EFFECTS OF FOLIAR APPLICATION OF GIBBERELLIC ACID AND MICRONUTRIENTS (Fe, Mn) ON GROWTH AND YIELD OF STRAWBERRY

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This is to certify that the thesis entitled **"EFFECTS OF FOLIAR APPLICATION OF GIBBERELLIC ACID AND MICRONUTRIENTS (Fe, Mn) ON GROWTH AND YIELD OF STRAWBERRY"** submitted to the Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE in HORTICULTURE**, embodies the result of a piece of *bona fide* research work carried out by **MD SHAHADAT HUSSAIN,** Registration No. **09-03656** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: June, 2015

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DEDICATED TO

MY BELOVED PARENTS

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ABBREVIATIONS AND ACRONYMS

SAU	:Sher-e-Bangla Agricultural University
GA_3	: Gibbrellic Acid
Fe	: Iron
Mn	: Manganese
TSS	: Total Soluble Solid
NAA	: Naphthalene Acetic acid
IAA	: Indole-3 Acetic Acid
pH	: Potential hydrogen
ppm	: Parts per million
DM	: Dry matter
AEZ	: Agro-Ecological Zone
ANOVA	: Analysis of Variance
df	: Degrees of freedom
CV%	: Percentage of Coefficient of Variation
LSD	: Least Significant Difference

CHAPTER 1

INTRODUCTION

Strawberry (*Fragraria× annanasa*) is a very Delicious and nutritious exotic fruit in Bangladesh. It has protective effects against cancer diarrhoea, decentry, sluggish intestine, skin diseases etc. (Morgan, 2005). In climate like Bangladesh strawberry is well adapted but production as well as the quality is not satisfactory. In Bangladesh the winter season is shorter than what strawberry needs for better yield. The optimum temperature for strawberry production is 15^0-20^0 C with six hours continuous sunlight. Due this reason strawberry in Bangladesh shows lower yield and quality. Higher temperature is harmful for strawberry cultivation. High temperature may decrease fruit setting by reducing pollen germination and/or tube growth, stigmatic receptivity, or ovule longevity (Raquel and Rebecca, 1998). So if we can minimize the temperature effect we can have a satisfactory yield.

GA_3 have a potential effect on growth and yield of plant. Ga_3 may minimize the temperature effects (Raquel & Rebecca, 1998). GA_3 substitutes for pollination and fertilization, high temperatures probably have a much less negative impact on GA_3 treated plants (Raquel and Rebecca, 1998). GA_3 enhances chlorophyll synthesis and increases efficiency of photosynthetic materials thus increases the rate of photosynthesis (Sardoei and Shahdadneghad, 2014). GA_3 also helps in translocation of the nutrients and food material prepared by leaves to the growing point. That GA_3 treatment increased the absorption and tissue accumulation of N, P, K and micronutrients (Eidand Abou-leila,2006*)*. GA_3 increases cell division, causes cell enlargement thus causes tissues development and growth of the plant. GA_3 also increases flowering, fruit setting and the size of fruits (Williamson *et al*., 1995).

Iron plays an important role in promoting vegetative growth, flowering, yield and quality of several fruits like lemon (Supriya*et al*., 1993) and guava (Sheriff *et al*., 2000). Iron deficiency chlorosis is a common nutritional disorder chiefly

associated with high pH or calcareous soils affecting plants (Borowski and Michalek, 2011; Fernandez *et al*., 2006). Iron deficiency impairs fruit quality and yield, and can ultimately lead to plant death (Alvarez-Fernandez *et al*., 2003, 2006; Fernandez *et al*., 2006). Manganese plays a key role in photosynthesis, as the photosystem II-water oxidizing system has an absolute Mn requirement. Adequate Mn is critical in this system. Manganese (Mn) acts as an enzyme activator for nitrogen assimilation. Impairment of lignin biosynthesis in Mn-deficient plants, especially in the roots, is associated with increased pathogenic attack, particularly soil-born fungi, because lignin serves as a barrier against pathogenic infection (Marschner, 1995).

The objective of the study is

- To find out the effects of GA_3 and Iron-Manganese on growth and yield of strawberry.

CHAPTER II

REVIEW AND LITERATURE

Strawberry is one of the most popular fruit in the whole world also in Bangladesh. However, it is new fruit crop in Bangladesh but its demand and production area is increasing day by day. Strawberry is an herbaceous perennial plant, which can be grown as an annual or perennial crop under commercial cultivation. The plant comprises a shorten stem or crown from which arises leaves, runners, roots, auxiliary crowns and inflorescences. GA_3 is a plant growth regulator which influences the growth and development of most of the crops. Other hand manganese and iron are essential micronutrient have also some stimulatory effect on various characters of plants. Some of important and informative works have so far been done in home and abroad related to this experimentation have been presented in this chapter.

2.1 Influences of GA_3

Miranda-stalder*et al.,* (1990) reported that GA3 enhances various morphological features and yield of strawberry (*Fragaria x. ananassa*) 'Sequóia'.

The beneficial effect of GA_3 on different plants were recorded by Shedeed*et al*., 1991 on croton plant, Eraki (1994) on Quen Elizabeth rose plants, Bedour *et al*., (1994) on *Ocimum basillicum*, they concluded that gibberellic acid is used to regulating plant growth through increasing cell division and cell elongation. Azuma *et al.*, (1997) said GA_3, increases stem length, the number of flower per plant and induces fruit setting.

An experiment was conducted by Asghar *et al*., (1997) and effect of GA_3, Planofix (NAA) and Cultar (Paclobutrazol) on growth and yield of

okra was observed. GA_3 increased different growth and yield related characters. However, GA_3 also increased pod length and diameter.

AL- Rawi *et al.,* (1999) noticed that , the spraying of GA_3 concentration (50 and 100 ppm) on fig trees cv. Aswod Diala at depressed period reduced the proportion of fruit cracking and increased the firmness, leaf area , total chlorophyll , percentage of carbohydrate .

Abo – Zaid (2000) conducted a research to study effects of GA_3 on pear trees in Egypt. From which he experienced that, spraying of GA_3 at conc. of (100 and 150 ppm) has increased the vegetative growth and fruit firmness.

An experiment was conducted at Abass *et al.*, (2009) to investigate the effects of pruning 50 % and spraying with N, Ca and GA_3 at conc. Of 0.3%, 1%, 200 mg/L each other in single way or combination on the leaf area, total chlorophyll, percentage of carbohydrate, calcium pictate, Firmness, type of cracking and total cracking on ripe Fruits of Fig cv. Aswod Diala. Results indicated that Ca and GA_3 in single way or combination together with N produced a significant increase in leaf area, total chlorophyll content,f ruit percentage of carbohydrate, calcium pictate, Firmness and reducing percentage of type of cracking and total cracking compared with control treatment. The treatment of (P + N + Ca + GA_3) was significantly increased leaf area, total chlorophyll, percentage of carbohydrate, calcium pictate, Firmness.

The effect of gibberellic acid (GA_3) on the vegetative growth, flowering characteristics and yield of three strawberry cultivars were investigated, by Paroussi *et al.*, (2002). He experienced that all GA_3 application increased petiole length and leaf area of the strawberry plants and reduced time needed for inflorescence emergence, accelerated flowering and increased the number of flower buds and open flowers in most growing conditions. GA_3 200 mg/l increased the percentage of aborted

flowers plus malformed fruits, resulting in a significant decrease in total marketable yield.

