The Pharma Innovation Journal 2023; 12(11): 822-832

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; 12(11): 822-832

www.thepharmajournal.com
Received: 21-08-2023
Accepted: 30-10-2023

Himadri S Datta
College of Horticulture and Farming Systems Research, Assam Agricultural University, Nalbari, Assam, India

PC Barua
College of Agriculture, Assam Agricultural University, Jorhat, Assam, India

U Kotoky
College of Agriculture, Assam Agricultural University, Jorhat, Assam, India

R Das
College of Agriculture, Assam Agricultural University, Jorhat, Assam, India

H Saikia
College of Sericulture, Assam Agricultural University, Jorhat, Assam, India

HK Deva Nath
AAU-Zonal Research Station, Assam Agricultural University, Shillongani, Assam, India

Corresponding Author:
Himadri S Datta
College of Horticulture and Farming Systems Research, Assam Agricultural University, Nalbari, Assam, India

Response of crop geometry and mulch on growth and yield of strawberry (*Fragaria x ananassa* Duch.)

Himadri S Datta, PC Barua, U Kotoky, R Das, H Saikia and HK Deva Nath

Abstract
Spacing and mulch have got substantial impact on crop growth and yield. The purpose of this study was to study the effect of spacing and mulch on growth and yield of Strawberry. The field experiment was laid out in randomised block design (RBD) with three replications involving twenty treatments comprising of five plant spacings *viz*., 20 cm x 30 cm, 30 cm x 30 cm, 30 cm x 40 cm, 40 cm x 40 cm, 40 cm x 60 cm and four different mulch applications *viz*., paddy straw, red mulch, silver black mulch and no mulch. The data revealed that the highest number of leaves per plant (44.55), number of flowers per plant (38.69) was recorded in the widest spacing 40 cm x 60 cm. The plants under wider spacing 40 cm x 40 cm yielded fruits with the highest fruit weight (17.96 g), number of fruits per plant (32.31) and fruit yield per plant(644.31 g per plant). However, the highest marketable yield (11.80 t ha^{-1}) was obtained in 20 cm x 30 cm. It can be concluded that the treatment combination of 40 cm x 40 cm spacing with silver black mulch was found to be the most viable economic proposition for strawberry.

Keywords: Spacing, mulch, strawberry, growth, yield

Introduction
Strawberry (*Fragaria* × *ananassa* Duch.) is a natural hybrid species which belongs to the Rosaceae family that is cultivated all over the world for its aggregate accessory fruits. The growth and yield of strawberry can be enhanced by crop geometry and crop management practices. Crop geometry plays a remarkable role for enhancement of crop yield through effective utilization of solar radiation, nutrients and underground resources bringing about better photosynthate formation. Proper crop geometry aids in adequate harvesting of solar radiation and sufficient absorption of nutrients and moisture from the soil due to well developed root system which can be accommodated by making changes in inter and intra row spacing. Mulching controls or increases soil temperature, maintains soil moisture, improves water and fertilizer absorption, reduces weed growth and most importantly keeps produce quality high until harvesting by avoiding the direct contact of the fruit with the soil (Kijchavengkul *et al*., 2008) [32]. The present investigation aimed to study the effect of spacing and mulch on growth and yield of strawberry.

Materials and Methods
The study was conducted at the farmer's field at Jorhat district of India during the consecutive years 2019-2020 and 2020-2021. The field experiment plot was laid out in factorial randomized block design and consisted of three replications. The tissue culture strawberry plants of variety Sweet Charlie were planted in open condition in the experimental plot. There were 20 treatment combinations comprising of five plant spacings *viz*., 20 cm x 30 cm (S_1), 30 cm x 30 cm (S_2), 30 cm x 40 cm (S_3), 40 cm x 40 cm (S_4), 40 cm x 60 cm (S_5) and four different mulch applications *viz*., paddy straw (M_1), red mulch (M_2), silver black mulch (M_3) and no mulch (M_4).
Recommended package of practice was followed. Growth parameters *viz*. plant height, number of leaves per plant, number of runners per plant, number of flowers per plant, and yield parameters namely number of fruits per plant, fruit weight, fruit yield per plant and marketable fruit yield per hectare were recorded at proper time during the crop cycle. The data recorded during field experimentation were subjected to the statistical analysis of variance using factorial randomised block design as described by Panse and Sukhatme (1985) [52]. The results were statistically analyzed with the help of a windows-based computer package OPSTAT (Sheoran *et al*. 1998) [62] and SPSS software.

T_1 S_1M_1 20 cm x 30 cm with paddy straw mulch
T_2 S_1M_2 20 cm x 30 cm with red mulch
T_3 S_1M_3 20 cm x 30 cm with silver black mulch
T_4 S_1M_4 20 cm x 30 cm with no mulch
T_5 S_2M_1 30 cm x 30 cm with paddy straw mulch
T_6 S_2M_2 30 cm x 30 cm with red mulch
T_7 S_2M_3 30 cm x 30 cm with silver black mulch
T_8 S_2M_4 30 cm x 30 cm with no mulch
T_9 S_3M_1 30 cm x 40 cm with paddy straw mulch
T_{10} S_3M_2 30 cm x 40 cm with red mulch
T_{11} S_3M_3 30 cm x 40 cm with silver black mulch
T_{12} S_3M_4 30 cm x 40 cm with no mulch
T_{13} S_4M_1 40 cm x 40 cm with paddy straw mulch
T_{14} S_4M_2 40 cm x 40 cm with red mulch
T_{15} S_4M_3 40 cm x 40 cm with silver black mulch
T_{16} S_4M_4 40 cm x 40 cm with no mulch
T_{17} S_5M_1 40 cm x 60 cm with paddy straw mulch
T_{18} S_5M_2 40 cm x 60 cm with red mulch
T_{19} S_5M_3 40 cm x 60 cm with silver black mulch
T_{20} S_5M_4 40 cm x 60 cm with no mulch

Results and Discussion

Plant height: The effect of spacing and mulch on plant height is shown in Table 1 and Table 2. The interaction of spacing and mulching has recorded significant effect for all the treatments. At 90 days after planting treatment combination T_{15} (40 cm x 40 cm spacing with silver black mulch) registered maximum plant height (26.70 cm).The interactions involving spacing and mulching showed significant differences for plant height at 180 DAP. Treatment combination T_3 (20 cm x 30 cm spacing with silver black mulch registered maximum plant height (31.80 cm).Optimum spacing is one, which enables the plants to make the best use of conditions at their disposal. Too close spacing interferes with normal plants development and increase competition, while too wide spacing may result in excessive vegetative growth of plant and abundant weed population due to more feeding area available (Temesgen and Kebena, 2019) [71]. In the initial stage of crop growth, the maximum height in low density plants might be due to the fact that wider spacing provides better space for proper distribution of roots and supportive environment in root growth that comprises of optimal moisture distribution. This results in enhanced root activities which might have led to better nutrient uptake, subsequently better dry matter formation and gas exchange that helps in better plant height as compared to the closer spaced plants. These results are also supported by Hazarika *et al*. (2019) [19], Sonkar *et al*. (2012) [68] and Tariq *et al*. (2013) [70] in strawberry. At later stages of crop growth, plant height was found maximum in closer spacing which decreased gradually as the plant spacing increased. This could be due to the competition for sunlight, air and nutrients among the plants for which plants might tend to grow vertically in search of more light and air and thereby became taller. Similar views were expressed by Chezhiyan *et al*. (1986) [13] and Sharma (2007) [60] in Chrysanthemum. It is quite natural that when more plants per unit area are retained, mutual shading was more, which tended the plants to grow taller. The findings are in conformity with results of Sheoran *et al*. (2014) [63] and Mane *et al*. (2006) [41]. The possible reasons for increased plant height due to the application of mulches might be due to congenial environment in root zone because of lower weed population, optimum soil moisture level and favourable soil temperature. Weed free condition increased the plant height due to less competition for light, space and nutrient. The results are in accordance with those of Mohanty *et al*. (2002) [45], Shirgure *et al*. (2003) [64], Khokhar *et al*. (2004) [31], Kher *et al*. (2010) [30] and Sharma *et al*. (2004) [59].

