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Effect of different crop covers on growth of strawberry (*Fragaria* × *ananassa* Duch)

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Abstract

The present investigation was conducted to assess the influence of different crop covers on the growth, flowering and fruiting parameters of strawberry (*Fragaria* × *ananassa* Duch.) during *Rabi* season of 2024-25 at Dr. Sharadchandra Pawar College of Agriculture, Baramati. The experiment comprised multiple crop covers. The primary objective was to study the effect of different crop covers on growth of strawberry. The experiment followed a Randomized Block Design (RBD) with 10 treatments and three replications. Results revealed significant variations across treatments for all observed parameters. Among the treatments, insect net white consistently recorded superior performance with maximum plant height (22.37 cm), plant spread (34.71 cm), crown number (4.73), leaf area (134.35 cm²) and flower count (34.87), as well as the highest fruit set (80.14%). Red crop cover also showed competitive results, with early flower initiation (29.07 days), higher reproductive success and fruit quality attributes. Conversely, polypaper polyethylene consistently underperformed, showing the lowest values across most growth and yield parameters. Yield attributes such as average fruit weight (19.54 g), number of fruits per plant (27.93) were maximized under insect net white. The enhanced performance under these treatments is attributed to their ability to create a favourable microclimate, promoting improved light diffusion, moderate canopy temperature, optimal humidity and enhanced physiological processes including photosynthesis, carbon assimilation and assimilate translocation.

The findings suggest that insect net white and red crop covers significantly improve strawberry growth, flowering, fruit development and overall yield by modifying the microenvironment during critical crop stages. These crop covers offer a practical and effective strategy for improving productivity in protected strawberry cultivation under semi-arid conditions.

Keywords: Assimilation, crop covers, strawberry and microclimate.

Introduction

Strawberry (*Fragaria xananassa* Duch.), an octoploid species (2n=8x=56) of the family Rosaceae, is an economically significant horticultural crop grown across diverse agro-climatic zones. It is an aggregate, non-climacteric fruit derived from the receptacle tissue, propagated asexually through runners and exhibits short-day photoperiodic flowering behaviour. Due to its adaptability, high consumer demand and nutritional richness including high levels of vitamin C, folates, anthocyanins and dietary fibre it is cultivated extensively in temperate and subtropical regions (Darnell and Schmidt, 1997) [5].

Globally, strawberry cultivation spans over 80 countries, with total production exceeding 9.18 million metric tonnes in 2021. Asia remains the leading producer, with China alone contributing nearly 40% of the global output (FAO, 2023) [6]. In India, cultivation is concentrated in states like Maharashtra, Himachal Pradesh and Haryana, with Maharashtra accounting for approximately 56% of national production. However, recent advances in protected cultivation have enabled expansion into non-traditional regions, where Haryana has achieved notably higher productivity (17.63 MT/ha) compared to Maharashtra (6.82 MT/ha).

Strawberries are nutritionally rich fruits, comprising approximately 97% edible portion and 80-90% water content. They offer significant health benefits due to their composition, which includes soluble solids (7-10.2°B), sugars (4.5-10%), dietary fiber (0.9-2%) and essential nutrients such as vitamin C (58.8 mg/100g) and folate (24 µg/100g).