GA_3 is an essential growth hormone known to be actively involved in various physiological activities such as growth, flowering, and ion transport (Takei *et al*. 2002, Khan and Samiullah, 2003).

El-Sabagh and Mostafa (2003) in their work on carnation cv. "Red sim" demonstrated that gibberellic acid foliar application surprisingly affected plant growth and its subsequent flower production potential

The effect of growth hormones on the morphology of shoot of lentil was examined by Naeem *et al*., (2004). Different concentrations of hormone were used. GA_3 showed a marked elongation in the length of shoot and increase in the number of internodes and compound leaves. The combined dose of GA_3+IAA, GA_3+kinetin and GA_3+IAA+kinetin showed a significant increase in length and number of internodes as well as in the number of compound leaves. In GA_3 treated plants, early flowering with higher number of floral buds was recorded. The mixed doses of GA_3 with IAA and kinetin revealed early flowering.

Morales-Payan (2005) reported that GA_3 application significantly affected leaves fresh and dry weight of *Coleus amboinicus Lour.* At the same time, Gul *et al*., (2006) noted that GA_3 foliar spray enhanced the height and ornamental wealth of *Araucaria heterophylla* plants.

GA_3 is a natural growth hormone and is a part of a type of plant hormones called gibberellins. GA_3 promotes cell division and a number of plant development mechanisms and encourages numerous desirable effects such as plant height, uniform flowering, reduced time to flowering and increased flower number and size (Srivastava and Srivastava, 2007).

Two field experiments were carried out by Abdel–Moutyand El-Greadly (2008) during the two successive seasons of 2005 and 2006. To observe the effects of GA_3 on growth and yield characteristics of okra. The obtained results indicated that The application 3 of GA_3 as foliar spray with 50 ppm gained the better plant growth and pods yield as well as its physical and chemical properties.

Fathonah and Sugiyarto (2009). Studied the effects of IAA and GA_3 toward the growing and saponin content of purwaceng (*Pimpinella alpina*). The result showed that giving IAA and GA_3 differently affect the growth *P. alpina*. In variable of the height, the optimal wet weight and dry weight of the plant in GA_3 treatment optimum number of leaves in found in 50 ppm whereas the leave width in IAA treatment was 200 ppm.

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. Findings showed that GA_3 (75 ppm) has favorably influenced all vegetative attributes of 'Chandler' strawberry over control. Similarly, fruit set was increased, and production of malformed and button berries was reduced, but albinism remained unchanged. Although individual berry weight was slightly reduced, but fruit number, total as well as marketable yield was increased tremendously over control with no adverse effect on fruit quality parameters. In all, spraying GA_3 both during was much more effective in achieving the desirable results than single application of GA_3 either during mid-November or mid-February.

Rasheed (2010) carried out an experiment to investigate the influence of foliar sprays with Gibberellic Acid (GA_3) and Benzyladenin (BA) in growth a yield of Strawberry plant. Three experimental treatments was included a three level of Gibberellic Acid 0 , 150 , 300 mg/l and three level of Benzyladenin 0, 900 , 1800 mg/l. The concentration of 300mg/L

GA_3 significantly superior than the control treatment on the height of plant , length of runner , Length of first internode of the runner , number of runner per plant , number of plantlet per runner , leaf area per plant , number of leave as per plant and also increased leaves content of nitrogen and phosphorus in treated plants. He also showed that GA_3 at a rate of 300 mg/L induced a significant increase in the length of the flower punch and the number of the flower punches per plant, the number of flowers per plant, the number of fruits per plant as compared with the control. Treating Strawberry with GA_3 at 150 mg/L significantly gave the longest fruits while GA_3 at 300 mg/L significantly gave the highest yield. Strawberry with GA_3 and BA significantly increased the percentage of the dry matter, T.S.S, T.S.S/total acidity, total carbohydrate, protein content and tannins while decreased the percentage of acidity in the fruits. Treating Strawberry plants with GA_3 and BA and the interaction increased fruiting earlier than control treatment

An experiment was conducted by Rashid (2010) to conclude the effect of GA_3 on onion, He experienced that GA_3 with concentration of 100 ppm increased plant height, leaf number and different bulb related attributes. He sensed a positive effect of GA_3 on onion growth and yield.

Hassanpouraghdam *et al.,* (2011) conducted an experiment with following treatments: control (foliar spray with distilled water), GA_3 foliar application at 100, 200 and 300 mg/l plus foliar spray with formulated GA_3 tablet prepared at 100 mg/l concentrations in Lavender. The results showed that the highest amounts for volatile oil content and yield shoed by 300 mg/l GA_3 treatment. It was also observed that GA_3 produces higher amount of volatile acid production, chlorophyll percentage and leave fresh weight.

Abbas (2011) conducted an experiment to examine the effects of GA_3 on carrot. In using the GA_3concentration at (50 ppm) led to increase

significantly the studied characteristics particularly plant height cm, number of branch/ plant, number of flower/ plant, shoot fresh weight, fresh weight of biological weight, shoot dry weight, dry weight of biological weight gm/plant, chlorophyll content, when compared with the other concentrations levels and controlling plants. And GA_3 decreases significantly some of the studied characteristics as root fresh weight, root dry weight and soluble carbohydrate which that compared with the controlling plants.

Roy and Nasiruddin (2011) conducted an experiment to study the effect of GA_3 on growth and yield of cabbage consisted of four concentrations of GA_3, viz., 0, 25, 50 and 75 ppm. Significantly the minimum number of days to head formation (43.54 days) and maturity (69.95 days), highest diameter (23.81 cm) highest yield (45.22 kg/plot and 104.66 t/ha) was recorded with 50 ppm GA_3 while control (0 ppm GA_3) treatment gave the inferior result.

Effects of day-length and GA_3 on flowering and endogenous hormone levels during flowering process of *Rhynchostylisgigantea* (Lindl.) Ridl. were studied. It was observed that GA_3 had effects only on number of leaves per plant. Where GA_3 seemed to drop t-ZR. The reducing ABA and increasing t-ZR in leaf and/ or shoot might be related to flower buds initiation and early flowering of *R. gigantea*, especially. (Phengphachanh *et al*., 2011).

Jamal Uddin *et al*., (2012) conducted an experiment to study the responses of gibberellic acid concentrations on the growth and yield of strawberry germplasm at Horticulture Farm, Sher-e-Bangla Agricultural University. The experiment consisted of different GA_3 concentrations viz. control, 50 ppm, 75 ppm and 100 ppm. Tallest plant (31.4 cm), the maximum number of leaves (11.1), maximum leaf area (64.5 cm^2), maximum number of flower bud (30.0) and highest number of flower (28.7) was recorded from 75 ppm GA_3treated strawberry plant.

Maximum number of fruits (25.9/plant), fruit weight (13.2 g) and yield (336.6 g) per plant were found with 75 ppm GA_3 application, whereas the minimum was recorded in control. Foliar application with 75 ppm GA_3 showed the best performance on growth and yield of strawberry. Application of GA_3 also increased the sweetness of the berries in comparison to control.

