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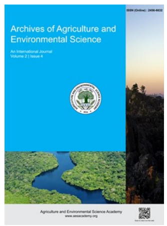

ORIGINAL RESEARCH ARTICLE

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Productivity of strawberry as influenced by mulch materials and gibberellin under net house condition

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ABSTRACT

Plant growth regulators in combination with mulch materials have been shown to regulate physiological processes related to plant growth and development. The experiment was conducted to investigate the responses of different mulch materials and GA_3 on plant morphological, physiological and yield attributes of strawberries during the period from November 2020 to March 2021. The experimental treatments included three different mulch materials: black polythene, white polythene, saw dust, and control (no mulch); and GA_3 (0 and 200 ppm) were studied. According to the findings, strawberries grown with sawdust and GA_3 had the highest chlorophyll content (SPAD value) (48.23), relative water content (76.45%), leaf area (48.23 cm^2), maximum number of fruits (19.66) and fruit yield (321 g/plant). In contrast, individual fruit weight (18g) was the highest for plants grown in sawdust without GA_3. Black polythene mulch showed no satisfactory improvement in the growth and yield characteristics of strawberry plants. Therefore, sawdust based mulching and GA_3 may be recommended to obtain better strawberry growth and yield.

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INTRODUCTION

In the Rosaceae family, the strawberry (*Fragaria ananassa* Duch.) is one of the world's most delicious fruits. It is a great source of vitamins and minerals, and it has a delicious flavor and aroma (Kher *et al*., 2010). It is a short-day plant that grows best in temperate climates, but it can also be grown in tropical and subtropical climates (Bakshi *et al*., 2014). A stronger generic diversity, higher heterozygosity, and a wider range of improved varieties, as well as off-season production, have all contributed to an increase in interest in strawberry cultivation in recent years (Durner, 2018). Due to their pleasant taste and refreshing nature, strawberries have gained popularity in recent years, but their main problem is their fruit yield and quality. Mulching is a practice that aids in proper plant growth and development by modifying soil temperature, improving nutrient availability, and preserving moisture (Kher *et al*., 2010).

Mulching had a significant impact on the microclimate around the plants by modifying the radiation budget and increasing vegetative growth (Soliman *et al*., 2015). As the day progresses, mulch protects the soil from heat buildup and improves thermal conditions in the early morning. Synthetic mulch and organic mulch have distinct ways of improving water efficiency. Soil temperature prevents organic mulch from evaporating as quickly as plastic mulch, which is impervious and therefore does not evaporate as quickly. Plastic mulches are less likely to evaporate due to soil temperature than organic mulches because of their impermeable nature. They raise soil temperatures while also influencing plant physiology, which results in poor performance (Arun *et al*., 2016). Plant residues are broken down by enzymes that are activated when organic mulches are applied to the soil (Sas-Paszt *et al*., 2014).

Strawberry yields can be increased by using improved varieties, efficient chemical fertilizer use, and various agronomic practices. Aside from that, growth-regulating chemicals are becoming increasingly important in strawberry cultivation for modifying vegetative growth, flowering, and fruiting, all of which affect total yield and quality. Enzymes that are activated when organic mulches are applied to the soil break down plant residues (Palei *et al.*, 2016). Vishal *et al.* (2016) found that exogenously applied growth regulators improved strawberry vegetative growth, flowering, yield, and physicochemical quality. As a result, gibberellic acid (GA_3) application has the potential to control strawberry growth, flowering, and early and out-of-season cropping. It has been demonstrated that applying GA_3 to the foliage of a variety of horticultural crops increases yield and quality (Sharma and Singh, 2009).

A limited amount of information has been published on strawberry production in terms of the best mulch materials to use in a protected environment with GA_3. As a result, the present investigation was conducted to study the effect of different mulching materials and GA_3 on morphological, physiological and yield attributes of strawberry.

MATERIALS AND METHODS

Plant materials and growing conditions

The experiment was carried out under natural lighting at the Horticulture Farm of Sher-e-Bangla Agricultural University in Dhaka, Bangladesh, from November 2020 to March 2021. In the current study, gibberellic acid (0 and 200 ppm GA_3) was used with various mulch materials (no mulch, sawdust, white and black polythene). For the experiment, a randomized complete block design with three replications was employed. The cv. Festival strawberries were planted in raised beds with 60 cm x 30 cm spacing underneath a net house. During the experiment, the average temperature was 24±3°C during the day and 13±2°C at night, with a relative humidity of 65–80%. All essential cultural practices and plant protection measures were implemented across all plots throughout the experiment. In each replication, growth, yield, and physicochemical parameters were measured on randomly selected plants. Throughout the experiment, all essential cultural practices and plant protection measures were followed across all the plots. Growth and yield contributing parameters were measured on randomly selected plants in each replication.

