



Growth Performance of Strawberry (*Fragaria × ananassa* Duch.) as Influenced by Plant Spacing and Mulch

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Open Access

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Conflict of interests: The author has declared that no conflict of interest exists.

How to cite this article?

Datta, H.S., Barua, P.C., Kotoky, U., et al., 2025. Growth Performance of Strawberry (*Fragaria × ananassa* Duch.) as Influenced by Plant Spacing and Mulch. *Research Biotica* 7(2), 30-37. DOI: 10.54083/ResBio/7.2.2025/30-37.

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Abstract

Crop growth in strawberry is influenced by spacing and mulch material. The experiment was undertaken for exploring the response of plant spacing and mulch material on plant spread which is an important growth character of Strawberry. The trial was arranged in factorial randomised block design (RBD). It included twenty treatments in triplicate replications consisting of four distinct mulch materials namely, paddy straw, red colored mulch, silver-black colored mulch and without mulch along with five plant spacings namely, 20 cm × 30 cm, 30 cm × 30 cm, 30 cm × 40 cm, 40 cm × 40 cm and 40 cm × 60 cm. The pooled data showed that silver-black colored mulch in combination with plant spacing of 40 cm × 40 cm produced the higher plant spread in direction of North-South (48.47 cm) as well as East-West (50.81 cm), respectively, in strawberry at the end of the crop duration. It can be concluded that the treatment combination of silver-black colored mulch with plant spacing of 40 cm × 40 cm was recognized as the more efficacious growth approach in terms of plant spread for strawberry which may have effect on crop yield.

Keywords: *Fragaria × ananassa* Duch, Mulch, Plant spread, Spacing, Strawberry

Introduction

Strawberry (*Fragaria × ananassa* Duch.), a naturally occurring hybrid in the Rosaceae family is cultivated round the globe for its highly nutritious aggregate fruits. Strawberry is a shallow rooted crop and primarily feeds from the surface, making it highly dependent on the moisture and temperature conditions of the upper soil layer for its growth (Sharma et al., 2013; Das et al., 2022). Plant spacing and crop management practices may enhance the crop growth in strawberry. Plant spacing contributes through sufficient solar radiation harvesting and absorbing sufficient nutrients and water from the soil owing to properly developed root system by adjusting inter and intra row spacing as necessary. Appropriate spacing helps in flow of air to the plants, leading to temperature moderation and photosynthesis increases, promoting the plants to compete for sunlight, nutrients and

water. Mulching is also an important practice in horticulture, which provides tremendous benefits to crops (Saren and Das, 2023). Mulching regulates soil temperature and soil moisture, enhancing absorption of water and fertilizer as well as weed reduction. Mulches provide the perfect environment which encourages plant growth (Kijchavengkul et al., 2008; Kader et al., 2019; Ezaddin and Salih, 2022; Datta et al., 2024). Strawberry has started gaining importance in Assam and selection of an appropriate plant spacing and mulch material is also one of the most important criteria to achieve the desired growth performance in strawberry. The growth performance of strawberry in terms of plant spread is yet to be tested under optimum plant spacing and mulch condition. In view of these facts the research work has been taken up to figure out the impact plant spacing and mulch has on strawberry growth character plant spread.

Article History

RECEIVED on 17th October 2024

RECEIVED in revised form 26th April 2025

ACCEPTED in final form 03rd May 2025

Materials and Methods

The trial was performed at Dhankhuloi village (Latitude 26°47'27.6648" N and Longitude 94°2'36.6756" E) of Jorhat district in India from November to April in the years 2019-2020 and 2020-2021. The soil samples gathered from the experimental plot was analyzed and belonged to silty loam textural class with soil pH of 7.15. The experimental site was characterized by a subtropical climatic condition with hot and humid summer and relatively dry and cool winter. The tissue culture strawberry plants of variety Sweet Charlie were planted in open condition in the experimental plot. The field experiment plot with 20 treatments (Table 1) was ordered in factorial randomized block design replicated in triplicate that comprised five plant spacings namely, 20 cm × 30 cm (A_1), 30 cm × 30 cm (A_2), 30 cm × 40 cm (A_3), 40 cm × 40 cm (A_4) and 40 cm × 60 cm (A_5) along with four distinct mulch materials namely, paddy straw (B_1), red colored mulch (B_2), silver-black colored mulch (B_3) and without mulch (B_4), respectively. There were 60 numbers of field plots in the experimental area of 300 m² of individual plot size 1.5 m × 2 m and the

