EFFECT OF DIFFERENT MULCHES AND GIBBERELLIC ACID ON GROWTH, YIELD AND QUALITY OF STRAWBERRY

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CERTIFICATE

This is to certify that the thesis entitled, **“EFFECT OF DIFFERENT MULCHES AND GIBBERELLIC ACID ON GROWTH, YIELD AND QUALITY OF STRAWBERRY”** *submitted to the Department of Horticulture, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirement for the degree of* **MASTER OF SCIENCE (MS) in HORTICULTURE** embodies the results of a piece of bona fide research work, carried out by **MD. SHAHJAHAN ALI**, Registration No. **19-10352** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma, elsewhere in the country or abroad.

I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

Dated: December, 2021

Place: Dhaka, Bangladesh

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Dedicated to

My Beloved Parents

Who has always helped me and
Believed that I could do it

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ABSTRACT

BY

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Mulching plays an important role for reducing moisture loss, weed growth, and increasing yield of fruits and vegetables. The present experiment aimed to find out the effect of different mulch materials and gibberellin on growth, yield, and quality of strawberry under net house condition during the period from October 2020 to February 2021. The experimental treatments included four mulch materials: no mulch, black polythene, white polythene, and sawdust and two levels of gibberellic acid (0 and 200 ppm GA_3). The treatments showed significant effect on leaf area, SPAD value, relative water content, number of fruits, and yield per plant, as well as quality traits i.e. total soluble solid, reducing sugar, phenol and anthocyanin content of strawberry. Organic mulch (sawdust) produced higher yields and quality than synthetic mulch (black and white polythene) and no mulch conditions. GA_3 treated plants performed better than non-GA_3 sprayed plants. In terms of interaction effects, sawdust mulch plants treated with GA_3 produced the highest fruit yield (321g) per plant, while black polyethylene plants treated with no GA_3 produced the lowest fruit yield (118g). Therefore, sawdust and GA_3 are beneficial for increasing the growth, yield, and quality attributes of strawberry plants.

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Abbreviations	Elaborations
%	Percentage
ANOVA	Analysis of variance
GA_3	Gibberellic Acid
^0C	Degree Celsius
BARI	Bangladesh Agricultural Research Institute
cm	Centimeter
cm^2	Centimeter (square)
CV%	Percentage of Coefficient of Variation
df	Degrees of Freedom
et al.	and others (at elli)
G	Gram
Mg	Milligram
LSD	Least Significant Difference
MP	Muriate of Potash
TSP	Triple Super Phosphate
Ppm	Parts per Million
RCBD	Randomized Complete Block Design
SAU	Sher-e-Bangla Agricultural University
SRDI	Soil Resources Development Institute
pH	Hydrogen ion conc.
FAO	Food and Agriculture Organization

CHAPTER I

INTRODUCTION

In the Rosaceae family, 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). Strawberries contain vitamins A (60 UI/100g edible portion) and C (30-120mg/100g edible portion), as well as 5% total sugar, 0.90 - 1.85% acids, fibre, pectin (0.55%), and water (90%) (Sharma *et al*., 2002). 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). Strawberries have gained popularity in recent years due to their pleasant taste and refreshing nature, but their main problem is their fruit yield and quality. Strawberry cultivation is limited by adverse weather conditions such as heavy rains, hail, and temperature fluctuations, especially during flowering and fruiting. Temperature increases in the growing environment reduced fruit quality, such as soluble solids, in the berries and other fruits. It is better to cultivate strawberries under a shed house to protect them from adverse weather conditions.

Adding mulch to the soil enhances growth by improving nutrient availability in the soil, conserving water and decreasing moisture conservation while encouraging plant development and changing soil temperature (Keramat *et al*., 2011). 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. Organic mulches not only improve soil structure, but they also slow down the release of nutrients and keep the soil temperature stable (Shirgure *et al*., 2003). 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. Because of their impermeable nature, plastic mulches are less likely to evaporate than their organic counterparts due to soil temperature. 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). Due to the activity of microorganisms, organic mulches with a high carbon to nitrogen ratio (such as sawdust) may temporarily deplete soil nitrogen.

It is possible to increase strawberry yields by using improved varieties, efficient chemical fertilizer use, and various agronomic practices. Aside from that, growth-regulating chemicals are becoming increasingly important in the strawberry for the modification of their vegetative growth, flowering, and fruiting, which affect total yield as well as quality (Bisht *et al*., 2018). Vishal *et al*. (2016) found that exogenously applied growth regulators had a positive effect on strawberry vegetative growth, flowering, yield, and physico-chemical quality attributes. As a result, the application of gibberellic acid (GA_3) has the potential to control strawberry growth, flowering, as well as early and out-of-season cropping. It has been proven that applying GA_3 to the foliage of numerous horticultural crops has increased their yield and quality (Sharma and Singh, 2009). Increased photosynthetic efficiency from GA_3 could lead to higher yields by delaying senescence and improving growth and development of chloroplasts (Yuan and Xu, 2001).

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. Considering the above mentioned facts, the present investigation was undertaken with the following objectives-

1. To find out the effect different mulches and GA_3 on growth and yield of strawberry

2. To determine the suitable mulch material for yield and quality of strawberry

CHAPTER II

REVIEW OF LITERATURE

Strawberry (Fragaria × annanasa) is one of the most popular fruits in the world. Strawberry plants are commercially obtained through vegetative propagation of mother plants, which produce daughter or runner plants currently used by strawberry growers for fruit production. Considering the world production area, around 10 billion quality strawberry transplants are required every year. Researches on various side of its production technology have been carried out worldwide. Among these researches a limited number of works have been done on GA_3 and mulch materials. Very few numbers of works were reported where the effect GA_3 and/or in combination with mulch materials was studied. However, some of the researches and their findings related to the present study carried out at home and abroad are reviewed in this chapter under the following heads.

2.1 Effect of GA_3 on growth, yield and quality of strawberry

Ghimire *et al.* (2021) conducted an experiment to know the effects of various ripening agents of banana fruits (Malbhog) and applied seven treatments consisting of distilled water, Gibberellic acid (GA_3) @ 100 ppm, GA_3 @ 200 ppm, GA_3 @ 300 ppm, kinetin @ 3 ppm, kinetin @ 5 ppm, and kinetin @ 7 ppm. The maximum loss in weight, Total Soluble Solids, the highest color score, pH, Total Soluble Solids/Titratable Acidity TA and Pulp peel ratio were observed in banana sprayed with distilled water whereas the minimum value for TSS, pulp peel ratio, peel color rating, TSS/TA were observed in GA_3 @ 300 ppm treated fruits. The maximum and minimum shelf-life was observed in GA_3 @ 300 ppm and distilled water respectively.

Sharma *et al.* (2020) found that GA_3 had stimulate effect on the fruit of strawberry ripening, testimonial by reduce the activity of respiration and detain the synthesis of anthocyanin and breakdown of chlorophyll gibberellic acid influence the growth, flowering and fruiting etc.

Saha *et al.* (2019) conducted an experiment to study the effect of different plant growth regulators (PGRs) on growth, yield and quality of strawberry (Fragaria × ananassa Duch.)

cv.Winter Dawn, grown under shade net. The experiment was laid out with nine treatments, viz., GA_3 (20 and 40 ppm), NAA (20 and 40 ppm), Cycocel (500 and 750 ppm), BA (25 and 50 ppm) and Control (water spray), applied as foliar spray at 15 and 30 DAP. The results revealed that, application of GA_3 @ 40 ppm significantly improved vegetative growth, flowering, fruiting parameters over control, while Cycocel @ 750 ppm resulted in earlier flower initiation and improved fruit weight. However, GA_3 @ 40 ppm resulted in significantly highest productivity and fruit quaity in terms of TSS, TSS:acid ratio, ascorbic acid and anthocyanin content.

Khodair *et al.* (2018) set up an experiment and observed that spraying (GA_3) and paclobutrazol (PB) led to increase bunch and finger weights the fruit characteristics of banana. There was an improvement of chemical fruit constituents in term of increasing total soluble solids (TSS %), sugars contents and decreasing the total acidity percentages due to spray of GA_3 or Paclobutrazol (PB) singly or interaction of them compared to the control treatment. Then, it could be concluded that spraying 40 ppm GA_3 thrice. As well as spraying paclobutrazol (PB) at (2g) /L seems to be the promising treatment under this experiment conditions to get the best results with regard to yield and fruit quality.

Singh *et al.* (2018) conducted an experiment to observe the effect of PGR's on growth and yield of Stawberry. Auxins and gibberellins were identified as potent PGRs for improving growth, flowering, yield and post-harvest life parameters. The maximum plant height, number of leaves, flowers and fruits, total yield and chemical parameters like ascorbic acid, total soluble solids, phenolic compound, anthocyanin and total sugars were recorded under PGR treatment.

El-Rhman *et al.* (2017) carried out an experiment to assess the effect of foliar sprays by GA_3 at (10, 20 and 40 ppm), NAA at (10, 20 and 40 ppm) and algae extract at (0.5, 1and 2 %) on vegetative growth, yield, fruit quality and fruit retention percentage of mango tree cv. "Hindi". It was found that spraying mango trees with GA_3, NAA and algae extract by all concentrations was very effective in improving all vegetative growth parameters, fruit set, and fruit retention parameters, yield as (kg) / tree and number of fruits or weight (kg) /

tree. Also, data recorded that all treatments slightly increased all fruit physical properties and enhanced total soluble solids TSS, total and reducing sugars and finally enhanced ascorbic acid in both seasons compared to control. Meanwhile, it reduced acidity percentage compared with the control treatment. The best results for all parameters were obtained by spraying mango tree with GA_3 at 40ppm which recorded the highest values in both seasons compared with control and other treatments.

Noor *et al.* (2017) conducted a field study during the Rabi season and used six levels of GA_3, viz. 0, 30, 50, 70, 90 and 110 ppm. GA_3 treatments significantly increased plant height than the control plants. GA_3 with 30 to 90 ppm significantly increased number of branches and leaves, leaf area, leaf area index (LAI), leaf dry matter and total dry matter at different growth stages. GA_3 at 30 to 70 ppm gradually increased crop growth rate (CGR), net assimilation rate (NAR) and relative growth rate (RGR) and declined advanced growth stages. Number of dry pods /plant, number of seeds /pod, 1000 seed weight, fresh fodder, fresh pod, dry seed yield and harvest index also significantly increased. Positive significant correlations were found among growth parameters and as well as yield contributing characters.

Rustam *et al.* (2017) conducted an experiment under protected condition to study the effect of foliar application of GA_3 on growth and yield of strawberry. The results revealed that the applications of GA_3 at 100 ppm significantly influenced on reproductive parameters such as minimum days to flowering, maximum number of flowers per plant, maximum fruit set/plant, maximum number of fruit per plant and highest yield/plant.

Strawberry plant growth, leaf area, flowering, and fruiting responses were all evaluated after GA_3 application by Thakur *et al.* (2017). They confirmed that the application of GA_3 resulted in the highest flower counts, fruit counts, percentage fruit set, fruit size, fruit weight, and increase in fruit yield.

Fagherazzi *et al.* (2017) used different concentrations of GA_3 (0, 40, 80 and 160 mg L^{-1}) on strawberry production and observed that GA_3 mostly modifying the productive characteristics of plants, such as early flowering and increasing fresh fruit weight. An increase in the plant height and in the total number of runners emitted by the plant due to the increase in GA_3 (160 ppm) was also observed.

Palei *et al*. (2016) conducted an experiment using different concentrations of GA_3 (25, 50 and 100 ppm) and recorded different vegetative characters like plant height (cm), plant spread (cm), petiole length (cm), leaves per plant, runners per plant and different reproductive characters like days taken to first flower, number of flowers per plant, number of fruits per plant and different fruit characters like Length:diameter ratio, Juice (%), TSS (°Brix), Ascorbic acid (mg/100g), acidity etc.

A pot experiment was conducted by Ahmad Dar *et al.* (2015) in the natural conditions of net house to evaluate the effect of four concentrations of GA_3 (0, 10^{-7} M, 10^{-6} M and 10^{-5} M), alone and in combination with phosphorus (40 kg P ha^{-1}), on growth, biochemical and yield attributes of fenugreek. Compared to control, the combination of GA_3 and phosphorus (P40 + 10^{-6} M GA_3) significantly increased the activities of nitrate reductase and carbonic anhydrase enzymes; it also enhanced the seed yield and the content of total chlorophyll and carotenoids.

Rajbhar *et al.* (2015) observed that using GA_3 result more TSS, increased number of fruits and juice content in strawberry. The application of GA_3 also increased the ascorbic acid and acidity content in strawberry.

A field trail was conducted by Thakur *et al.* (2015) to evaluate the effect of GA_3 (25, 50 & 75 ppm) and plant growth promoting rhizobacteria (Bacillus licheniformis CKA 1, Bacillus subtilis CB 8A, Bacillus sp. RG_1, Bacillus sp. S_1 and Bacillus sp. S_2) on growth, fruiting and physico-chemical characteristics of strawberry cultivar 'Chandler'. Study has shown that the plant growth promoting rhizobacteria (PGPR) along with GA_3 @ 75 ppm found to be best treatments in terms of increased growth, fruiting and physico-chemical characteristics. The maximum plant height, leaf area, number of crowns and plant biomass on dry weight basis (g/plant) were recorded in this treatment. The maximum fruit total soluble solids (TSS), ascorbic acid and total sugars were highest with the application of plant growth promoting rhizobacteria and GA_3 @75 ppm.

Saima *et al.* (2014) used different bio-regulators (GA_3 and cycocel) on strawberry plants and revealed that the application of GA3 resulted in the most flowers and fruits per plant.

Nishad *et al.* (2014) proved best 200 ppm GA_3 in respect of plant height, number of leaves per plant, leaf area, plant spread, petiole length and number of runners per plant. It indicated increased plant height, plant spread, maximum leaf area and maximum leaves number/plant. It was also revealed that petiole length and number of runners per plant were maximum due to application of GA_3.

Khunte *et al.* (2014) observed that gibberellic acid promotes growth endogenously and has direct effect on various parameters such as cell elongation, fruit set, germination, flowering and fruit development, yield, quality of strawberry.

Quintero *et al.* (2013) sprayed different doses of GA_3 (300, 600 and 900 $mg.L^{-1}$) and found increased fruit size linked to strawberry production where TSS and firmness had fluctuating responses. It is concluded that regulators, in the average of their doses, were able to increase the fruit size and production.

Kumar *et al.* (2013) sprayed GA_3 on strawberry plants and discovered that GA_3-treated plants had the highest juice content of fruits, TSS, ascorbic acid, total sugar content, and pH of fruit.

Eshghi *et al.* (2012) showed that GA_3 had a significant effect on vegetative and reproductive growth of strawberries, such as augmentation of root length, number of flowers, and inflorescences. The increased leaf area in this study is also associated with elongation of epidermal cells in the leaf lamina due to the use of GA_3.

Kumar *et al.* (2012) conducted an experiment on the influence of plant growth regulators on growth, yield and quality of strawberry. GA_3 gave the best results in terms of vegetative growth, runner production, ascorbic acid and acidity of strawberry and also showed higher number of flowers, fruits per plant, yield, total soluble solid and total sugar of strawberry.

Rajesh *et al.* (2012) used different growth promoters (GA3, NAA, and cytosol) on strawberry plants and exposed that GA_3 has a greater influence on vegetative growth than the other growth promoters. GA_3 increased plant height, petiole length, leaf number and area, branch crown, runner production, and also increased vitamin C and acidity in strawberries.

Rakesh *et al.* (2012) applied different concentrations of foliar spray of gibberellic acid (25, 50, and 75 ppm) to strawberries and found that plants treated with 75 ppm gibberellic acid showed an increase in all the vegetative characteristics, the highest number of fruits, yield/plant, pH value of fruits, and cost benefit ratio.

Moneruzzaman *et al*. (2011) carried out an experiment to investigate the effects of gibberellic acid (GA_3) on the growth and development of the red jambu air madu fruits (*Syzygium samarangense*). Various horticultural parameters were monitored during two seasons of fruit growth with the application of three concentrations of GA_3 at 20, 50 and 100 mg/L. It was observed that the application of GA_3 at 50 mg/L increased fruit length and diameter. Furthermore, it enhanced faster fruit growth and color development in addition to increasing fruit number, weight and yield. It also decreased premature fruit dropping. However, spraying with 20 mg/L GA_3 increased the number of buds and fruit setting and reduced bud dropping before anthesis. With regard to fruit quality, the application of GA_3 at 50 mg/L increased total soluble solids (TSS), total sugar, total biomass and total flavonoids content in the fruits compared with the control treatment. In addition, anthocyanin content, total phenol and antioxidant activity was higher in GA_3 treated fruits.

An experiment was conducted by Nasiruddin and Roy (2011) to study the effect of GA_3 on growth and yield of cabbage. The experiment was consisted of four concentrations of GA_3, viz., 25, 50 and 75 ppm. Significantly the minimum number of days to head formation and maturity were recorded with 50 ppm GA_3. The application of different concentrations of GA_3 was influenced independently on the growth and yield of cabbage. Significantly the highest yield was recorded from 50 ppm GA_3.