Soil characteristics

The experimental plot's soil was collected from the research field, which is medium-high land in nature. The experimental soil had a sandy loam texture. The nutrient status of the farm soil beneath the experimental plot was collected and analyzed at the Soil Resource and Development Institute in Dhaka, Bangladesh, and the results are shown in Table 1.

Table 1. Physical and chemical properties of the initial soil.

Characteristics	Value
% Sand	27
% Silt	43
% Clay	30
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.10
Available S (ppm)	45

Measurements of growth parameters

Plant height and leaf number at harvest were measured using five plants in each treatment and replication. During the flowering and fruiting stages, the plant height was measured from the base to the top of the main plant.

SPAD chlorophyll meter reading

The chlorophyll content of the first fully expanded leaves was measured using a SPAD-502 chlorophyll meter (Minolta, Tokyo, Japan). On both treated and control plants, measurements were taken at the middle of the leaf lamina. In the flowering and fruiting stages, five randomly selected plants from each treatment and replication were measured.

Relative water content (RWC)

According to Smart and Bingham (1974), the RWC was calculated. Second/third fully expanded leaves were pooled for each treatment and replication, and their fresh weight (FW) was determined. When the leaves were ready, they were soaked in water for 12 hours at room temperature in order to restore their turgidity. As soon as possible, all excess water was removed from the tissue, and the turgid weight (TW) was calculated. Afterwards, the samples were dried in an oven at 60°C for 24 hours in order to determine their dry weights (DW). RWC was calculated by using the following formula.

Measurements of flower, yield and yield traits

For each treatment and replication, five randomly selected plants were selected to record observations on days to flowering of strawberry. Yields per plant (g) were calculated by averaging the harvests of all five plants in each treatment and each replication to arrive at a total. Strawberry pickings were done every two days for a total of five to seven pickings. The weight of fruits (g) from each selected plant was measured using an electronic top pan balance on each date of harvest. The quantity of fruits/plants was determined by counting the ripe fruits.

Statistical analyses

A randomized complete block design (RCBD) was used in the experiments, with three replications for each treatment and five plants in each replicate. Statistical analyses were conducted with IBM SPSS Statistics 21 (IBM Corp, Armonk, NY, USA). When $P<0.05$, the mean value across treatments was considered statistically significant. The replicated data was used to calculate the mean ± SE for all results. The graphs were made with the Microsoft Excel program. We used ANOVA to examine the impact of GA_3 and mulch materials on various growth, yield, and quality metrics, as well as the interaction between the two.

RESULTS AND DISCUSSION

Plant height (cm)

Plant height of strawberry was varied significantly due to combined effect of GA_3 and mulch materials in both flowering and fruiting stage. In comparison to non-GA_3 treated plants, the height of all GA_3 sprayed plants was increased. At flowering stage, the highest plant height (19.5 cm) was found in sawdust mulching with GA_3 treated plant followed by white polyethylene with GA_3 (19.33 cm) treated plant and the lowest (14.66 cm) was observed in black polythene with no GA_3 followed by (13.50 cm) control (no mulch and GA_3) (Figure 1A). A similar trend was found for the plant height during fruiting stage. The highest plant height (21.5 cm) was found in sawdust (Table 2). Rakesh *et al.* (2014) noticed that the application of GA_3 to strawberry plants promotes vegetative growth, plant height and runner production. It occurs as GA_3 increases cell elongation and opposite occurs in non GA_3 treatment. Thakur *et al.* (2017), who also reported strawberry plant height, increase with the application of gibberellic acid. Organic mulch produced superior results with the maximum plant height compared to other treatments (Addo, 2021). Soliman *et al.* (2015) observed that sawdust mulch increased strawberry height by favorable environment by reducing soil moisture, weed emergence, water loss, increased nitrogen, recycling of nutrients and adding of organic matter to the soil.