Table 1: Effect of spacing, mulch and spacing and mulch (S x M) interaction on Plant height (cm) at 90 days after planting

Treatment	Plant height (cm) at 90 DAP		
	2019-2020	2020-21	Pooled
Spacing (S)			
S_1	22.63^a	22.56^a	22.59^a
S_2	22.41^{ab}	22.31^a	22.36^{ab}
S_3	22.21^b	22.19^a	22.20^b
S_4	22.26^b	22.23^a	22.25^b
S_5	21.42^c	21.19^b	21.30^b
S.Ed(±)	0.16	0.17	0.12
CD(P=0.05)	0.33	0.35	0.24
Mulches (M)			
M_1	18.68^c	18.62^c	18.65^c
M_2	25.37^b	25.17^b	25.27^b
M_3	26.25^a	26.20^a	26.23^a
M_4	18.44^c	18.40^c	18.42^d
S.Ed(±)	0.15	0.15	0.10
CD(P=0.05)	0.30	0.31	0.21

Interaction (S x M)							
Treatment combination	**2019-20**	**2020-21**	**Pooled**	**Treatment combination**	**2019-20**	**2020-21**	**Pooled**
T_1 (S_1M_1)	19.19	19.07	19.13	T_{11} (S_3M_3)	26.55	26.42	26.49
T_2 (S_1M_2)	25.93	25.87	25.90	T_{12} (S_3M_4)	18.28	18.41	18.35
T_3 (S_1M_3)	26.71	26.66	26.69	T_{13} (S_4M_1)	18.44	18.40	18.42
T_4 (S_1M_4)	18.69	18.63	18.66	T_{14} (S_4M_2)	25.61	25.57	25.59
T_5 (S_2M_1)	18.73	18.65	18.69	T_{15} (S_4M_3)	26.67	26.72	26.70
T_6 (S_2M_2)	25.71	25.52	25.62	T_{16} (S_4M_4)	18.33	18.23	18.28
T_7 (S_2M_3)	26.59	26.49	26.54	T_{17} (S_5M_1)	18.37	18.35	18.36
T_8 (S_2M_4)	18.61	18.59	18.60	T_{18} (S_5M_2)	24.26	23.57	23.91
T_9 (S_3M_1)	18.68	18.61	18.65	T_{19} (S_5M_3)	24.74	24.71	24.72
T_{10} (S_3M_2)	25.33	25.31	25.32	T_{20} (S_5M_4)	18.30	18.15	18.22

	2019-20	2020-2021	Pooled
S.Ed(±)	0.33	0.34	0.24
CD(P=0.05)	0.66	0.70	0.47

Table 2: Effect of spacing, mulch and spacing and mulch (S x M) interaction on Plant height (cm) at 180 DAP

Treatment	Plant height (cm) at 180 DAP		
	2019-2020	2020-21	Pooled
Spacing (S)			
S_1	28.35[a]	28.02[a]	28.18[a]
S_2	28.16[ab]	27.88[ab]	28.02[b]
S_3	27.97[bc]	27.82[b]	27.90[b]
S_4	27.83[c]	27.61[c]	27.72[c]
S_5	27.29[d]	27.18[d]	27.24[d]
S.Ed(±)	0.12	0.08	0.06
CD(P=0.05)	0.24	0.16	0.12
Mulches(M)			
M_1	24.66[c]	24.54[c]	24.60[c]
M_2	31.11[b]	30.66[b]	30.88[b]
M_3	31.74[a]	31.53[a]	31.64[a]
M_4	24.18[d]	24.07[d]	24.13[d]
S.Ed(±)	0.11	0.07	0.05
CD(P=0.05)	0.22	0.14	0.11

Interaction (S x M)							
Treatment combination	**2019-20**	**2020-21**	**Pooled**	**Treatment combination**	**2019-20**	**2020-21**	**Pooled**
T_1 (S_1M_1)	25.27	25.17	25.22	T_{11} (S_3M_3)	31.83	31.58	31.70
T_2 (S_1M_2)	31.57	30.65	31.11	T_{12} (S_3M_4)	24.58	24.47	24.53
T_3 (S_1M_3)	31.88	31.72	31.80	T_{13} (S_4M_1)	24.61	24.53	24.57
T_4 (S_1M_4)	24.68	24.52	24.60	T_{14} (S_4M_2)	31.04	30.67	30.86
T_5 (S_2M_1)	24.86	24.61	24.73	T_{15} (S_4M_3)	31.79	31.52	31.65
T_6 (S_2M_2)	31.31	30.71	31.00	T_{16} (S_4M_4)	23.87	23.75	23.81
T_7 (S_2M_3)	31.85	31.61	31.73	T_{17} (S_5M_1)	23.89	23.84	23.86
T_8 (S_2M_4)	24.64	24.60	24.62	T_{18} (S_5M_2)	30.80	30.60	30.70
T_9 (S_3M_1)	24.66	24.56	24.61	T_{19} (S_5M_3)	31.35	31.25	31.30
T_{10} (S_3M_2)	30.82	30.69	30.75	T_{20} (S_5M_4)	23.13	23.03	23.08
	2019-20			**2020-2021**	**Pooled**		
S.Ed(±)	0.24			0.16	0.12		
CD(P=0.05)	0.48			0.33	0.25		

Number of leaves: The interactions involving spacing and mulching exhibited significant effect on number of leaves at 180 DAP for both the years of study as depicted in Table 3. Treatment combination T_{19} (40 cm x 60 cm spacing with silver black mulch) registered maximum number of leaves (55.50) while minimum number of leaves (28.07) was observed in T_4. Wider spacing recorded more number of leaves per plant than closer spacing which might be due to minimum competition among plants for light and other resources along with no overlapping from adjoining plants which might have enabled the plants to utilize its energy for maximum leaf production. In case of closer spacing, lesser photosynthesis due to greater competition among higher number of plants per unit area resulted in less number of leaves. These observations are in concurrence with the findings of Narkar (2016) [48] and Bhatia *et al*. (2017) [9]. The black polyethylene mulch gave the higher number of leaves per plant which might be due to higher soil moisture and temperature conservation as well as reduced nutrient losses by suppressing the weed population. The microclimate condition improved by the mulches might have provided a suitable condition for producing higher number of leaves in the plants The results are also in agreement with the findings of Kumar and Dey (2011) [34], Kher *et al*. (2010) [30], Rhakho *et al*. (2014) [57] and Bakshi *et al*. (2014) [7]. Red mulch gave lesser number of leaves than silver black mulch which might be due to the fact that the red mulch fade over the growing season giving lighter pinkish color; allowed some light to penetrate the mulch and for which the potential of red mulch could not be fully exploited. Similar views expressed by Posada *et al*. (2011) [54] and Locascio *et al*. (2005) [39].