Influence of GA_3, NAA and CCC at three different concentrations on different growth parameters of cabbage were studied by Lendve *et al.* (2010) found that application of GA_3 was significantly superior over most of the treatments in terms of number of the leaves, plant spread, leaf area, fresh and dry weight of the plant, shape index of head, length of root, fresh and dry weight of root.

A study was conducted by Roy *et al.* (2010) to study the effect of starter solution and GA_3 on growth and yield of cabbage. The two factor experiment consisted of four levels of starter solution, viz., 0, 1.0, 1.5 and 2.0 % of urea and four concentrations of GA_3, viz., 0, 25, 50 and 75 ppm. The highest yield was obtained from 1.5 % starter solution which was significantly different from other solutions, and the lowest yield was recorded from the control. Significantly the highest was found from the treatment of 50 ppm GA_3, while the lowest yield was recorded from control. In case of combined effect, the highest yield of cabbage was obtained from the treatment combination of 1.5 % starter solution+590 ppm followed by 1.5 % starter solution+75 ppm GA_3 while the lowest yield was produced by the control treatment.

Yu *et al.* (2010) conducted an experiment with '8398' cabbage plants with 7 true leaves and 'Jingfeng No.1' cabbage plants with 9 true leaves were vernalized in incubator. Then, '8398' cabbage plants vernalized for 18 days and 'Jingfeng No. 1'cabbage plants were vernalized for 21 days were treated by high temperature of 37 C for 12 hours to explore the changes of endogenous hormone during de-vernalization in cabbage . The results showed that GA_3 content had less changes, IAA content rose and ABA content decreased during de-vernalization. Compared with CK (vernalization period), GA3 and ABA content decreased significantly, whereas IAA content rose significantly when devernalization ended. Lower GA_3 and ABA content, and higher IAA content can benefit the accomplishment of devernalization.

A field experiment was conducted by Chauhan and Tandel (2009) during the Rabi season and found that spray of GA_3 and NAA significantly influenced the performance of growth, yield and quality characters of cabbage. The best plant growth regulator treatments for growth, yield and quality characters of cabbage was GA_3 @100 mgl-1 foliar spray at 30 and 45 days after transplanting (DAT) followed by NAA @100 mgl-1 foliar spray at 30 and 45 DAT.

De camacaro *et al.* (2013) observed that foliar application of gibberellic acid on vegetative attributes like crown height, crown spread, petiole length, leaf number, leaf area; flowering and fruit set, fruit size; production of albino, malformed and button berries, total yield and marketable fruit yield and quality parameters like juice content, TSS, ascorbic acid contents, acidity etc. were recorded significantly.

Roussos *et al.* (2009) had observed relatively higher antioxidant activity in strawberry juice such as high phenolic and flavonoid content. However, no significant effect was reported on pH, titratable acidity, organic acid and carbohydrates content. They have further confirmed highest total anthocyanin content in fruits after treatment with the plant hormones.

Experiments were conducted by Sharma and Singh (2009) to observe the effects of foliar application of gibberellic acid on vegetative growth, flowering, fruiting and various disorders in 'Chandler' strawberry. Observations were recorded on vegetative attributes like crown height, crown spread, petiole length, leaf number, leaf area; flowering and fruit set, fruit size; production of albino, malformed and button berries, total yield and marketable fruit yield and quality parameters, like juice content, TSS, ascorbic acid contents, acidity etc. Results indicated that GA_3 (75 ppm) spray either during mid-November or mid-February or at both times has favorably influenced all vegetative attributes 8 of 'Chandler' strawberry over control. Similarly, fruit set was increased, and production of malformed and button berries was reduced, but albinism remained unaffected.

Dhengle and Bhosale (2008) carried out an experiment and investigated the effect of GA_3 and/or NAA (both at 25, 50, 75 or 100 ppm) on the yield and yield parameters of cabbage. The highest yield was obtained with GA_3 at 50 ppm followed by NAA at 50 ppm. Combinations and higher concentrations of plant growth regulators proved less effective.

Ebeed *et al.* (2008) set up an experiment to know the effect of Gibberellic Acid and Male Bud Removal on Yield and Fruit Quality of Banana Plants. In this experiment, grand nain banana bunches were sprayed twice (just after emergence of the last hand and one month later) with GA_3 at 100 and 200 ppm in presence or with removing male bud. Results indicated that 3 removing male bud and spraying GA had a positive effect on improving yield and fruit quality. However, 3 removing male bud with spraying GA_3 at 200ppm twice after emergence of the last hand and one month later seem to be the promising treatment under this experiment conditions.

El-Shabasi *et al.* (2008) conducted an experiment to study the effect of ethrel (ethephon), GA_3 and uniconazole on strawberry plants. The results indicated that GA_3 application increased plant petiole. GA_3, ethrel and uniconazole increased total carbohydrate percentage in the foliage of strawberry plants. GA_3 and ethrel increased the number of flowers and the monthly and total yield.

Yadlod and Kadam (2008) conducted a field experiment to find out the effect of growth substances, micronutrients and waxol on growth, yield, and storage life of banana (*Musa* spp). Higher concentrations of IAA (80 ppm) and GA_3 (80 ppm) and micronutrients mixture 1% two spray enhanced the height, pseudostem girth and number of leaves. Early maturity vwas introduced with IAA (80 ppm) and GA_3 80 ppm delayed the maturity. Maximum weight of bunch was recorded with two sprays of 1% micronutrient mixture, maximum number of hands and fingers were recorded by IAA 80 ppm. Maximum length, girth and weight of mature finger (185.60 gm) were recorded in micronutrient mixture 1 % with two sprays. It was found that application of IAA 80 ppm, GA_3 80 ppm and two sprays of 1 % micronutrients mixture were effective for plant growth, finger attribute and yield.

Tripathi and Shukla (2006) investigated the effects of different concentrations of GA_3 (25, 50, and 100 ppm) on strawberry flowering and yield parameters. The results showed that plants treated with GA_3 at a concentration of 100 ppm took the fewest days to produce their first flower, had longer flowering times, and produced the most fruits per plant. The maximum duration of harvesting and yield per plant for plants treated with GA_3 at a concentration of 100 ppm were also recorded.

Singh and Singh (2006) conducted an experiment to study the response of bio-fertilizers and bio-regulators on strawberry crops and discovered that using 100 ppm GA_3 was most effective in increasing fruit set, early flowering, and yield. The application of GA_3 also resulted in the highest TSS, total sugar, and ascorbic acid content.

Paroussi *et al.* (2002) found that gibberellic acid (GA_3) application increased petiole length and leaf area of the strawberry plants. It reduced the time needed for inflorescence emergence, accelerated flowering and increased the number of flower buds and open flowers in different growing conditions.

An experiment was conducted by Yadav *et al*. (2000) during the rabi season to investigate the effects of NAA at 50, 100 and 150 ppm, gibberellic acid at 50, 100 and 150 ppm and succinic acid at 25o, 500 and 750 ppm, applied 2 spraying levels on growth and yield of cabbage cv. Golden Acre. The maximum plant height and plant spread was resulted from 2 sprays with gibberellic acid at 150 ppm. The highest number of open leaves and yield was obtained in the treatment with 2 sprays of gibberellic acid at 100 ppm.

Dharmender *et al.* (1996) conducted an experiment to find out the effect of GA_3 or NAA (both at 25, 50 or 75 ppm) on the yield of cabbage. They recorded the highest yield following treatment with GA_3 at 50 ppm followed by NAA at 50 ppm. They also reported that combination and higher concentrations of plant growth regulators proved less effective and were uneconomic in comparison to control.

Martinez *et al.* (1994) conducted an experiment to determine the effect of GA_3 on postharvest ripening in strawberry fruit using various biochemical parameters. The results revealed that GA_3 inhibits strawberry fruit ripening, as evidenced by a reduction in respiratory activity and a delay in anthocyanin synthesis and chlorophyll degradation.

Islam *et al.* (1993) determined the effective concentration of NAA and GA_3 for promoting growth, yield and ascorbic acid content of cabbage. They used 12.5, 25, 50 and 100 ppm of both the NAA and GA_3. They found that ascorbic acid content increased up to 50 ppm when sprayed twice with both the growth regulator, while its content was declined afterwards. They also added that two sprays with 50 ppm GA_3 was suitable both for higher yield and ascorbic acid content of cabbage.

Patil *et al.* (1987) conducted an experiment in a field trial with the cultivar Pride applied GA_3 and NAA each at 25, 50, 75 and 100 ppm one month after transplanting. Significant increase in number of outer and inner leaves was noticed with both GA_3. Head formation and head maturity was 13 and 12 days earlier with 50 ppm GA_3. The maximum number of leaves and the highest yield were obtained with 50 ppm GA_3.

Islam (1985) conducted an experiment with applying various growth regulators (CCC, GA_3, NAA and IBA) at 30 days after transplanting of 32 days old seedlings and found that GA_3 increased the plant height, number of loose leaves per plant, size of leaf and finally the yield.

2.2 Effect of different mulch materials on growth, yield and quality of strawberry

Paunovic *et al.* (2020) conducted an experiment using three mulch materials (sawdust, black foil and control) to determine the effect of mulches on soil properties, growth and yield of black currant. The soil covered with sawdust had a stimulating effect on nutrient content (humus, N, P and K) and microbial count in the soil. Sawdust mulch favoured the modification of soil microclimate through temperature reduction and maintenance of moderate soil moisture throughout the growing season. The relationship of physical, chemical and biological properties of the soil in black currants under sawdust mulch contributed to an increase in fruit yield and bush growth compared to bare soil and foil mulch. The results indicated that mulching with sawdust is an effective method for growth and yield improvement in black currants.

Iwuagwu *et al.* (2020) evaluated the growth and yield responses of pepper to sawdust mulch and NPK 15:15:15 fertilizer rates (0, 150, 300 and 450 kg ha^{-1}) applied sole and in combination with sawdust. It was found that combined use of sawdust mulch and NPK fertilizer increased significantly growth and yield of pepper compared to when either the mulch or the fertilizer was applied sole. The results obtained in this study showed that maximum pepper production can be achieved by combined use of sawdust mulch plus 300 kg ha^{-1} NPK 15:15:15 fertilizer.

Yimer (2020) made a review focused on to summarize information on different mulch material and effect of different mulch material on yield and yield component of garlic. The beneficial effect of mulch not only on yield of garlic, but also extend to quality of clove, to create congenial condition for growth this include regulating soil moisture and temperature, reduce salinity and weed control. Organic mulches are derived from plant and animal materials such as straw, hay, peanut hulls, leaf mold, compost, sawdust, woodchips, shavings and animal manures. Organic mulch are efficient in reduction of nitrates leaching, improve soil physical properties, prevent erosion, supply organic matter, regulate temperature and water retention, improve nitrogen balance, take part in nutrient cycle as well as increase the biological activity.

Ike *et al.* (2019) used various mulching materials (polythene sheet, trampoline sheet, sawdust, grasses and control) and observed that the highest fruit yield was from the plot mulched with sawdust. The result showed that the plot mulched with sawdust had greater fruit yield compared to the other mulching materials in both cropping seasons. The application of sawdust would reduce weed infestation and also enhances high fruit yield.

Jahan *et al.* (2018) used five different colored polyethylene films like black, white, blue, olive and silver were used as a treatment factor in filed condition to investigate the impact of different plastic film on the growth environment, yield parameters and phytochemical properties of lettuce. The maximum soil pH and temperature were found under black filming plots. Phytochemical concentrations and nutritive value of lettuce were also significantly affected by the colored plastic treatments. Furthermore, the chlorophyll, Vitamin C content, yield, anthocyanin, phenols and carotenoids contents were increased in plants grown in soil covered with black polyethylene.

Malik *et al.* (2018) conducted a field experiment to elucidate the effect of organic and inorganic mulches on the growth and yield of the chili crop. The mulching material includes organic (wheat straw) and inorganic (black and white polyethylene) with a control treatment of un-mulched/uncovered plot. It was observed that the maximum plant height and fruit yield were observed in white polyethylene mulch treatment.

Ahmed *et al.* (2017) conducted an experiment to know the influence of exogenous hormone on strawberry fruit quality and used two factors: cultivars (Camarosa and Camaroga) and foliage exogenous hormone (auxin (IBA), gibberellic acid (GA_3) or cytokinin (6-BA) with 0 and 50 ppm used either singly or in multi-combinations. The result showed that fruits of 'Camarosa' was higher on percentage of Titratable acidity (TA %), vitamin C, dry and organic matters than 'Camaroga' cv. Singly application of GA_3 increased the fruits contents of TA%, anthocyanin and vitamin C. Fruit levels of anthocyanin, TSS, dry and organic matters had increased by using the combination exogenous hormones. The results also indicated that the response of two cultivars to the effect of exogenous hormones was greatly appeared on fruit levels of TA %, anthocyanin and vitamin C.

Ahmed *et al.* (2017) set up an experiment to study the effect of runners' removal rates beside mothers full removal "no runners", five runners left, ten runners left and Without runners' removal and foliar spray of gibberellic acid 0 ppm, 25 ppm and 50 ppm and their interactions on vegetative growth, chemical properties, physiological traits, yield and quality of strawberry "Fortuna cv." planted under mixed planting system which fixed many runners beside mother plant with different density. Gibberellic acid (GA_3) was sprayed three time in 30 days intervals. The result indicated that foliar application of 25 ppm of gibberellic acid (GA_3) with removing all runners caused an increase in plant height, size, weight and shape index of the fruits. gibberellic acid (GA_3) at 25 ppm gave also the highest number of early fruits and early yield during both seasons, GA_3 also gave the highest value of TSS, vitamin C, number of leaves, number of fruits and the yield too.

Helaly *et al.* (2017) investigated the effects of different polyethylene mulches, namely black and double face (white on black) and discovered that the white on black polyethylene mulching treatment produced the highest significant maximum value of plant height, stem diameter, number of branches per plant, and leaf area.

Munoz *et al.* (2017) investigated the differences in physicochemical and microbial soil quality caused by the use of wheat straw or black polythene in strawberry cultivation. The black polythene mulch showed positive effects on soil physicochemical properties (water content, pH, effective cation exchange capacity, elemental analysis of total carbon and nitrogen, dissolved and total organic carbon, and soil stability by percentage of water-stable aggregates) as compared to straw mulching.

Pandey *et al.* (2016) used different kinds of mulch materials (rice husk, white polythene, black polythene, and no mulch) in soil to observe their effects on the soil physicochemical changes and on the growth, production, and quality of strawberries. White polythene mulch was effective in conserving soil moisture, which was higher as compared to no mulch. The maximum number of leaves and highest chlorophyll content at the time of harvest was observed in the case of white polythene mulch.

Lima *et al.* (2016) conducted an experiment to analyze the effect of sawdust mulch on the soil characteristics, growth and flower yield of the anthurium. Soil temperature, moisture, organic matter, bulk density and water retention conditions were improved, while the leaf area of plants and the yield of flower stalks were increased when the soil were mulched with sawdust. In addition to increasing soil organic matter, however, no change occurred in the level of nutrients in plants.

Rehman *et al.* (2015) observed the effect of different mulching materials (newspaper, black plastic, wheat straw, pine needle, saw dust mulch and control) on the fruit size and yield of Strawberry under the agro-climatic conditions of Mansehra. Results of the experiment showed that the maximum number of fruit/plant, maximum fruit size, single fruit weight, fruit diameter and yield were recorded for the sawdust mulch.

Soliman *et al.* (2015) conducted an experiment using different mulches (black polyethylene, clear polyethylene and non-mulched) on strawberry production and revealed that black polythene mulch increased the number of leaves, crown, leaf area, dry mass/plant, number of flowers and flowered earlier than non-mulched. The application of black polyethylene mulch increased most yield potential characters such as yield/plant and average fruit weight in a positive and significant way. Furthermore, black polyethylene significantly enhanced most fruit quality characteristics, such as total soluble solids, total titratable acidity, ascorbic acid, and reducing, non-reducing, and total sugars.

Pandey *et al.* (2015) found that among the different mulches (black, transparent polyethylene, straw mulch, silver mulch, wheat straw and no mulch) tested, black polythene performed the best in terms of growth, early flowering, fruiting and yield parameters.

Bakshi *et al.* (2014) carried out a study to evaluate the effects of different mulching materials (paddy straw, wheat straw, dry grass, transparent polyethylene, black polyethylene, and no mulch) on the growth, yield, and quality of strawberries. All the treatments improved the vegetative growth, yield and quality of strawberries, but black polythene mulch gave the best results in terms of reducing weed population, increasing plant height, plant spread, number of leaves per plant, number of flowers per plant, number of fruits per plant, fruit weight, yield, total soluble solids, vitamin-c and total sugars.

An experiment on brinjal (*Solanum melongena* L.) having seven growth regulators viz., control, 30 ppm GA_3, 40 ppm GA_3, 50 ppm GA_3, 20 ppm NAA, 40 ppm NAA, and 60 ppm NAA was conducted by Moniruzzaman *et al.* (2014) to find out the suitable variety responsive to growth regulators and to determine the suitable dose of growth regulator for brinjal production. The GA_3 (Gibberellic acid) and NAA (Naphthalene acetic acid) had no significant effect on plant height and stem diameter at the end of the crop period and days to 100% flowering. GA_3 40 ppm produced highest percentage of long and medium styled-flower, leaf photosynthesis and Fv/Fm (efficiency of photosystem II), number of fruits /plant and fruit yield.