Low in calories (32 kcal/100g), strawberries also contain proteins (0.67 g/100g), carbohydrates (7.68 g/100g), ash (0.40 g/100g) and lipids (0.30 g/100g), making them a valuable dietary component (Giampieri *et al*., 2012) [7].
The use of coloured materials like shade nets and plastic films and different green shade net in different percentage like 35, 50, 75 and 90% to cover plants and change the light they receive. The quality of light affects plant physiology of crops (Casierra Posada and Pena-Olmos, 2015) [2-3], this can lead to improvements in fruit production and quality, mainly due to the plant's response to light through phytochromes (Casierra Posada *et al*., 2012) [4]. Photo-selective shade nets modify light quality by increasing diffuse light (scattered light) and selectively absorbing different spectral bands (Shahak, 2008a) [24]. Higher plants have developed various photoreceptors in plants, including chlorophylls, phtyochromes, cryptochromes, phototropins and ones that react to green lightallow them to detect specific wavelengths and monitor their environment. On this subject, Photoreceptors in plants detect different light ranges: ultraviolet (300-400 nm), blue light (400-510 nm) is absorbed by chlorophylls, cryptochromes and phototropins; green light (510-610 nm) Red light (610-720nm)and yellow light (570-590 nm) are absorbed by carotenes and this different light spectrum having their different effect on the plant physiological and biochemical process of plants and also vegetative growth, fruit quality, etc change according to light wavelength (Meisel *et al*., 2011) [15].
Low tunnels, being cost-effective and easy to install, provide a controlled microclimate by moderating temperature, humidity and light intensity, thus improving photosynthetic efficiency and reducing abiotic stress. Moreover, the use of photo-selective shade nets can alter light quality particularly the red to far-red ratio thereby influencing phytochrome-mediated responses that govern flowering, fruit development and antioxidant synthesis.There has been relatively limited research focused specifically on using low tunnels to enhance crop production therefore, this research aims to study the effect of different crop covers on growth of strawberry.

2. Materials and Methods

The experiment was conducted at Dr. Sharadchandra Pawar college of Agriculture, Baramati over a period of one season from November, 2024 to March, 2025. The experimental site was located at an elevation of 550 m above mean sea level with 18.1324958° North latitudes and 74.5429029° East longitudes. The experiments aimed to Effect of different crop covers on growth, yield and quality of strawberry was arranged in a Randomized Block Design (RBD) with 10 treatments and 3 replications. Each treatment was applied to raise beds (5.0 × 1.0 ×0.15 m) with 30 × 30 cm spacing.

2.1 Growth parameter

Five randomly selected, vigorous plants from each treatment were tagged for observation. Data on growth at monthly intervals throughout the experimental period at 30, 60, 90and 120 days after transplanting (DAT) and yield parameters were recorded. Plant height was measured from the ground level to the tip of the mature leaf and expressed in centimeters (cm). Plant spread was measured in both East-West and North-South directions and the average was expressed in centimeters (cm). The total number of crowns per plant was determined through visual observation. Leaf area was measured by selecting three representative leaves from each plant and using a leaf area meter; the average leaf area was calculated and expressed in square centimeters (cm^2). The total number of runners was recorded visually from the tagged plants.

2.2 Flowering Parameters

The number of days from transplanting to the emergence of the first flower bud was recorded. This parameter indicates the earliness of flowering under different treatments.
The time required for 50% of the plants to initiate flowering was recorded visually. It helps assess uniformity in flowering and is important for synchronized fruit production.
The total number of flowers per plant was counted from flowering to harvest. This determines the fruiting potential and reproductive efficiency of the plant.

2.3 Fruit Parameters

Fruit set was calculated as the ratio of the number of fruits formed to the number of flowers, expressed in percentage. It reflects successful pollination and fertilization under different covers.
Fruits were counted per plant during each harvest and averaged. This parameter directly influences the total yield of the crop.
Individual fruit weights were recorded and averaged using an electronic balance. Fruit weight contributes significantly to yield and consumer acceptability.

3. Result and Discussion

3.1 Growth Parameters

3.1.1 Plant height (cm)

The data presented in Table 1 revealed significant differences in plant height at various growth stages due to the influence of crop covers. At 30 DAT, the tallest plants (13.83 cm) were recorded under green shade net 75%, while the shortest (7.45 cm) occurred in the control. By 60 DAT, red crop cover led to the highest plant height (16.12 cm), statistically on par with insect net white (15.98 cm), green shade net 75% (15.68 cm) and others. A similar trend continued through 90 and 120 DAT, where insect net white consistently resulted in the maximum height (22.37 cm at 120 DAT), significantly outperforming polypaper-polyethylene, which recorded the lowest (17.89 cm).
This variation may be attributed to differences in light transmission, spectral quality, and microclimatic conditions induced by each cover. Crop covers like red and white non-woven and insect nets are known to improve photosynthetic activity and carbon assimilation by enhancing light diffusion, as noted by Shamir *et al.* (2001) [26], Swagatika *et al.* (2006) [31] and Yan Qiuyan*et al.* (2011) [36]. Improved soil temperature regulation and gas exchange beneath these covers also support better physiological responses and nutrient uptake (Sirohi *et al*., 2002) [29].

