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IMPACT OF MULCHING AND PLANTING DENSITY ON PHENOLOGY, YIELD AND FRUITING CHARACTERS OF STRAWBERRY (*FRAGARIA* × *ANANASSA* DUCH.) cv. WINTER DAWN

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Abstract

Mulching and planting density plays a vital role in influencing positive impact on yield and quality in strawberry production. Improper mulching and planting density promotes undersized, compact and unmarketable fruit with high disease incidence, results in lesser productivity. An investigation was conducted at University Orchard, Lovely Professional University, Punjab to study the impact of different mulching and planting density practices on the performance of strawberry (*Fragaria* × *ananassa* Duch.) cv. Winter Dawn. The results revealed that the phenological traits like 'Number of leaves per plant', 'plant spread' and 'leaf area' found to be maximum with M_2 (Green mulch) and planting density of S_3 (30 × 45 cm). With regard to the effect of mulches on yield characters the treatment M_2 (Green mulch) in combination with the planting density S_3 (30 × 45 cm) showed increased value for 'fruit set percentage', 'yield per plant', including several fruiting parameters *viz.,* 'fruit length', 'fruit girth' and 'fruit weight'.

Key words : Strawberry, mulching, planting density, phenology, yield.

Introduction

Strawberry (*Fragaria* × *ananassa* Duch.), one among the ancient fruit crop belongs to the family Rosaceae. It is one of most important temperate fruit, valued for its attractive shape, colour, distinct pleasant aroma and refreshing nature. The commercial cultivation of strawberry taken up in around 73 countries of the world. In India, strawberry cultivation ranges from hilly regions to cool climatic zones over an area of 0.77 lakh ha with an annual production of 5.20 lakh tonnes (Anonymous, 2017). Generally, strawberry cultivation confined with temperate zones, but due to potentiality, it has now been slowly gets introduced to subtropical regions (Asrey and Singh, 2004).

Recently, strawberry has become the favourite fruit crop among the growers, especially near towns and cities. Due to its remunerative price, the area now began to increasing rapidly (Singh and Asrey, 2005). It is amongst the top ten fruit crops, which give quicker and high net returns per unit area on the capital interests, as a crop ready for harvesting within six months of planting (Sharma and Sharma, 2003). Different factors found to influence the growth and yield of strawberry. Among, mulching and planting density plays a vital role in influencing positive impact on yield and quality in strawberry production.

Plastic mulches plays a vital role in crop cultivation, which are helpful in increasing the per unit area production of several fruit crops. Mulching help to increases the soil temperature by 5-7^{0}C, which results in better root proliferation and quicker germination. Albinism, a major physiological disorder is due to photo active radiation that would be influenced with certain type of mulch used. In such point of view, it is necessary to study on the effect of mulches over the growth and development of strawberry.

Planting density plays a major role in influencing the growth and yield related traits of any herbaceous fruit crop. With suitable plant density, plants can effectively use the environmental conditions and also inter or intra

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specific competition is found to be minimum. In such sense, for strawberry, spacing acts as a reservoir for storing plant nutrients and their translocation to growing fruits for better yield and quality (Ahmad, 2009). Hence, with this background, the present investigation was conducted to access the effect of mulching and planting density on phenology, yield and fruiting characters on strawberry cv. Winter Dawn.

Materials and Methods

The present investigation on 'Impact of mulching and planting density on phenology, yield and fruiting characters of strawberry (*Fragaria × ananassa* Duch.) cv. Winter Dawn' was carried out at Lovely Professional University, Phagwara (Punjab), India. The runners of strawberry cultivar Winter Dawn was procured from farmer's field at Bhangu farm, near Patiala. The field experiment was carried out from October, 2015 to April, 2016 by incorporating four types of mulches *viz.,* black (M_1), green (M_2), blue (M_3) and white (M_4) with three planting densities *viz.,* 30 × 15cm (S_1), 30 × 30cm (S_2) and 30 × 45cm (S_3) comprising total of 13 treatment combinations including control replicated thrice. Experimentation was laid out in Factorial Randomized Blocks Design (FRBD).