Table 3: Effect of spacing, mulch and spacing and mulch (S x M) interaction on Number of leaves produced per plant at 180 DAP

Treatment	Number of leaves produced at 180 DAP		
	2019-2020	2020-21	Pooled
Spacing (S)			
S_1	39.85[e]	39.21[e]	39.53[e]
S_2	41.73[d]	41.09[d]	41.41[d]
S_3	42.85[c]	42.14[c]	42.50[c]
S_4	44.15[b]	43.43[b]	43.79[b]
S_5	45.00[a]	44.10[a]	44.55[a]
S.Ed (±)	0.17	0.17	0.12

CD(P=0.05)	0.34			0.35		0.24	
Mulches (M)							
M_1	32.86^c			32.27^c		32.57^c	
M_2	51.82^b			51.10^b		51.46^b	
M_3	54.15^a			53.19^a		53.67^a	
M_4	32.03^d			31.42^d		31.72^d	
S.Ed(±)	0.15			0.15		0.11	
CD(P=0.05)	0.31			0.31		0.22	
Interaction (S x M)							
Treatment combination	**2019-20**	**2020-21**	**Pooled**	**Treatment combination**	**2019-20**	**2020-21**	**Pooled**
T_1 (S_1M_1)	31.47	30.86	31.17	T_{11} (S_3M_3)	54.14	53.15	53.65
T_2 (S_1M_2)	47.54	46.96	47.25	T_{12} (S_3M_4)	32.20	31.81	32.00
T_3 (S_1M_3)	52.20	51.10	51.65	T_{13} (S_4M_1)	33.24	32.86	33.05
T_4 (S_1M_4)	28.20	27.93	28.07	T_{14} (S_4M_2)	53.84	53.07	53.45
T_5 (S_2M_1)	32.19	31.60	31.90	T_{15} (S_4M_3)	55.80	54.87	55.34
T_6 (S_2M_2)	50.85	50.03	50.44	T_{16} (S_4M_4)	33.72	32.91	33.31
T_7 (S_2M_3)	52.58	51.85	52.21	T_{17} (S_5M_1)	34.96	34.07	34.52
T_8 (S_2M_4)	31.30	30.87	31.09	T_{18} (S_5M_2)	54.27	53.79	54.03
T_9 (S_3M_1)	32.45	31.96	32.20	T_{19} (S_5M_3)	56.03	54.96	55.50
T_{10} (S_3M_2)	52.61	51.66	52.14	T_{20} (S_5M_4)	34.71	33.56	34.14
	2019-20			**2020-2021**	**Pooled**		
S.Ed(±)	0.33			0.25	0.21		
CD(P=0.05)	0.68			0.50	0.42		

Number of runners per plant: The observations related to runner production as influenced by different treatments are presented in Table 4. The interactions involving spacing and mulching showed significant differences for number of runners per plant in the second year of study and pooled data whereas in the first year it showed non-significant effect. Treatment combination T_{15} (40 cm x 40 cm spacing with silver black mulch) gave maximum number of runners per plant (3.93) while minimum number of runners (0.00) was observed in treatment combinations of different spacings with paddy straw and no mulch. Runner initiation in strawberry is a complex response believed to be largely stimulated by temperature, photoperiod, plant type and cultivar. Production of quality planting material of strawberry through runner depends on some factors like nutritional status of soil, vegetative growth of plants. Good vegetative growth, minimum load of fruit generally leads to the better growth of runners. It was reported that increased growth of plant in the form of height and number of leaves accumulated more photosynthates, which increased runners as observed by Orde *et al*. (2021) [50], Deb *et al*. (2014) [16] and Beer (2014) [8]. Flowering inhibits the formation of runners, and that flowering is primarily controlled by temperature. If temperature is inhibitive for flowering, runner formation is then promoted in a photoperiod-dependent manner. The temperature of the site also affected the runner formation. Long-days and higher temperatures promote runner formation in the seasonal flowering strawberries. These are in similar views with Li *et al*. (2020) [28] and Sharma *et al*. (2014) [61]. One interesting feature of Strawberry is a strong trade-off and obvious antagonism between runner formation and flowering induction as indicated by Hytönen and Kurokura (2020) [23] and Bradford *et al*. (2010) [15] in their works. Higher or lower number of runners might be due to the differences in the prevailing agro climatic conditions, inherent potential of varieties for runner production and appropriate cultural practices adopted for strawberry culture based on opinion of Kumar *et al*. (2020) [36]. The higher number of runners in wider spacing could be due to reduced interplant competition for soil resources. In addition, high light intensity which reportedly favours runner production might have been received under the wider spaced plants. Similar results were found by Bielinski (2013) [15] and Hazarika *et al*. (2019) [19] in strawberry. Plants grown on silver black polyethylene produced more runners than with paddy straw and bare soil which might be due to favourable microclimatic conditions in plastic mulch. The results from present study were supported by findings of Himelrick (1982) [21] and Das *et al*. (2007) [14].

Table 4: Effect of spacing, mulch and spacing and mulch (S x M) interaction on Number of runners produced per plant

Treatment	**Number of runners**		
	2019-2020	**2020-21**	**Pooled**
Spacing (S)			
S_1	1.35^c	1.27^c	1.31^d
S_2	1.40^c	1.33^c	1.37^{cd}
S_3	1.51^{bc}	1.40^c	1.46^c
S_4	1.88^a	1.85^a	1.87^a
S_5	1.70^{ab}	1.60^b	1.65^b
S.Ed(±)	0.11	0.08	0.07
CD(P=0.05)	0.23	0.16	0.14
Mulches (M)			
M_1	0.12^c	0.12^c	0.12^c
M_2	2.76^b	2.63^b	2.69^b
M_3	3.38^a	3.21^a	3.30^a
M_4	0.013^c	0.00^c	0.007^c

S.Ed(±)	0.10			0.07			0.06
CD(P=0.05)	0.21			0.15			0.13
Interaction (S x M)							
Treatment combination	**2019-20**	**2020-21**	**Pooled**	**Treatment combination**	**2019-20**	**2020-21**	**Pooled**
T_1 (S_1M_1)	0.06	0.06	0.07	T_{11} (S_3M_3)	3.27	3.00	3.13
T_2 (S_1M_2)	2.40	2.13	2.27	T_{12} (S_3M_4)	0.00	0.00	0.00
T_3 (S_1M_3)	2.93	2.87	2.90	T_{13} (S_4M_1)	0.20	0.20	0.20
T_4 (S_1M_4)	0.00	0.00	0.00	T_{14} (S_4M_2)	3.27	3.33	3.30
T_5 (S_2M_1)	0.07	0.06	0.07	T_{15} (S_4M_3)	4.00	3.87	3.93
T_6 (S_2M_2)	2.46	2.20	2.33	T_{16} (S_4M_4)	0.07	0.00	0.03
T_7 (S_2M_3)	3.07	3.07	3.07	T_{17} (S_5M_1)	0.13	0.13	0.13
T_8 (S_2M_4)	0.00	0.00	0.00	T_{18} (S_5M_2)	3.00	3.00	3.00
T_9 (S_3M_1)	0.13	0.13	0.13	T_{19} (S_5M_3)	3.67	3.27	3.47
T_{10} (S_3M_2)	2.67	2.47	2.57	T_{20} (S_5M_4)	0.00	0.00	0.00
	2019-20			**2020-2021**	**Pooled**		
S.Ed(±)	0.23			0.16	0.14		
CD(P=0.05)	NS			0.33	0.28		

Number of flowers produced plant^{-1}: Data with regards to number of flowers produced per plant are presented in Table 5. The interactions involving spacing and mulching showed significant differences on number of flowers. Treatment combination T_{15} (40 cm x 40 cm spacing with silver black mulch) gave maximum number of flowers (54.40) while minimum number of flowers (15.78) was observed in T_4.The number of flowers per plant was less with closer spacing which might be due to higher competition of plants for nutrients, water, space and light. Strawberries grown in wider spacing are supposed to receive more light by their photosynthetic leaves than strawberries grown in closer spacing due to their higher canopy area. Spacing at medium and wider spacing resulted in highest number of flowers per plant. The increase in number of flowers due to spacing can be correlated with the significant effect of the treatments on vegetative growth characters because of which higher levels of organic reserves conducive for better floral development generated thereby increasing the number of flowers. These findings are in line with the results reported by Al-Ramamneh *et al*. (2013) [3], Kumar *et al*. (2016) [35], Sonkar *et al*. (2012) [68] and Nagdeve *et al*. (2021) [47]. Maximum number of flowers was recorded when silver black polythene was used as mulch which might be due to increase in the soil temperature, reduced reserve carbohydrates and supply of nutrients throughout the crop growth period. During winter months of December and January, the synthetic mulches raised the soil temperature more effectively as compared to organic mulches. Silver black colour polythene have more capacity to regulate soil temperature than other mulch materials making more favourable microclimate for the growth and flowering of plant. Decreased water loss and soil temperature regulation, reduced soil erosion and suppressed weeds in turn promoted vegetative growth that positively reflected on flowering traits. The findings are in conformity with Ali and Radwan (2008) [2], Sanas *et al*. (2018) [58] and Kaur and Singh (2009) [28].