3.1.2 Plant spread (cm)

The data presented in Table 1 revealed significant differences in plant spread at various crop stages due to the influence of different crop covers. At 30 DAT, the widest plant spread (16.93 cm) was recorded under insect net white, followed closely by red crop cover (16.72 cm), while the narrowest spread (12.81 cm) was observed under polypaper polyethylene. At 60 DAT, insect net white maintained the highest spread (27.58 cm), which was statistically on par with red crop cover (27.30 cm), saree crop cover (26.54 cm) and green shade net 50% (26.36 cm). The lowest plant spread at this stage was again found under polypaper polyethylene (21.63 cm). At 90 DAT, insect net white continued to show the maximum plant spread (33.47 cm), followed by red crop cover (32.89 cm) and saree crop cover (32.17 cm), whereas polypaper polyethylene remained the lowest (25.78 cm). At 120 DAT, the widest spread was again observed under insect net white (34.71 cm), statistically at par with red crop cover (34.33 cm), saree crop cover (33.38 cm) and green shade net 50% (33.00 cm). The minimum spread at this stage was recorded under polypaper polyethylene (26.53 cm). The observed variation in plant spread may be attributed to the differences in light quality, canopy temperature and humidity conditions created by each cover. Crop covers like insect net white and coloured non-woven fabrics enable better light diffusion and uniform radiation distribution, which enhances photosynthetic efficiency throughout the canopy and promotes lateral vegetative growth. Additionally, moderated temperatures and improved microclimate under such covers reduce plant stress, facilitating more robust canopy development. These findings are supported by the work of Shamir *et al*. (2001) [26], Swagatika *et al*. (2006) [31], Medany *et al*. (2009) [14] and Yan Qiuyan*et al*. (2011) [36], who reported that diffused light and controlled environments under shade nets enhance leaf expansion and canopy spread by optimizing photosynthetic activity and growth conditions.

3.1.3 Number of crowns per plant
The data presented in Table 1 indicated significant differences in the number of crowns per plant at various crop growth stages due to the influence of different crop covers. At 30 DAT, the highest number of crowns (1.87) was recorded under insect net white, followed by red crop cover (1.80), while the lowest (1.13) was observed under polypaper-polyethylene. At 60 DAT, insect net white continued to show the highest crown count (2.27), statistically on par with red crop cover (2.20), saree crop cover (2.07) and green shade net 50% (2.00). The minimum number of crowns at this stage was again found under polypaper polyethylene (1.33).

At 90 DAT, insect net white recorded the maximum number of crowns (3.27), followed by red crop cover (3.07), whereas polypaper-polyethylene continued to result in the fewest (1.93). At 120 DAT, insect net white showed the highest crown development (4.73), statistically at par with red crop cover (4.33), while the lowest number of crowns (2.47) was observed under polypaper-polyethylene.

Variation in crown production may be due to favourable microclimates created by covers like insect net white and red non-woven, which enhance light diffusion and maintain optimal temperatures, supporting axillary bud development. In contrast, high heat and poor light penetration under polypaper polyethylene likely reduced crown formation. These findings align with Soliman *et al*. (2015) and Kumar *et al*. (2020) [11], who emphasized the role of environmental factors in crown development.

3.1.4 Leaf area (cm²)
The data presented in Table 2 revealed that leaf area was significantly influenced by the use of different crop covers across all growth stages. At 30 DAT, the maximum leaf area (66.62 cm²) was recorded under insect net white, followed closely by red crop cover (66.06 cm²), while the lowest value was observed under polypaper-polyethylene (42.39 cm²). A similar trend was seen at 60 DAT, where insect net white (105.27 cm²) and red crop cover (104.36 cm²) maintained significantly higher leaf areas compared to polypaper-polyethylene (81.31 cm²).

At 90 DAT, insect net white continued to exhibit the highest leaf area (130.02 cm²), statistically on par with red crop cover (128.31 cm²), while the lowest (109.26 cm²) was again recorded under polypaper-polyethylene. At 120 DAT, insect net white registered the maximum leaf area (134.35 cm²). The minimum leaf area (112.95 cm²) remained associated with polypaper-polyethylene treatment.