number of plants per plot varied as per plant spacing treatments. A gap of 50 cm was left between two adjacent plots. Raised beds of 15-20 cm in height were prepared for planting the strawberry plants. In case of paddy straw mulching treatments, paddy straw was spread uniformly over the beds, where the thickness of straw was 5 cm and plastic mulches (30 micron) of silver-black colored and red colored of the treatments were spread after bed preparation. Vermicompost application was made to the experimental plot as preplanting application. Vermicompost @ 2.5 t ha⁻¹ was applied one fortnight before planting the strawberry plants and it was mixed thoroughly during bed preparation. NPK 19:19:19 was applied through foliar spraying @ 5 g l⁻¹ water at ten days interval after one month of planting. NPK 19:19:19 is a water soluble fertilizer, which helped the strawberry crop to meet its major nutrition requirements of N, P and K. Foliar application of Tracel at the rate of 5 g l⁻¹ of water was done after one month of planting at monthly intervals. Tracel is water soluble thereby facilitating ready uptake of nutrients by plants.

Table 1: Treatment details used in the experiment

Notation	Combination	Treatment details
T ₁	A ₁ B ₁	20 cm × 30 cm and paddy straw mulch.
T ₂	A ₁ B ₂	20 cm × 30 cm and red colored mulch.
T ₃	A ₁ B ₃	20 cm × 30 cm and silver-black colored mulch.
T ₄	A ₁ B ₄	20 cm × 30 cm and without mulch.
T ₅	A ₂ B ₁	30 cm × 30 cm and paddy straw mulch.
T ₆	A ₂ B ₂	30 cm × 30 cm and red colored mulch.
T ₇	A ₂ B ₃	30 cm × 30 cm and silver-black colored mulch.
T ₈	A ₂ B ₄	30 cm × 30 cm and without mulch.
T ₉	A ₃ B ₁	30 cm × 40 cm and paddy straw mulch.
T ₁₀	A ₃ B ₂	30 cm × 40 cm and red colored mulch.
T ₁₁	A ₃ B ₃	30 cm × 40 cm and silver-black colored mulch.
T ₁₂	A ₃ B ₄	30 cm × 40 cm and without mulch.
T ₁₃	A ₄ B ₁	40 cm × 40 cm and paddy straw mulch.
T ₁₄	A ₄ B ₂	40 cm × 40 cm and red colored mulch.
T ₁₅	A ₄ B ₃	40 cm × 40 cm and silver-black colored mulch.
T ₁₆	A ₄ B ₄	40 cm × 40 cm and without mulch.
T ₁₇	A ₅ B ₁	40 cm × 60 cm and paddy straw mulch.
T ₁₈	A ₅ B ₂	40 cm × 60 cm and red colored mulch.
T ₁₉	A ₅ B ₃	40 cm × 60 cm and silver-black colored mulch.
T ₂₀	A ₅ B ₄	40 cm × 60 cm and without mulch.

Growth parameter viz. the plant spread was measured individually at 90 days after planting and 180 days after planting to assess the plant spread in the directions of both East-West as well as North-South using a scale. Plant spread in cm was expressed from the mean of two measurements obtained. The data were taken at defined interval during the crop cycle. The statistical analysis of variance of recorded data using factorial randomized block design were done

as outlined by Panse and Sukhatme (1985). The overall significance of the differences among the treatments was assessed, by means of critical differences (CD) at 5% level of significance. Statistical analysis of the results was carried out using SPSS software together with OPSTAT which is a computer package based on windows that computed the standard error of the difference in mean (SEd) and critical difference (CD) among the treatments at 5% level of

significance (Sheoran *et al.*, 1998).

Results and Discussion

Plant Spread

The influence plant spacing and mulching have on plant spread in North-South direction are depicted in table 2 and table 3, and East-West direction in table 4 and table 5. The interaction of spacing and mulching has recorded effect for all the treatments in the experiment.