Table 5: Effect of spacing, mulch and spacing and mulch (S x M) interaction on Number of flowers produced per plant

Treatment	**Number of flowers per plant**						
	2019-2020		**2020-21**			**Pooled**	
Spacing (S)							
S_1	31.41^d		29.88^e			30.65^e	
S_2	33.14^c		30.95^d			32.04^d	
S_3	35.35^b		33.33^c			34.34^c	
S_4	38.93^a		36.60^b			37.76^b	
S_5	39.19^a		38.20^a			38.69^a	
S.Ed(±)	0.34		0.30			0.22	
CD(P=0.05)	0.69		0.60			0.45	
Mulches (M)							
M_1	26.29^c		24.31^c			25.30^c	
M_2	47.40^b		45.33^b			46.36^b	
M_3	49.67^a		47.79^a			48.73^a	
M_4	19.05^d		17.74^d			18.40^d	
S.Ed(±)	0.30		0.27			0.20	
CD(P=0.05)	0.61		0.54			0.40	
Interaction (S x M)							
Treatment combination	**2019-20**	**2020-21**	**Pooled**	**Treatment combination**	**2019-20**	**2020-21**	**Pooled**
T_1 (S_1M_1)	22.47	21.78	22.12	T_{11} (S_3M_3)	48.89	46.29	47.59
T_2 (S_1M_2)	42.48	40.20	41.34	T_{12} (S_3M_4)	18.76	17.82	18.29
T_3 (S_1M_3)	44.16	42.53	43.34	T_{13} (S_4M_1)	28.33	25.71	27.02
T_4 (S_1M_4)	16.54	15.01	15.78	T_{14} (S_4M_2)	51.34	49.05	50.20
T_5 (S_2M_1)	24.68	22.08	23.38	T_{15} (S_4M_3)	55.50	53.30	54.40
T_6 (S_2M_2)	43.55	41.63	42.59	T_{16} (S_4M_4)	20.54	18.32	19.43
T_7 (S_2M_3)	46.36	44.07	45.21	T_{17} (S_5M_1)	29.62	27.90	28.76

T_8 (S_2M_4)	17.97	16.02	17.00	T_{18} (S_5M_2)	52.23	50.64	51.44
T_9 (S_3M_1)	26.34	24.10	25.22	T_{19} (S_5M_3)	53.44	52.75	53.09
T_{10} (S_3M_2)	47.40	45.14	46.27	T_{20} (S_5M_4)	21.46	21.50	21.48
	2019-20			**2020-2021**	**Pooled**		
S.Ed(±)	0.68			0.60	0.45		
CD(P=0.05)	1.37			1.21	0.90		

Number of fruits per plant: The data on number of fruits per plant as influenced by the different treatments has been presented in Table 6. The interactions involving spacing and mulching showed significant effect on number of fruits per plant. Treatment combination T_{15} (40 cm x 40 cm spacing with silver black mulch) gave maximum number of fruits per plant (50.49) while minimum number of fruits (10.84) was observed in T_4.Mulching and spacing, individually and in combination, significantly influenced the yield characters in strawberry. The variations in the number of fruits per plant are mainly due to factors such as temperature fluctuations, water regime, and the incidence of diseases during the growing seasons. With suitable plant density, plants can effectively use the environmental conditions and also inter or intra 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. Increase in number of fruits per plant with reducing plant density was due to the formation of more leaves due to more space being available for plants to spread that led to more leaf area, number of flower per plant and percent berry set thereby augmented the fruit number. The results are in agreement with the findings of De Lima *et al.* (2021) [15], Bhatia *et al.* (2017) [9], Ayeni *et al.* (2020) [6]. Sonkar *et al.* (2012) [68], Hazarika *et al.* (2019) [19] and Paranjpe *et al.* (2008) [53]. The results indicated that the number of fruits per plant was maximum with silver black mulch which might be due to production of maximum number of flowers per plant. Silver black polyethylene enhanced the number of flowers which could be due to the decreased water loss and soil temperature regulation which in turn might increased the number of fruits. Silver black mulch might also improved the fruit set by reducing the drop of flowers owing to reduced moisture stress and hence increased the fruit set percent. Better performance of silver polyethylene mulch might be due to reflection of light into the lower canopy of the plant which increased the photosynthetic rate, thereby increased the number of fruits per plant. It was found that although red mulch color faded during the growing season, higher yields in red plastic mulch compared to straw mulch may be due to the red plastic mulch ability to produce a greater FR:R ratio which generated a positive phytochrome response.These findings are in line with the results of Shokouhian and Asghari (2015) [65], Franquera and Mabesa (2016) [18], Pandey *et al.* (2016) [51], Kaur and Kaur (2017) [29], Bakshi *et al.* (2014) [7] and Sujatha *et al.* (2018) [69].

Table 6: Effect of spacing, mulch and spacing and mulch (S x M) interaction on Number of fruits per plant

Treatment	**Number of fruits**						
	2019-2020			**2020-21**		**Pooled**	
Spacing (S)							
S_1	24.92^e			23.44^c		24.18^e	
S_2	26.30^d			24.49^c		25.39^d	
S_3	28.87^c			27.27^b		28.07^c	
S_4	32.95^a			31.68^a		32.31^a	
S_5	31.34^b			30.49^a		30.91^b	
S.Ed(±)	0.51			0.77		0.46	
CD(P=0.05)	1.04			1.56		0.92	
Mulches (M)							
M_1	20.23^c			18.79^c		19.51^c	
M_2	39.65^b			37.83^b		38.74^b	
M_3	42.65^a			41.57^a		42.11^a	
M_4	12.97^d			11.70^d		12.34^d	
S.Ed(±)	0.46			0.69		0.41	
CD(P=0.05)	0.93			1.40		0.83	
Interaction (S x M)							
Treatment combination	**2019-20**	**2020-21**	**Pooled**	**Treatment combination**	**2019-20**	**2020-21**	**Pooled**
T_1 (S_1M_1)	17.05	15.41	16.23	T_{11} (S_3M_3)	42.61	40.66	41.64
T_2 (S_1M_2)	34.98	33.25	34.11	T_{12} (S_3M_4)	12.79	11.47	12.13
T_3 (S_1M_3)	36.36	34.73	35.54	T_{13} (S_4M_1)	22.64	20.47	21.55
T_4 (S_1M_4)	11.31	10.38	10.84	T_{14} (S_4M_2)	44.90	43.63	44.27
T_5 (S_2M_1)	18.37	17.05	17.71	T_{15} (S_4M_3)	50.76	50.23	50.49
T_6 (S_2M_2)	36.14	33.15	34.64	T_{16} (S_4M_4)	13.51	12.38	12.94
T_7 (S_2M_3)	38.08	36.14	37.11	T_{17} (S_5M_1)	22.77	21.54	22.16
T_8 (S_2M_4)	12.60	11.63	12.11	T_{18} (S_5M_2)	42.48	41.67	42.07
T_9 (S_3M_1)	20.32	19.50	19.91	T_{19} (S_5M_3)	45.44	46.10	45.77
T_{10} (S_3M_2)	39.76	37.45	38.60	T_{20} (S_5M_4)	14.66	12.65	13.65
	2019-20			**2020-2021**	**Pooled**		
S.Ed(±)	1.02			1.55	0.93		
CD(P=0.05)	2.08			3.13	1.85		