The increased leaf area under insect net and red crop covers may be due to improved light diffusion and favourable microclimatic conditions that enhance chlorophyll synthesis and leaf expansion. These covers regulate temperature and humidity, reduce stress and promote better photosynthetic activity. Similar effects were reported by Shamir *et al*. (2001) [26], Swagatika *et al*. (2006) [31], Medan y*et al*. (2009) [14] and Yan Qiuyan*et al*. (2011) [36].

3.1.5 Number of runners per plant
The data presented in Table 2 showed significant variation in the number of runners per plant under different crop cover treatments at successive crop stages. At 30 DAT, the lowest number of runners was observed under green shade net 75% (0.20) which was statistically at par with green shade net 35% (0.27) and insect net white (0.40). The maximum number of runners was recorded under polyp per-polyethylene (0.67). At 60 DAT, minimum number of runners seen under green shade net 75%(0.53) which was statistically at par with green shade net 50% (0.67)and green shade net 35% (0.73).The maximum runner counts were observed under polypaper-polyethylene(1.73).

At 90 DAT, the least number of runners was noticed same treatment in green shade net 75% (1.27). The highest number of runners was found in polyp per-polyethylene (3.33).

At 120 DAT, the lowest number of runners was found under green shade net 75%(1.87)which was statistically on par with green shade net 35% (0.20).the highest number of runners (4.07) was recorded under polypaper-polyethylene.

The increased runner formation under polypaper-polyethylene may be due to higher soil moisture and warmer microclimatic conditions that favour vegetative growth. These conditions likely influence hormonal activity, promoting runner development. In contrast, reduced runner formation under high-shade nets could result from lower light intensity and cooler temperatures, which suppress vegetative propagation. These observations align with findings by Smeets (1956) [30] and Johnson (2023) [10], who noted that light, temperature and moisture significantly impact stolon development in strawberry.

3.2 Flowering Parameters
3.2.1 Days to flower Initiation
The data presented in Table 3 revealed significant differences in the number of days taken for flower initiation among the various crop cover treatments. The earliest flower initiation was observed under red crop cover (29.07 days), while the latest flowering was recorded under

polypaper polyethylene (41.67 days). The advancement of flower initiation under red crop cover and insect net may be attributed to the enhancement of light quality, particularly the red to far-red light ratio, which promotes phytochrome-mediated floral induction. These materials also create a favourable microclimate that supports faster transition from vegetative to reproductive phases. In contrast, the delay under polypaper-polyethylene may be due to excessive temperature and reduced light quality, which suppress floral signalling. These results are in conformity with the findings of Rajapakse and Shahak (2007) [19], Ilic *et al*. (2011) [9], Nadalini*et al*. (2017) [17] and Verma *et al*. (2024) [34], who reported that crop covers can modulate flowering time by altering light spectrum and microclimate conditions.

3.2.2 Days to 50% flowering

Significant differences were also observed in days to 50% flowering in Table 3. The red colour crop cover led to the earliest 50% flowering (46.00 days). In contrast, the polypaper-polyethylene treatment resulted in a considerable delay (60.67 days).

These variations can be explained by differences in microclimatic modifications induced by the covers. Red crop cover and insect net facilitated light diffusion and reduced thermal stress, which supported earlier and more uniform flowering. Similar responses were documented by Singh and Kaur (2020) [28] and Pollard and Chundari (1988) [18], who highlighted the role of light quality in regulating photoperiodic flowering responses in strawberry under protected environments.

3.2.3 Number of flowers per plant

As indicated in Table 3, the number of flowers per plant differed significantly among treatments. Insect net white recorded the highest flower count (34.87), which was at par with red crop cover (34.53), while the lowest was seen in polypaper-polyethylene (25.00).

This variation may be linked to improved physiological conditions under insect net and red crop covers, which support better vegetative growth and assimilate translocation to reproductive organs. Enhanced photosynthetic efficiency under these covers likely contributed to higher floral bud development. These results are consistent with the findings of Singh and Kaur (2020) [28], Verma *et al*. (2024) [34] and Pollard and Chundari (1988) [18], who reported an increase in flower production under microclimate-modifying structures due to better radiation use and growth conditions.