The interactions involving spacing and mulching showed non-significant differences for plant spread in direction of North-South at 90 days after planting as shown in table 2 during the 2nd year and pooled data; while it showed significant effect in the 1st year with treatment combination

T₁₉ registering the higher plant spread (42.66 cm). The interactions involving spacing and mulching showed non-significant differences for plant spread at 180 days after planting, as shown in table 3, during both years of study and combined data with T₁₅ registering the higher plant spread (48.47 cm). The interactions involving spacing and mulching showed significant differences for plant spread in direction of East-West at 90 days after planting as shown in table 4 for both the years of study. Treatment combination T₁₉ with silver-black colored mulch and plant spacing of 40 cm × 60 cm registered higher plant spread (45.06 cm); while minimum plant spread (28.73 cm) was observed in T₄. The interactions effect involving spacing and mulching showed non-significant differences, as shown in table 5, for plant

Table 2: Effect of spacing, mulch and mulch (A × B) interaction on plant spread (cm) in direction of North-South at 90 days after planting

Treatment	Plant spread (cm) in North-South direction at 90 days after planting						
	2019-2020	2020-21	Pooled				
Spacing (A)							
A ₁	35.75 ^e	34.43 ^e	35.10 ^e				
A ₂	36.07 ^d	34.96 ^d	35.52 ^d				
A ₃	36.51 ^c	35.36 ^c	35.94 ^c				
A ₄	36.97 ^b	35.85 ^b	36.41 ^b				
A ₅	37.49 ^a	36.36 ^a	36.92 ^a				
SEd (±)	0.03	0.13	0.07				
CD (<i>p</i> =0.05)	0.07	0.26	0.13				
Mulches (B)							
B ₁	33.94 ^c	33.17 ^c	33.56 ^c				
B ₂	38.91 ^b	38.20 ^b	38.55 ^b				
B ₃	42.27 ^a	40.72 ^a	41.49 ^a				
B ₄	31.11 ^d	29.49 ^d	30.30 ^d				
SEd (±)	0.03	0.11	0.06				
CD (<i>p</i> =0.05)	0.06	0.23	0.12				
Interaction (A × B)							
Treatment combination	2019-20	2020-21	Pooled	Treatment combination	2019-20	2020-21	Pooled
T ₁ (A ₁ B ₁)	33.16	32.14	32.65	T ₁₁ (A ₃ B ₃)	42.14	40.62	41.38
T ₂ (A ₁ B ₂)	38.26	37.18	37.72	T ₁₂ (A ₃ B ₄)	31.23	29.52	30.37
T ₃ (A ₁ B ₃)	41.33	39.68	40.50	T ₁₃ (A ₄ B ₁)	34.42	33.60	34.01
T ₄ (A ₁ B ₄)	30.27	28.74	29.50	T ₁₄ (A ₄ B ₂)	39.28	38.76	39.02
T ₅ (A ₂ B ₁)	33.42	32.76	33.09	T ₁₅ (A ₄ B ₃)	42.65	41.29	41.97
T ₆ (A ₂ B ₂)	38.47	37.70	38.09	T ₁₆ (A ₄ B ₄)	31.55	29.74	30.64
T ₇ (A ₂ B ₃)	41.75	40.17	40.96	T ₁₇ (A ₅ B ₁)	34.84	34.26	34.54
T ₈ (A ₂ B ₄)	30.65	29.22	29.93	T ₁₈ (A ₅ B ₂)	39.76	39.15	39.45
T ₉ (A ₃ B ₁)	33.87	33.12	33.50	T ₁₉ (A ₅ B ₃)	43.50	41.81	42.66
T ₁₀ (A ₃ B ₂)	38.80	38.19	38.49	T ₂₀ (A ₅ B ₄)	31.85	30.23	31.04
	2019-20			2020-2021			Pooled
SEd (±)	0.07			0.26			0.13
CD (<i>p</i> =0.05)	0.14			NS			NS

Table 3: Effect of spacing, mulch and spacing and mulch (A × B) interaction on plant spread (cm) in direction of North-South at 180 days after planting