Number of leaves plant^{-1}

At flowering stage, the highest number of leaves plant^{-1} (12.33) was observed from the treatment of GA_3 with white polythene mulch and the lowest number of leaves plant^{-1} (8.33) was recorded from the treatment of black polythene with no GA_3. At fruiting stage, it was found that the highest number of leaves plant^{-1} (13.66) was found from the treatment of GA_3 with white polythene mulch. The lowest number of leaves plant^{-1} (10.33) was observed from the treatment combination of GA_3 with sawdust mulch (Table 2). Kumra *et al.* (2018) observed that exogenous application of GA_3 induced higher number of leaves in strawberries. Kaur and Mirza (2018) observed that number of leaves plant^{-1} was influenced significantly by white transparent mulch which may be due to better conservation of moisture.

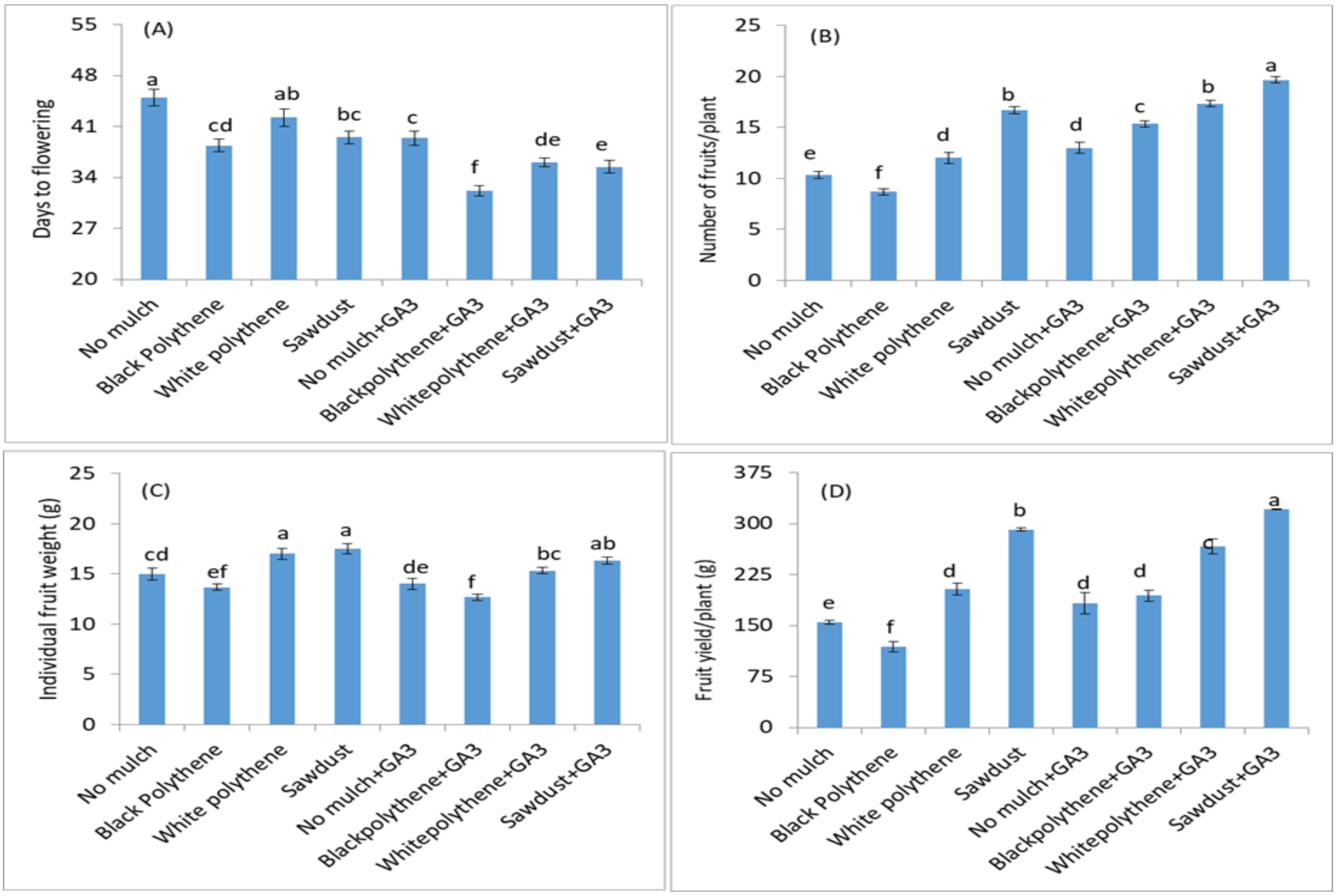

Figure 1. *Average days to flowering (A), number of fruits/plant (B), individual fruit weight (g) (C) and fruit yield/plant (g) (D) of strawberry grown with different mulch materials and GA_3. Mean ± S.E. (n = 15). Means followed by same letter(s) in a column do not differ significantly at 5 % level of LSD.*

Table 2. Effect of GA_3 and mulch materials on plant height and number of leaves plant^{-1} of strawberry.