Masarirambi *et al.* (2013) carried out a study to determine the effect of white plastic, sawdust mulches and control on growth, yield of cabbage, weed suppression and conservation of soil moisture on a loamy soil. The results indicated that there was no significant difference in yield of cabbage heads from plots mulched with white plastic or sawdust while the control produced relatively the lowest yield of cabbage. The results showed that both white plastic and sawdust mulches conserved moisture.

Kumar *et al.* (2012) carried out a field experiment to study the impact of different mulching materials (wheat straw, paddy straw, cut grass, green polythene, red polythene, pine needles, black polythene, white polythene and coconut husk) on the growth, yield, and quality of strawberries. All the treatments improved the vegetative growth, yield and quality of strawberries, but white polythene gave the best results in terms of plant height, plant spread, and petiole length, leaf per plant, flower per plant, fruit per plant, yield, length-to-diameter ratio, juice content, total soluble solid, total sugar, vitamin C and acidity of strawberry.

Singh and Kamal (2012) observed the effect of soil mulching with inorganic mulches (black polythene, transparent polythene, silver color polythene) and no mulch on soil temperature and tomato yield. The results revealed that the highest soil temperature was obtained under the black plastic mulch during the early growth season due to less shade on the surface. The yield was increased with black plastic mulch in the temperate region.

Rajablariani *et al.* (2012) used different plastic mulches (blue, black, clear, red, and silver on black) to evaluate the growth and yield of tomatoes and found that black and silver/black plastic mulches suppressed weeds which were encouraged under clear, blue, and red mulches. The number of branches and leaves were better for the plants grown over plastic compared to bare soil. The highest early yield was obtained in clear plastic, likely due to light entering and raising soil temperature.

Kher *et al.* (2010) conducted an experiment for standardization of mulching material to maximize growth and yield of strawberries under sub-tropical conditions. Plant height (cm), plant spread (cm), leaf area (cm^2), fruit weight (g) and fruit yield (g/plant) were significantly higher in plants mulched with black polyethylene than those either mulched with transparent polythene.

Kour and Singh (2009) used six mulching treatments (black polythene, white polythene, paddy straw, saw dust, dry grasses and control) to evaluate the effect of different mulching treatments on growth, yield and quality of strawberry. The maximum number of leaves, flowers, fruits and fruit yield were observed with white polythene. Highest TSS, sugar percentage and ascorbic acid percentage were also observed with white polythene.

Ravneet and Sarabjeet (2009) used six mulching treatments (black polythene, white polythene, paddy straw, saw dust, dry grasses, and control) to evaluate the effect of different mulching treatments on the growth, yield, and quality of strawberries. The maximum number of leaves, flowers, fruits and fruit yield were observed with white polythene. The highest TSS, sugar percentage, and ascorbic acid percentage were also observed with white polythene.

Medina *et al.* (2008) conducted an experiment to determine the effects of various plastic mulches (white on black, black, green, grey on grey, grey on black and grey on brown) on microclimate conditions, growth and yields of day-neutral strawberry grown under high tunnels. Black mulch caused excessive soil and air temperatures in tunnels, but was found adequate outdoors. The best growth and yield was obtained with green and white mulches under high tunnels.

Farias-Larios *et al.* (1997) carried out an experiment to determine the effect of three plastic mulch colours (black, white, and clear) on soil temperature, and fruit yield of watermelon. White plastic mulches increased fruit weight and total yield as compared with production. White polyethylene mulch has an important effect, and clear plastic could be a practical management tool for the increase of watermelon production and enhancement of fruit quality under tropical conditions.

Orozco-Santos *et al.* (1995) found that white polyethylene mulch on Cataloup fruit reduced whitefly populations, aphids caught in yellow traps and virus incidence with respect to bare soil (control). Also, soil temperatures in the morning, midday and afternoon were significantly increased in the white polyethylene mulch. Total fruit yield was positively influenced by the white mulched plot.

Singh *et al.* (1977) conducted an experiment to study the effect of mulching (Sawdust and rice husk) on sprouting, vegetative growth, yield and quality of potato. Sawdust mulch hastened and improved the sprouting in potato seed tubers. Sawdust mulch enhanced the plant height at the early stages of growth and improved the yield of potato.

2.3 Effect of GA_3 and different mulch materials on growth, yield and quality of strawberry

Kumar *et al.* (2022) under had taken a field experiment to study the effect of plant growth regulators and mulches on growth and yield of strawberry (Fragaria x ananassa Duch.) cv. Chandler. The results revealed that the different plant growth regulators and mulches effect on growth and yield of strawberry. Maximum plant height, number of leaves per plant, length of leaves and length of the petiole, number of flower per plant, number of fruit per plant and fruit weight per berry were recorded with GA_3 75ppm + black polyethylene. On the other hand, minimum values of these parameters were recorded in treatment Control. The minimum days taken to produce the first flower, days taken to 50% flowering were recorded with NAA 20ppm +black polyethylene, and the maximum days recorded with treatment control.

Mwaura *et al.* (2021) carried out an experiment to know the effect of nitrogen fertilizer, mulch and gibberellic acid on the fruit size, flesh thickness and firmness of multipurpose pumpkin. Application of N at 150kg N/ha and black mulch resulted to fruit size of and flesh thickness which was higher than the other treatments. The effect of GA_3 on the plant height, number of leaves, flowers, and fruits of multipurpose pumpkins was found significant.

Kaur and Mirza (2018) conducted an experiment to study the response of different mulches and PGR's on growth, yield and quality of Strawberry. GA_3 and NAA were used at concentrations of 50 and 100ppm in combination with three mulching materials viz., black, white polyethylene and straw mulch. The results showed that maximum plant height (cm), no of leaves/plant, leaf area (cm^2) were recorded in GA_3 100 ppm with white transparent mulch, whereas number of flowers, number of fruits, fruit weight, yield, TSS, acidity and ascorbic acid were recorded high with the application of GA_3 100ppm+Black polythene mulch.

Paikra (2018) carried out an experiment to know the combined effect of mulching and GA_3 on phisico-chemical changes in Guava. Mulching is a agricultural practices to cover the soil with plastic or straw/wheat dust on the top of the soil therefore, to control weed, excessive water evaporation and conservation of soil moisture. Plant growth regulators modify or regulate physiological processes in an appreciable measure in the plant when used in a small concentration and also play an important role in fruit set, fruit production, fruit weight and fruit size without causing any adverse effect in fruit quality.

Prasad *et al.* (2012) observed the effect of different mulches and PGRs (GA_3) on growth, flowering, fruiting and yield of strawberry using several treatments GA_3+ Black polythene mulch, GA_3+Transparent polyethylene mulch, GA_3 + Paddy straw mulch, NAA + Black polythene mulch, NAA + Transparent polythene mulch, NAA + Paddy straw mulch along with one control. The result revealed that the maximum plant height (cm), maximum number of flower, minimum days taken to first flowering, first fruit set, early maturity of fruits, early harvesting, number of fruit/plant and maximum yield were recorded observations on GA_3+Black polythene mulching.

Minz and Manorama (2010) conducted an experiment of Douglus cultivar with treatments GA_3 (25, 50, 100 ppm) with black polyethylene mulch, GA_3 (25, 50, 100 ppm) with transparent polyethylene mulch, GA_3 (25, 50, 100 ppm) with paddy straw mulch, NAA (10, 20, 40 ppm) with black polyethylene mulch, NAA (10, 20, 40 ppm) with transparent polythene mulch, NAA (10, 20, 40 ppm) with paddy straw mulch along with one control. Result revealed that the different mulching with PGRs application significantly affect the plant growth, yield and quality of fruit. The minimum days taken to first flowering ,first fruit set, maximum plant height, fruit length and breadth (cm), Juice (%), TSS (°Brix), acidity (%), Total sugars (%), Reducing sugar (%), Ascorbic acid (mg/100g fruit) and phenol (mg/100g fruit) content were observed with GA_3 100ppm + Black polyethylene mulch. So it can be noted that significant increase in growth, yield and quality could be obtained by the application of GA_3 (100 ppm) with black polyethylene mulch.

Sharma and Singh (1990) conducted an experiment with GA_3 treatment at 10, 75, 100 or 150 ppm. GA_3 applied as 2 sprays combined with covering with plastic mulches, all gave significantly higher yields of cv. Pusa. Significant data on plant height, plant spread, fruit numbers/plant, individual fruit weight, and fruit TSS and acidity were recorded. The treatments gave the increased vegetative growth and highest yield.

CHAPTER III

MATERIALS AND METHODS

The experiment was carried out to study the growth and yield of strawberry as influenced by different level of gibberellic acid (GA_3) and mulching material. The materials and methods that were used for conducting the experiment are presented under the following heads:

3.1 Experimental location

Under natural lighting, the experiment was conducted at the Horticulture Farm of Sher-e-Bangla Agricultural University in Dhaka, Bangladesh in October 2020 to February 2021. According to the National Mapping Organization of Bangladesh, Dhaka is located at 23°42′37″ N (Latitude), 90°24′26″ E (Longitude), and has an average elevation of 4 meters (13.12 ft.).

3.2 Characteristics of soil

Selected soil of the experimental plot was collected from SAU field which was medium high land in nature. The soil belongs to the Modhupur Tract (UNDP, 1988) under AEZ No. 28. The soil texture of the experimental soil was sandy loam. The nutrient status of the farm soil under the experimental plot with in a depth 0-20 cm were collected and analyzed in the Soil Resource and Development Institute Dhaka, and result have been presented in Appendix I.

3.3 Climatic condition

The experimental site was situated in the subtropical climatic zone, characterized by heavy rainfall during the months from April to September and scanty rainfall during the rest of the year (Rabi season). Details of weather data in respect of maximum and minimum temperature (°C), relative humidity (%) and rainfall (cm) during the study period were collected from the Bangladesh Meteorological Department (climate division), Agargaon, Dhaka-1207 (Appendix- II).

3.4 Plant materials and growing conditions

Strawberries of the cv. Festival were collected from Jannat Nursary, Agargaon, Dhaka and planted in raised beds at 60 cm x 30 cm spacing under a netting house (Plate 1a). The average temperature was 23±2℃ in daytime and 13±2℃ at night, with a relative humidity of 65 to 70%. GA3 (0 and 200 ppm) was employed in the present study with different mulch materials (no mulch, sawdust, white and black polythene) (Plate 2). During the experiment, all essential cultural practices and plant protection measures were followed across all the plots. Growth, yield and physicochemical parameters were measured on randomly selected plants in each replication.

3.5 Treatments of the experiment

The experiment was comprised of two factors.

Factor A: Gibberellic acid

1. G_0 = No GA_3
2. G_1 = 200 ppm GA_3

Factor B: Mulch materials

1. M_0 = No mulch
2. M_1 = Black polythene
3. M_2 = White polythene
4. M_3 = Sawdust

Treatment combinations – Eight treatment combinations were as follows:

G_0M_0, G_0M_1, G_0M_2, G_0M_3, G_1M_0, G_1M_1, G_1M_2, G_1M_3

3.6 Experimental design

A randomized complete block design with five replications was used for the experiment. The layout of the experiment was prepared for distributing the combination of GA_3 and mulch materials. GA_3 consisted of 2 different concentrations and mulch materials consisted of 4 different types. The 8 treatment combinations of the experiment were assigned.

3.7 Preparation of the main field and planting of seedling

The plot selected for the experiment was opened in the last week of October, 2020 with a power tiller, and was exposed to the sun for a few days, after, which the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain a good tilth. Weeds and stubbles were removed and finally obtained a desirable tilth of soil for transplanting. The land preparation was completed on 25th October 2020. The individual plots were made by making ridges (20 cm high) around each plot to restrict lateral runoff of irrigation water. Healthy and uniform sized seedlings/plantlets were planted in the experimental field on 1st November, 2020.

Plate 1: Strawberry seedling (a) and foliar application of GA_3 on plant (b).

Plate 2: Strawberries grown with different types of mulch

3.8 Fertilizers and manure application

Manures and fertilizers were applied to the experimental plot considering the recommended fertilizer doses of strawberry (Table 1). The total amount of Cow dung, TSP, Gypsum and half of MOP was applied as basal dose at the time of land preparation. On the other hand the total amount of urea and half of MOP was applied at three equal installments at 15, 25 and 35 days after transplanting.

Table 1: Doses and fertilizer application method in strawberry field

Fertilizers and manures	Doses/ha
Cow dung	30 ton
Urea	250 kg
TSP	200 kg
MOP	220 kg
Gypsum	150 kg

Source: KRISHI PROJUKTI HATBOI (Handbook on Agro-Technology), 9th edition Bangladesh Agricultural Research Institute, Gazipur-1701, Bangladesh

3.9 Preparation and application of GA_3

200 ppm solution of GA_3 was prepared by dissolving 200 mg of it in a small quantity of distilled water prior to dilution with 2 pellets of Na_2CO_3 in one liter of volumetric flask. Then it was volumed up to 1000 ml with distilled water. GA_3 as per treatment were applied at two times 15 and 35 days after transplanting by a mini hand sprayer (Plate 1 b).

3.10 Intercultural operations

3.10.1 *Weeding*

Weeding is an important intercultural operation for successful production of strawberry for both commercial and research level. Weeds of different types were removed and collected from the field manually as and when necessary. The collected weeds were piled in bunds or in case of certain weeds, taken home to feed animals.

3.10.2 *Irrigation*

Light over-head irrigation was provided with a watering cane to the plots immediately after transplanting and it was continued for a week for rapid and well establishment of the planted seedlings. Irrigation was also applied as and when necessary.

3.10.3 *Disease and pest management*

Diseases and pests is a major limiting factor to strawberry production. Experimental strawberry plants were treated with Malathion 250 EC and Cupravit 50 WP to prevent unwanted disease problems @0.5 ml/L and 2 g/L. On the other hand, leaf feeder is one of the important pests during growing stage. Leaf feeder was controlled by Pyrithrum @ 1.5

ml/L. Those fungicides and pesticide were sprayed two times, first at vegetative growing stage and next to early flowering stage to manage pests and diseases.

3.11 Harvesting of fruits

Harvesting of fruits was done after the fruits reached at maturity stage. Mature fruits were harvested when fruits turned to red in color with waxy layer on surface of fruits. Harvesting was done manually. Proper care was taken during harvesting to prevent damage of strawberry fruits. Fruits were harvested from January 2020 to February 2021.

3.12 Data collection: Growth, yield and physiochemical parameters were measured on randomly selected plants in each replication.

3.12.1 *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.

3.12.2 *SPAD 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.

3.12.3 *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 65°C for 24 hours in order to determine their dry weights (DW). RWC was calculated by using the following formula.

$$RWC\ \% = ((FW - DW) / (TW - DW)) * 100.$$

3.12.4 *Floral trait*

Five randomly selected plants were chosen for each treatment and replication to record observations on days to flowering per plant.

3.12.5 *Measurements of yield and yield contributing traits*

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.

3.12.6 *Total soluble solids content*

The TSS content of strawberry was measured by a digital refractometer (MA871; Romania). A drop of strawberry juice was obtained by dropper and placed on the refractometer prism. The refractometer showed a reading of total soluble solids.

3.12.7 *p^H determination*

A digital pH meter was used to assess pH of individual treated strawberries' fruit juices (HI 2211; Romania).

3.12.8 *Titratable acidity (TA %)*

In order to measure titratable acidity, a 5 g sample was macerated in a mortar and pestle. After filtering it and adding distilled water, the total volume was 100ml. A conical flask was then filled with 10 ml of the stock solution and 2 drops of phenolphthalein were added. 0.1N NaOH was used to titrate the solution. On the basis of triplicate analyses, the total acid content was calculated in maleic acid equivalents.

3.12.9 *Ascorbic acid determination*

The Oxidation-Reduction Titration Method (Tee *et al*. 1988) was used to calculate the Ascorbic acid content of strawberries. The fruit was blended and filtered with Whatman No.1 filter paper. Oxalic acid (5%) was used to make a volume of 100ml. We used the dye solution 2, 6-dichlorophenol indophenol to carry out the titrations. L-ascorbic acid as the known sample, the mean observations provided the amount of dye required to oxidize an unknown concentration of a specific amount of L-ascorbic acid solution. 5ml of the solution was used for each titration, and the last point of titration was determined by the pink color, which lasted for 10 seconds. As a result, a burette reading was taken and stored.

3.12.10 *Reducing sugars content*

To measure reducing sugars, the phenol-sulfuric acid method was used (Dubois *et al*. 1956). A total of 0.2 g fresh fruit was homogenized and the extract was filtered using deionized water. 0.4 ml of 5% phenol was added to 2 ml of the solution. The mixture was then quickly diluted with 2 ml of 98% sulphuric acid. The test tubes were kept at room temperature for 10 minutes before being placed in a water bath at 30°C for 20 minutes to allow for colour development. The spectrophotometer was used to measure the absorbance at 540 nm. The same method was used to make a blank solution, except that distilled water was used instead of fruit extract in this case. Reducing sugar content was expressed as mg g^{-1} fresh weight (FW).