Turkyilmaz (2012) suggested that gibberellic acids increased seed germination, the length, fresh and dry weight of the root and shoot, chlorophyll and carotenoid contents of wheat under different saline condition.

Ayyub *et al*., (2013) conducted an experiment and found that application of GA_3(100 mg/Kg) at different growth stages of okra predominantly boosted the stem elongation, number of leaves per plant, number of pods per plant, number of seeds per pod, seed weight and seed yield. He concluded that foliar application of GA_3 may be an effective strategy for maximizing the growth and yield of okra.

Asadi *et al*., (2013) Gibberellins have important role in several important biochemical and morphogenetic responses in plants. Treatments including: GA_3 (0, 25 and 50 mg/L) arranged in a completely randomized design with 4 replications. The effect of GA_3 applications were evaluated on yield, flowering and vegetative characteristics. Marketable yield, Square meter yield, average fruit weight, fertilized flowers and not fertilized flower, Leaf and branch crown, did not affect by GA_3 application significantly, while number flower on inflorescence and Runner significantly increased.

Shahid *et al*., (2013) conducted an experiment on where different concentrations (0, 50, 100 & 200 ppm) of gibberellic acid (GA_3) and naphthalene acetic acid (NAA), alone or in combinations were sprayed on okra The number of leaves per plant and plant height number of

podsper plant, pod length, pod fresh and dry weight, seed yield and seed quality was maximum in plants receiving foliar spray of both GA_3 and NAA @ 200+200 ppm.

Lolaei *et al*., (2013) conducted an experiment to study the effect of gibberellic acid (GA_3 on the strawberry yield and fruit quality. Results indicated that the treatment of gibberellic acid (150) ppm have the greatest effect on the amount of leaf number, and fruit number. Gibberellic acid (GA_3) spray at 50, 100 and 150 ppm increased fruit weight compared to the control. GA_3 spray delayed fruit ripening, as reflected by lower T.S.S. contain.

Khunte *et al*., (2014) conducted an experiment to observe the effects of different growth regulator on strawberry. He experienced that all the doses of GA_3 (100 ppm, 150 ppm, 200 ppm) treatments increased fruit size, specific gravity etc.

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) up to the concentration of 250 mg/L^{-}

Kazemi (2014) carried out an experiment to investigate the effect of 2 levels of gibberellic acid (10^{-4} and 10^{-8}) and 2 levels of potassium nitrate (6 and 8 mM) spray on the growth, leaf NPK content, yield and quality parameters of tomato. The application of gibberellic acid and potassium alone or in combination increased plant height, number of branches, number flowers per cluster, number fruits per cluster and faster fruit growth in addition to increasing fruit number, fruit firmness, weight and yield. The chlorophyll content, leaf NPK content, blossomend rot and nitrate reductase activity were not affected by application of GA_3 alone or in combination, With regard to fruit quality, the application of GA_3 at

10^{-8}mM, 8 mM potassium nitrate and 10^{-8}mM GA_3+ 8 mM potassium nitrate increased fruit lycopene content, total soluble solids, vitamin C and titratable acidity compared with the control treatment.

2.2 Influences of micronutrients

2.2.1 Iron related

Iron plays an important role in the synthesis of chlorophyll and also helps in the absorption of other nutrients. As a constituent of chlorophyll and cytochrome, it regulates respiration, photosynthesis, reduction of nitrate and sulphate. Micronutrients such as zinc and iron play an important role in promoting vegetative growth, flowering, yield and quality of several fruits like lemon (Supriya *et al*., 1993) and guava (Sheriff *et al.*, 2000).

Chaturvedi *et al.*, (2005) concluded that application of ferrous sulphate at 0.2 percent with zinc sulphate at 0.4 per cent in strawberry increased the number of leaves (29.93 and 23.24), flowers (2.22 and 3.33), fruit set (2.6 and 2.8), fruits (16.10 and 16.88) and fruit yield (133.82 and 140.47g) per plant; plant height (18.85 and 18.28 cm) and ascorbic acid content (66.1 and 65.94 mg). Increase in fruit weight (8.12 and 7.98g) and acidity (0.97 and 0.96%), TSS content (9.42 and 9.330 Brix) of fruits were also found with 0.2 per cent of ferrous sulphate and 0.4 per cent of zinc sulphate. The number of runners also increased with the 0.4 per cent zinc sulphate. Higher concentration of zinc sulphate resulted in enhanced shelf life of fruits (2.95 days) at ambient temperature. On the other hand, higher concentration of ferrous sulphate had toxic effect on the plant and retarded the growth, yield and quality attributes.

Abbas *et al*., (2009) conducted a field experiments to study the impact of trace elements on nutrient uptake and yield of wheat. Micronutrient, i.e. Fe was applied @ 0, 4, 8, 12 and 16 kg/ha alone as well as combined in a same trial, in the form of Iron sulphate. Results showed application

of Fe showed a significant response to wheat at lower rates. High rates of Fe reduced or did not affect the growth and yield contributing parameters. The best results were obtained when applied Fe @ 12 Kg/ha with recommended NPK. Increasing rates of Fe dose up to 12 kg/ha increased grain yield while higher rate did not have any significant effect.

An experiment was conducted by Rotaruto (2011) to investigate the effects of P and Fe application on the biomass production and nutrient status of two soybean (*Glycine max. L.*) The results showed that combined application of P and Fe increased dry matter production and nutrient acquisition for both soybean cultivars. Concentrations of Fe in leaves differed significantly among cultivars at both sufficient and insufficient mineral nutrition. It demonstrated that there was a positive effect of P and Fe adequate nutrition on plant growth and nutrient status.

Davarpanah *et al*., (2013) effect foliar application of Fe-EDDHA on yield and some quantitative and qualitative characteristics of Iranian pomegranate (CV. Malas-e-Saveh) were assessed. Results show that 2000 mg/L of foliar iron concentration have statistically differences with controls on Yield, Fruit Number, Fruit size, Total soluble solids (TSS), Total soluble solids to titratable acidity (TSS/TA) and dry weight in conclusion foliar iron with concentration of 2000 mg/L could increase the performance, the number of fruit per tree, fruit size, total soluble solids and dry weight in Pomegranate trees.

A study was conducted by Aboutalebi and Hassanzadeh (2013) to understand the effects of iron and zinc on sweet lime (*Citrus limmetta*). Results showed that treatments had significant effect on characteristics as fruit volume, yield, vitamin-C, total acid, fruit peel water percent and leaf iron and zinc content. It was recommend as 10 mg/L iron and zinc sulfates during June to improve the quality and quantity characteristics and yield of sweet lime.

Pena-Olmos *et al*., (2014) carried out an experiment under greenhouse conditions in Tunja (Colombia) in order to evaluate the effect of Fe^{2+} toxicity on the growth of broccoli plants. The total DM decreased drastically in the plants subjected to excess Fe2+, the growth indices progressively decreased with increases in the Fe^{2+} concentrations in the substrate and the distribution of DM in the organs varied as a function of the needs of the plants, with 15.85 and 11.10% less DM in the roots of the plants subjected to Fe^{2+} than in the control plants, at 100 and 250 mg/L, respectively.

Pingoliya *et al*, (2014) conducted a review experiment to study the effects of iron application on wheat. It was observed that a little amount of iron enhanced the growth, yield and quality of chick pea.