Treatments	Plant height (cm)		Number of leaves plant^{-1}	
	Flowering stage	Fruiting stage	Fruiting stage	Fruiting stage
No mulch	14.00 de	16.66 d	10.83 b	11.66 bcd
Black Polythene	13.50 e	13.73 e	8.33 c	10.50 cd
White polythene	15.75 cd	16.83 d	10.50 b	13.00 ab
Sawdust	18.00 ab	20.66 ab	8.83 c	10.66 cd
No mulch+GA_3	17.50 bc	19.50 bc	11.66 ab	12.33 abc
Black polythene+GA_3	17.90 ab	18.33 cd	10.33 b	11.33 bcd
White polythene+GA_3	19.33 ab	19.83 abc	12.33 a	13.66 a
Sawdust+GA_3	19.50 a	21.50 a	10.33 b	10.33 d
CV%	6.45	5.05	7.11	9.75
$LSD_{0.05}$	1.91	1.62	1.29	1.99

Means followed by same letter(s) in a column do not differ significantly at 5 % level of LSD.

Table 3. Combined effect of GA_3 and mulch materials on leaf area, SPAD value and relative water content of strawberry.

Treatments	Leaf area (cm^2)	Chlorophyll content (SPAD value)	Relative water content (%)
No mulch	69.33 ef	42.06 e	61.16 d
Black Polythene	66.08 f	40.70 f	70.99 b
White polythene	73.06 cd	43.86 c	72.23 b
Sawdust	79.06 ab	47.00 ab	72.18 b
No mulch+GA_3	71.66 de	43.50 cd	65.90 c
Black polythene+GA_3	67.97 ef	42.50 de	73.87 ab
White polythene+GA_3	76.00 bc	45.90 b	73.16 ab
Sawdust+GA_3	80.97 a	48.23 a	76.45 a
CV%	1.99	1.75	2.88
$LSD_{0.05}$	2.53	1.35	3.56

Means followed by same letter(s) in a column do not differ significantly at 5 % level of LSD.

Leaf area (cm^2), SPAD value and Relative water content (RWC)

The maximum leaf area was found in sawdust mulching plants treated with GA_3 (81 cm^2), which was statistically similar to sawdust mulching plants (79 cm^2), whereas the minimum leaf area was found in black polythene mulch plants (66 cm^2) (Table 3). Bist *et al.* (2018) found that the application of GA_3 significantly increase leaf spread and leaf area. The increase in plant spread and leaf area of strawberry plant may be due the growth regulated by gibberellins by causing cell elongation in mature petiole of strawberry plant system. Ali and Gaur (2013) reported Compared to other mulches made of paddy straw and clear polyethylene, sawdust mulch has a positive effect on strawberry leaves. This may be attributed to improved soil hydrothermal regimes and the suppression of weeds, which reduced competition between the plant and the weed and enabled the plant to produce more leaves with larger leaf areas.

At the flowering stage, sawdust mulching plants treated with GA_3 had the highest chlorophyll content (48.23), while black polythene mulching plants treated with no GA_3 had the lowest (40.70) (Table 3). We found that sawdust mulched plants treated with GA_3 had considerably increased chlorophyll content in their leaves during the flowering stage of the experiment. Our findings were similar to those found in a study of strawberry plants in which GA_3 sprayed plants had higher chlorophyll content (Abbas *et al.*, 2021). Sawdust treatments had significantly higher chlorophyll content than other treatments in bluberry leaves (Gumbrewicz and Calderwood, 2022).