3.12.11 *Anthocyanin content*

1.0 g fruit pulp mixed with 1 ml 85% ethanol + 15% HCl 1.5N. After the extraction, 1 mL of sample solution was taken and diluted to 10 ml. An absorbance measurement was performed at a wavelength of 535 nm. The anthocyanin concentration was calculated as follows: Anthocyanin (mg per 100 g fresh wt.) = (absorbance at 535nm x volume of extraction solution x 100)/ sample weight in g x 98.2. The same procedure as described above is used to prepare reference solutions, except that the fruit extract is replaced with distilled water (Lapornik *et al*. 2005).

3.12.12 *Phenolic content*

The phenol content was determined by Singleton, Orthofer, and Lamuela-Raventós (1999). Fresh fruits (250 mg) were homogenized in 85% methanol. The extract was centrifuged at 3,000 g for 15 minutes at 10°C and the supernatant was collected. A total of 2 ml of the supernatant has been added to 2 ml of Folin and Ciocalteu's reagent. Each test tube received a 7.5% sodium carbonate solution (2 ml), and after 30-45 minutes, the absorbance was measured at a wavelength of 725 nm against a reagent blank. A standard curve was created with gallic acid to determine the concentration of total phenols in the unknown sample.

3.13 Statistical analyses

A randomized complete block design (RCBD) was used in the experiments, with four replications for each treatment and five plants in each replicate. Statistical analyses were conducted with Statistics 10 (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.

CHAPTER IV

RESULTS AND DISCUSSION

Strawberry is an important delicious fruit in Bangladesh. GA_3 and mulch are important factor to increase strawberry yield. With the respect the experiment was conducted to find out the growth and yield of strawberry as influenced by GA_3 and mulch materials. The analysis of variance (ANOVA) of the data on different growth and yield parameters are presented in Appendices. The results have been presented and discussed with the help of table and graphs and possible interpretations are given under the following sub-headings:

4.1 Growth and physiological parameters

4.1.1 Plant height (cm)

Significant influence was found on the plant height of strawberry with application of GA_3 and non GA_3 both flowering and fruiting stage (Table 2 and Appendix III). Results revealed that all GA_3 sprayed plants showed increased plant height compared to the non GA_3 treated plants. At flowering stage, the highest plant height (18.55 cm) was recorded from the G_1 treatment (200 ppm GA_3). The lowest plant height (15.31 cm) was found from the G_0 treatment (No GA_3). At fruiting stage, the highest plant height (19.79 cm) was observed with the treatment G_1 (200 ppm GA_3) and the lowest plant height (16.97 cm) was observed from the G_0 treatment (No GA_3). Rakesh *et al.* (2014), Qureshi *et al.* (2013), Eshghi *et al.* (2012) and Kumar *et al.* (2012) 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.

Different types of much materials showed significant variation on plant height of strawberry both flowering and fruiting stage (Table 2 and Appendix III). At flowering stage, the highest plant height (18.75 cm) was recorded under M_3 treatment (sawdust mulch) which was statistically identical to M_2 (17.54 cm) treatment (white polythene mulch). The lowest plant height (15.70 cm) was recorded under M_2 treatment (black polythene) which was statistically identical to M_0 (15.75 cm) treatment. At fruiting stage, the highest plant height (21.08 cm) was found from the treatment M_3 (sawdust mulch). The lowest plant height (16.03 cm) was observed under M_1 treatment (black polythene).

Soliman *et al.* (2015) and Qureshi *et al.* (2012) 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. Black polythene decreases plant height by raising soil temperature. Extreme heat stress (even in the presence of adequate soil moisture) can cause a reduction in plant stomatal conductance, which reduces plant transpiration rate, causing reductions in plant productivity and yield.

Plant height of strawberry at different growth stages was varied significantly due to combined effect of GA_3 and mulch materials both flowering and fruiting stage (Table 3 and Appendix III). At flowering stage, the highest plant height (19.50 cm) was observed from the treatment combination of G_1M_3 which was statistically identical with G_1M_2 (19.33 cm), G_0M_3 (18.00 cm), G_1M_1 (17.90 cm). The lowest plant height (13.50 cm) was recorded from the treatment combination of G_0M_1 which was significantly identical to G_0M_0 (14.00 cm) but different from other treatment combinations. At fruiting stage, it was found that the highest plant height (21.50 cm) was found from the treatment combination of G_1M_3 which was statistically identical to the treatment combinations of G_1M_2 (19.83 cm), G_0M_3 (20.66 cm). The lowest plant height (13.73 cm) was observed from the treatment combination of G_0M_1 which was significantly different from other treatment combinations but it was statistically identical with G_0M_0.

4.1.2 Number of leaves plant^{-1}

Significant influence was found for number of leaves plant^{-1} of strawberry as influenced by GA_3 and non GA_3 both flowering and fruiting stage (Table 2 and Appendix III). At flowering stage, results revealed that the highest number of leaves plant^{-1} (11.16) was recorded from the G_1 treatment (200 ppm GA_3). The lowest number of leaves plant^{-1} (9.62) was found from the treatment G_0 (No GA_3). But at fruiting stage, no significant difference was found for number of leaves of strawberry as influenced by GA_3 and non GA_3 (Table 2 and Appendix III). Bist *et al.* (2018), Palei *et al.* (2016) and Rajbhar *et al.* (2015) reported increase in number of leaves in strawberry following use of GA_3. Kaur *et al.* (2009) also noticed that exogenous application of GA_3 induced higher number of leaves in strawberries. The ability of gibberellins to stimulate the process of cell division and expansion in epidermal and parenchyma cells has been well documented. Such activities in the meristematic tissue of leaf primordial in GA_3 treated plants might be higher and perhaps a greater number of leaves with broader leaf lamina and petiole of longer length.

Different types of much materials showed significant variation on number of leaves of strawberry both flowering and fruiting stage (Table 2 and Appendix III). At flowering stage, the highest number of leaves plant^{-1} (11.41) was recorded under M_2 treatment (white polythene) which was statistically identical to M_0 (11.25) treatment. The lowest number of leaves plant^{-1} (9.33) was recorded under M_1 treatment (black polythene) which was statistically identical to M_3 (9.58) treatment (sawdust mulch). At fruiting stage, the highest number of leaves plant^{-1} (13.33) was found from the treatment M_2 (white polythene). The lowest number of leaves plant^{-1} (10.50) was observed under M_3 treatment (sawdust mulch) which was statistically similar to M_1 (10.91) treatment (black polythene). Kaur and Mirza (2018), Kour and Singh (2009) observed that number of leaves plant^{-1} was influenced significantly by white transparent mulch which may be due to better conservation of moisture. Optimum soil heat includes better biological function of soil and light penetration. It greatly influences the vegetative growth of plants. Under sawdust mulch, optimum soil temperature and moisture are available but due to large sized leaf, the number of leaves plant^{-1} is low.

Number of leaves plant^{-1} of strawberry at different growth stages was varied significantly due to combined effect of GA_3 and mulch materials both flowering and fruiting stage (Table 3 and Appendix III). At flowering stage, the highest number of leaves plant^{-1} (12.33) was observed from the treatment combination of G_1M_2 which was statistically similar to the treatment combinations of G_1M_0 (11.66). The lowest number of leaves plant^{-1} (8.33) was recorded from the treatment combination of G_0M_1 which was statistically similar to the treatment combination of G_0M_3 (8.83). At fruiting stage, it was found that the highest number of leaves plant^{-1} (13.66) was found from the treatment combination of G_1M_2 which was statistically identical to the treatment combination of G_0M_2 (13.00), G_1M_0 (12.33). The lowest number of leaves plant^{-1}(10.33) was observed from the treatment combination of G1M3 which was significantly similar to the treatment combination of G_1M_1 (10.33), G_0M_1 (10.50), G_0M_3 (10.66), G_0M_0 (11.66).

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	Flowering stage	Fruiting stage
GA_3				
G_0	15.31 b	16.97 b	9.62 b	11.45 a
G_1	18.55 a	19.79 a	11.16 a	11.91 a
CV%	6.45	5.05	7.11	9.75
$LSD_{0.05}$	0.95	0.81	0.64	0.99
Mulch materials				
M_0	15.75 b	18.08 b	11.25 a	12.00 ab
M_1	15.70 b	16.03 c	9.33 b	10.91 bc
M_2	17.54 a	18.33 b	11.41 a	13.33 a
M_3	18.75 a	21.08 a	9.58 b	10.50 c
CV%	6.45	5.05	7.11	9.75
$LSD_{0.05}$	1.35	1.14	0.91	1.41

G_0 = No GA_3, G_1 = 200 ppm GA_3, M_0 = no mulch, M_1 = black polythene, M_2 = white polythene, M_3 = sawdust. 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 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
G_0M_0	14.00 de	16.66 d	10.83 b	11.66 bcd
G_0M_1	13.50 e	13.73 e	8.33 c	10.50 cd
G_0M_2	15.75 cd	16.83 d	10.50 b	13.00 ab
G_0M_3	18.00 ab	20.66 ab	8.83 c	10.66 cd
G_1M_0	17.50 bc	19.50 bc	11.66 ab	12.33 abc
G_1M_1	17.90 ab	18.33 cd	10.33 b	11.33 bcd
G_1M_2	19.33 ab	19.83 abc	12.33 a	13.66 a
G_1M_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

G_0 = No GA_3, G_1 = 200 ppm GA_3, M_0 = no mulch, M_1 = black polythene, M_2 = white polythene, M_3 = sawdust. Means followed by same letter(s) in a column do not differ significantly at 5 % level of LSD.

4.1.3 Leaf Area

Significant influence was found for leaf area of strawberry as influenced by GA_3 and non GA_3 (Table 4 and Appendix IV). Results revealed that the maximum leaf area plant^{-1} (74.15 cm^2) was recorded from the G_1 treatment (200 ppm GA_3). The minimum leaf area plant^{-1} (71.88 cm^2) was found from the G_0 treatment (No GA_3). Bist *et al.* (2018), Vishal *et al*. (2016), Kumar *et al.* (2013) and Qureshi *et al.* (2013) 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. This could be the fact that gibberellins increased cell division, cell elongation and cell length due to increase in epidermal and parenchyma cell.

Different types of mulch materials showed significant variation on leaf area of strawberry (Table 4 and Appendix IV). The maximum leaf area plant^{-1} (80.02 cm^2) was recorded under M_3 treatment (Sawdust mulch). The minimum leaf area plant^{-1} (67.02 cm^2) was recorded under M_1 treatment (black polythene). Ali and Gaur (2013), Singh *et al.* (2005), Sharma *et al.* (2003) reported the positive role of sawdust mulch in enhancing leaf area of strawberry than other mulches of paddy straw, clear polyethylene mulch. This may be attributed to better soil hydrothermal regimes and suppression of weeds which decreased the competition among the plants and weeds and helped the plant to produce more leaves with more leaf area. The enhancement of soil properties like cation exchange capacity and soil microbial activity also led to the growth of the leaf acquiring more leaf area.

Leaf area plant^{-1} of strawberry at different growth stages was varied significantly due to combined effect of GA_3 and mulch materials (Table 5 and Appendix IV). The maximum leaf area plant^{-1} (80.97 cm^2) was observed from the treatment combination of G_1M_3 which was statistically similar to the treatment combination of G_0M_3 (79.06 cm^2). The minimum leaf area plant^{-1} (66.08 cm^2) was recorded from the treatment combination of G_0M_1 which was statistically similar to the treatment combination of G_0M_0 (69.33 cm^2) and G_1M_1 (67.97 cm^2).

4.1.4 SPAD reading

Significant influence was found for chlorophyll (SPAD value) content of strawberry as influenced by GA_3 and non GA_3 (Table 4 and Appendix IV). The maximum chlorophyll content (45.03) was found under G_1 treatment (200 ppm GA_3). The reason was due to application of GA_3 that boosted the process of photosynthesis which needed more light absorption and water, thus higher chlorophyll content. GA_3 acted to accumulate nutrition elements from plant parts to positions which GA_3 accumulated. Some of these nutrition elements became parts of new chlorophyll molecule (Shahid *et al.*, 2011). GA_3 supplies the required nutrition for chlorophyll formation while manganese activates the enzymes which accelerate the process. Sardoei and Shahdadneghad (2014) conducted an experiment to evaluate the effect of gibberellic acid on photosynthetic pigments of marigold (*Calendula officinalis* L.). It was observed that GA_3 significantly increased the photosynthetic pigments (Chlorophyll a and Chlorophyll b). But in control plants, there was no application of GA_3 and above activity was less promoted, thus resulted in lower chlorophyll.

Different types of much materials showed significant variation on chlorophyll content of strawberry both flowering and fruiting stage (Table 4 and Appendix IV). The maximum chlorophyll content plant^{-1} (47.61) was recorded under M_3 treatment (sawdust mulch). The minimum chlorophyll content plant^{-1} (41.60) was recorded under M_1 treatment (black polythene). Decoteau *et al.* (1988) affirmed that plants grown on different types of plastic mulches respond to even the small changes in ambient light induced by mulch color. The exact reason is beyond the comprehension of authors however possibly the higher chlorophyll content in plant grown on white mulch may be attributed to differential of synthesis and degradation of chlorophyll on white polythene. Further, the high activity of enzyme chlorophyllase may also be attributed to less chlorophyll content in the leaves under control. The differential values of the chlorophyll may be due to differences in degree of light reflection by the mulches. In case of white polythene mulch it appears that plant was still in vegetative active phase as evidenced in terms of higher chlorophyll content.

Chlorophyll content plant^{-1} of strawberry at different growth stages was varied significantly due to combined effect of GA_3 and mulch materials (Table 5 and Appendix IV). The maximum chlorophyll content plant^{-1} (48.23) was observed from the treatment combination of G_1M_3 which was statistically similar to the treatment combinations of G_0M_3 (47.00). The minimum chlorophyll content plant^{-1} (40.70) was recorded from the treatment combination of G_0M_1.

4.1.5 Relative water content

Significant influence was found for relative water content (%) of strawberry as influenced by GA_3 and non GA_3 (Table 4 and Appendix IV). Results revealed that greater relative water content (72.34 %) was recorded from the G_1 treatment (200 ppm GA_3). Lower relative water content (69.14 %) was found from the G_0 treatment (No GA_3). Habibi *et al.* (2021), Kaya *et al.* (2006) and Bakhtenko (2001) 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. It occurs because photosynthetic activity, transpiration rate, stomatal conductance and sub-stomatal conductance are increased with the foliar spray of GA_3 under normal and water stress conditions.

Different types of mulch materials showed significant variation on relative water content of strawberry (Table 4 and Appendix IV). The relative water content (74.32 %) was recorded greater under M_3 treatment (Sawdust mulch) which was statistically identical with M_2 (White polythene) and M_1 (Black polythene) treatment. The relative water content (63.53 %) was recorded lower under M_0 treatment. Chen *et al.* (2016) and Zhao *et al.* (2014) characterized the photosynthesis efficiency, canopy temperature and highest relative leaf water content under the effect of soil mulching. Sawdust mulch can conserve soil water and decrease temperature because it increases residue accumulation and reduces soil disturbance on the soil surface compared to others. So the relative water content under sawdust mulch is high.

Relative water content (%) of strawberry at different growth stages was varied significantly due to combined effect of GA_3 and mulch materials (Table 5 and Appendix IV). The greater relative water content (76.45 %) was observed from the treatment combination of G_1M_3 which was statistically similar to the treatment combination of G_1M_1 (73.87 %) and G_1M_2 (73.16 %). The lower relative water content (61.16 %) was recorded from the treatment combination of G_0M_0.

Table 4: Effect of GA_3 and mulch materials on leaf area, SPAD value and relative water content of strawberry

Treatments	Leaf area (cm^2)	SPAD value	Relative water content (%)
GA3			
G_0	71.88 b	43.40 b	69.14 b
G_1	74.15 a	45.03 a	72.34 a
CV%	1.99	1.75	2.88
$LSD_{0.05}$	1.26	0.67	1.78
Mulch materials			
M_0	70.50 c	42.78 c	63.53 b
M_1	67.02 d	41.60 d	72.43 a
M_2	74.53 b	44.88 b	72.69 a
M_3	80.02 a	47.61 a	74.32 a
CV%	1.99	1.75	2.88
$LSD_{0.05}$	1.79	0.95	2.52

G_0 = No GA_3, G_1 = 200 ppm GA_3, M_0 = No Mulch, M_1 = Black polythene, M_2 = White polythene, M_3 = Sawdust. Means followed by same letter(s) in a column do not differ significantly at 5 % level of LSD.

Table 5: Combined effect of GA_3 and mulch materials on leaf area, SPAD value and relative water content of strawberry

Treatments	Leaf area (cm^2)	SPAD value	Relative water content (%)
G_0M_0	69.33 ef	42.06 e	61.16 d
G_0M_1	66.08 f	40.70 f	70.99 b
G_0M_2	73.06 cd	43.86 c	72.23 b
G_0M_3	79.06 ab	47.00 ab	72.18 b
G_1M_0	71.66 de	43.50 cd	65.90 c
G_1M_1	67.97 ef	42.50 de	73.87 ab
G_1M_2	76.00 bc	45.90 b	73.16 ab
G_1M_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

G_0 = No GA_3, G_1 = 200 ppm GA_3, M_0 = No Mulch, M_1 = Black polythene, M_2 = White polythene, M_3 = Sawdust. Means followed by same letter(s) in a column do not differ significantly at 5 % level of LSD.