Plants were planted on raised beds of 1.5×1 m^2 distance during the second fortnight of October. The phenological traits *viz.,* Number of leaves per plant, Plant spread, Leaf area and Fruit set percentage were recorded. In addition, yield and fruit characters *viz.,* Yield per plant, Fruit length, Fruit girth, Fruit shape index and Fruit weight were also assessed. All the data were subjected to statistical analysis as outlined by Panse and Sukhatme (1985). The various comparisons were made after working out the standard errors and critical difference at 5 per cent level of significance.

Results and Discussion

Impact on phonological traits in strawberry cv. Winter Dawn

Observations recorded on 'Number of leaves per plant' exhibited significant differences among the mulches and planting density including their interaction (table 1). Among the type of mulches, the treatment M_2 *i.e.,* Green mulch registered the maximum 'Number of leaves per plant' (39.93). The minimum 'Number of leaves per plant' was recorded in control (29.31). Among the planting density, the treatments under S_3 *i.e.,* 30 × 45 cm recorded the maximum 'Number of leaves per plant' (36.23). With regard to interaction, the treatment M_2S_3 recorded the maximum 'Number of leaves per plant' (43.34). Observations recorded on 'plant spread (E-W)' exhibited significant differences among the mulches and planting density including their interaction (table 1). Among the type of mulches, the treatment M_2 *i.e.,* Green mulch registered the maximum 'plant spread (E-W)' (19.63 cm). The minimum 'plant spread (E-W)' was recorded in control (13.42 cm). Regarding planting density, the treatments under S_3 *i.e.,* 30 × 45 cm recorded the maximum 'plant spread (E-W)' (19.77 cm). With regard to interaction, the treatment M_2S_3 recorded the maximum 'plant spread (E-W)' (22.11 cm), which was on par with M_1S_3 (21.46 cm). Observations recorded on 'plant spread (N-S)' showed significant differences with type of mulches and planting density including their interaction (table 1). Among the type of mulches, the treatment M_2 *i.e.,* Green mulch registered the maximum 'plant spread (N-S)' (20.58 cm). The minimum 'plant spread (N-S)' was recorded in control (14.20 cm). Among the planting density, the treatments under S_3 *i.e.,* 30 × 45 cm recorded the maximum 'plant spread (N-S)' (20.75 cm). With regard to interaction, the treatment M_2S_3 recorded the maximum 'plant spread (N-S)' (22.98 cm) and the minimum 'plant spread (N-S)' was registered in control (13.35 cm).

Observations recorded on 'leaf area' showed significant differences with type of mulches and planting density including their interaction (table 2). Among the type of mulches, the treatment M_2 *i.e.,* Green mulch registered the maximum 'leaf area' (50.01 cm^2). Among the planting density, the treatments under S_3 *i.e.,* 30 × 45 cm recorded the maximum 'leaf area' (46.92 cm^2). With regard to interaction, the treatment M_2S_3 recorded the maximum 'leaf area' (59.81 cm^2) and it was followed by M_2S_2 (57.34 cm^2). The minimum 'leaf area' was registered in M_4S_1 (27.32 cm^2).

The present study clearly indicated that plant growth parameters such as 'Number of leaves per plant', 'plant spread' and 'leaf area' significantly influenced with mulching treatments. Among different mulching treatments, treatment M_2 (Green mulch) resulted increased 'Number of leaves per plant', 'plant spread' and 'leaf area'. The increase with regard to those growth parameters was attributed to sufficient soil moisture near root zone and minimized evaporation loss due to mulching. The extended moisture retention and moisture availability greatly leading to higher uptake of nutrient for proper growth and development of plants as compared other mulches including control. The changes in soil temperature below various types of mulch could be attributed to different manners of heating and heat transfer to soil and also to heat accumulation during day and loss during night. Similar findings were in accordance with Dean ban et al. (2004), Ali and Gaur (2007) in strawberry and Aruna *et al*. (2007) in tomato.