3.3 Fruit Parameters

3.3.1 Fruit set (%): The data presented in Table 3 indicated significant variation in fruit set percentage among the crop cover treatments. The highest fruit set was recorded under insect net white (80.14%), which was statistically on par with red crop cover (79.93%) and saree crop cover (79.37%). In contrast, the lowest fruit set was observed under polypaper-polyethylene (60.54%).

Although the crop covers were removed by the time of flowering, the improved vegetative growth and flower quality under favourable microclimatic conditions earlier in the season likely contributed to enhanced fruit set. Crop covers such as insect nets and red non-woven fabric may have promoted better pollination success and reproductive efficiency by reducing abiotic stress and improving overall plant health. These results are in agreement with Leech *et al*. (2000) [12], Yadav *et al*. (2010) [35] and Rana *et al*. (2022) [21], who reported that favourable pre-flowering conditions play a critical role in determining fruit set percentage in strawberry.

3.3.2 Number of fruits per plant

The number of fruits per plant showed a marked variation across treatments in Table 3. Insect net white recorded the maximum fruit count (27.93), which at par with red crop cover (27.60). Minimum fruit number (15.13) was noted under polypaper-polyethylene.

This variation can be attributed to the beneficial influence of certain crop covers on vegetative growth, flower development and fruit set. The better fruit number under insect net and red crop covers may be due to improved microclimate conditions during early growth stages, which positively influenced reproductive success. These findings are in conformity with those of Hasanein *et al*. (2011) [8], Singh *et al*. (2012) [27] and Verma *et al*. (2024) [34], who emphasized the role of pre-flowering environmental conditions in determining fruit load.

3.3.5 Average fruit weight (g)

The data in Table 3 showed that average fruit weight was significantly influenced by crop cover treatments. Insect net white recorded maximum fruit weight (19.54 g), followed by red crop cover (19.24 g), saree crop cover (19.06 g) and green shade net 50% (18.73 g), while the minimum fruit weight (13.39 g) were recorded under polypaper-polyethylene..

Table 1: Effect of different crop covers on plant height (cm), plant spread (cm) and number of crowns/ plant of Strawberry

Treatments	Plant height (cm)				Plant spread (cm)				No. of crowns / plant			
	30 DAT	60 DAT	90 DAT	120 DAT	30 DAT	60 DAT	90 DAT	120 DAT	30 DAT	60 DAT	90 DAT	120 DAT
T_1.White colour crop cover (17GSM non-woven)	8.61	25.23	30.88	31.83	15.64	14.01	20.13	22.02	1.60	1.87	2.80	3.07
T_2.Blue colour crop cover (17GSM non-woven)	9.56	24.23	28.92	29.71	15.16	14.05	17.77	19.49	1.33	1.60	2.33	2.67
T_3.Red colour crop cover (17GSM non-woven)	10.35	27.30	32.89	34.33	16.72	16.12	20.45	22.21	1.80	2.20	3.07	4.33
T_4.Polypaper-polyethylene (200 micron)	9.33	21.63	25.78	26.53	12.81	12.75	16.09	17.89	1.13	1.33	1.93	2.47
T_5.Insect Net White	9.99	27.58	33.47	34.71	16.93	15.98	20.61	22.37	1.87	2.27	3.27	4.73
T_6.Green shade net 35%	9.49	24.50	29.99	31.21	15.43	13.98	17.66	20.38	1.47	1.80	2.60	3.27
T_7.Green shade net 50%	9.34	26.36	31.98	33.00	16.16	15.44	18.89	20.37	1.67	2.00	2.80	3.20
T_8.Green shade net 75%	13.83	23.67	28.18	28.99	14.61	15.68	18.39	20.03	1.20	1.53	2.20	2.53
T_9.Saree crop cover	10.59	26.54	32.17	33.38	16.32	15.37	18.64	19.99	1.67	2.07	2.87	3.33
T_{10}.Control	7.45	24.43	29.27	30.72	15.27	14.37	17.36	18.53	1.47	1.73	2.40	3.00
SEM±	0.53	0.74	0.89	0.86	0.51	0.64	0.32	0.18	0.08	0.09	0.11	0.08
CD @ 5%	1.58	2.20	2.64	2.58	1.50	1.93	0.96	0.52	0.25	0.28	0.33	0.24