4.2 Yield and Yield contributing parameters

4.2.1 Days to flowering

Significant influence was found for days to flowering of strawberry as influenced by GA_3 and non GA_3 (Figure 1 and Appendix V). Results revealed that all plants under GA_3 treatment required minimum days to flowering compared to the non GA_3 treated plants. The minimum days (35.80 days) were recorded from the G_1 treatment (200 ppm GA_3). The maximum days (41.29 days) were found from the G_0 treatment (No GA_3). Kumar *et al.* (2014), Jamal Uddin *et al.* (2012), Sharma and Singh (2009) and Paroussi *et al.* (2002) reported that flowering is boosted and early flowering is induced by 200 ppm GA_3 treatment. The possible reason of inducing early flowering is due to the stimulation of Florigen hormone by gibberellic acid.

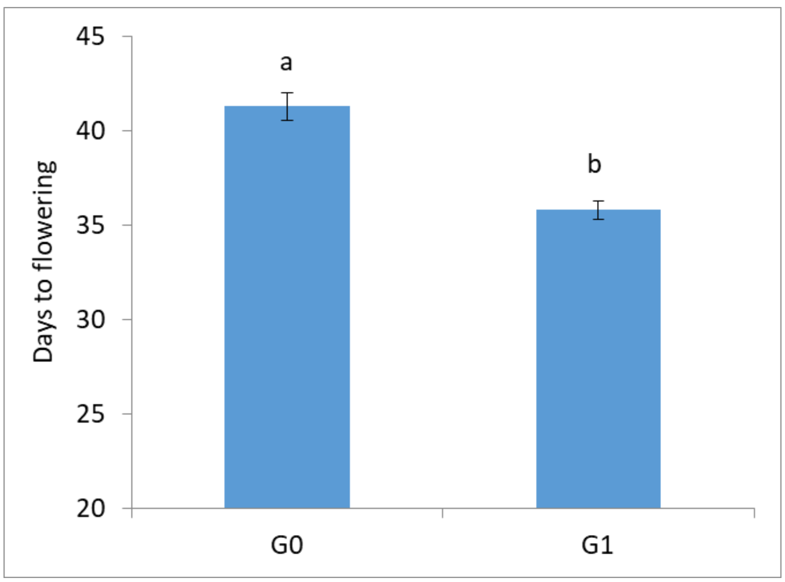

Figure 1: Effect of GA_3 on days to flowering of strawberry

G_0 = No GA_3, G_1 = 200 ppm GA_3

Different types of mulch materials showed significant variation on days to flowering of strawberry (Figure 2 and Appendix V). The minimum days (35.30 days) were recorded from the M_1 treatment (black polythene). The maximum days (42.20 days) were found from the M_0 treatment (No mulch). Tegen *et al.* (2016), Younis *et al.* (2012), Liu *et al.* (2011), Zhang *et al.* (2009), Solaiman *et al.* (2008) 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.

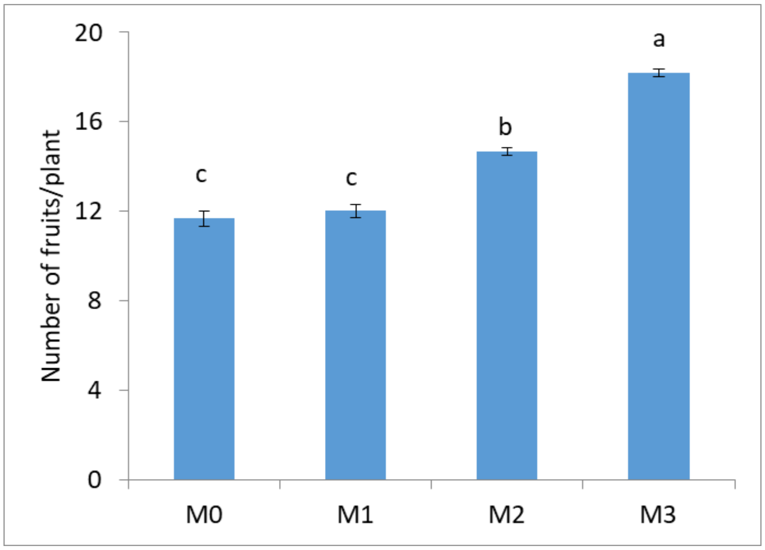

Figure 2: Effect of mulch materials on days to flowering of strawberry

M_0 = No Mulch, M_1 = Black polythene, M_2 = White polythene, M_3 = Sawdust

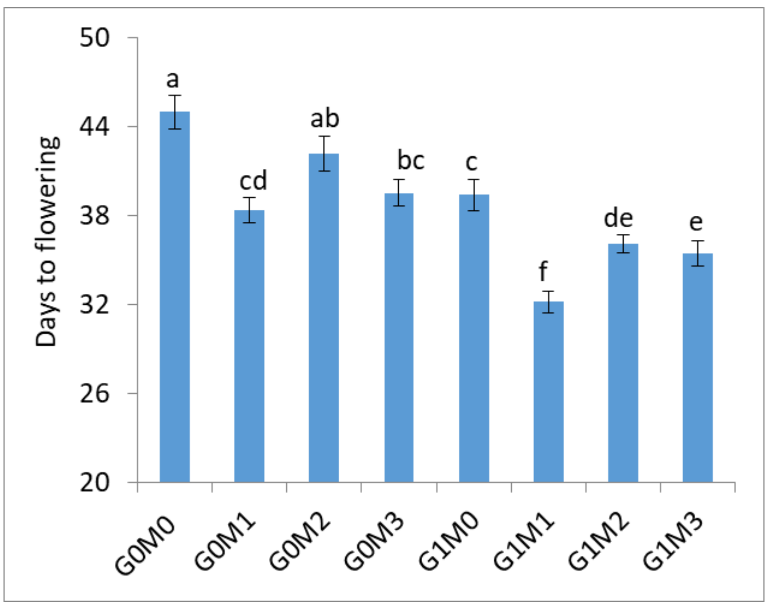

Figure 3: Combined effect of GA_3 and mulch materials on days to flowering of strawberry

G_0 = No GA_3, G_1 = 200 ppm GA_3, M_0 = No Mulch, M_1 = Black polythene, M_2 = White polythene, M_3 = Sawdust

The number of days to flowering of strawberry at different growth stages was varied significantly due to combined effect of GA_3 and mulch materials (Figure 3 and Appendix

V). The minimum days (32.20 days) were observed from the treatment combination of G_1M_1 which was significantly different from other treatment combinations. The maximum days (45.00 days) were recorded from the treatment combination of G_0M_0 which was statistically similar to the treatment combination of G_0M_2 (42.22 days).

4.2.2 Number of fruits plant^{-1}

Significant influence was found for number of fruits plant^{-1} of strawberry as influenced by GA_3 and non GA_3 (Figure 4, Plate 2 and Appendix V). Results revealed that all plants treated with GA_3 gave maximum number of fruits compared to the non GA_3 treated plants. The highest number of fruits plant^{-1} (16.33) was found in the treatment G_1 (200 ppm GA_3). The lowest number of fruits (11.91) was observed in G_0 treatment (No GA_3). Ramteke *et al.* (2015), Saima *et al.* (2014), Kumar *et al.* (2014) and Ouzounidou *et al.* (2010) found maximum number of fruits in treatment with GA_3. Higher number of fruits under GA_3 treatment might be due to the fact that gibberellic acid causes the production of large number of flowers with rapid elongation of peduncle, acceleration the development of differentiated inflorescences and leading to full development of flower buds having all reproductive parts functional and accumulate higher starch, carbohydrates and photosynthates (Iqbal *et al.*, 2011) which increases the fruit set and number of fruits per plant.

Different types of mulch materials showed significant variation on number of fruits plant^{-1} of strawberry (Figure 5 and Appendix V). The highest number of fruits plant^{-1} (18.16) was recorded under M_3 treatment (sawdust mulch). The lowest number of fruits plant^{-1}(11.66) was recorded under M_0 treatment (No mulch) which was statistically similar to the M_1 treatment (12.00). Shashidhar *et al.* (2009) noted that low temperature and moderate moisture of the soil mulched with sawdust during the growing season stimulated an increase in nutrient levels and microbial activity in the soil and acted as a catalyst for root activities, including the uptake of water and nutrients (Pandey *et al*., 2016). The ensuing changes in the structure of microbiological characteristics and processes in the soil may be attributed to changes in soil physical and chemical properties and led to an increase in more number of flowers and yield of black currants grown under sawdust mulch (Kher *et al.* 2010, Stark *et al.* 2007).

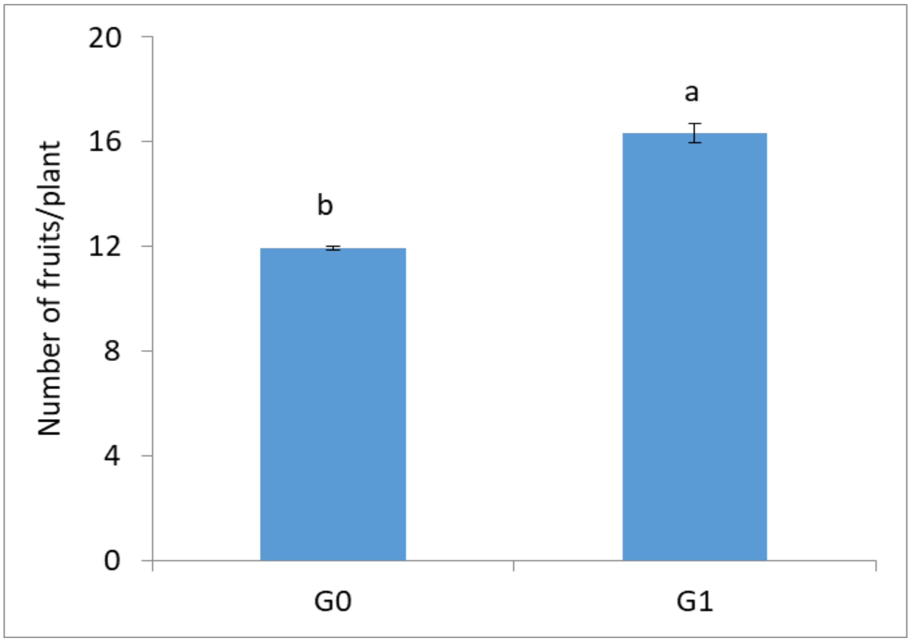

Figure 4: Effect of GA_3 on the number of fruits plant^{-1} of strawberry
G_0 = No GA_3, G_1= 200 ppm GA_3

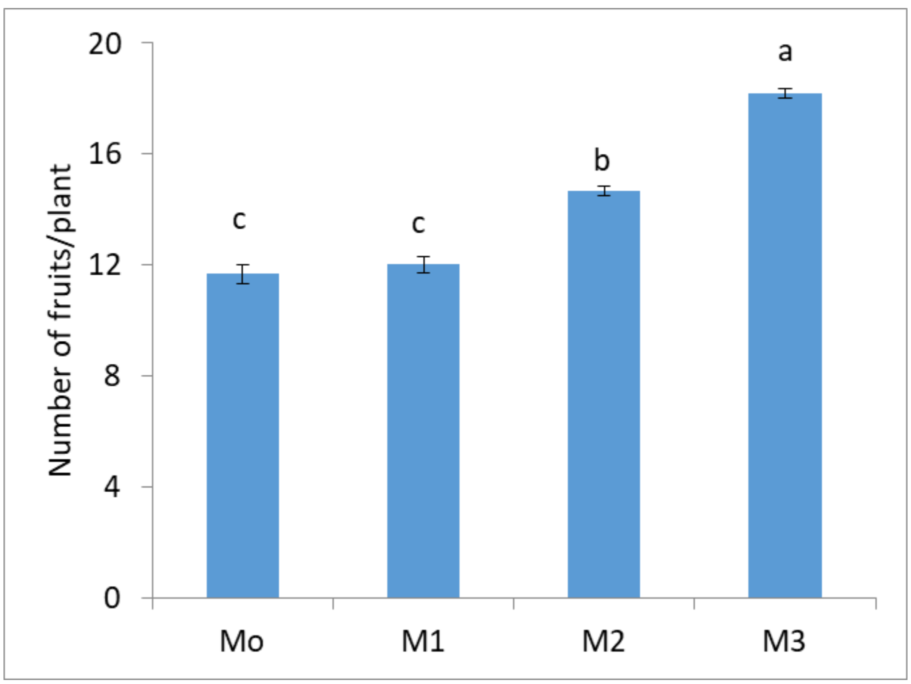

Figure 5: Effect of mulch materials on the number of fruits plant^{-1} of strawberry
M_0 = No Mulch, M_1 = Black polythene, M_2 = White polythene, M_3 = Sawdust

Number of fruits plant^{-1} of strawberry was varied significantly due to combined effect of GA_3 and mulch materials (Figure 6 and Appendix V). The highest number of fruits plant^{-1} (19.66) was observed from the treatment combination of G_1M_3 which was statistically different from other treatment combinations. The lowest number of fruits plant^{-1} (8.66) was recorded from the treatment combination of G_0M_1.

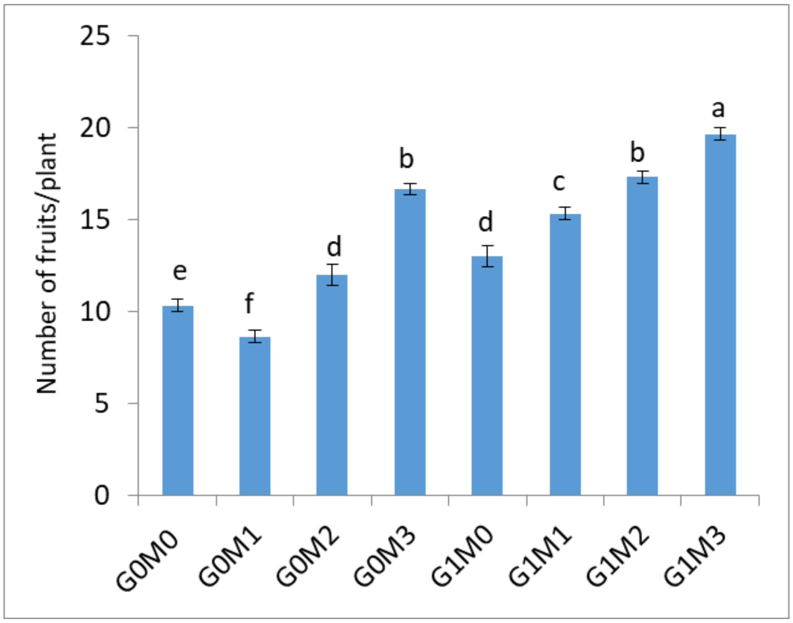

Figure 6: Combined effect of GA_3 and mulch materials on the number of fruits plant^{-1} of strawberry

G_0 = No GA_3, G_1 = 200 ppm GA_3, M_0 = No Mulch, M_1 = Black polythene, M_2 = White polythene, M_3 = Sawdust

4.2.3 Individual fruit weight

Significant influence was found for individual fruit weight of strawberry as influenced by GA_3 and non GA_3 (Figure 7 and Appendix V). Results revealed that individual fruit weight of all GA_3 treated plants was comparatively low than the non GA_3 treated plants. Individual fruit weight (15.79 g) was found maximum in the G_0 treatment (No GA_3). Individual fruit weight (14.58 g) was found minimum in the treatment G_1 (200 ppm GA_3). Asadi *et al.* (2013), Sharma and Singh (2009) 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.

Different types of mulch materials showed significant variation on individual fruit weight of strawberry (Figure 8 and Appendix V). Individual fruit weight (16.91 g) was recorded maximum under M_3 treatment (sawdust mulch) which was identical to M_2 treatment (white polythene). Individual fruit weight (13.16 g) was recorded minimum under treatment M_1 (Black polythene). 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.

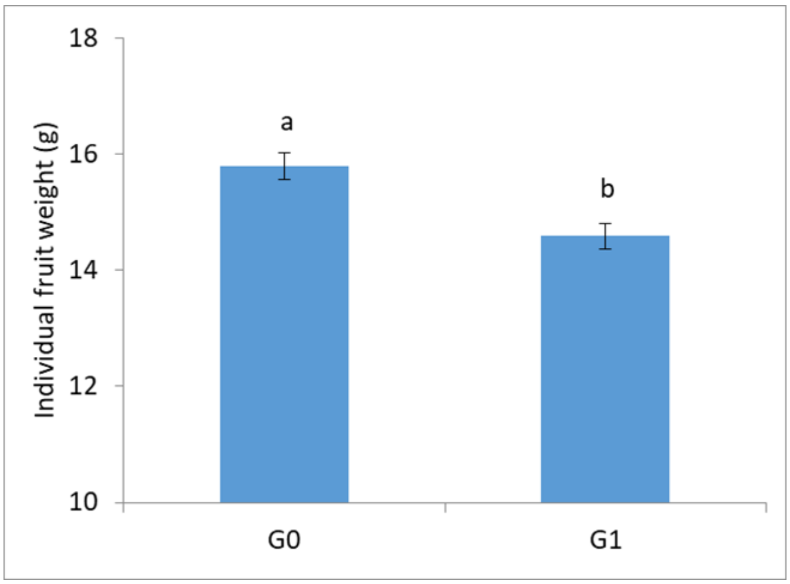

Figure 7: Effect of GA_3 on individual fruit weight of strawberry

G_0 = No GA_3, G_1= 200 ppm GA_3

Individual fruit weight of strawberry was varied significantly due to combined effect of GA_3 and mulch materials (Figure 9 and Appendix V). Individual fruit weight (17.50 g) was observed maximum from the treatment combination of G_0M_3 which was statistically similar to the treatment combination G_0M_2 (17.00 g) but different from other treatment combinations. Individual fruit weight (12.66 g) was recorded minimum from the treatment combination of G_1M_1 which was statistically similar to the treatment combination of G_0M_1 (13.66 g).