Among different spacing, the planting density S_3 (30

Table 1 : Effect of mulching and planting density on 'Number of leaves per plant', 'Plant spread E-W (cm)' and 'Plant spread N-S (cm)' in strawberry cv. Winter Dawn.

Treatments	Number of leaves per plant				Plant spread E-W (cm)				Plant spread N-S (cm)			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
C	28.43	29.60	29.90	**29.31**	12.88	13.45	13.93	**13.42**	13.35	14.21	15.03	**14.20**
M_1	30.12	32.21	36.11	**32.81**	15.13	20.23	21.46	**18.94**	15.91	21.12	22.34	**19.79**
M_2	36.22	40.23	43.34	**39.93**	15.56	21.23	22.11	**19.63**	16.45	22.31	22.98	**20.58**
M_3	29.13	34.32	37.56	**33.67**	14.76	19.57	21.14	**18.49**	15.13	20.43	21.93	**19.16**
M_4	28.45	31.45	34.23	**31.38**	14.76	19.59	20.23	**18.19**	15.23	20.32	21.45	**19.00**
MEAN	**30.47**	**33.56**	**36.23**	**33.42**	**14.62**	**18.81**	**19.77**	**17.74**	**15.21**	**19.68**	**20.75**	**18.55**
Source	**SEd**		**CD (0.05%)**		**SEd**		**CD (0.05%)**		**SEd**		**CD (0.05%)**	
M	**0.42**		**0.85**		**0.221**		**0.45**		**0.231**		**0.47**	
S	**0.32**		**0.66**		**0.171**		**0.35**		**0.179**		**0.37**	
M × S	**0.72**		**1.47**		**0.382**		**0.78**		**0.400**		**0.82**	

Treatment details

C	Control	**S**	**Spacing**
M	**Mulching**	S_1	30 x 15 cm
M_1	Black mulch	S_2	30 x 30 cm
M_2	Green mulch	S_3	30 x 45 cm
M_3	Blue mulch		
M_4	White mulch		

× 45 cm) showed increased 'Number of leaves per plant', 'leaf area' and 'plant spread'. The results are in agreement with the findings of Milivojevic (2005), stated that the higher planting density 30 × 30 cm enhanced vegetative growth of strawberries 'Marmolada' and 'Elsanta' compared to lesser planting distance of 20 × 30 cm. Similarly, strawberry under wider spacing tends to receive more light by their photosynthetic leaves due to their higher canopy. Abdel-Mawgoud *et al*. (2010) too related the increase in growth of strawberry is mainly due to higher photosynthesis production that reflected from increasing leaf area and No. of leaves.

Similarly, with regard to interaction effect, the plants under green mulch (M_2) with planting density of S_3 (30 × 45 cm) had better values for growth related characters. It might be due to better soil hydrothermal regimes, better moisture conservation and suppression of weeds (Tarara, 2000). Many researchers have reported better growth of strawberry plant under green polythene mulch with wider plant density (Singh and Asrey, 2005; Singh *et al*., 2006). Generally, plastic mulches with right plant density affects canopy development, radiation interception, evaporation of water from soil under the crop, dry matter production, weed competition and ultimately, the seed yield of a crop in the farming system (Lopez-Bellido *et al*., 2005). The treatments with closer spacing covered with other mulches had lesser values, which could be attributed to minimum crop growth, as reflected in crop plant height, causing late canopy of crop. Singh *et al*. (2001) and Sinkeviciene *et al*. (2009) also observed similar results for different crops.