An experiment by Kazemi (2014) was conducted to observe the effect of foliar application of iron, calcium and zinc sulfate reproductive growth, yield and some qualitative characteristics of strawberry fruit were investigated. As result has shown iron, calcium and zinc sulfate increased dry weight, leaf area, length of roots of strawberry. Sprays of iron at 1000 mg/L combination with zinc and calcium improved number of flowers, weight of primary and secondary fruit. In general, spraying iron at 1000 mg/L with zinc sulfate at 150 mg/L, and calcium at 10 mM concentration was recommended for increasing the strawberry yield.

A Field experiments were carried out by Eleyan *et al*., (2014) to study the effect of foliar application of iron on growth, yield and fiber quality of some cotton cultivars. The results showed that cultivars significantly varied in studied parameters except position of the first sympodial node, fiber strength in both seasons and each of boll weight in the first season and earliness in second season. Foliar application of iron indicated marked improvement and produced significant effect on increasing plant height, sympodial branches, bolls number, boll weight, seed cotton yield. The data revealed that, the application of iron at 200 mg/L

recorded the maximum growth, yield and quality properties in the most examined treatments

Webb and Hallas (2015) have shown that restriction of the iron supply can cause marked reduction in growth and crop yield of strawberry before the onset of characteristic symptoms of iron deficiency. Fruit yield was reduced some 40% in control than that of adequately supplied with iron. Iron content of dry leaf, leaf was increased. Five of these (zinc, manganese, copper, magnesium, potassium) showed a decrease in percentage content in dry leaf matter as growth increased. Nitrogen and phosphorus contents did not vary too much, but the calcium content in the leaf showed a steady in Grease in percentage content as growth increased.

İncesu *et al*., (2015) observed that from an experiment that Control plants produced the most leaf area, whereas plants grown without Fe with a concentration of produced the least. Significant differences in SPAD and iron chlorosis scale was found in iron treatments.

Zain *et al*., (2015) conducted an experiment to evaluate the wheat performance by foliar application of micronutrients. Results showed that foliar application of micronutrients substantially improved plant height, spike length cm, spikelets/spike, grains/spike, test weight, Tillers/m^2, grain and biological as well as harvest index of wheat. Among treatments, foliar application of $FeSO_4$ + $ZnSO_4$ + $MnSO_4$ remained comparatively better regarding yield related attributes of wheat.

According to Rout and Sahoo (2015) Iron is an essential micronutrient for almost all living organisms because of it plays critical role in metabolic processes such as DNA synthesis, respiration, and photosynthesis. Further, many metabolic pathways are activated by iron, and it is a prosthetic group constituent of many enzymes. An imbalance between the solubility of iron in soil and the demand for iron by the

plant are the primary causes of iron chlorosis. It serves as a component of many vital enzymes such as cytochromes of the electron transport chain, and it is thus required for a wide range of biological functions. In plants, iron is involved in the synthesis of chlorophyll, and it is essential for the maintenance of chloroplast structure and function

2.2.2 Manganese related

Moreover manganese acts as an activator of many enzymes, (more than 35 different enzymes). Manganese has important role on activates several enzymes which involve to oxidation reactions, carboxylation, carbohydrates metabolism, phosphorus reactions and citric acid cycle. Of the most important these enzymes, protein manganese in Photosystem II and superoxide dismutase can be pointed. There is more than 90% of superoxide dismutase in chloroplasts which about 4 to 5 percent of it is in mitochondria (Mukhopadhyay and Sharma, 1991; Jackson *et al*., 1978).

It is commonly accepted that floral and fruiting organs are especially sensitive to Mn deficiency due to limited supply through the phloem and xylem (Marschner, 1995). There is a much higher demand for Mn and other micronutrients during the generative growth (flowering and seed set) even if the Mn level is in the adequate range (Reuter et al., 1988).

Broschat (1991) stated that with foliar application of four soluble Mn sources, only manganese sulfate consistently increased Mn concentrations in the pygmy date palm leaves.

Mn is required in both lower and high plants for the Hill reaction – the water splitting and oxygen evolving system in photosynthesis. Photosystem II contains a Mangano protein which catalyses the early stages of O2 evolution. Exogenous application of manganese in

adequate amount may result an increase in photosynthetic activity and growth rate of cells (Cramer and Nowak, 1992).

Foliar Mn application increases fruit set and yield in many plant species including soybean, wheat, sorghum, corn, wheat, and lupins (Mascagni and Cox, 1985 and Modaihsh, 1997).

Brennan, 1996 in a field experiment compared the responses of narrow-leafed sweet lupins (*Lupinus angustifolius* L.) to foliar sprays of different sources of manganese (Mn) in three years at six sites in Western Australia. The relative effectiveness of manganese chelate (EDTA; 14% Mn) and manganese sulfate (25% Mn) applied as foliar sprays for alleviating Mn deficiency of lupins was assessed. He found Manganese chelate, manganese sulfate, and the Mangasol sprays were equally effective. For all sources, 1.0 kg Mn/ha sprayed on the foliage was required to produce maximum seed yield and reduce split seed to an acceptable level (<4%). In all years, manganese sulfate banded with the seed produced similar seed yields as Mn sprayed on the foliage.

The function of Mn at the cellular level of plant is to bind firmly to lamellae of chloroplast, possibly to the outer surface of thylakoid membranes, affecting the chloroplast structure and photosynthesis (Lidon and Teixeira, 2000).

Manganese deficiency causes low pollen fertility and shortage of carbohydrates supply for fruit and seed development (Sharma *et al*., 1991).Foliar application of Mn is used mainly to correct Mn deficiency during the early seedling establishment and during reproductive growth (Bergmann, 1992). Thus, Mn has two roles in the plant metabolic processes: as an essential micronutrient and as a toxic element when it is in excess (Kochian*et al*., 2004; Ducic and Polle, 2005).

This investigation was carried out during 2001 and 2002 growing seasons by El-Seginy *et al*., (2003) on Anna apple trees aiming to study

the effect of foliar sprays with gibberellin and a mixture of chelated (Fe, Zn and Mn) alone or in combination on fruit set, fruit drop percentage, some leaf mineral content, yield and fruit quality. Results revealed that, mixture of chelated Fe, Zn and Mn treatments with Ga3 influenced fruit set and reduced fruit drop significantly. Yield as weight or number of fruits/tree, as well as fruit quality (average fruit weight, firmness, TSS, acidity and total sugar) were generally improved under all treatments as compared with the control.

Study carried out by Teixeira *et al*., (2004) to see the effects of the leaf application of Mn and Zn rates were evaluated. There were of five rates of Mn(0, 75, 150, 300, and 600 g/ha) and five rates of Zn (0, 50, 100, 200, and 400 / ha) applied via leaves at the 25th day, or both alternatively parceled at 25 and 35 days after emergence (DAE). The combined application of Mn and Zn caused an increase in plant height, primary yield components as number of grains per pod, number of pods per plant, and productivity itself. The maximum technical efficiency was obtained with 315 g/ha Mn and 280 g/ha Zn for a bean productivity corresponding to 60% above control.

According to results of some experiments on apple trees (Thalheimer and Paoli, 2002) and orange trees (Papadakis *et al*, 2005), foliar application of manganese sulfate was more effective than manganese chelate in increasing leaf Mn concentrations.