Treatment	Plant spread (cm) in North-South direction at 180 days after planting						
	2019-2020	2020-21	Pooled				
Spacing (A)							
A ₁	40.88 ^c	40.90 ^b	40.89 ^d				
A ₂	41.81 ^b	41.01 ^b	41.41 ^c				
A ₃	41.94 ^b	42.27 ^a	42.10 ^b				
A ₄	42.46 ^a	42.53 ^a	42.49 ^{ab}				
A ₅	42.52 ^a	42.61 ^a	42.57 ^a				
SEd (±)	0.22	0.34	0.20				
CD (<i>p</i> =0.05)	0.45	0.69	0.40				
Mulches (B)							
B ₁	39.27 ^c	39.10 ^c	39.19 ^c				
B ₂	43.32 ^b	43.21 ^b	43.26 ^b				
B ₃	47.29 ^a	47.70 ^a	47.49 ^a				
B ₄	37.81 ^d	37.45 ^d	37.63 ^d				
SEd (±)	0.20	0.30	0.18				
CD (<i>p</i> =0.05)	0.40	0.62	0.36				
Interaction (A × B)							
Treatment combination	2019-20	2020-21	Pooled	Treatment combination	2019-20	2020-21	Pooled
T ₁ (A ₁ B ₁)	38.53	38.86	38.70	T ₁₁ (A ₃ B ₃)	47.57	48.56	48.06
T ₂ (A ₁ B ₂)	42.19	42.32	42.25	T ₁₂ (A ₃ B ₄)	37.75	38.01	37.88
T ₃ (A ₁ B ₃)	45.97	46.35	46.16	T ₁₃ (A ₄ B ₁)	40.02	39.23	39.62
T ₄ (A ₁ B ₄)	36.83	36.05	36.44	T ₁₄ (A ₄ B ₂)	43.80	44.10	43.95
T ₅ (A ₂ B ₁)	39.04	38.87	38.96	T ₁₅ (A ₄ B ₃)	48.22	48.72	48.47
T ₆ (A ₂ B ₂)	43.26	42.51	42.88	T ₁₆ (A ₄ B ₄)	37.78	38.07	37.93
T ₇ (A ₂ B ₃)	47.05	46.49	46.77	T ₁₇ (A ₅ B ₁)	39.45	39.53	39.49
T ₈ (A ₂ B ₄)	37.90	36.17	37.03	T ₁₈ (A ₅ B ₂)	44.22	43.59	43.91
T ₉ (A ₃ B ₁)	39.32	39.01	39.16	T ₁₉ (A ₅ B ₃)	47.63	48.37	48.00
T ₁₀ (A ₃ B ₂)	43.12	43.52	43.32	T ₂₀ (A ₅ B ₄)	38.81	38.97	38.88
		2019-20				2020-2021	
SEd (±)		0.44				0.68	
CD (<i>p</i> =0.05)		NS				NS	
							Pooled
							0.41
							NS

spread at 180 days after planting across the two study years as well as the pooled data with T₁₅ registering the higher plant spread (50.81 cm). T₁₉ registered higher plant spread at 90 days after planting in both directions of North-South and East-West; while T₁₅ registered the higher plant spread at 180 days after planting in both directions.

Plant spread of strawberry plants increased considerably with advanced age of crop growth. Differences in plant spread observed in the study between North-South direction and East- West direction may be due to the moisture fluctuations in the directions. The above finding conforms to the study of Sharma *et al.* (2014) and Neetu and Sharma (2018). Pandey *et al.* (2024) in their study on strawberry mentioned about

congenial microclimatic condition under open field and contribution of adequate photosynthesis to good vegetative character. Kousalya Bai *et al.* (2023) mentioned in their study about maximum length and weeping growth of leaf petioles which lean outwards resulting in maximum plant spread of strawberry.

The maximum plant spread observed in the wider spacing could possibly be attributed to the availability of more space for root growth and shoot growth, which helps in higher nutrient and water uptake from the soil. More amount of sunshine in wider spacing might have enhanced photosynthesis rate and thereby growth of plants. Lack of competition for productive factors viz. nutrients, water, light

Table 4: Effect of spacing, mulch and spacing and mulch (A × B) interaction on plant spread (cm) in direction of East-West at 90 days after planting