Fruit weight (g)

A significant variation in fruit weight was observed due to the treatments and the data recorded has been presented in Table 7. The interactions involving spacing and mulching showed non-significant effect on fruit weight and treatment combination T_{15} registering maximum fruit weight (23.12 g).In wider spacing, more leaf surface is exposed to sunlight and indirectly greater amount of assimilates accumulated in the various organs of the plant leading to increased berry weight and as the spacing increases; there is less competition for nutrients. With the increase in planting density, there may be a decrease in the crown's fresh mass which in turn, decreases the concentration of carbohydrates and consequently also causes interference in fresh fruit mass which may occur due to the competition for carbohydrates and assimilates. When the planting density is too low, each individual plant may perform at its maximum capacity. In close spaced plants, low fruit weight obtained which might be due to less percent radiation interception which led to severe competition for metabolites and caused reduction in fruit weight. Similar result was obtained by Singh *et al*. (2018) [67], De Lima *et al*. (2021) [15] and Hazarika *et al*. (2019) [19]. The results found that plants under silver black mulch produced larger fruit which might be due to better plant growth owing to the favourable hydrothermal regime of the soil and a completely weed free environment. Mulch surface colour can induce changes in the plant microclimate (e.g., spectral balance and quantity of light, root zone temperatures) that can act through natural regulatory systems within the growing plant and affect fruit production. Increase in fruit weight under silver black mulch was directly related to the reduced weed density and high weed control efficiency that resulted in increased availability of soil water and nutrients to the plants that subsequently enhanced fruit weight. The results are in accordance with the findings of Rao *et al*. (2016) [56], Iqbal *et al*. (2015) [25].

Table 7: Effect of spacing, mulch and spacing and mulch (S x M) interaction on Fruit weight (g)

Treatment	Fruit weight(g)						
	2019-2020			2020-21			Pooled
Spacing (S)							
S_1	16.53^{c}			16.37^{c}			16.45^{c}
S_2	17.15^{bc}			16.42^{c}			16.79^{c}
S_3	17.58^{ab}			17.09^{b}			17.33^{b}
S_4	18.22^{a}			17.70^{a}			17.96^{a}
S_5	18.09^{a}			17.69^{a}			17.88^{a}
S.Ed(±)	0.36			0.28			0.23
CD(P=0.05)	0.73			0.56			0.45
Mulches (M)							
M_1	13.62^{c}			13.05^{c}			13.33^{c}
M_2	20.82^{b}			20.55^{b}			20.69^{b}
M_3	22.71^{a}			22.08^{a}			22.40^{a}
M_4	12.91^{d}			12.52^{d}			12.71^{d}
S.Ed(±)	0.32			0.24			0.20
CD(P=0.05)	0.65			0.50			0.40
Interaction (S x M)							
Treatment combination	**2019-20**	**2020-21**	**Pooled**	**Treatment combination**	**2019-20**	**2020-21**	**Pooled**
T_1 (S_1M_1)	12.59	12.27	12.43	T_{11} (S_3M_3)	22.64	22.41	22.52
T_2 (S_1M_2)	20.12	20.61	20.36	T_{12} (S_3M_4)	13.24	12.93	13.09
T_3 (S_1M_3)	22.14	21.58	21.86	T_{13} (S_4M_1)	14.26	13.68	13.97
T_4 (S_1M_4)	11.27	11.01	11.14	T_{14} (S_4M_2)	21.11	20.89	21.00
T_5 (S_2M_1)	12.91	12.16	12.53	T_{15} (S_4M_3)	23.68	22.57	**23.12**
T_6 (S_2M_2)	20.76	20.09	20.42	T_{16} (S_4M_4)	13.84	13.65	13.74
T_7 (S_2M_3)	22.32	21.61	21.96	T_{17} (S_5M_1)	14.86	14.39	14.63
T_8 (S_2M_4)	12.63	11.82	12.22	T_{18} (S_5M_2)	21.15	20.91	21.03
T_9 (S_3M_1)	13.49	12.73	13.11	T_{19} (S_5M_3)	22.78	22.26	22.52
T_{10} (S_3M_2)	20.95	20.28	20.62	T_{20} (S_5M_4)	13.56	13.18	13.37
	2019-20			**2020-2021**	**Pooled**		
S.Ed(±)	0.72			0.55	0.45		
CD(P=0.05)	NS			NS	NS		

Fruit yield per plant (g): The data with regard to fruit yield per plant (g) as influenced by different treatments are presented in Table 8. The interactions involving spacing and mulching showed significant effect on fruit yield per plant. Treatment combination T_{15} (40 cm x 40 cm spacing with silver black mulch) gave maximum fruit yield per plant (1167.91 g) while minimum fruit yield per plant (121.17 g) was obtained in T_4.The maximum yield per plant was recorded in the widest plant spacing followed by medium and closest plant spacing. The widest spaced plants produced higher fruit yield per plant possibly because there were availability of sufficient nutrients, moisture and sunlight per plant due to the low plant density. The 'striving' wider spaced plants might have translocated more of their photo assimilates into their fruits making them larger and heavier than those produced by the plants in the closest spacing. As spacing increased, yield per plant increased, probably because wider spacing created less interplant competition. Similar results were observed by Maurya *et al*. (2013) [42] and Kultur *et al*. (2001) [33]. Plants under silver black mulch produced higher yield per plant because of larger fruits that might be due to better plant growth owing to favourable hydrothermal regime of soil and complete weed free environment. Plastic mulch significantly improved the number of fruits per plant which

could be probably related to the conservation of optimum moisture and improved microclimate both beneath and above the soil surface which increased number of flowers and better fruit set. The results are supported by findings of Islam *et al*. (2021) [26], Iqbal *et al*. (2009) [24], Bakshi *et al*. (2014) [7] and Kher *et al*. (2010) [30]. Bhujbal *et al*. (2015) [10] also noted increased fruit yield under polythene mulch due to better water utilization, higher uptake of nutrients and excellent soil-water-air relationship with higher oxygen concentration in root zone. Higher yields observed from plants grown with red plastic mulch compared to straw mulch and no mulch could be due to better reflection of far red to red light by red mulch that might modify gene expression through phytochrome and increased fruit size and yield. Similar views were made by Kasperbauer (2000) [27] and Posada *et al*. (2011) [54].

Table 8: Effect of spacing, mulch and Spacing and mulch (S x M) interaction on Fruit yield per plant (g)

Treatment	Fruit yield per plant(g)						
	2019-2020			2020-21			Pooled
Spacing (S)							
S_1	462.69^e			434.74^c			448.72^e
S_2	499.02^d			447.81^c			473.41^d
S_3	560.56^c			516.93^b			538.74^c
S_4	664.58^a			624.03^a			644.31^a
S_5	617.77^b			592.97^a			605.37^b
S.Ed(±)	14.22			19.09			11.90
CD(P=0.05)	28.80			38.80			23.71
Mulches (M)							
M_1	277.42^c			246.84^c			262.13^c
M_2	826.77^b			779.05^b			802.90^b
M_3	971.17^a			920.57^a			945.87^a
M_4	168.33^d			146.74^d			157.54^d
S.Ed(±)	12.72			17.07			10.65
CD(P=0.05)	25.76			34.71			21.21
Interaction (S x M)							
Treatment combination	**2019-20**	**2020-21**	**Pooled**	**Treatment combination**	**2019-20**	**2020-21**	**Pooled**
T_1 (S_1M_1)	214.73	189.18	201.96	T_{11} (S_3M_3)	964.59	911.27	937.93
T_2 (S_1M_2)	703.58	685.56	694.57	T_{12} (S_3M_4)	169.77	148.34	159.05
T_3 (S_1M_3)	804.81	749.51	777.16	T_{13} (S_4M_1)	321.97	280.18	301.08
T_4 (S_1M_4)	127.64	114.70	121.17	T_{14} (S_4M_2)	948.15	912.34	930.25
T_5 (S_2M_1)	237.10	207.13	222.11	T_{15} (S_4M_3)	1201.12	1134.70	**1167.91**
T_6 (S_2M_2)	750.57	665.59	708.08	T_{16} (S_4M_4)	187.08	168.91	178.00
T_7 (S_2M_3)	849.69	780.76	815.22	T_{17} (S_5M_1)	338.65	309.31	323.98
T_8 (S_2M_4)	158.74	137.74	148.24	T_{18} (S_5M_2)	898.33	871.98	885.15
T_9 (S_3M_1)	274.64	284.40	261.52	T_{19} (S_5M_3)	1035.66	1026.60	1031.13
T_{10} (S_3M_2)	833.22	759.69	796.45	T_{20} (S_5M_4)	198.44	164.00	181.22
	2019-20			**2020-2021**	**Pooled**		
S.Ed(±)	28.45			38.18	23.81		
CD(P=0.05)	57.60			77.60	47.42		