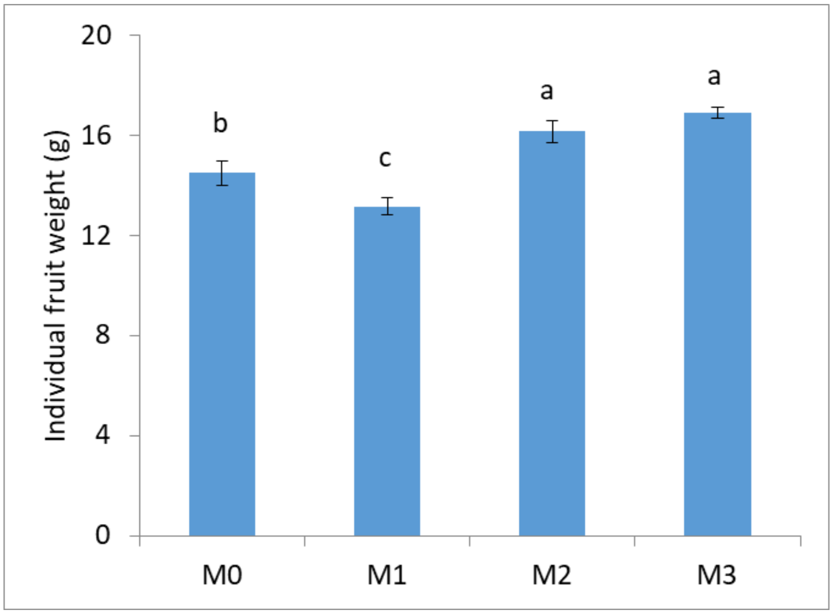

Figure 8: Effect of mulch materials on individual fruit weight of strawberry
M_0 = No Mulch, M_1 = Black polythene, M_2 = White polythene, M_3 = Sawdust

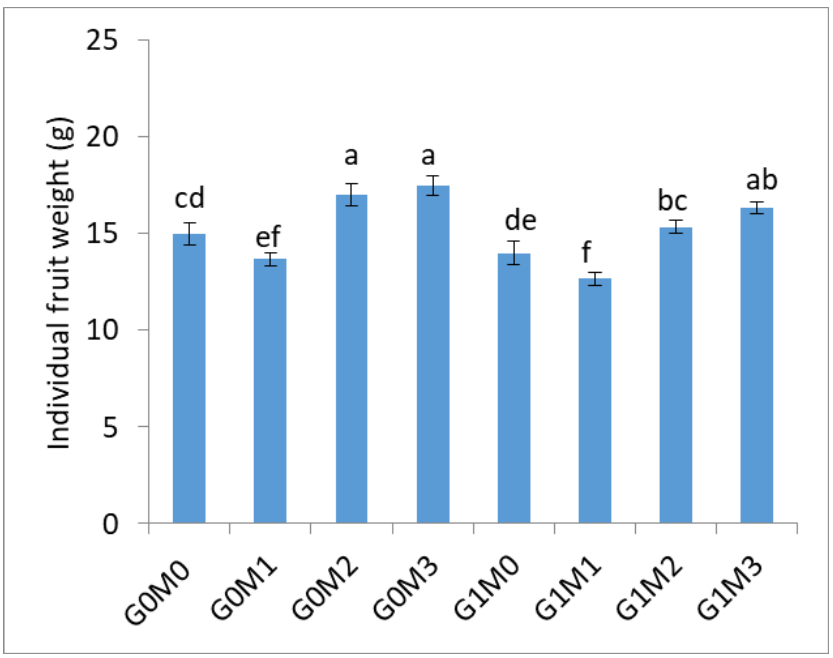

Figure 9: Combined effect of GA_3 and mulch materials on individual fruit weight of strawberry
G_0 = No GA_3, G_1 = 200 ppm GA_3, M_0 = No Mulch, M_1 = Black polythene, M_2 = White polythene, M_3 = Sawdust

Plate 3: Strawberry production using various mulch materials and gibberellic acid (a: no GA_3 b: 200 ppm GA_3)

4.2.4 Fruit yield plant^{-1}

Significant influence was found for fruit yield plant^{-1} of strawberry as influenced by GA_3 and non GA_3 (Figure 10, Plate 3 and Appendix V). Results revealed that fruit yield of all GA_3 treated plants was comparatively high than the non GA_3 treated plants. The maximum fruit yield plant^{-1} (241.00 g) was found in the treatment G_1 (200 ppm GA_3). The minimum fruit yield plant^{-1} (192.08 g) was found in the treatment G_0 (No GA_3). Paikra (2018), Kumar *et al.* (2017), Kumar *et al.* (2016), Ramteke *et al.* (2015) and Thakur *et al.* (2015) 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.

Different types of mulch materials showed significant variation on fruit yield plant^{-1} of strawberry (Figure 11 and Appendix V). The maximum fruit yield plant^{-1} (306.17 g) was recorded under M_3 treatment (sawdust mulch). The minimum fruit yield plant^{-1} (156.50 g) was recorded under the treatment M_1 (Black polythene) which was statistically identical to M_0 treatment (168.67 g). Paunovic *et al.* (2020), Iwuagwu *et al.* (2020), Ike *et al.* (2019)

and Awodoyin, *et al.* (2010) observed that mulching increased growth and fruit yield of plants through modification of the crop growing environment by reducing weed infestation, soil moisture depletion and ameliorating soil temperatures. Mulch could also improve leaf photosynthetic capacity beside the role of polyethylene for enhanced root growth, as well as, absorption of each of water and nutrients and thereby, enhanced metabolic activities within plant during the period of growth and reproduction process, which possessed much shoot number per plant and width leaf area with high leaf chlorophyll content as mentioned before that induced more photosynthetic rates. This in turn built high yield of carbohydrates which gave rise to more cell division and enlargement inducing more vegetative vigorous plants ,this reflect to produce more total yield.

Fruit yield plant^{-1} of strawberry was varied significantly due to combined effect of GA_3 and mulch materials (Figure 12 and Appendix V). The maximum fruit yield plant^{-1} (321.00 g) was observed from the treatment combination of G_1M_3 but different from other treatment combinations. The minimum fruit yield plant^{-1} (118.67 g) was recorded minimum from the treatment combination of G_0M_1 which was statistically different from other treatment combinations.

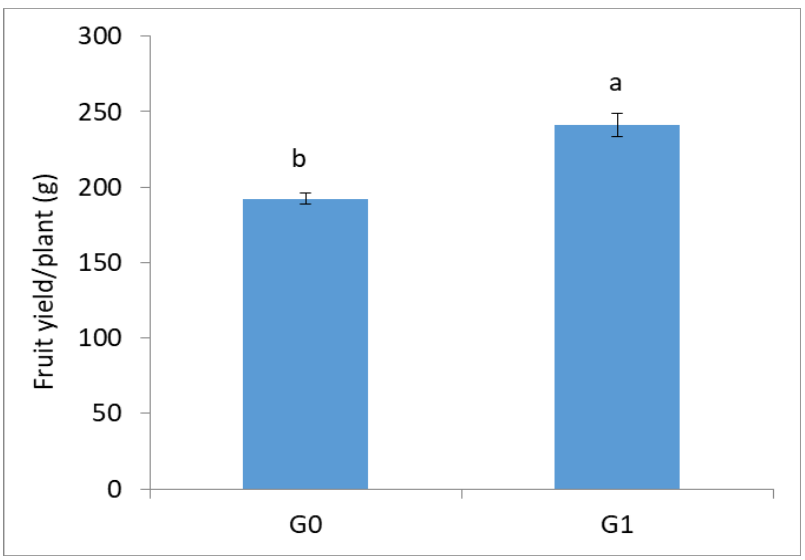

Figure 10: Effect of GA_3 on fruit yield plant^{-1} of strawberry

G_0 = No GA_3, G_1= 200 ppm GA_3

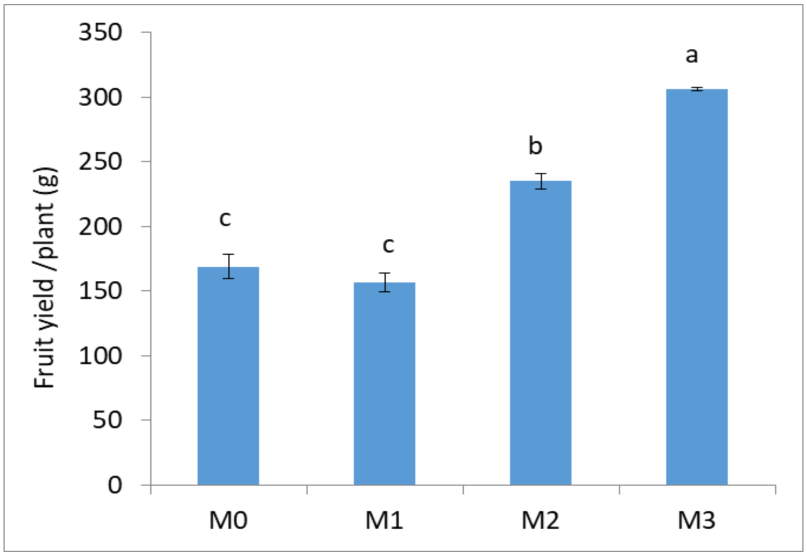

Figure 11: Effect of mulch materials on fruit yield plant^{-1} of strawberry

M_0 = No Mulch, M_1 = Black polythene, M_2 = White polythene, M_3 = Sawdust

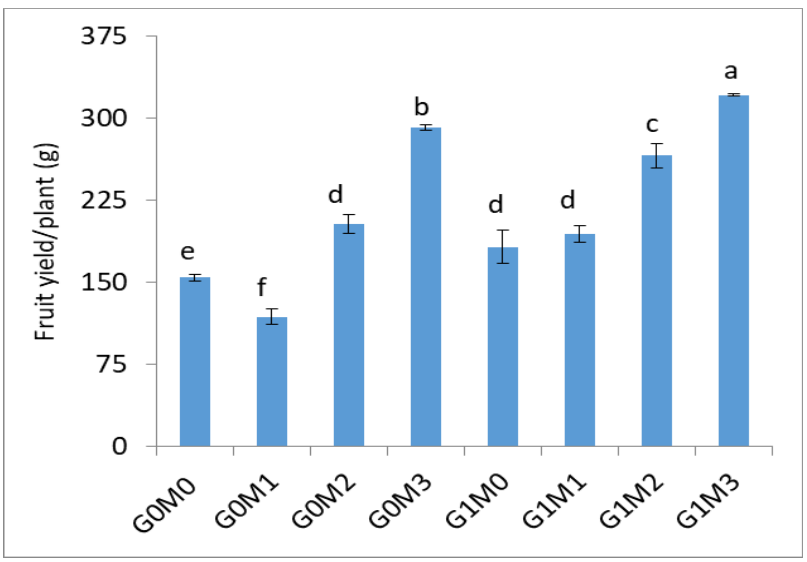

Figure 12: Combined effect of GA_3 and mulch materials on fruit yield plant^{-1} of strawberry
G_0 = No GA_3, G_1 = 200 ppm GA_3, M_0 = No Mulch, M_1 = Black polythene, M_2 = White polythene, M_3 = Sawdust

4.3 Quality Parameters

4.3.1 Total soluble solids (TSS %)

Significant influence was found for total soluble solids (TSS %) of strawberry as influenced by GA_3 and non GA_3 (Table 6 and Appendix VI). Results revealed that all GA_3 sprayed plants showed increased total soluble solids (TSS) compared to the non GA_3 sprayed plants. The highest TSS of strawberry (7.80 %) was found in the treatment G_1 (200 ppm GA_3). The lowest TSS (7.22 %) was observed in treatment (No GA_3). Palei *et al.* (2016), Liu *et al.* (2014), Khunte *et al.* (2014) and Kumar *et al.* (2012) recorded higher TSS of strawberry fruits with the application GA_3 as compared to untreated plants. This might be due to the treatment effect on physiological accumulation of sugar and change in metabolism which eventually resulted in more retention of TSS and total sugars. By the activity of invertase enzyme, which break down sucrose into fructose and glucose, hence resulting in increased reducing sugars.

Different types of mulch materials showed significant variation on total soluble solids (TSS %) of strawberry (Table 6 and Appendix VI). The highest TSS (8.45 %) was recorded under M_3 treatment (sawdust mulch) which was statistically similar to the M_0 (7.94 %) treatment (No mulch). The lowest TSS (6.41 %) was recorded under the treatment M_1 (black polythene). Strik, B.C. and Davis, A.J. (2021), Strik *et al.* (2020), Strik *et al.* (2017) and Choi *et al.* (2011) found that sawdust mulch lead to higher TSS than other mulches. Higher fruit quality is related to weed free environment, higher moisture conservation, optimum soil or canopy temperature and maximum nutrient uptake under sawdust mulch treatment.

Total soluble solids (TSS %) of strawberry were varied significantly due to combined effect of GA_3 and mulch materials (Table 7 and Appendix VI). The highest TSS (8.90 %) was observed from the treatment combination of G_1M_3 which was statistically identical to the treatment combination of G_1M_0 (8.06 %) but different from other treatment combinations. The lowest TSS (6.30 %) was recorded from the treatment combination of G_0M_1 which was statistically similar to the treatment combination of G_0M_2 (6.76 %) and G_1M_1 (6.53 %).

4.3.2 p^H

No significant influence was found for pH value of strawberry as influenced by GA_3 and non GA_3. (Table 6 and Appendix VI).

Different types of mulch materials showed significant variation on pH value of strawberry (Table 5 and Appendix IV). The highest pH value (3.31) was recorded under M_3 treatment (sawdust mulch) which was statistically similar to the M_0 (3.29) treatment (No mulch). The lowest pH value (3.12) was recorded under the treatment M_1 (black polythene) which was statistically identical to the M_2 (3.15) treatment (white polythene). Sadek *et al.* (2021), Sas-Paszt *et al.* (2014) and Kumar *et al.* (2012) determined the highest pH value in the study of strawberries applying sawdust mulching. Available phosphorus, nitrogen, exchangeable potassium, calcium concentrations and electrical conductivity were significantly increased in the soil under sawdust treatment and contributed to acidification of the soil.

pH value of strawberry was varied significantly due to combined effect of GA_3 and mulch materials (Table 7 and Appendix VI). The highest pH (3.35) was observed from the treatment combination of G_1M_3 which was statistically identical to the treatment combination of G_0M_0 (3.33) but different from other treatment combinations. The lowest pH value (3.08) was recorded from the treatment combination of G_0M_1 which was statistically similar to the treatment combination of G_1M_2 (3.12).

4.3.3 Titratable Acidity (TA %)

No significant influence was found for titratable acidity content of strawberry as influenced by GA_3 and non GA_3. (Table 6 and Appendix VI). Khunte *et al*. (2014) reported that PGRs did not have significant effect on titratable acidity.

Different types of mulch materials showed significant variation on titratable acidity content of strawberry (Table 6 and Appendix VI). The highest titratable acidity (0.46%) was recorded under M_1 treatment (black polythene). The lowest titratable acidity (0.36%) was recorded under the treatment M_3 (sawdust mulch) which was statistically identical to the M_0 (0.38%) treatment (control) and M_2 (0.40 %) treatment (white polythene). The increase in total acidity might be due to higher moisture and nutrient availability, higher root activities including higher uptake of water and nutrients, high photosynthesis and other enzymatic activities and accumulation of more carbohydrates in presence of optimum soil moisture and their involvement at metabolic level in regulating vital physiological and biochemical processes seem to increase total acidity in fruit. This is in conformity with the findings of Sharma *et al.* (2003) and Hassan *et al*. (2000). Absorption of solar radiation, conduction of heat to the soil and vice versa, heat loss through evaporation, heat loss from mulch itself as radiation and conduction resulted in differential soil thermal regime and played role in modifying micro site conditions (Kasperbauer *et al*., 2001).

Titratable acidity content of strawberry was varied significantly due to combined effect of GA_3 and mulch materials (Table 7 and Appendix VI). The highest titratable acidity (0.48%) was observed from the treatment combination of G_1M_1 which was statistically identical to the treatment combination of G_0M_1 (0.44%), G_1M_0 (0.40%), G_1M_2 (0.41%) but different from other treatment combinations. The lowest titratable acidity (0.35%) was recorded from the treatment combination of G_0M_3 which was statistically similar to the treatment combination of G_0M_0 (0.36%), G_0M_2 (0.38%) and G_1M_3 (0.37%).