Table 2: Effect of different crop covers on leaf area (cm^2) and number of runner/ plant of Strawberry

Treatments	Leaf area (cm^2)				No. of Runner / plant			
	30 DAT	60 DAT	90 DAT	120 DAT	30 DAT	60 DAT	90 DAT	120 DAT
T_1-White colour crop cover (17GSM non-woven)	58.89	99.16	122.32	127.94	0.40	0.93	2.07	2.67
T_2-Blue colour crop cover (17GSM non-woven)	55.72	93.20	115.83	120.95	0.53	1.53	3.13	2.73
T_3-Red colour crop cover (17GSM non-woven)	66.06	104.36	128.31	131.70	0.67	1.33	2.40	3.60
T_4-Polypaper-polyethylene (200 micron)	42.39	81.31	109.26	112.95	0.73	1.73	3.33	4.07
T_5-Insect Net White	66.62	105.27	130.02	134.35	0.33	0.80	1.87	2.40
T_6-Green shade net 35%	57.08	95.12	118.49	124.73	0.27	0.73	1.73	2.20
T_7-Green shade net 50%	61.29	98.67	123.25	128.25	0.40	0.67	1.93	2.33
T_8-Green shade net 75%	56.32	94.85	118.04	123.99	0.20	0.53	1.27	1.87
T_9-Saree crop cover	63.28	101.40	126.23	130.04	0.60	1.40	2.27	2.80
T_{10}-Control	50.88	91.79	116.93	123.35	0.47	0.87	2.13	2.47
SEM±	0.30	0.44	0.36	0.56	0.05	0.08	0.07	0.12
CD @ 5%	0.90	1.30	1.08	1.66	0.14	0.16	0.20	0.37

Table 3: Effect of different crop covers on yield attributing parameter of Strawberry

Treatments	Daysto flower initiation	Days to 50% flowering	Number of flowers/ Plant	Number of fruits / plant	Fruit set (%)	Average fruit weight (gm)
T_1-White colour crop cover (17GSM non-woven)	32.87	49.67	32.67	24.60	75.31	18.37
T_2-Blue colour crop cover (17GSM non-woven)	34.40	53.67	28.20	20.60	73.05	17.39
T_3-Red colour crop cover (17GSM non-woven)	29.07	46.00	34.53	27.60	79.93	19.24
T_4-Polypaper-polyethylene (200 micron)	41.67	60.67	25.00	15.13	60.54	13.39
T_5-Insect Net White	32.27	48.33	34.87	27.93	80.14	19.54
T_6-Green shade net 35%	33.73	53.67	32.07	24.07	75.08	18.06
T_7-Green shade net 50%	35.67	51.67	33.53	25.67	76.55	18.73
T_8-Green shade net 75%	39.20	55.00	28.33	20.80	73.42	17.77
T_9-Saree crop cover	32.73	49.00	33.93	26.93	79.37	19.06
T_{10}-Control	34.53	50.00	29.53	21.93	74.27	17.46
SE_m±	0.35	0.45	0.26	0.14	0.56	0.33
CD @ 5%	1.05	1.35	0.79	0.42	1.68	0.98

Heavier fruits under insect net and red crop covers may result from improved microclimatic regulation, enhanced photosynthetic efficiency and increased assimilate flow to fruit tissues during development. These findings are supported by Swagatika *et al*. (2006) [31], who reported that favourable environmental conditions prior to flowering lead to enhanced fruit filling and weight gain.

4. Conclusion
The results of the study clearly indicate that the application of various crop covers significantly influences strawberry growth, flowering and yield performance. Notably, treatments involving insect net white consistently exhibited superior outcomes across multiple parameters, including plant height, canopy spread, leaf area, crown development and runner production. These improvements can be attributed to the favourable microclimatic modifications induced by the covers. Furthermore, these treatments led to earlier flowering, a higher number of flowers and fruits and enhanced fruit size and weight. Overall, the findings highlight the efficacy of insect net white and red non-woven crop covers in optimizing the crop microenvironment, promoting key physiological functions and thereby improving strawberry productivity under subtropical conditions.

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