Marketable fruit yield per hectare (t ha^{-1})

The data on marketable fruit yield per hectare as influenced by different treatments have been presented in Table 9. The interactions involving spacing and mulching showed significant effect on marketable fruit yield per hectare during both the years of study. Treatment combination T_3 (20 cm x 30 cm spacing with silver black mulch) gave maximum marketable fruit yield (22.75 t ha^{-1}) while minimum marketable fruit yield (0.36 t ha^{-1}) was observed in T_{20}.Marketable yield is a better indicator of productivity in strawberry than total yield. Strawberry production is heavily prone to field and post-harvest losses due to high susceptibility to fungal diseases as mentioned by Hong *et al*. (2022) [22]. Plant spacing affected marketable yield significantly. Narrower spacing produced higher yield per unit area than the wider spacing but wider plant spacing lowered Botrytis incidence. The reason for the higher marketable fruit yield in the narrow spacing could be attributed to more plant population per unit area. These results clearly indicated that farmers may lose much more yield if they do not use appropriate planting distance. The smaller spacing between plants probably resulted in a more deficient aeration of plants, increasing the vegetation's moisture indexes. Excess moisture, in turn, leads to the increased occurrence of pathological diseases. The closer spacing and the incidence of rot diseases relation are positively correlated, more severe in closer spacing between plants. These results were in conformity with the findings of Amare and Gebremedhin (2020) [4], Legard *et al*. (2000) [37], Getahun and Bikis (2015) [19], De Lima *et al*. (2021) [15] and Maboko *et al*. (2011) [40]. The results disagrees with Tariq *et al*. (2013) [70] and Ara *et al*. (2007) [5] who found that the higher marketable fruits were recorded from wider spacing rather than closer spacing and that could be due to variability in the soil type and differences in the growing environment or attributed to having less competition for water and nutrients in wider spacing than in closer ones. This clearly indicated that plant spacing should be determined by considering cultivar, site and management practices required. All colored plastic mulch significantly had higher marketable yield compared to bare soil. The increase in marketable yield of mulched plot was probably associated with the conservation of moisture and improved microclimate both beneath and above the soil surface and great weed control, especially in silver black mulch. Fruits grown without

mulch become infected by soil borne organisms which results in reduced marketable yield. The results are in conformity with the views of DeVetter *et al*. (2017) [17]. Menzel (2020) [43], Singh and Yadav (2017) [66], Adnan *et al*. (2017) [1] and Rajablariani *et al*. (2012) [55]. In the study, higher temperatures had a negative effect on the performance of the plants and the plants continued to produce a marketable crop towards the end of the season at lower rate although the fruits were small. The incidence of small fruit increased over the season, possibly due to higher temperatures, whereas the incidence of misshapen fruit reflected periods of low temperatures during flower development. Rain can cause the fruit to become water soaked or cracked. The incidence of fruit defects varies widely with the growing system and weather. Similar observations were made by Menzel (2021) [44]. Spoilage of fruits was observed in the form of eating by the birds and microbial rotting under field condition in similar views with Neetu and Sharma (2018) [49].

Table 9: Effect of spacing, mulch and spacing and mulch (S x M) interaction on Marketable Fruit yield (t ha^{-1})

Treatment	Marketable Fruit yield (t ha^{-1})						
	2019-2020			2020-21			Pooled
Spacing (S)							
S_1	12.04^a			11.56^a			11.80^a
S_2	11.24^b			10.30^b			10.77^b
S_3	9.81^d			8.94^c			9.38^d
S_4	10.61^c			9.83^b			10.22^c
S_5	6.47^e			6.18^d			6.32^e
S.Ed(±)	0.25			0.33			0.21
CD(P=0.05)	0.51			0.67			0.41
Mulches (M)							
M_1	3.55^c			3.21^c			3.38^c
M_2	16.43^b			15.40^b			15.91^b
M_3	19.62^a			18.35^a			18.98^a
M_4	0.54^d			0.48^d			0.51^d
S.Ed(±)	0.23			0.29			0.18
CD(P=0.05)	0.46			0.60			0.37
Interaction (S x M)							
Treatment combination	**2019-20**	**2020-21**	**Pooled**	**Treatment combination**	**2019-20**	**2020-21**	**Pooled**
T_1 (S_1M_1)	4.09	3.69	3.89	T_{11} (S_3M_3)	18.99	17.65	18.32
T_2 (S_1M_2)	20.10	19.91	20.00	T_{12} (S_3M_4)	0.53	0.47	0.50
T_3 (S_1M_3)	23.37	22.12	22.75	T_{13} (S_4M_1)	3.66	3.27	3.46
T_4 (S_1M_4)	0.61	0.54	0.58	T_{14} (S_4M_2)	16.59	15.71	16.15
T_5 (S_2M_1)	3.94	3.54	3.74	T_{15} (S_4M_3)	21.68	19.85	20.77
T_6 (S_2M_2)	18.76	16.91	17.83	T_{16} (S_4M_4)	0.52	0.51	0.52
T_7 (S_2M_3)	21.59	20.17	20.88	T_{17} (S_5M_1)	2.57	2.40	2.48
T_8 (S_2M_4)	0.66	0.57	0.62	T_{18} (S_5M_2)	10.48	10.01	10.24
T_9 (S_3M_1)	3.51	3.18	3.35	T_{19} (S_5M_3)	12.46	11.97	12.22
T_{10} (S_3M_2)	16.23	14.48	15.35	T_{20} (S_5M_4)	0.38	0.33	0.36
	2019-20			**2020-2021**	**Pooled**		
S.Ed(±)	0.51			0.66	0.42		
CD(P=0.05)	1.03			1.34	0.83		

Conclusion

The study revealed that the optimum spacing and appropriate mulch material had a substantial impact on crop growth, yield and quality of strawberry. The results indicated that 40 cm x 40 cm spacing with silver black mulch recorded maximum number of runners, number of flowers, fruit weight, total number of fruits per plant, fruit yield per plant. The research investigation highlighted the fact that crop geometry and management practices govern yield parameters and shelf life of the high valued crop, strawberry.

Acknowledgement: We would like to thank the competent authority of Assam Agricultural University, Jorhat, India for providing necessary guidance, support and assistance during the course of investigation.

Competing interest: The authors declare that they have no competing interests.