Soil application of Mn is problematic, since its efficiency depends on many soil factors, including soil pH. A suitable method for the correction and /or prevention of Mn deficiency in plants is the foliar application of ionic or chelated solution forms of this nutrient (Papadakis *et al*, 2007).

El-Sheikh *et al*., (2007) found that Florida Prince and Desert Red peach trees were sprayed once, twice and thrice a year with combinations of

chelate at the rate 0.7g/L Fe, 0.3 g/L Zn and 0.3 g/L Mn led in improving chlorophylls (a, b) content and increase in yield, fruit weight, fruit size and fruit firmness.

Naiema (2008) mentioned that the treatment of Le-Conte pear trees with 3.6 % chelated microelements (Zn, Fe and Mn) gave an increase in fruit weight, fruit size and yield.

Al-Hawezi (2008) conducted an experiment to observe the effect of Mn on grapeberry. He found that foliar spraying of Mn increased TSS in grape berry.

Dordas (2009) found that manganese application increased the chlorophyll content and number of fruit per plant compared with the control treatment with no difference between the two rates of Mn, but it did not affect the mean fruit weight.

An investigation was carried out by Hassan *et al*., (2010) on "Hollywood" plum trees Sendyon village, Kalubia governorate, Egypt; Aiming to study the effect of foliar sprays with Aminofert, gibberellins, and a mixture of Fe, Zn, and Mn alone or in combination of GA_3 + Aminofert or GA_3 + a mixture of chelated "Fe, Zn, and Mn" on fruit set, yield, fruit quality, and leaf mineral content. All the treatments increased significantly fruit set, yield as weight; or number of fruits/tree, as well as, fruit characteristics (Firmness, TSS, Flesh thickness, and Acidity) were improved under all treatments as compared to the control.

Tavassoli *et al.*, (2010) conducted an experiment to investigate zinc (Zn) and manganese (Mn) nutrition effects on greenhouse tomato (*Lycopersicon esculentum* Mill. cv. HAMRA) in a perlite-containing media. Results showed that the highest fresh-fruit yield, fruit and leaf dry matter and content of Mn and Zn in fruit were obtained from single or combined application of Mn and Zn in concentrations equal to the full Hoagland's nutrient solution. In addition, Zn and Mn nutrition

significantly affected the fruit concentrations of crude protein, nitrogen and phosphorus, while the effect of these treatments on fruit size of tomato was not significant.

Manganese is one of the main micronutrients, which has an important role in plant as a component of enzymes involved in photosynthesis and other processes. Manganese is part of an important antioxidant (superoxide dismutase) structure that protects plant cells by deactivating free radicals which can destroy plant tissue. Manganese plays vital roles in photosynthesis, as a structural component of the Photosystem II watersplitting protein. It also serves as electron storage and delivery to the chlorophyll reaction centers (Diedrick, 2010; Millaleo*et al*., 2010).

Manganese plays an important role in chlorophyll production and its presence is essential in Photosystem II, also involved in cell division and plant growth. RNA polymerase is activated by manganese. Manganese has an effective role in lipids metabolism. (Mousavi *et al*., 2011)

Experiments were conducted Jabeen and Ahmed (2011) effects of exogenous application of some essential micronutrients (B and Mn) through foliar spray against the adverse effects of salt stress on growth and biochemical activities of sunflower plants. Foliar applications of B through H_3BO_3 and Mn through $MnCl_2$ and their mixture were found to improve all the studied growth parameters and biochemical activities of sunflower plant irrespective to their growth under non-saline or saline conditions. The growth and yield component as a result of the mixture of foliar spray was higher than spray of single element.

Effects of foliar sprays of zinc and manganese sulfates on the fruit yield and quality as well as leaf nutrients concentration of pomegranate were studied by Hasani *et al*., (2012) growing season in an orchard. Zinc and manganese sulfates were applied two times at the rate of 0, 0.3 and 0.6

percent under a factorial design on the base of completely randomized blocks. Mn sprays had positive significant effects on the fruit yield, the aril/peel ratio, TSS, weight of 100 arils, juice content of arils, anthocyanin index, fruit diameter and leaf area.

Yousefi and Zandi (2012) carried out an experiment to determine the response of pumpkin (*Cucurbita pepo* L.) to zinc and manganese fertilizers at Agricultural Research Farm of Qazvin, Iran during 2011. Subplots, which consisted of split plots, comprised of four foliar application levels (no spray application as control, Zn as ZnSo4, Mn as MnSo4 and Zn+Mn) of micronutrients at flowering stage. Seed number, seed yield, fruit yield and oil content of pumpkin showed significant response to foliar spray of Mn and Zn. The highest seed yield (797 kg/ha) was obtained from foliar spray of Zn+Mn.

Yasari (2012) found that plant height decreased but mowing height increased when manganese was applied. These results also confirmed that the number of axillary shoots increased when Mn singly or in combination with P, Zn were applied to the soil. With an increase in the application rates of manganese, it was observed that seed yield, like other components of yield, exhibited a rising trend, so that comparison of the means revealed that the lowest seed yield was recorded in control and that the largest seed yield was achieved when the maximum rates of phosphorous, manganese, and zinc combinedly used.

Eiada *et al., (*2013) carried out at a study on pomegranate orchard, Horticultural Station Al-mahaweel, in the province of Babylon. It was aimed to investigate the influence of spraying manganese and zinc solutions on 12 years old trees of Salemy pomegranate cultivar. Manganese was applied with four levels i.e., 0, 20, 40 and 60mg/L. The obtained results showed that 60 mg/l manganese with 3% zinc recorded the highest leaf area, chlorophyll content, fruit set and the highest fruit weight. Whereas, the lowest values of these parameters were recorded

with control treatment. Also, Mn with Zn gave the lowest value of splitting fruit.

Asadollahi and Mozaffari (2013) carried out an experiment to investigate the effect of manganese (Mn) and salinity on some growth traits and chemical composition of pistachio (*Pistaciavera* L.) seedlings with two factors of salinity (0, 75, 150, 225 and 300mM NaCl) and Mn (0, 12, 24 and 36 µM Mn from $MnSO_4$ source). Results showed that application of 12 and 24 µM Mn increased dry weight of shoots and leaf number by 29 and 24 percent in comparison with zero level of Mn, respectively. Application of Mn increased Mn, Zn, P and K concentration. Overall results of this research showed that salinity reduced vegetative growth, and since Mn has positive effects on some growth traits.

Abdallah and Hana (2013) studied the response of Giza 90 and Giza 92 cotton cultivars to foliar application of a combined of each of iron, manganese and zinc. The resultsshowedthatcultivars significantly varied in each of plant height, number of sympodial branches per plant.

Yadegari (2013) Conducted an experiment to study the effect of Fe, Zn, Cu and Mn foliar applications in Borago on yield and essence production. Results showed that Mn, Fe, Zn, and Cu had the significant effectiveness in percentage of essence, DPPH, carotenoids, flavonoids, phenols, weight of fresh and dry root matter, number of flower, and weight of dry and fresh of flower and weight of dry and fresh shoot matter. Combinations of 400ppm of Fe, Zn, Cu and Mn (produced the greatest amounts in most of measured characters. The most weight of dry flower and number of flower per plant were 14.8, 16.8 gr and 10.9, 13.9 in 1st and 2nd year and made by combination of Mn, Fe, Zn, and Cu treatment.