Impact on yield and fruiting related traits in strawberry cv. Winter Dawn

Observations recorded on 'fruit set percentage' exhibited significant differences among the type of mulches and planting density alone. The interaction effect did not exhibit any significance (table 2). Among the type of mulches, the treatment M_2 *i.e.,* Green mulch registered the maximum 'fruit set percentage' (83.95%), which was found to be on par with M_1 (81.92%) The minimum 'fruit set percentage' was recorded in control (73.48%). Among planting density, the treatments under S_1 *i.e.,* 30 x 15 cm recorded the maximum 'fruit set percentage' (82.78%) and the minimum 'fruit set percentage' was recorded in S_3 (76.44%).

Observations recorded on 'yield per plant' exhibited significant differences among the mulches and planting density including their interaction (table 3). Among the type of mulches, the treatment M_2 *i.e.,* Green mulch registered the maximum 'yield per plant' (253.07 g). It was followed by M_1 (222.16 g) The minimum 'yield per plant' was recorded in control (112.87 g). Regarding planting density, the treatments under S_2 *i.e.,* 30 × 30 cm recorded the maximum 'yield per plant' (198.44 g) and the minimum 'yield per plant' was recorded in S_3 (192.54 g). With regard to interaction, the treatment M_2S_2 recorded the maximum 'yield per plant' (259.71 g), which was found to be on par with M_2S_3 (254.45 g) and the minimum 'yield per plant' was registered in control (108.00 g).

Table 2 : Effect of mulching and planting density on 'Leaf area (cm^2)' and 'Fruit set percentage (%)' in strawberry cv. Winter Dawn.

Treatments	Leaf area (cm^2)				Fruit set percentage (%)			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
C	31.37	32.66	32.99	**32.34**	78.73	71.10	70.60	**73.48**
M_1	32.24	48.14	50.13	**43.50**	85.05	82.90	77.80	**81.92**
M_2	32.88	57.34	59.81	**50.01**	87.52	85.35	78.99	**83.95**
M_3	30.64	38.54	42.78	**37.32**	83.38	81.14	78.53	**81.02**
M_4	27.32	38.78	48.89	**38.33**	79.21	76.35	76.29	**77.28**
MEAN	**30.89**	**43.09**	**46.92**	**40.30**	**82.78**	**79.37**	**76.44**	**79.53**
Source	**SEd**		**CD (0.05%)**		**SEd**		**CD (0.05%)**	
M	**0.51**		**1.04**		**0.98**		**2.02**	
S	**0.39**		**0.80**		**0.76**		**1.56**	
M × S	**0.88**		**1.80**		**1.70**		**NS**	

Treatment details

C	Control	**S**	**Spacing**
M	**Mulching**	S_1	30 x 15 cm
M_1	Black mulch	S_2	30 x 30 cm
M_2	Green mulch	S_3	30 x 45 cm
M_3	Blue mulch		
M_4	White mulch		

Observations recorded on 'fruit weight' showed significant differences with type of mulches and planting density including their interaction (table 3). Among the type of mulches, the treatment M_2 *i.e.,* Green mulch registered the maximum 'fruit weight' (19.07 g). The minimum 'fruit weight' was recorded in control (15.22 g). Among the planting density, the treatments under S_3 *i.e.,* 30 × 45 cm recorded the maximum 'fruit weight' (17.88 g), which was on par with S_2 (17.69 g). The minimum 'fruit weight' was recorded in S_1 (16.23 g). With regard to interaction, the treatment M_2S_3 recorded the maximum 'fruit weight' (20.02 g), which was on par with M_2S_2 (19.81 g). However, the minimum 'fruit weight' was registered by control (14.98 g).