References

1. Adnan MM, Rahim, MA Haque T, Hossain MM. Growth and yield performance of strawberry (*Fragaria* × *Ananassa* Duch.) as influenced by variety and mulch materials. *Fundam. Appl. Agri.*, 2017;2(1):202-206.
2. Ali RAM, Radwan EA. Effect of organic and synthetic mulches on some fresh strawberry cultivars. J. Agric. Environ. Sci. Alex Univ. Egypt. 2008;7(3):167-193.
3. Al Ramamneh E, Al Rawashdeh Z, Karajeh M, Abu-Romman S. Plant response of strawberry to intra-row spacing and growing conditions in South of Jordan. Asian. J. Pl. Sci. 2013;12(5):201-207.
4. Amare G, Gebremedhin H. Effect of plant spacing on yield and yield components of Tomato (*Solanum lycopersicum* L.) in Shewarobit, Central Ethiopia. Scientifica; c2020. p. 1-6.
5. Ara N, Bashar M, Begum, S, Kakon S. Effect of spacing and stem pruning on the growth and yield of tomato. Int. J Sustain. Crop Prod. 2007;2(3):35-39.
6. Ayeni OS, Makinde EA, Odeyemi OM, Sobukola OP. Plant density due to intra-row spacing on growth, weed control and yield of Golden melon. Int. J Veg. Sci., 2020, 1-22.

7. Bakshi P, Bhat DJ, Wali VK, Sharma A, Iqbal M. Growth, yield and quality of strawberry (*Fragaria* x *ananassa* Duch.) cv. Chandler as influenced by various mulching materials. African J Agril. Res., 2014;9(7):701-706.
8. Beer K. Effect of vermicompost and biofertilizers on growth, yield, quality and leaf nutrient contents of Strawberry. Ph.D. Thesis submitted to Banaras Hindu University, Varanasi; c2014.
9. Bhatia SK, Sharma R, Kumar R. Effect of different planting time and spacing on growth, yield and quality of strawberry (*Fragaria × ananassa*) cv. Ofra. Int. J Pure App. Biosci. 2017;5(5):207-211.
10. Bhujbal P, Tambe T, Ulemale P. Effects of mulches on flowering, fruiting, yield and pest disease incidence of tomato (*Lycopersicon esculentum* mill.). *Bioscan*., 2015;10(1): 465-468.
11. Bielinski MS. Effects of planting densities on the performance of strawberry cultivars under high tunnels. Proc. Florida State Hort. Soc., 2013;126: 95-106.
12. Bradford E, Hancock JF and Warner RM. Interactions of temperature and photoperiod determine expression of repeat flowering in Strawberry. J Amer. Soc. Hort. Sci. 2010;135(2): 102-107.
13. Chezhiyan N, Nanjan K and Abdul Khader Md. Effect of spacing and pinching in *Chrysanthemum indicum* L. cv. "Co. 1". South Ind. Hort. 1986;34:397-400.
14. Das B, Vishal N, Jana RR, Dey P, Pramanick KK, Kishore DK. Performance of strawberry cultivars grown on different mulching materials under sub-humid, sub-tropical conditions of Eastern India. Ind. J Horti. 2007;64(2):136-143.
15. De Lima MJ, Welter PD, Soares dos Santos MF, Kavcic W, Miranda Costa B, Fagherazzi AF, *et al*. Planting density interferes with strawberry production efficiency in Southern Brazil. Agron. 2021;11:408.
16. Deb P, Sangma DK, Prasad BVG, Bhowmick N, Dey K. Effect of different mulches on vegetative growth of strawberry (cv. Tioga) under Red and Lateritic Zone of West Bengal. Int. J Basic Appl. Biol. 2014;2(2):77-80.
17. DeVetter LW, Zhang H, Ghimire S, Watkinson S, Miles CA. Plastic biodegradable mulches reduce weeds and promote crop growth in day-neutral strawberry in Western Washington. Hort. Sci. 2017;52(12):1700-1706.
18. Franquera EN, Mabesa RC. Colored plastic mulch effects on the yield of lettuce (*Lactuca sativa* L.) and soil temperature. J. Adv. Agrl. Technol. 2016;3(3):155-159.
19. Getahun D, Bikis D. Responses of tomato varieties to intra-row spacing under rain-fed production. Agril. Sci. Res. J. 2015;5(12):171-179.
20. Hazarika TK, Lalrinfeli L, Lalchhanmawia J. Nautiyal BP. Effect of planting density on growth, yield and quality of strawberry (*Fragaria* × *ananassa*) cv. Camarosa. Ind. J Agril. Sci. 2019;89(3):489-493.
21. Himelrick DG. Effect of polythene mulch color on soil temperatures and strawberry plant response. Adv. Strawberry Prod. 1982;1:15-16.
22. Hong S, Kim TY, Won SJ, Moon JH, Ajuna HB, Kim KY, Ahn YS. Control of fungal diseases and fruit yield improvement of strawberry using *Bacillus velezensis* CE 100. Microorg. 2022;10(365):1-15.
23. Hytönen T, Kurokura T. Control of flowering and runnering in strawberry. Hort. J. 2020;89(2):96-107.
24. Iqbal Q, Amjad M, Ali MR, Ali MA, Ahmad R. Vegetative and reproductive evaluation of hot peppers under different plastic mulches in poly/plastic tunnel. Pak. J. Agri. Sci. 2009;46(2):113-118.
25. Iqbal M, Bakshi P, Kumar R, Wali VK, Bhushan B. Influence of mulching on fruit quality of aonla (*Emblica officinalis* Gaertn.) cv. NA-7. Econ. Envt. Cons. 2015;21(3):263-268.
26. Islam F, Quamruzzaman AKM, Mallick SR. Effect of different mulch paper on growth and yield of different high value vegetables in Bangladesh. Agril. Sci. 2021;12(3):237-246.
27. Kasperbauer MJ. Strawberry yield over Red versus Black plastic mulch. Crop Sci. 2000;40(1):171-174.
28. Kaur R, Singh S. Impact of mulching on growth, fruit yield and quality of strawberry. Asian J. Hort. 2009;4:1-64.
29. Kaur P, Kaur A. Effect of various mulches on the growth and yield of strawberry cv. chandler under sub-tropical conditions of Punjab. Int. J Recent Trends Sci. Techno. 2017;25(1):21-25.
30. Kher R, Baba JA, Bakshi P. Influence of planting time and mulching material on growth and fruit yield of strawberry cv. Chandler. Ind. J Hort. 2010;67(4):441-444.
31. Khokhar UU, Prashad J, Sharma MK. Influence of growth regulators on growth yield and quality of strawberry cv. Chandler. Haryana J Hort. Sci. 2004;33(3/4):186-18.
32. Kijchavengkul T, Auras R, Rubino M, Gouajia M, Fernanadez RT. Assessment of aliphatic–aromatic copolyester biodegradable mulch films. Part I: Field study. Chemosphere. 2008;71:942-953.
33. Kultur F, Harrison HC, Staub JE. Spacing and genotype affect fruit sugar concentration, yield, and fruit size of muskmelon. Hort. Sci. 2001;36(2):274-278.
34. Kumar S, Dey P. Effects of different mulches and irrigation methods on root growth, nutrient uptake, water use efficiency and yield of strawberry. Sci. Horti. 2011;127(3):318-324.
35. Kumar K, Singh CN, Beniwal VS, Pinder R. Effect of spacing on growth, flowering and corm production of gladiolus (*Gladiolus* sp.) cv. American Beauty. Int. J Envt. Agril. Biotechnol. 2016;1(3):550-554.
36. Kumar U, Sonkar P, Dhakad A. Study on strawberry (*Fragaria x ananassa* Duch.) varieties for growth, fruit bio-chemical and yield parameters under western malwa plateau conditions of Madhya Pradesh. J Pharmacog. Phytochem. 2020;9(2):1070-1073.
37. Legard DE, Xiao CL, Mertely JC, Chandler CK. Effects of plant spacing and cultivar on incidence of Botrytis fruit rot in annual strawberry. Plant Dis. 2000;84:531-538.
38. Li Y, Hu J, Wei H, Jeong BR. A long-day photoperiod and 6-benzyladenine promote runner formation through upregulation of soluble sugar content in strawberry. Int. J Mol. Sci. 2020;21(14):2-16.
39. Locascio SJ, Gilreath JP, Olson S, Hutchinson CM, Chase CA. Red and black mulch color affects production of Florida strawberries. Hort. Sci. 2005;40(1):69-71.
40. Maboko MM, Du Plooy CP, Chiloane S. Effect of plant population, fruit and stem pruning on yield and quality of hydroponically grown tomato. Afri. J Agril. Res. 2011;6:5144-5148.
41. Mane PK, Bankar GH, Makne SS. Effect of spacing, bulb size and depth of planting on growth and bulb production in tuberose (*Polianthes tuberosa* L.) cv. Single. Ind. J