4.3.4 Ascorbic acid (mg/100g)

Significant influence was found for ascorbic acid of strawberry as influenced by GA_3 and non GA_3 (Table 6 and Appendix VI). Results revealed that all GA_3 sprayed plants showed increased ascorbic acid compared to the non GA_3 treated plants. The highest ascorbic acid of strawberry (44.53 mg/100g) was found in the treatment G_1 (200 ppm GA_3). The lowest ascorbic acid (30.81 mg/100g) was observed in G_0 treatment (No GA_3). Bhople *et al.* (2019), Khunte *et al*. (2014), Kumar *et al*. (2011), Wahdan *et al*. (2011) observed that GA_3 application had significant effect on ascorbic acid of fruits. This is due to positive influence on sink strength (reproductive growth) as evidenced by more TSS and juice mass (%) in fruit of auxin treated trees in comparison with control and other growth regulators like GA_3. Different types of mulch materials showed significant variation on ascorbic acid of strawberry (Table 6 and Appendix VI). The highest ascorbic acid (41.25 mg/100g) was recorded under M_1 treatment (black polythene) which was statistically similar to the M_3 (40.85 mg/100g) treatment (sawdust mulch). The lowest ascorbic acid (32.42 mg/100g) was recorded under the treatment M_0 (No mulch) which was statistically identical to the M_2 (36.15 mg/100g) treatment (white polythene). Helaly *et al.* (2017) and Ochmian *et al.* (2008) indicated that plants (black currants) grown on sawdust mulch increased the vitamin C content in the berries. They reported that the improvement in vitamin C content under sawdust mulch may be due to its effect in promoting plant growth and metabolism, thus enhancing the chemical composition.

Ascorbic acid content of strawberry was varied significantly due to combined effect of GA_3 and mulch materials (Table 6 and Appendix VI). The highest ascorbic acid (50.56 mg/100g) was observed from the treatment combination of G_1M_3 which was statistically identical to the treatment combination of G_1M_2 (45.43 mg/100g), G_1M_1 (44.80 mg/100g) but different from other treatment combinations. The lowest ascorbic acid (27.52 mg/100g) was recorded from the treatment combination of G_0M_0 which was statistically similar to the treatment combination of G_0M_2 (26.88 mg/100g), G_0M_3 (31.14 mg/100g). Singh *et al.*, (2007), Mathad and Jholgiker (2005) noted that ascorbic acid content of fruits was influenced significantly by different application of plant growth regulators and mulches. This is due to positive influence on sink strength (reproductive growth) as evident by more TSS and juice mass (%). The good and higher fruit quality is related to higher moisture conservation in soil, free of weed and maximum nutrient uptake under sawdust mulch treatment.

4.4.7 Total Sugar (%)

Significant influence was found for total sugar of strawberry as influenced by GA_3 and non GA_3 (Table 6 and Appendix VI). Results revealed that all GA_3 sprayed plants showed increased sugar content compared to the non GA_3 treated plants. The maximum content of total sugar content of strawberry (6.55%) was found in the treatment G_1 (200 ppm GA_3). The minimum content of total sugar content (5.84%) was observed in G_0 treatment (No GA_3). The study of Lal and Das (2017), Al-Atrushy (2016), Rokaya *et al.* (2016), Thakur *et al.* (2015) and Sharma and Singh (2009) showed that the application of gibberellic acid significantly increased the total sugar level in fruit juice of strawberry and grape. The significant increase in sugar contents might be due to accumulation of carbohydrates in strawberry fruits as a result of increased supply/ absorption of GA_3. Different types of mulch materials showed significant variation on total sugar content of strawberry (Table 5 and Appendix VI). The maximum content of total sugar (6.62%) was recorded under M_3 treatment (sawdust mulch). The minimum content of total sugar (5.90%) was recorded under the treatment M_1 (white polythene) which was statistically identical to the M_0 (5.96%) treatment. Kher *et al.* (2010) and Singh *et al.* (2010) depicted that the application of sawdust mulch recorded maximum TSS, total sugars and crude protein. Higher fruit quality is related to weed free environment, higher moisture conservation, favourable hydrothermal regime of soil and maximum nutrient uptake which may be good response in terms of growth, flowering and quality traits under sawdust mulch treatment.

Total sugar content of strawberry was varied significantly due to combined effect of GA_3 and mulch materials (Table 7 and Appendix VI). The maximum content of total sugar (6.84%) was observed from the treatment combination of G_1M_3 which was statistically identical to the treatment combination of G_1M_2 (6.78%) but different from other treatment combinations. The minimum content of total sugar (5.51%) was recorded from the treatment combination of G_0M_1 which was statistically similar to the treatment combination of G_0M_0 (5.63%).

Table 6: Effect of GA_3 and mulch materials on chemical parameters of strawberry

Treatments	TSS (%)	pH	TA (%)	Ascorbic acid (mg/100g)	Total sugar (%)
GA_3					
G_0	7.22 b	3.21 a	0.38 b	30.81 b	5.84 b
G_1	7.80 a	3.22 a	0.42 a	44.53 a	6.55 a
CV%	7.08	1.15	7.23	9.30	1.42
$LSD_{0.05}$	0.465	0.032	0.039	3.066	0.077
Mulch materials					
M_0	7.94 a	3.29 a	0.38 b	32.42 b	5.96 c
M_1	6.41 c	3.12 b	0.46 a	41.25 a	5.90 c
M_2	7.23 b	3.15 b	0.40 b	36.15 b	6.30 b
M_3	8.45 a	3.31 a	0.36 b	40.85 a	6.62 a
CV%	7.08	1.15	11.23	9.30	1.42
$LSD_{0.05}$	0.658	0.045	0.056	4.336	0.108

G_0 = No GA_3, G_1 = 200 ppm GA_3, M_0 = No Mulch, M_1 = Black polythene, M_2 = White polythene, M_3 = Sawdust. Means followed by same letter(s) in a column do not differ significantly at 5 % level of LSD.

Table 7: Combined effect of GA_3 and mulch materials on chemical parameters of strawberry

Treatments	TSS (%)	pH	TA (%)	Ascorbic acid (mg/100g)	Total sugar (%)
G_0M_0	7.81 b	3.33 a	0.36 c	27.52 c	5.63 d
G_0M_1	6.30 c	3.08 d	0.44 ab	37.70 b	5.51 d
G_0M_2	6.76 c	3.18 c	0.38 bc	26.88 c	5.82 c
G_0M_3	8.00 b	3.26 b	0.35 c	31.14 c	6.41 b
G_1M_0	8.06 ab	3.25 b	0.40 abc	37.33 b	6.28 b
G_1M_1	6.53 c	3.17 c	0.48 a	44.80 a	6.28 b
G_1M_2	7.70 b	3.12 cd	0.41 abc	45.43 a	6.78 a
G_1M_3	8.90 a	3.35 a	0.37 bc	50.56 a	6.84 a
CV%	7.08	1.15	11.23	9.30	1.42
$LSD_{0.05}$	0.931	0.064	0.079	6.133	0.154

G_0 = No GA_3, G_1 = 200 ppm GA_3, M_0 = No Mulch, M_1 = Black polythene, M_2 = White polythene, M_3 = Sawdust. Means followed by same letter(s) in a column do not differ significantly at 5 % level of LSD.

4.4.5 Phenolic content (mg/g)

Significant influence was found for phenolic content of strawberry as influenced by GA_3 and non GA_3 (Figure 13 and Appendix VI). Results revealed that all GA_3 sprayed plants showed increased phenolic content compared to the non GA_3 treated plants. The highest phenolic content of strawberry (5.71 mg/g) was found in the treatment G_1 (200 ppm GA_3). The lowest phenolic content (5.18 mg/g) was observed in G_0 treatment (No GA_3). Gundogdu *et al.* (2021), Alrashdi *et al.* (2017), Filimon *et al.* (2016) and Tian (2014) determined that pre-harvest application of gibberellin on 'El-Bayadi' table grapes confirmed better yield, and high-quality with equilibrated sugar/acid ratio, a higher accumulation of anthocyanins and phenolic contents in berries, improving the economic factor of grapes by way of increasing coloration intensity and uniformity.

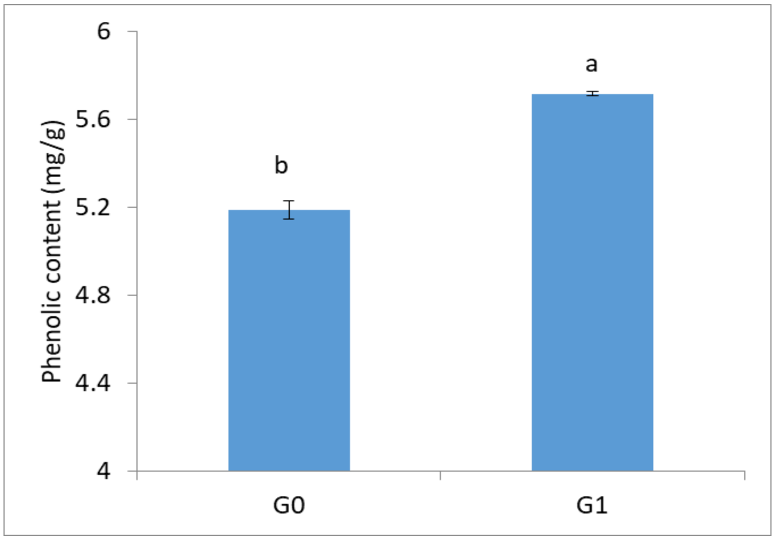

Figure 13: Effect of GA_3 on phenolic content (mg/g) of strawberry

G_0 = No GA_3, G_1 = 200 ppm GA_3

Different types of mulch materials showed significant variation on phenolic content of strawberry (Figure 14 and Appendix VI). The highest phenolic content (5.81 mg/g) was recorded under M_3 treatment (sawdust mulch) which was statistically similar to the M_1 (5.76 mg/g) treatment (black polythene). The lowest phenolic content (5.02 mg/g) was recorded under the treatment M_2 (white polythene) which was statistically identical to the M_0 (521.17) treatment (control). Jahan *et al.* (2018), Kim *et al*. (2011) and Johkan *et al*. (2010) showed that the phenolic content was higher in the lettuce grown under black polythene compared to other ones and indicated that black mulch might be manipulated to enhance plant metabolism and improve the antioxidant properties of lettuce. Different light quality that is influenced by varied polythene mulches greatly impacts on qualitative traits of lettuce like Vitamin C, carotenoids, phenols, and black polyethylene treatment plants were found to have better values for these traits compared to other mulches. Ye *et al.* (2017) stated that the morphological traits, antioxidant enzyme activities, photosynthetic pigments content and bioactive contents content in *Anoectochilus roxburghii* were different due to the treatment of the different colored polythene mulch.

Phenolic content of strawberry was varied significantly due to combined effect of GA_3 and mulch materials (Figure 15 and Appendix VI). The highest phenolic content (6.41 mg/g) was observed from the treatment combination of G_1M_3 which was statistically different from other treatment combinations. The lowest phenolic content (4.87 mg/g) was recorded from the treatment combination of G_0M_2 which was statistically similar to the treatment combination of G_0M_0 (4.96 mg/g), G_0M_3 (5.20 mg/g) and G_1M_2 (5.17 mg/g).

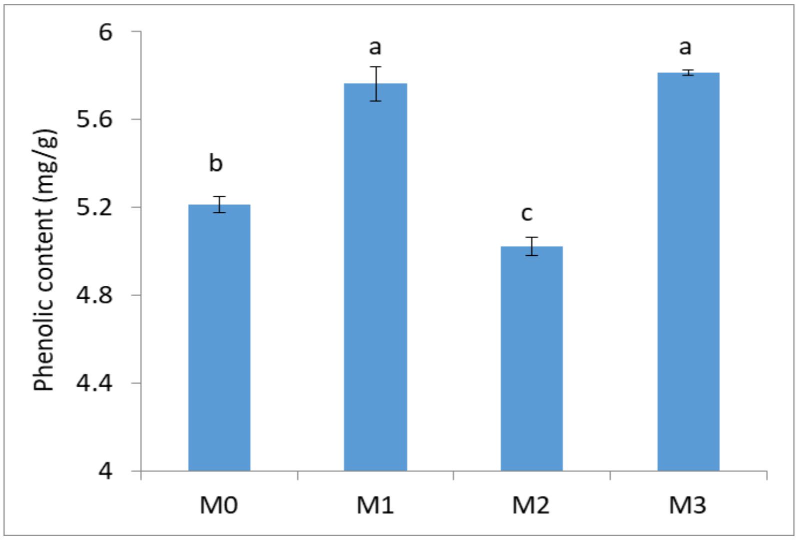

Figure 14: Effect of mulch materials on phenolic content (mg/g) of strawberry

M_0 = No Mulch, M_1 = Black polythene, M_2 = White polythene, M_3 = Sawdust

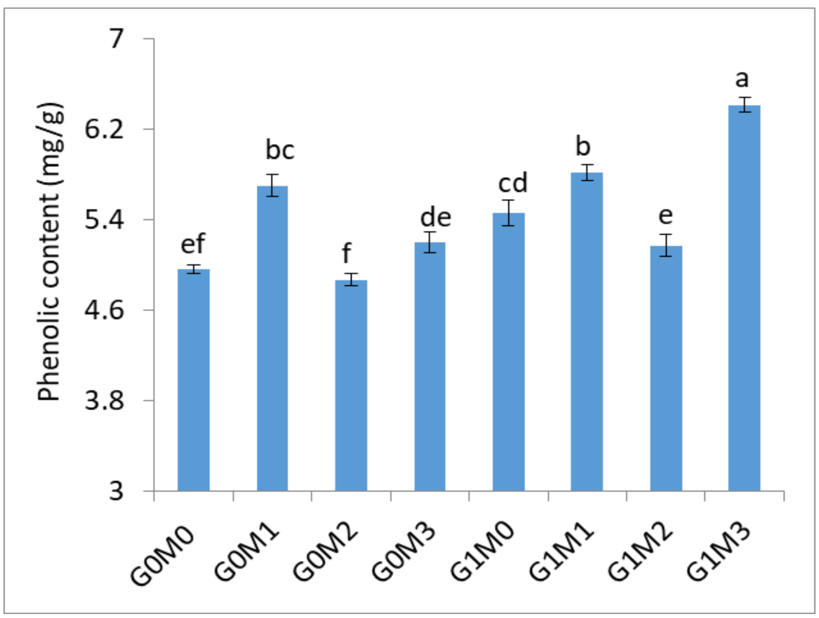

Figure 15: Effect of GA_3 and mulch materials on phenolic content (mg/g) of strawberry

G_0 = No GA_3, G_1 = 200 ppm GA_3, M_0 = No Mulch, M_1 = Black polythene, M_2 = White polythene, M_3 = Sawdust

4.4.6 Anthocyanin content (mg/100g)

Significant influence was found for anthocyanin content of strawberry as influenced by GA_3 and non GA_3 (Figure 16 and Appendix VI). Results revealed that all GA_3 sprayed plants showed increased anthocyanin content compared to the non GA_3 treated plants. The highest anthocyanin content of strawberry (28.34 mg/100g) was found in the treatment G_1 (200 ppm GA_3). The lowest anthocyanin content (27.05 mg/100g) was observed in G_0 treatment (No GA_3). Quintero *et al.* (2013) Fleishon *et al.* (2011) and Roussos *et al.* (2009) observed enhanced anthocyanin content in strawberry with the application of GA_3. The higher anthocyanin observed in the present study could be due to higher accumulation of carbohydrates due to increased photosynthesis and due to either direct or indirect involvement of GA_3 in the synthesis of anthocyanin pigment or its precursor or by involving in the movement of its precursor under the influence of plant growth regulators.

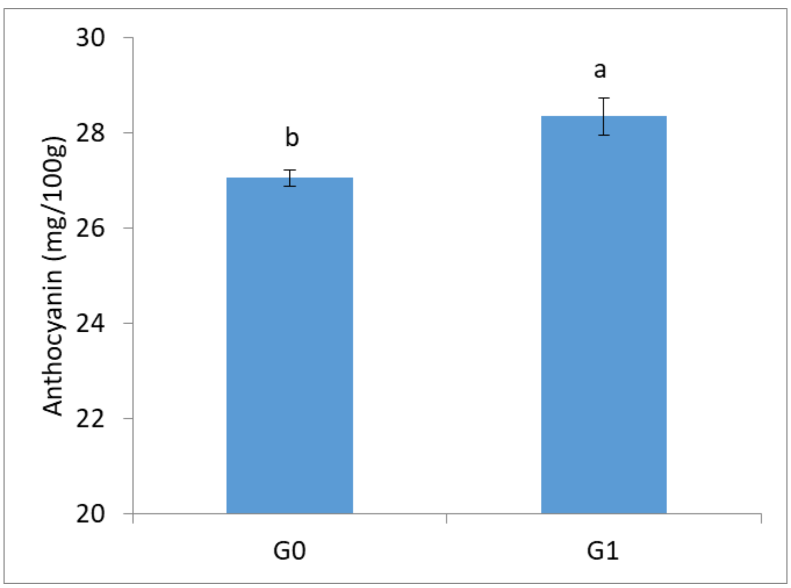

Figure 16: Effect of GA_3 on anthocyanin content (mg/100g) of strawberry
G_0 = No GA_3, G_1 = 200 ppm GA_3

Different types of mulch materials showed significant variation on anthocyanin content of strawberry (Figure 17 and Appendix VI). The highest anthocyanin content (30.15 mg/100g) was recorded under M_3 treatment (sawdust mulch) which was statistically similar to the M_2 (30.05 mg/100g) treatment (white polythene). The lowest ascorbic acid (25.15 mg/100g) was recorded under the treatment M_1 (black polythene) which was statistically identical to the M_0 (25.43 mg/100g) treatment (control). Todic *et al.* (2008), Anttonen *et al.* (2006), Yamane *et al.* (2006) and Moor *et al.* (2005) observed that strawberries grown with sawdust mulch have higher anthocyanin content than the ones grown up with black polythene and no mulch due to both more shortwave light reflections and plant surrounding optimum air and soil temperature.