Observations recorded on 'fruit length' exhibited significant differences among the mulches and planting density including their interaction (Table 4). Among the type of mulches, the treatment M_2 *i.e.,* Green mulch registered the maximum 'fruit length' (4.41 cm), which was found to be on par with both M_1 and M_3 (4.38 cm). The minimum 'fruit length' was recorded in control (3.11 cm). Among the planting density, the treatments under S_3 *i.e*., 30 × 45 cm recorded the maximum 'fruit length' (4.29 cm), which was on par with S_2 (4.25 cm). With regard to interaction, the treatment M_2S_3 recorded the maximum 'fruit length' (4.69 cm) and the minimum 'fruit length' was registered by control (3.08 cm). Observations recorded on 'fruit girth' showed significant differences with type of mulches and planting density including their interaction (table 4). Among the type of mulches, the treatment M_2 *i.e.,* Green mulch registered the maximum 'fruit girth' (3.31 cm). it was followed by M_1 (3.18 cm) found to be on par with M_4 (3.14 cm). Among the planting density, the treatments under S_3 *i.e.,* 30 × 45 cm recorded the maximum 'fruit girth' (3.23 cm). With regard to interaction, the treatment M_2S_3 recorded the maximum 'fruit girth' (3.49 cm), which was on par with M_2S_2 (3.44 cm) and M_4S_3 (3.42 cm). However, the minimum 'fruit girth' was registered by control (2.46 cm).

Observations recorded on 'fruit shape index' exhibited significant differences among the mulches and their interaction alone. The planting density did not exhibit any significance (table 4). Among the type of mulches, the treatment M_3 *i.e.,* Blue mulch registered the maximum 'fruit shape index' (1.47). It was followed by M_1 (1.38). With regard to interaction, the treatment M_3S_1 recorded the maximum 'fruit shape index' (1.56) and the minimum 'fruit shape index' was registered by M_4S_1 (1.18).

The present study clearly indicated that yield and fruiting related parameters significantly influenced with mulching treatments. Among different mulching treatments, treatment M_2 (Green mulch) resulted increased 'fruit set percentage', 'yield per plant', 'fruit weight', 'fruit length', 'fruit girth' and 'fruit shape index'. The increase with regard to those yield parameters was attributed to proper growth and developmental activities of plant that reflected on yield regimes. The crop under green mulch recorded maximum fruit weight, fruit length, fruit width and higher yield mainly because of better physiological activity owing to favourable hydrothermal

Table 3 : Effect of mulching and planting density on 'Yield per plant (g)' and 'Fruit weight (g)' in strawberry cv. Winter Dawn.

Treatments	'Yield per plant (g)'				'Fruit weight (g)'			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
C	117.59	113.01	108.00	**112.87**	14.98	15.23	15.45	**15.22**
M_1	226.85	227.69	211.94	**222.16**	16.68	17.65	17.78	**17.37**
M_2	245.06	259.71	254.45	**253.07**	17.38	19.81	20.02	**19.07**
M_3	198.83	202.49	198.59	**199.97**	15.78	16.86	17.12	**16.59**
M_4	177.89	189.29	189.72	**185.63**	16.32	18.91	19.01	**18.08**
Mean	**193.24**	**198.44**	**192.54**	**194.74**	**16.23**	**17.69**	**17.88**	**17.27**
Source	**SEd**		**CD (0.05%)**		**SEd**		**CD (0.05%)**	
M	**2.47**		**5.06**		**0.21**		**0.44**	
S	**1.91**		**3.92**		**0.17**		**0.34**	
M × S	**4.28**		**8.76**		**0.37**		**0.76**	

Treatment details

C	Control	**S**	**Spacing**
M	**Mulching**	S_1	30 x 15 cm
M_1	Black mulch	S_2	30 x 30 cm
M_2	Green mulch	S_3	30 x 45 cm
M_3	Blue mulch		
M_4	White mulch		

Table 4 : Effect of mulching and planting density on 'Fruit length (cm)', 'Fruit girth (cm)' and 'Fruit shape index' in strawberry cv. Winter Dawn.