Agril. Res. 2006;40(1):64-67.
42. Maurya RP, Bailey JA, Chandler JA. Impact of plant spacing and picking interval on the growth, fruit quality and yield of okra (*Abelmoschus esculentus* (L.) Moench). Amer. J Agril. Forest. 2013;1(4):48-54.
43. Menzel CM. A review of productivity in strawberries: marketable yield has a linear, but inconsistent relationship with total yield, and cannot be predicted from total yield. J Hort. Sci. Biotechnol. 2020;96(2):135-144.
44. Menzel C. Higher temperatures decrease fruit size in strawberry growing in the subtropics. Horticulturae. 2021;7(34):1-13.
45. Mohanty S, Sonkar RK, Marathe RA. Effect of mulching on Nagpur mandarin cultivation in drought prone region of Central India. Indian J Soil Conserv. 2002;30(3):286-289.
46. Nagalakshmi S, Palanisamy D, Eswaran S, Sreenarayanan VV. Influence of plastic mulching in chilli yield and economics. South Ind. Hort. 2002;50(1/6):262-265.
47. Nagdeve NS, Khobragade HM, Thakare AA, Gajbhiye RP, Mandhare KS. Effect of plant spacing and pinching on growth and flower yield of annual chrysanthemum. Int. J Chem. Stud. 2021;9(1):491-495.
48. Narkar ND. Effect of spacing and plant growth regulators on growth and yield of Okra (*Abelmoschus esculentus* L. Moench) var. Varsha Uphar. Ph.D. Thesis submitted to Dr Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli; c2016.
49. Neetu and Sharma SP. Evaluation of strawberry cultivars for growth and yield characteristics in plain region of Chattisgarh, India. Int. J Curr. Microbiol. App. Sci. 2018;7(2):2835-2840.
50. Orde KM, Marini R, Demchak K, Sideman R. Albion strawberry responds to mulch treatments and low tunnels covered with photo selective films. Hort. Sci. 2021;56(9):1005-1014.
51. Pandey S, Tewari GS, Singh J, Rajpurohit D, Kumar G. Efficacy of mulches on soil modifications, growth, production and quality of strawberry (*Fragaria x Ananassa* Duch.). Int. J Sci. Nat. 2016;7(4):813-820.
52. Panse VG, Sukhatme PV. Statistical Methods for Agricultural Workers, Indian Council of Agricultural Research, New Delhi; c1985.
53. Paranjpe AV, Cantliffe DJ, Stoffella PJ, Lamb EM, Powell CA. Relationship of plant density to fruit yield of 'Sweet Charlie' strawberry grown in a pine bark soilless medium in a high roof passively ventilated greenhouse. Sci. Horti. 2008;115(2):117-123.
54. Posada FC, Fonseca E, Vaughan G. Fruit quality in strawberry (*Fragaria* sp.) grown on colored plastic mulch. Agron. Colomb. 2011;29(3):407-413.
55. Rajablariani HR, Hassankhan F, Rafezi R. Effect of colored plastic mulches on yield of tomato and weed biomass. Int. J Environ. Sci. Dev. 2012;3(6):590-593.
56. Rao KVR, Gangwar S, Bajpai A, Chourasia L, Kumar S. Effect of different mulches on the growth, yield and economics of Tomato (*Lycopersicon esculentum*). Int. J Agri. Sci. 2016;8(44):1885-1887.
57. Rhakho D, Maiti CS, Jamir S. Effect of mulching on economic yield of Strawberry cv. Chandler under Alfisols of Nagaland. Int. J Innov. Res. Stud. 2014;3(6):1-11.
58. Sanas K, Dilta BS, Singh S. Efficacy of mulch, N and K Application on plant growth and yield characters in annual chrysanthemum. Int. J Pure Appl. Biosci. 2018;6(6):1127-1138.
59. Sharma RR, Sharma VP, Pandey SN. Mulching influences plant growth and albinism disorder in strawberry under subtropical climate. Acta Hort. 2004;662:187-191.
60. Sharma SR. Effect of spacing and pinching on growth, flowering and yield of Chrysanthemum (*Chrysanthemum coronarium* L.) cv. Marry Mix. M.Sc. (Hort) Thesis submitted to Maharana Pratap University of Agriculture & Technology, Udaipur; c2007.
61. Sharma G, Yadav A, Thakur M. Studies on growth and flowering attributes of different strawberry cultivars (*Fragaria x ananassa* Duch.) in Himachal Pradesh. Asian J Adv. Basic Sci., 2014;3(1):1-4.
62. Sheoran OP, Tonk DS, Kaushik LS, Hasija RC, Pannu RS. Statistical software package for agricultural research workers. In: Recent Advances in information theory, Statistics & Computer Applications. Hooda, D.S. and Hasija, R.C. (Eds.). Department of Mathematics Statistics, CCS HAU, Hisar; c1998. p. 139-143.
63. Sheoran S, Dudi OP, Beniwal BS, Dalal RPS. Growth and yield of tuberose (*Polianthes tuberosa* L.) cv. Prajwal as inference by nitrogen and spacing. Natl. Sem. on Reorient. of Agril. Res. to Ensure Natl. F. Sec., RCT. 2014;280:114.
64. Shirgure PS, Sankar RK, Singh S, Panigrahi P. Effect of different mulches on soil moisture conservation, weed reduction, growth and yield of drip irrigated Nagpur mandarin (*Citrus reticulata*). Ind. J Agril. Sci. 2003;73(3):148-152.
65. Shokouhian AA, Asghari A. Study on the effect of mulch on yield of some strawberry cultivars in Ardabil condition. Int. Conf. Agric. Eco. Bio. Eng. 2015, 20-23.
66. Singh BK, Yadav KS. Response of mulching on strawberry under field condition. J. Bio. Innov. 2017;6(5):761-767.
67. Singh A, Senthilkumar S, Sharma M, Singh SK. Impact of mulching and planting density on phenology, yield and fruiting characters of Strawberry (*Fragaria* × *ananassa* duch.) cv. Winter Dawn. Plant Arch. 2018;18(2):1899-1904.
68. Sonkar P, Ram RB, Meena ML. Effect of various mulch materials and spacing on growth, yield and quality of Strawberry. Hort. Flora Res. Spectrum. 2012;1(4):323-327.
69. Sujatha S, Suchitra VD, Swami V, Subbaramamma P, Uma Krishna K, Saravanan L. Influence of mulching materials on growth and yield of strawberry (*Fragaria* × *ananassa* Duch.) cv. Camarosa under shadenet conditions of coastal Andhra Pradesh. Int. J Agril. Sci. 2018;14(1):219-224.
70. Tariq R, Qureshi KM, Hassan I, Rasheed M, Qureshi US. Effect of planting density and growing media on growth and yield of Strawberry. Pak. J Agric. Res. 2013;26(2):113-123.
71. Temesgen T, Kebena T. Effects of varieties and intra row spacing on yield of maize (*Zea mays* L.) under supplementary irrigation at Guliso, Western Ethiopia. Int. J Environ. Sci. Nat. Res. 2019;19(5):556024.