Eleyan *et al*., (2014) conducted a Field experiments to study the effect of foliar application of manganese and iron on growth, yield and fiber quality of some cotton cultivar. Treatments five foliar applications of micronutrients (0, 100 and 200mgl-1 for both manganese, and iron) were applied in sub-plots. Foliar application of manganese and ironboth indicated marked improvement and produced significant effect ($P \leq 0.05$) on increasing plant height, sympodial branches, earliness in response, bolls number, boll weight, seed cotton yield. Alsothe data revealed that, the application of manganese and iron at 200 mgl-1recorded the maximum growth, yield and quality properties in the most examined treatments.

This experiment was conducted by Ali *et al*., (2014) to study the effect of foliar spray of micronutrients on quality of peach fruits at Horticulture Farm, University of Agriculture Peshawar during 2010. The treatments were Zn, Cu, Fe, Mn, B The fruit quality was evaluated and maximum fruit length, diameter and yield were noted in Mn + Zn + Cu + Fe + B. The juice pH decreased and the juice acidity increased in a linear fashion after foliar spray of micronutrients. The total soluble solids of fresh fruit juice ranged 7.01% - 8.88% and vitamin C ranged from 4.80% - 7.90% after foliar spray.

CHAPTER III

MATERIALS AND METHODS

This chapter includes the information regarding methodology that was used in execution of the experiment. It contains a short description of location of the experimental site, climatic condition, materials used for the experiment, treatments of the experiment, data collection procedure and statistical analysis etc.

3.1 Experimental sites

The experiment was conducted at Horticulture Farm, Sher-e-Bangla Agricultural University, Dhaka, during the period from July 2014 to March 2015. Location of the site is $23^0$74' N latitude and $90^0$35' E longitudes with an elevation of 8 meter from sea level (UNDP - FAO, 1988) in Agro-Ecological Zone of Madhupur Tract (AEZ No. 28).

3.2 Climatic conditions

Experimental site was located in the subtropical monsoon climatic zone, set apart by heavy rainfall during the months from May to September (Kharif season) and scantly of rainfall during the rest of the year (Rabi season). Plenty of sunshine and moderate low temperature prevails during October to March (Rabi season), which is suitable for strawberry growing in Bangladesh.

3.3. Experimental Materials

Plantlets of the strawberry cultivar (Festival) have been collected from the tissue culture laboratory, BRAC. On the other hand,GA_3 and micronutrients (Iron and Manganese) have been collected from 2a-Biotech Lab, Sher-e-Bamgla Agricultural University, Sher-e-bangla Nagar, Dhaka-1207.

3.4. Methodology of Production

3.4.1. Pot preparation

The experiment was pot experiment conducted in the Horticultural farm of Sher-e- Bangla Agricultural University. First of all pots having height of 10 inch and diameter of 12 inch was collected from a local shop at Mirpur -10, Dhaka. Then the soil was prepared outside of the pot mixing soil, compost, sand in a proportion of 2:1:1. Mixed fertilizer of N, P, K and S was added to the soil during preparation. Then pot was filled with the prepared soil.

3.4.2. Preparation of GA_3spray solution

Dry powdery formulated GA_3 was used to make GA_3 spray solution. First 150 mg of GA_3 was mixed in 10 ml of ethanol. Then the primary solution was taken in a sprayer of one liter. And then the sprayer was fill up to the mark to make 150 ppm solution. (Plate 1a)

3.4.3Preparation of micronutrient solution

150 mg each of the Crystal formulated micronutrients ($FeSO_4$for Iron and $MnSO_4$for manganese) were measured by Electronic Precision Balance. Then each of the micronutrients were taken in a 1L hand sprayer. 100 to 150 ml water was added first and mixed thoroughly. Then the sprayer was filled up to the mark.

3.4.4. Transplanting of plantlets

108 runners were settled up for transplanting. Runners were transplanted in such a way that crown does not go much under soil or does not remain in shallow. Runners were planted in pot on November 2015.

3.4.5. Tagging of plants

Plants were tagged on November 2014 using card.

3.4.6. Design of the experiment

The experimental design was Completely Randomized Design (CRD).There were 9 treatments and 3 replication of this experiment.

3.4.7. Treatments of the experiment

Factor- A: Frequency of Gibberellic Acid application (G)

GA_3 employed on experiment are given below

G_0- Control (Spraying water)

G_1- GA_3Once spray at 15 Days after Transplanting @ 150 ppm

G_2- GA_3Twice spray at 15 and 30 Days after Transplanting @ 150 ppm

Factor- B: Micronutrients (M)

Micronutrients employed on experiment are given below

M_0- Control (Spraying water)

M_1- Foliar spray of Iron as @ 150 ppm

M_2- Foliar spray of Manganese @150 ppm

Factor- B / **Factor- A**	**Control (M_0)**	**Iron (M_1)**	**Manganese (M_2)**
Control (G_0)	G_0M_0	G_0M_1	G_0M_2
GA_3 Once spray (G_1)	G_1M_0	G_1M_1	G_1M_2
GA_3 Twice spray (G_2)	G_2M_0	G_2M_1	G_2M_2

3.4.8. Application of the treatments

GA_3 solution as well as the micronutrients were applied as foliar application with a hand sprayer as in the evening. Spraying of a similar amount of tap water will be served as control treatment.

3.4.9. Intercultural operations

Weeding:

Weeding was performed in all pots as and when required to keep plant free from weeds.

Watering:

Frequency of watering depended upon soil moisture status by observing visually. However, avoided water logging as it is detrimental to plants.

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.

Fruit management:

In order to protect the fruits from being birds, the pots were covered with net throughout the time of strawberry ripening. Straw mulch was provided for prevention of fruits from touching the soil.

Harvesting of fruits:

Harvesting of fruits was done after fruits reached at maturity stage. Mature fruits were harvested when fruits turned to red in color with waxy layer on surface of fruits. Fruits were harvested from first week of February 2015 to last week of March 2015

3.4.10. Parameters

Data were collected from each pot. Data were collected under the following heading:

- Plant height
- Number of leaves per plant
- Leaf area
- Chlorophyll percentage
- Days to first flowering
- Days to first fruit setting
- Days to first fruit harvesting
- Number of flower bud/plant
- Number of flower/plant
- Number of fruit /plant
- Fruit length
- Fruit diameter
- Single fruit weight
- Brix (%)
- Total Fruit weight per plant

3.5. Data collection

3.5.1. Measurement of plant height

Plant height of each plant was measured in cm by using meter scale and mean was calculated three times at 30, 40 and 50DAT. (Plate 1b)

3.5.2. Number of leaves

Number of leaves per plant were recorded by counting all the leaves from each plant and mean was calculated three times at 30, 40 and 50DAT.

3.5.3. Leaf area measurement

Leaf area was measured by destructive method using CL-202 Leaf Area Meter (USA) (Plate 2c).Mature leaf (from 4th node) were measured once at 50 days after transplanting and expressed in cm^2. Five mature leaves from each plant were measured and then average it after that mean was calculated. (Plate 1c)

3.5.4. Chlorophyll percentage

Chlorophyll percentage was taken by non-destructive method using 'Konica Minolta SPAD meter'. Five mature leaves from each plant were measured and then average it after that mean was calculated. (Plate 1d)

3.5.5. Days to flowering, fruit setting and harvesting

Days to flowering, fruiting and harvesting were counted by visual observation from the date of strawberry plantlets transplanting.