Treatments	Fruit length (cm)				Fruit girth (cm)				Fruit shape index			
	S_1	S_2	S_3	MEAN	S_1	S_2	S_3	MEAN	S_1	S_2	S_3	MEAN
C	3.08	3.11	3.13	**3.11**	2.46	2.62	2.63	**2.57**	1.25	1.19	1.19	**1.21**
M_1	3.87	4.61	4.66	**4.38**	2.98	3.24	3.31	**3.18**	1.30	1.42	1.41	**1.38**
M_2	3.89	4.64	4.69	**4.41**	2.99	3.44	3.49	**3.31**	1.30	1.35	1.34	**1.33**
M_3	3.88	4.60	4.65	**4.38**	2.48	3.21	3.29	**2.99**	1.56	1.43	1.41	**1.47**
M_4	3.28	4.28	4.31	**3.96**	2.78	3.23	3.42	**3.14**	1.18	1.33	1.26	**1.26**
MEAN	**3.60**	**4.25**	**4.29**	**4.05**	**2.74**	**3.15**	**3.23**	**3.04**	**1.32**	**1.34**	**1.32**	**1.33**
Source	**SEd**		**CD (0.05%)**		**SEd**		**CD (0.05%)**		**SEd**		**CD (0.05%)**	
M	**0.05**		**0.10**		**0.04**		**0.08**		**0.02**		**0.03**	
S	**0.04**		**0.08**		**0.03**		**0.06**		**0.01**		**NS**	
M × S	**0.09**		**0.18**		**0.07**		**0.13**		**0.03**		**0.06**	

Treatment details

C	Control	**S**	**Spacing**
M	**Mulching**	S_1	30 x 15 cm
M_1	Black mulch	S_2	30 x 30 cm
M_2	Green mulch	S_3	30 x 45 cm
M_3	Blue mulch		
M_4	White mulch		

regime of soil and complete weed free environment (Singh *et al*., 2006).

Among different spacing, the planting density S_3 (30 × 45 cm) showed increased 'fruit set percentage', 'yield per plant', 'fruit length', 'fruit girth' and 'fruit weight'. The closely planted crops produced statistically lower yield per plant and least fruit weight. However, if comparisons are based on number of fruits set per plant and fruit set percentage, then the more densely planted crops produced the highest numbers of fruits and greatest. When the planting density is too low, each individual plant may perform at its maximum capacity, but there are not enough plants as a whole to reach the optimum yield. Therefore, total yield of the crop becomes a limiting factor. The increase in yield with the wider plantings might be due to increased fruit weight. The findings are in line

with Ogendo *et al*. (2008) and Paranjpe *et al*. (2008).

Similarly, with regard to interaction effect, the plants under green mulch (M_2) with planting density of S_2 (30 × 30 cm) had better values for yield per plant. This might be due to the reason that the green mulch with 30 x 45 cm spacing created a better microclimate and made the field weed free. The results are in accordance with the findings of Johnson and Fennimore (2005). Moreover, the alterations in spacing provided competition to reduce vigorous vegetative growth, reflected in yield regimes. These findings are in line with the results reported by Wright and Sandrang (1993).

The enhancement in fruit length, fruit girth and fruit weight was found to be influenced and significantly reflected with their interaction effect. Wider spacing received sufficient light and better physiological activity reflected with higher fruit length, fruit girth and fruit weight in mulched treatments. However, the closer spacing accommodated more number of plants than wider spacing and resulted overlapping of leaves to their adjacent plants and intermingled of roots that increased competition for the available resources *viz.,* water, light and nutrients. Ahmad (2009) stated that wider spacing acted as sink for storing the nutrient and finally translocated to fruits which are the source of sink. These absorbed nutrients might have been utilized by the fruits as a result of which there was increase in fruit length, girth and weight. This was in line of Badiyala and Joolka (1983) observed that wider spacing have better sized fruits.

Conclusion

So, from the present study, it is clearly evident that the plants under green mulch (M_2) with planting density of S_2 (30 × 45 cm) had positiveness for phenology, fruiting and yield related traits.

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