Treatment	Plant spread (cm) in East-West direction at 90 DAP						
	2019-2020			2020-21		Pooled	
Spacing (A)							
A ₁	36.03 ^e			34.93 ^e		35.48 ^e	
A ₂	36.35 ^d			35.30 ^d		35.82 ^d	
A ₃	36.64 ^c			35.71 ^c		36.18 ^c	
A ₄	37.03 ^b			36.14 ^b		36.58 ^b	
A ₅	37.37 ^a			36.61 ^a		37.00 ^a	
SEd (±)	0.04			0.05		0.03	
CD (<i>p</i> =0.05)	0.08			0.10		0.06	
Mulches (B)							
B ₁	32.88 ^c			31.94 ^c		32.41 ^c	
B ₂	39.22 ^b			38.21 ^b		38.71 ^b	
B ₃	44.85 ^a			43.66 ^a		44.25 ^a	
B ₄	29.79 ^d			29.15 ^d		29.47 ^d	
SEd (±)	0.03			0.05		0.03	
CD (<i>p</i> =0.05)	0.07			0.09		0.06	
Interaction (A × B)							
Treatment combination	2019-20	2020-21	Pooled	Treatment combination	2019-20	2020-21	Pooled
T ₁ (A ₁ B ₁)	32.26	31.36	31.81	T ₁₁ (A ₃ B ₃)	44.81	43.59	44.20
T ₂ (A ₁ B ₂)	38.46	37.37	37.91	T ₁₂ (A ₃ B ₄)	29.68	29.16	29.42
T ₃ (A ₁ B ₃)	44.28	42.66	43.47	T ₁₃ (A ₄ B ₁)	33.20	32.25	32.72
T ₄ (A ₁ B ₄)	29.13	28.33	28.73	T ₁₄ (A ₄ B ₂)	39.53	38.59	39.06
T ₅ (A ₂ B ₁)	32.66	31.60	32.13	T ₁₅ (A ₄ B ₃)	45.17	44.15	44.66
T ₆ (A ₂ B ₂)	38.77	37.78	38.27	T ₁₆ (A ₄ B ₄)	30.21	29.58	29.89
T ₇ (A ₂ B ₃)	44.57	43.20	43.88	T ₁₇ (A ₅ B ₁)	33.38	32.62	33.00
T ₈ (A ₂ B ₄)	29.40	28.62	29.01	T ₁₈ (A ₅ B ₂)	40.16	39.06	39.61
T ₉ (A ₃ B ₁)	32.89	31.87	32.38	T ₁₉ (A ₅ B ₃)	45.44	44.68	45.06
T ₁₀ (A ₃ B ₂)	39.16	38.24	38.70	T ₂₀ (A ₅ B ₄)	30.52	30.07	30.29
	2019-20			2020-2021		Pooled	
SEd (±)	0.33			0.68		0.21	
CD (<i>p</i> =0.05)	0.68			NS		0.42	

etc. also might contributed to increased plant spread in wider spacing. The findings were in resemblance to those observed by Avari (1990), Mohanty *et al.* (1993), Dhemre *et al.* (1997) and Jat (2006). The findings are also in agreement with those of Ravindran *et al.* (1986), Chanda and Roychaudhury (1991), Janakiram and Rao (1995), Paranjpe *et al.* (2008), Tiwari *et al.* (2010), Pratibha *et al.* (2018) and Hazarika *et al.* (2019). Reddy *et al.* (2024) in their study on strawberry indicated that increased light exposure enhances photosynthesis, leading to better vegetative growth in strawberry. In another experiment, Das *et al.* (2022) noted that wider plant spacing provides more space for the root distribution which indicates a change in favourable environment for root growth through optimum moisture availability resulting in better nutrient

uptake and consequently better dry matter formation. Wankhade *et al.* (2025) also reported about optimal plant spread resulting from vigorous vegetative growth from wider planting distance. The increase in plant spread primarily might have resulted from formation of more number of branches and wider angle between primary and secondary branches. Matching observations were also made by Dubey *et al.* (2002), Deshmukh *et al.* (2014) and Siddappa *et al.* (2018).

Maximum plant spread under silver-black colored mulch may be explained to soil hydrothermal conditions, improved moisture retention and weed suppression. Generally, appropriate plant density of plastic mulches influences canopy growth, interception of radiation, soil-water

Table 5: Effect of spacing, mulch and spacing and mulch (A × B) interaction on plant spread (cm) in direction of East-West at 180 days after planting

