647	16.061	2.28
T_3	12.586	24.602	12.017	1.95
T_4	12.321	17.664	5.344	1.43
T_5	12.286	15.416	3.130	1.25

4. Conclusion

As per the general perception the strawberries are considered as temperate fruits. But with the advancement of cultivars which suited to subtropical areas, now farmers can grow strawberries easily by doing some engineering interventions. The combine effect of plastic mulch along with drip is found to be a boon for strawberries growers. The effect of mulch colour has also affected the yield in different treatments. The farmers can adopt black colour plastic mulch followed by silver plastic mulch along with drip irrigation for getting maximum benefit from strawberry crop. Generally, cultivation of strawberries must be avoided without the uses

of plastic mulches as it may fail to create conducive conditions for growing strawberry in the new areas.

5. Acknowledgement
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6. Conflict of Interest
The authors declare that there is no conflict of interest.

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