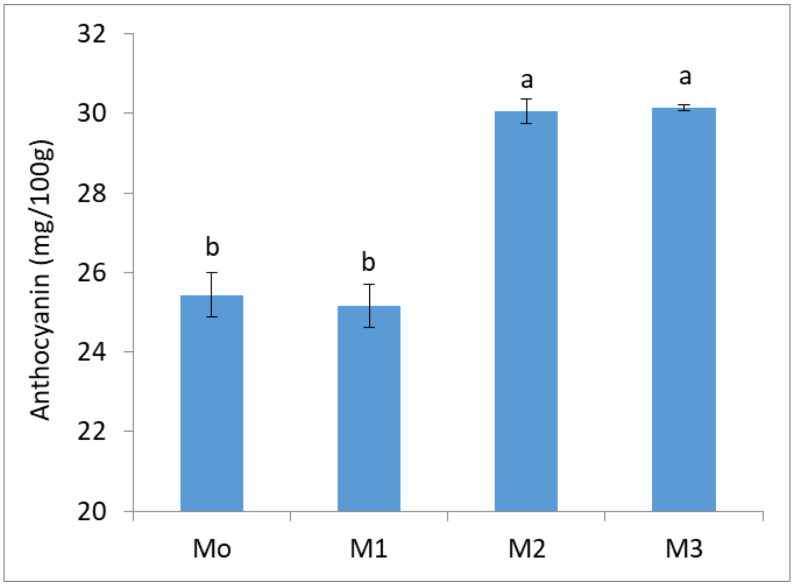

Figure 17: Effect of mulch materials on anthocyanin content (mg/100g) of strawberry
M_0 = No Mulch, M_1 = Black polythene, M_2 = White polythene, M_3 = Sawdust

Anthocyanin content of strawberry was varied significantly due to combined effect of GA_3 and mulch materials (Figure 18 and Appendix VI). The highest anthocyanin content (30.37 mg/100g) was observed from the treatment combination of G_1M_2 which was statistically identical to the treatment combination of G_0M_2 (29.74 mg/100g), G_0M_3 (30.06 mg/100g) and G_1M_3 (30.23 mg/100g) but different from other treatment combinations. The lowest anthocyanin content (23.84 mg/100g) was recorded from the treatment combination of G_0M_1 which was statistically similar to the treatment combination of G_0M_0 (24.55 mg/100g).

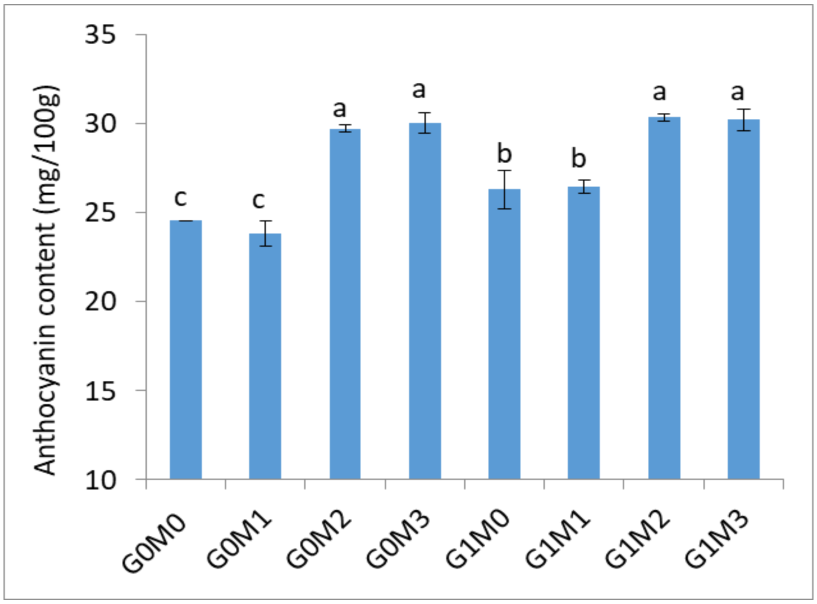

Figure 18: Effect of GA_3 and mulch materials on anthocyanin content (mg/100g) of strawberry

G_0 = No GA_3, G_1 = 200 ppm GA_3, M_0 = No Mulch, M_1 = Black polythene, M_2 = White polythene, M_3 = Sawdust

CHAPTER V

SUMMARY AND CONCLUSIONS

An experiment was conducted at the Horticultural Farm of Sher-e-Bangla Agricultural University, Dhaka to study the growth, yield and quality of strawberry as influenced by different types of mulch materials and gibberellic acid (GA_3). The experiment was comprised of two different factors such as two GA_3 levels viz. G_0 = No GA_3, G_1 = 200 ppm GA_3 and four types of mulch materials viz. M_0 = No mulch, M_1 = Black Polythene, M_2 = White Polythene, M_3 = Sawdust Mulch. The experiment was set up in Randomized Complete Block Design (factorial) with three replications. There were 8 treatment combinations. The experimental plot was treated as per treatment with GA_3 and mulch materials. Data on different growth and yield and yield contributing parameters were recorded and analyzed statistically. Results showed all the parameters studied in the present study were significantly influenced by different levels of GA_3, mulch materials and their combined effect.

Different growth parameters, influenced by GA_3, the highest plant height (18.55 cm and 19.79 cm), maximum number of leaves plant-1 (11.16 and 11.91) at flowering and fruiting stage respectively; maximum leaf area (74.15 cm^2); chlorophyll content plant^{-1} (45.03) and greater relative water content (72.34%) were recorded from G_1 treatment (200 ppm GA_3). Conversely, the lowest plant height (15.31 and 16.97 cm), minimum number of leaves plant^{-1} (9.62 and 11.45) at flowering and fruiting stage respectively, minimum leaf area (71.88 cm^2); chlorophyll content plant^{-1} (43.40) and lower relative water content (69.14 %) were recorded from no GA_3 treatment.

The yield and yield contributing parameters influenced by GA_3, the maximum number of fruits (16.33) plant^{-1}, minimum days for flowering (35.80 days), minimum individual fruit weight (14.58 g) and highest fruit yield plant^{-1}(241.00 g) were recorded under G_1 treatment (200 ppm GA_3). On the other hand, the minimum number of fruits (11.91) plant^{-1}, maximum days for flowering (7.35 days), maximum individual fruit weight (15.79 g) and lowest fruit yield plant^{-1} (192.08 g) were observed from the G_0 treatment (No GA_3).

The chemical parameters influenced by GA_3, the highest total soluble solids (7.80%), ascorbic acid content (44.53 mg/100g), phenolic content (5.71 mg/g), anthocyanin (28.34 mg/100g) and total sugar content (6.55 %) were recorded under G_1 treatment (200 ppm GA_3). On the other hand, the lowest total soluble solids (7.22%), ascorbic acid content (30.81 mg/100g), phenolic content (5.18 mg/g), anthocyanin (27.05 mg/100g) and total sugar content (5.84 %) were recorded under G_0 treatment (No GA_3). But GA_3 has no significant effect in case of pH and titratable acidity.

Again, different growth parameters, influenced by different mulch materials, the highest plant height (18.75 cm and 21.08 cm) at flowering and fruiting stage respectively; lowest number of leaves plant^{-1} (10.91) at fruiting stage, maximum leaf area (80.02 cm^2), maximum chlorophyll content plant^{-1} (47.61) and greater relative water content (74.32%) were recorded from M_3 treatment (sawdust mulch); while, the highest number of leaves plant^{-1}(11.41 and 13.33) at flowering and fruiting stage, respectively were found from M_2 treatment (white polythene). Conversely, the lowest plant height (15.70 cm and 16.03 cm), lowest number of leaves plant-1 (99.33) at flowering stage; and minimum leaf area (67.02 cm^2) and minimum chlorophyll content plant^{-1} (41.60) were observed under M_1 treatment (black polythene), whereas lower relative water content (63.53%) under M_0 treatment was found.

The yield and yield contributing parameters influenced by different mulch materials, the maximum number of fruits (15.50) plant^{-1}, maximum individual fruit weight (16.50g) and highest fruit yield plant^{-1} (254.67 g) were recorded under M_3 treatment (sawdust treatment). On the other hand, the minimum days for flowering (35.30 days), minimum individual fruit weight (11.50 g) and lowest fruit yield plant^{-1} (108.33 g) were observed from M_1 treatment (black polythene) whereas the minimum number of fruits (9.33) and maximum days for flowering (42.20) were recorded under M_0 treatment (No mulch).

The chemical parameters influenced by different mulch materials, the highest total soluble solids (8.45%), pH (3.31), anthocyanin content of fruits (30.15 mg/100g) and total sugar content (6.62 %) were recorded under M_3 treatment (sawdust mulch) while, the highest ascorbic acid content (41.25 mg/100g), titratable acidity (0.46%), phenolic content (5.81 mg/g) under M_1 treatment (black polythene) and highest total sugar content (5.96 %) under

M_0 treatment (No mulch) was found. On the other hand, the lowest total soluble solids (6.41%), pH (3.12), anthocyanin content of fruits (25.15 mg/100g) and total sugar content (5.90 %) were recorded from the M_1 treatment (black polythene) whereas, the lowest ascorbic acid (32.42 mg/100g) under M_0 treatment (No mulch); lowest titratable acidity (0.36%) under M_3 (sawdust mulch) and phenolic content (5.02 mg/g) under M_2 treatment (white polythene) were observed.

Considering, different growth parameters, influenced by combined effect of GA_3 and mulch materials, the highest plant height (19.50 cm and 21.50 cm) at flowering and fruiting stage respectively; lowest number of leaves plant^{-1} (10.33) at fruiting stage; maximum leaf area (80.97 cm^2), maximum chlorophyll content (48.23) and greater relative water content (76.45%) were recorded from the treatment combination of G_1M_3 while, the highest number of leaves plant^{-1} (12.33 and 113.66) at flowering and fruiting stage respectively from G_1M_2 treatment combination were found. Reversely, the lowest plant height (13.50 and 13.73 cm) at flowering and fruiting stage respectively, lowest number of leaves plant^{-1} (8.33) at flowering stage; minimum leaf area (66.08 cm^2) and minimum chlorophyll content (40.70) were observed from the treatment combination G_0M_1 whereas, lower relative water content (65.90%) were recorded from the treatment combination G_0M_0.

The yield and yield contributing parameters influenced by combined effect of GA_3 and mulch materials, the maximum number of fruits (19.66) plant^{-1} and highest fruit yield plant^{-1} (321.00 g) were recorded from the treatment combination G_1M_3 whereas, maximum individual fruit weight (17.50 g) under G_0M_3 treatment combination and the maximum days for flowering (45.00 days) under G_0M_0 treatment combination were observed. On the other hand, the minimum number of fruits plant^{-1} (8.66) and lowest fruit yield plant^{-1} (118.67 g) were observed from the treatment combination G_0M_1 whereas the minimum days for flowering (32.20 days) and minimum individual fruit weight (12.66 g) were recorded under G_1M_1 treatment combination.

The chemical parameters influenced by combined effect of GA_3 and mulch materials, the highest total soluble solids (8.90%), pH (3.35), ascorbic acid content of fruits (50.56 mg/100g), phenolic content (6.41 mg/g) and total sugar content (6.84 %) were recorded under G_1M_3 treatment combination while, the highest anthocyanin content of fruits (30.37

mg/100g) under G_1M_2 and titratable acidity content of fruit (0.48%) under G_1M_1 treatment combination were found. Reversely, the lowest total soluble solids (6.30%), pH content (3.18), anthocyanin content of fruits (23.84 mg/100g) and total sugar content (5.51 %) were recorded from the G_0M_1 treatment combination whereas, the lowest ascorbic acid (26.88 mg/100g) and phenolic content (4.87 mg/g) under G_0M_2 treatment combination and the lowest titratable acidity (0.35 %) under G_0M_3 treatment combination were observed.

Conclusion

It may be concluded from the result that G_1M_3 (sawdust mulch+200 ppm GA_3) performed the best in producing higher growth, yield and quality attributes of strawberry than other treatments comprised with other mulch materials and GA_3 under the present study. Similarly, interactions of G_1 (200 ppm GA_3) and M_3 (sawdust mulch) showed its superiority in producing higher growth, yield and quality.

Recommendation

The present research work has been conducted at the Sher-e-Bangla Agricultural University in one season only. Therefore, further trial of this research work may be carried out in different AEZ of Bangladesh before the final recommendation.

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APPENDICES

Appendix I. Characteristics of Horticulture Farm soil is analyzed by Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka.

A. Morphological characteristics of the soil of experimental field

Morphological features	Characteristics
Location	Horticulture Garden , SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained

Source: Soil Resource Development Institute (SRDI)

B. 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

Source: Soil Resource Development Institute (SRDI)

Appendices II: Monthly record of air temperature, rainfall, relative humidity, sunshine of the experimental site during the period from October 2020 to February 2021

Month	Air temperature (ºC)		Relative Humidity (%)	Rainfall (mm)	Sunshine Hours
	Maximum	Minimum			
October, 2020	32	26	72	175	6
November, 2020	30	19	66	35	8
December, 2020	26	14	63	15	9
January, 2021	25	13	54	7	9
February, 2021	28	16	49	25	8

Source: Bangladesh Meteorological Department (Climate & Weather Division) Agargaon, Dhaka –1207

Appendix III: Analysis of variance of the data on plant height and number of leaves plant^{-1} of strawberry as influenced by different mulch materials and GA_3

Source of variation	Degrees of freedom (df)	Mean Square			
		Plant height		Number of leaves plant^{-1}	
		Flowering stage	Fruiting stage	Flowering stage	Fruiting stage
Replication	2	1.872	1.6954	1.7604	0.656
Factor A	1	63.212**	47.601**	14.260**	1.260^{NS}
Factor B	3	13.183**	25.810**	7.121**	9.621**
A×B	3	2.279^{NS}	3.573**	0.399^{NS}	0.4270^{NS}
Error	16	1.278	0.966	0.697	1.218

**Significant at 5 % level of probability and NS: Non- Significant

Appendix IV: Analysis of variance of the data on leaf area, SPAD value and relative water content of strawberry as influenced by different mulch materials and GA_3

Source of variation	Degrees of freedom (df)	Mean Square		
		Leaf area (cm^2)	SPAD value	Relative water content (%)
Replication	2	21.716	0.125	2.274
Factor A	1	30.804**	15.843**	61.705**
Factor B	3	187.081**	41.811**	142.946**
A×B	3	0.360^{NS}	0.193NS	4.396^{NS}
Error	16	4.554	0.599	3.917

** Significant at 5 % level of probability and NS: Non-Significant

Appendix V: Analysis of variance of the data on days to flowering, fruiting, number of fruits plant^{-1}, individual fruit weight and yield plant^{-1} of strawberry as influenced by different mulch materials and GA_3

Source of variation	Degrees of freedom (df)	Mean Square			
		Days to flowering	Number of fruits	Individual fruit weight (g)	Yield plant^{-1} (g)
Replication	2	0.835	0.500	1.15**	437.80
Factor A	1	181.10**	117.042**	8.760**	14357.0**
Factor B	3	50.71**	54.375**	17.01^{NS}	28528.5**
A×B	3	1.43^{NS}	5.486**	0.149^{NS}	851.8**
Error	16	2.586	0.500	0.561	184.5

Appendix VI: Analysis of variance of the data on total soluble solids, pH, ascorbic acid, titratable acidity, phenolic content, anthocyanin and total sugar content of strawberry fruits as influenced by different mulch materials and GA_3

Source of variation	Degrees of freedom (df)	Mean Square						
		Total soluble solids (%)	p^{H}	Titratable acidity (%)	Ascorbic acid (mg/100g)	Total sugar (%)	Phenolic Content (mg/g)	Anthocyanin (mg/100g)
Replication	2	0.1038	0.0015	0.0006	6.32	0.0101	0.0064	1.8050
Factor A	1	2.0126**	0.001^{NS}	0.0068^{NS}	1129.43**	2.9715**	1.6964**	10.0622**
Factor B	3	4.6837**	0.0526**	0.0113**	105.48**	0.6827**	0.9372**	46.3625**
A×B	3	0.2281^{NS}	0.0131**	0.0002^{NS}	57.47**	0.0725**	0.3458**	1.8313**
Error	16	0.2607	0.0013	0.0018	11.52	0.0080	0.0220	0.6884