The data in Figure 2B shows that the differences between various mulching treatments were found to be insignificant in terms of RWC. Sawdust mulching with GA_3-treated plants resulted in a higher RWC (76.45%), whereas control (no mulch and GA_3) plants resulted in a lower RWC (61.16%) (Table 3). Habibi *et al.* (2021) concluded that GA_3 is successful in increasing the growth, RWC and photosynthesis relating attributes like gas exchange attributes and also successful in alleviating the adverse effect of water stress under normal and water stressed conditions. Chen *et al.* (2016) characterized the photosynthesis efficiency, canopy temperature and highest relative leaf water content under the effect of soil mulching. Compared to other mulches, sawdust mulch increases residue accumulation and decreases soil disturbance on the soil surface, which helps to conserve soil water and lower soil temperature.

Days to flowering

All plants sprayed with GA_3 required a minimum number of days to flower compared to the non-GA_3-sprayed plants. The minimum (31.83) days were required in black polyethylene mulch treated with GA_3 plants, closely followed by sawdust mulching with GA_3 plants (32.16 days). The plants that needed the most time to flower were those that had no mulch or GA_3 (43.66 days) (Figure 1A). All plants treated with GA_3 taken minimum days for flowering to fruit setting compared to the non GA_3 sprayed plants (Rana *et al*., 2020). Ughareja and Pandya (2023) reported that flowering is boosted and early flowering is induced by 100 ppm GA_3 treatment. The possible reason of inducing early flowering is due to the stimulation of Florigen hormone by gibberellic acid. Tegen *et al.* (2016) observed early flower initiation of the plants under black plastic mulch than other mulches. It might be due to adequate moisture contents and appropriate temperature of soil with least evaporation.

Number of fruits/plant

All plants treated with GA_3 gave the maximum number of fruits compared to the non-GA_3-treated plants. GA_3 treated sawdust mulching plants had the maximum number of fruits (19.66). The minimum number of fruits (11) was observed in black polythene mulch and no GA_3 (Figure 1B). Ramteke *et al.* (2015) found maximum number of fruits in GA_3 treated papaya plants Shashidhar *et al.* (2009) noted that during the growing season, sawdust mulched soil had low temperature and moderate moisture, which encouraged an increase in soil nutrient levels and microbial activity.

Individual fruit weight (g)

The individual fruit weight of all GA_3-treated plants was comparatively lower than the non-GA_3-treated plants. Individual fruit weight (18g) was the maximum in sawdust mulching with no GA_3 treated plants and the minimum (11g) fruit weight was found in plants in GA_3 treated plants with black polyethylene mulch (Figure 1C). Asadi *et al.* (2013) stated that gibberellic acid significantly increases the total and marketable yield but decreases the individual fruit weight of strawberry compared control fruits. The probable reason for the decrease in individual fruit weight is due to the production of more number of secondary and tertiary fruits by applying GA_3. Ghosh and Bera (2015) found that the plants mulched with sawdust gave highest average fruit weight in pomegranate over control. The soil moisture was higher and soil temperature was optimum in sawdust mulch as compared to control and other mulches which resulted in maximum individual fruit weight and gave higher yield of strawberry.

Fruit yield/plant (g)

The fruit yield per plant of all GA_3 treated plants was the maximum compared to the non GA_3 sprayed plants. The maximum fruit yield (321g) per plant was found in sawdust mulch plants treated with GA_3, whereas the minimum fruit yield (118g) was found in black polyethylene with no GA_3 (Figure 1D). Paikra (2018) found that the GA_3 gave best result in terms of plant growth, yield and fruit quality of strawberry as compared to other treatments. The increase in yield could be a reflection of the effect of GA_3 on growth and development following cell division and elongation and had also an indirect effect on the auxin metabolism and resulted higher number of marketable fruits and thereby increased the fruit yield. Ikeh *et al.* (2019) used various mulching materials (polythene sheet, trampoline sheet, sawdust, grasses, and control) and found that the plot mulched with sawdust produced more fruit than the other plots. Sawdust application reduces weed infestation while also increasing fruit yield. Paunovic *et al.* (2020) observed that mulching increased plant growth and fruit yield by modifying the crop growing environment by reducing weed infestation, depleting soil moisture, and improving soil temperatures.

Conclusion

In strawberry, organic mulch (sawdust) produced higher yields than synthetic (black and white polythene) and no mulch. GA_3-treated plants performed better than non-GA_3treated plants. The findings of the current indicate that combining sawdust mulching and GA_3 can be used successfully in strawberry production, and that it may be a better option for increasing strawberry growth and yield.

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Conflicts of interest

The authors declare no conflict of interest.

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