3.5.6. Measurement of fruit weight

Fruit weight was measured by Electronic Precision Balance in gram (Plate 1e). Total fruit weight of each treatment was obtained by addition of weight of the total fruit number and average fruit weight was obtained from division of the total fruit weight by total number of fruit.

3.5.7. Measurement of fruit length and Diameter

Fruit length and diameter were measured using Digital Caliper-515 (DC-515) in millimeter (mm). Mean was calculated each treatment (Plate 1f)

Measurement of Brix percentage

Brix percentages were measured by Portable Refractometer (ERMA, Tokyo, Japan) (Plate 1g; 1h). Every single fruit was blend and juice was collected to measure brix percentage. Mean was calculated for each treatment. Brix percentage of fruits was measured at room temperature.

3.5.9. Statistical analysis

Collected data were statistically analyzed using MSTAT-C computer package programmed. Mean for every treatments were calculated and analysis of variance for each one of characters was performed by F–test (Variance Ratio). Difference between treatments was assessed by Least Significant Difference (LSD) test at 5% level of significance (Gomez and Gomez, 1984).

3.5.10. Design and Layout of the Research Work

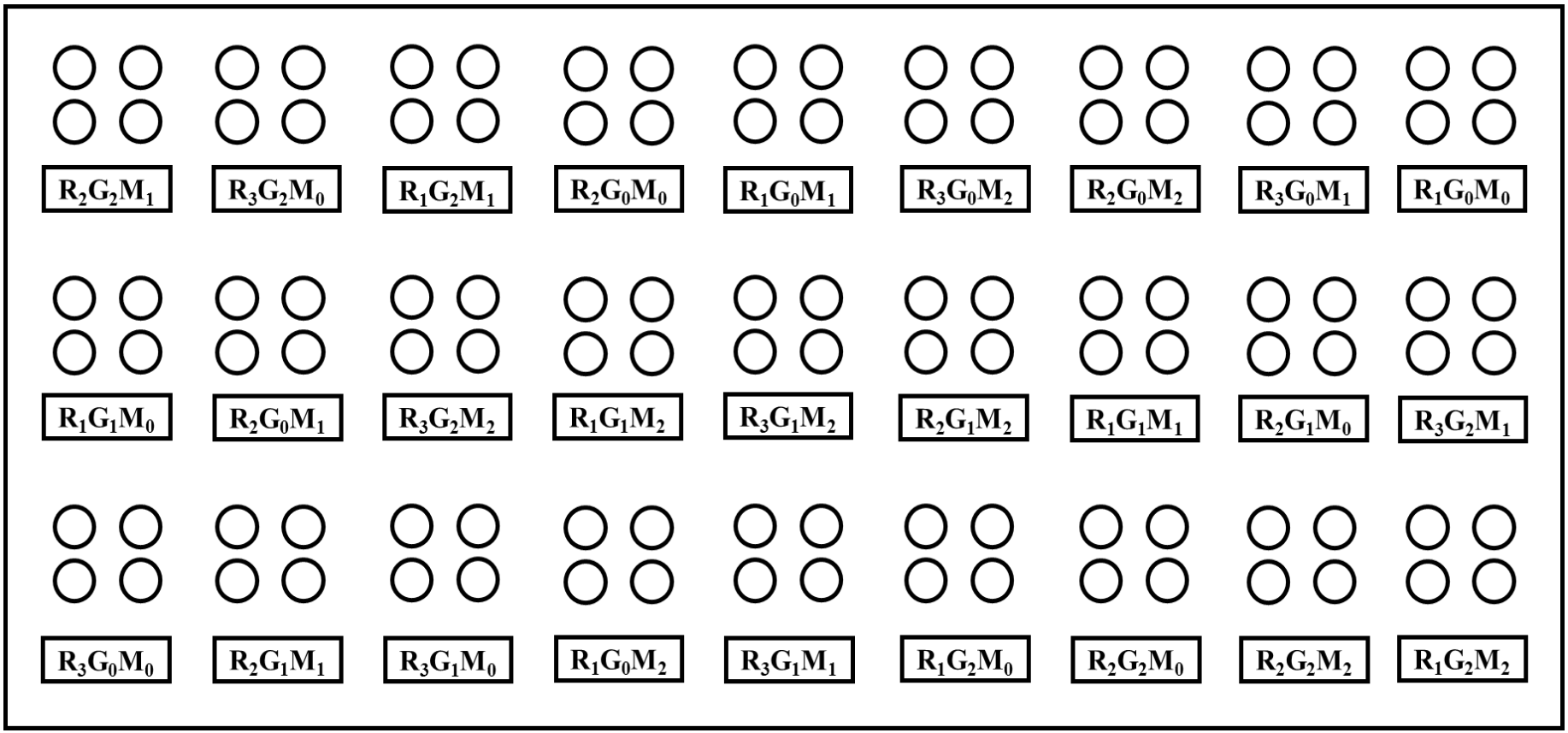
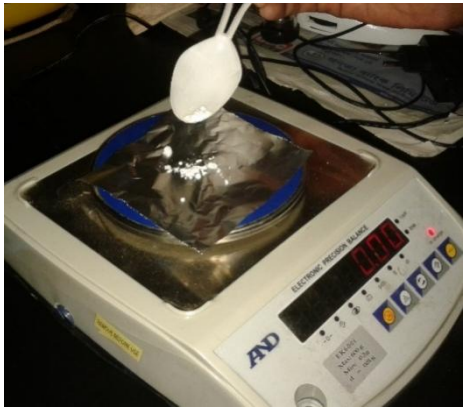
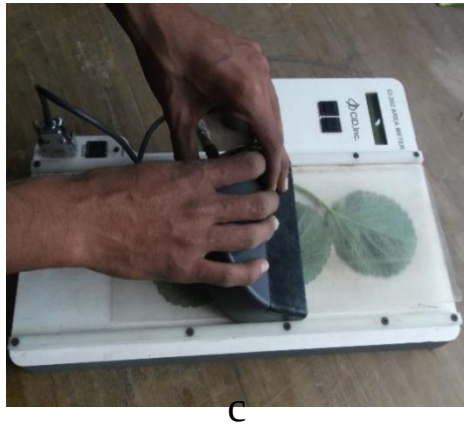


Fig 1: Showing the sketch of layout of the experiment



a

b



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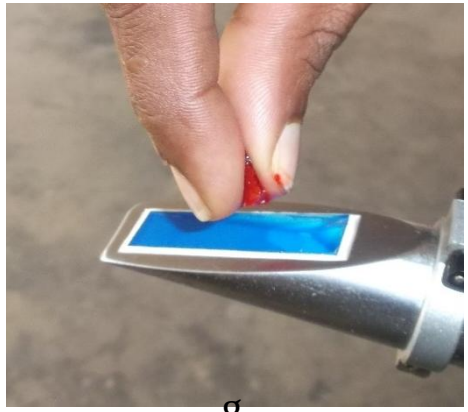
d

e

f



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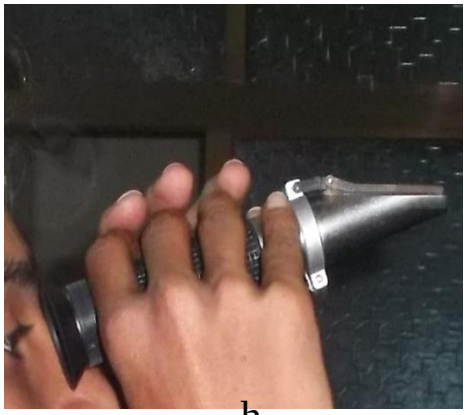

h

Plate1: a. Measurement of chemical substances to prepare spray solution; b. Measurement of Plant height using Meter scale c. Measurement of Leaf area using CL-202 Leaf Area Meter (USA); d. Measurement of chlorophyll percentage using SPADe. Measurement of Fruit weight using Electronic Precision Balance; f. Fruit length & diameter measurement using DigitalCaliper -515 (DC- 515); g. Taking fruit mash for measuring brix; h. Measurement of percentage of brix using Portable Refractometer (ERMA, Tokyo, Japan).