Treatment	Plant spread (cm) in East-West direction at 180 DAP						
	2019-2020		2020-21	Pooled			
Spacing (A)							
A ₁	41.91 ^c		40.98 ^b	41.44 ^c			
A ₂	42.17 ^c		41.35 ^b	41.76 ^c			
A ₃	42.83 ^b		42.12 ^a	42.47 ^b			
A ₄	43.51 ^a		42.51 ^a	43.01 ^a			
A ₅	43.18 ^{ab}		42.65 ^a	42.91 ^a			
SEd (±)	0.25		0.29	0.19			
CD (<i>p</i> =0.05)	0.51		0.58	0.38			
Mulches (B)							
B ₁	39.74 ^c		38.21 ^c	38.97 ^c			
B ₂	45.30 ^b		44.65 ^b	44.97 ^b			
B ₃	50.08 ^a		49.69 ^a	49.89 ^a			
B ₄	37.76 ^d		35.13 ^d	35.45 ^d			
SEd (±)	0.23		0.26	0.17			
CD (<i>p</i> =0.05)	0.46		0.52	0.34			
Interaction (A × B)							
Treatment combination	2019-20	2020-21	Pooled	Treatment combination	2019-20	2020-21	Pooled
T ₁ (A ₁ B ₁)	38.84	37.58	38.21	T ₁₁ (A ₃ B ₃)	49.98	49.58	49.78
T ₂ (A ₁ B ₂)	44.83	43.34	44.08	T ₁₂ (A ₃ B ₄)	36.06	35.66	35.86
T ₃ (A ₁ B ₃)	49.12	48.79	48.95	T ₁₃ (A ₄ B ₁)	40.41	38.29	39.35
T ₄ (A ₁ B ₄)	34.86	34.20	34.53	T ₁₄ (A ₄ B ₂)	46.01	45.64	45.82
T ₅ (A ₂ B ₁)	39.41	38.10	38.75	T ₁₅ (A ₄ B ₃)	51.19	50.44	50.81
T ₆ (A ₂ B ₂)	44.67	43.60	44.13	T ₁₆ (A ₄ B ₄)	36.42	35.69	36.06
T ₇ (A ₂ B ₃)	49.46	49.40	49.43	T ₁₇ (A ₅ B ₁)	39.77	38.86	39.32
T ₈ (A ₂ B ₄)	35.15	34.28	34.71	T ₁₈ (A ₅ B ₂)	45.97	45.67	45.82
T ₉ (A ₃ B ₁)	40.26	38.21	39.23	T ₁₉ (A ₅ B ₃)	50.67	50.23	50.45
T ₁₀ (A ₃ B ₂)	45.01	45.02	45.01	T ₂₀ (A ₅ B ₄)	36.32	35.82	36.07
	2019-20		2020-2021	Pooled			
SEd (±)	0.50		0.57	0.38			
CD (<i>p</i> =0.05)	NS		NS	NS			

evaporation, dry matter production, competition with weeds. The expansion in plant spread under plastic mulch could be a result of adequate soil moisture around the root zone and decreased evaporation losses brought about by mulching. The sustained moisture retention and availability could result in enhanced nutrient absorption that supports ideal plant growth and development compared to straw mulch and without mulch. Differences in soil temperature under various mulch types could result from distinct ways of heating and transferring heat to soil as well as heat retention throughout the day and heat loss at night. The treatments with narrower spacing both covered with straw mulch, as well as without mulch exhibited reduced plant

spread, could be caused by minimal crop growth, as shown by plant spread, resulting in poor crop canopy. The findings align closely with those noticed by Sharma *et al.* (2004), Lopez-Bellido *et al.* (2005), Singh and Asrey (2005), Ali and Gaur (2007), Aruna *et al.* (2007), Ban *et al.* (2009) and Sonkar *et al.* (2012). Similar observations also noted by Pires *et al.* (2006), Das *et al.* (2010), Qureshi *et al.* (2012) and Bakshi *et al.* (2014). Meena *et al.* (2023) in their study also observed that performance of plant growth characters were better under black polyethylene mulch.

Conclusion

The research indicated optimum spacing along with

appropriate mulch material significantly influenced strawberry crop growth. The results revealed that silver-black mulch in combination with plant spacing of 40 cm × 40 cm was recognized to have higher plant spread in the directions of both North-South as well as East-West in strawberry at the end of crop duration. The research emphasized that crop geometry and management practices influence growth characters of the high valued crop, strawberry. The results provided basic insights how plant spacing and mulch material affect the plant spread of strawberry plants, which may potentially improve the overall crop productivity. In future the research should concentrate on optimizing canopy coverage to enhance yield of 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.

Author's Contribution

HSD: Conceptualization, investigation, data analysis, writing original draft and revision; PCB: Conceptualization and revision; UK: Revision; RD: Revision; HS: Revision; HKDN: Revision.

Ethical Statement

The authors declare that no generative artificial intelligence tools were used in drafting or preparing this manuscript. The manuscript was written, interpreted and revised solely by the authors, who take full responsibility for its content.

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