CHAPTER IV
RESULTS AND DISCUSSION

The research work was accomplished to observe the effects of GA_3 and Micronutrient in yield and growth of strawberry. Strawberry showed differences in terms of different growth and yield related characters.

4.1 Plant Height

Significant variation was found among the GA_3 treatments in terms of plant height (Appendix-II). At all observations plant height of strawberry in treatments of G_2 (17.6 cm) showed the highest plant. Present study showed us plant height of strawberry due to foliar application of GA_3 application twice at 15 DAT and 30 DAT was highes tand lowest plant height was seen in the plants treated with no GA_3 (Fig: 2).GA_3 enhances cell division, increases plasticity of cell wall (Huttly and Phillips, 1995) and facilitates cell enlargement, and finally elongation of cell, tissue and internodes (Shah, 2004). GA_3 also facilities the uptake of essential nutrients to perform these activities. May that's why plant become taller. (Taiz and Zeiger, 1998; khan *et al*, 1998). Davis and Nunez (2000) and Ayyub *et al*., (2013) found the same result.

Significant variation was also found among the Micronutrient treatments in terms of plant height(Appendix-II). Plant height of strawberry in treatments of M_0, M_1 and M_2 at 30 DAT showed no significant variation, whereas M_2 (16.4cm, 17.2cm) showed tallest plant at 40 DAT and 50 DAT and M_0 (15.6cm, 16.3cm) showed the lowest plant height at 40 DAT and 50 DAT (Fig: 3). Present study showed us plant height of strawberry due to foliar application of manganese showed the tallest plant and strawberry plant treated with neither iron nor manganese was shortest. Manganese as an essential element plays a very important role on plant growth. Activating enzymes and co-enzymes manganese facilitates biochemical reactions within the plants, which may

enhance better growth. Teixeira *et al*., (2004) and Jabeen and Ahmed (2011) showed the same result.

Combination effect of GA_3 and micronutrients also showed significant difference in terms of plant height (Appendix-II). Where statistically significant difference was found among the treatment combinations at 30, 40, and 50 DAT. Finally the tallest plant was observed under G_2M_2 (18.2cm) treatment and shortest was found in G_0M_0 (15.3cm) treatment finally (Fig: 4).

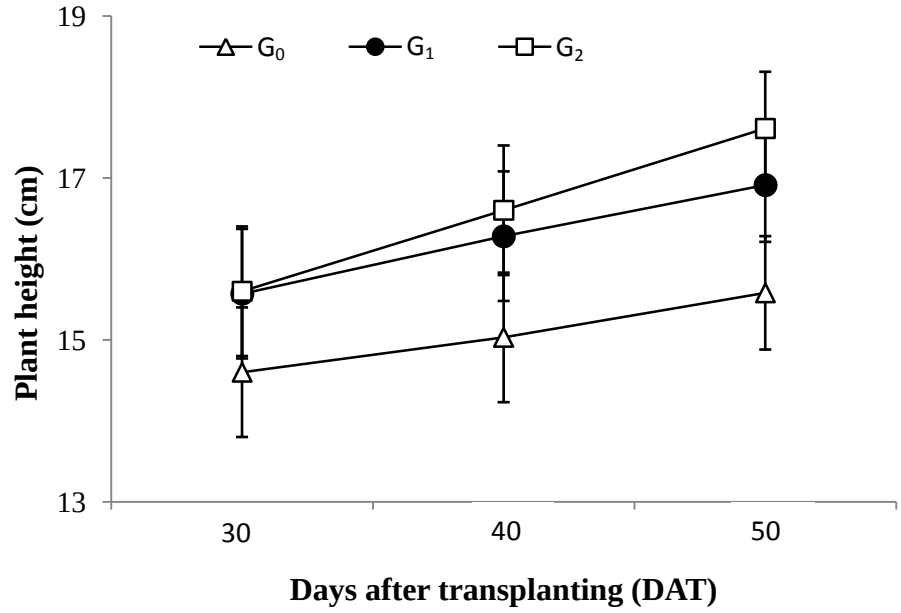

Figure 2. Performance of GA_3 on plant height at different days after transplanting

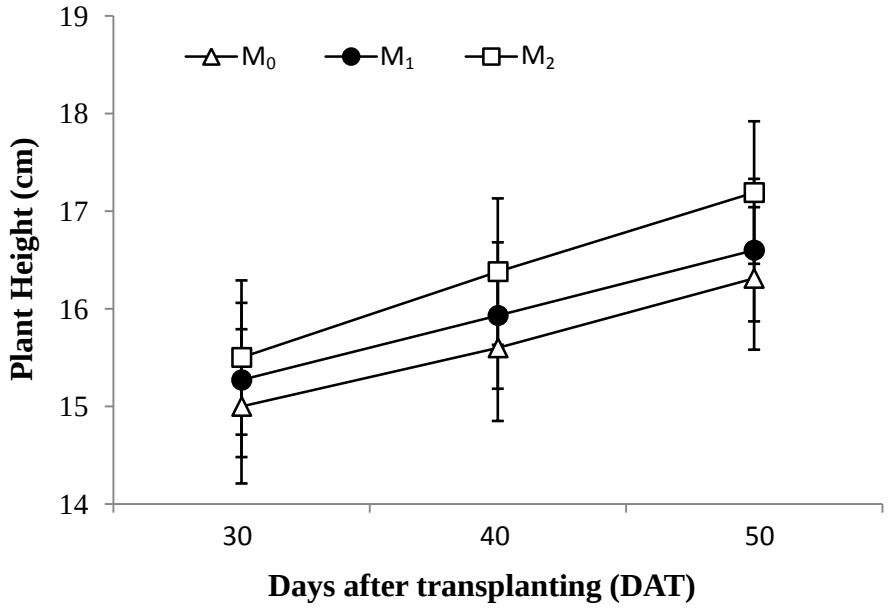

Figure 3. Performance of micronutrients on plant height at different days after transplanting

G_0-Control; G_1-GA_3 single application at 15 DAT; G_2- GA_3 double application at 15 DAT and 30 DAT; M_0-Control, M_1-Foliar application of Iron, M_2- Foliar application of Manganese.
Vertical bars represent the $LSD_{0.05}$ value.

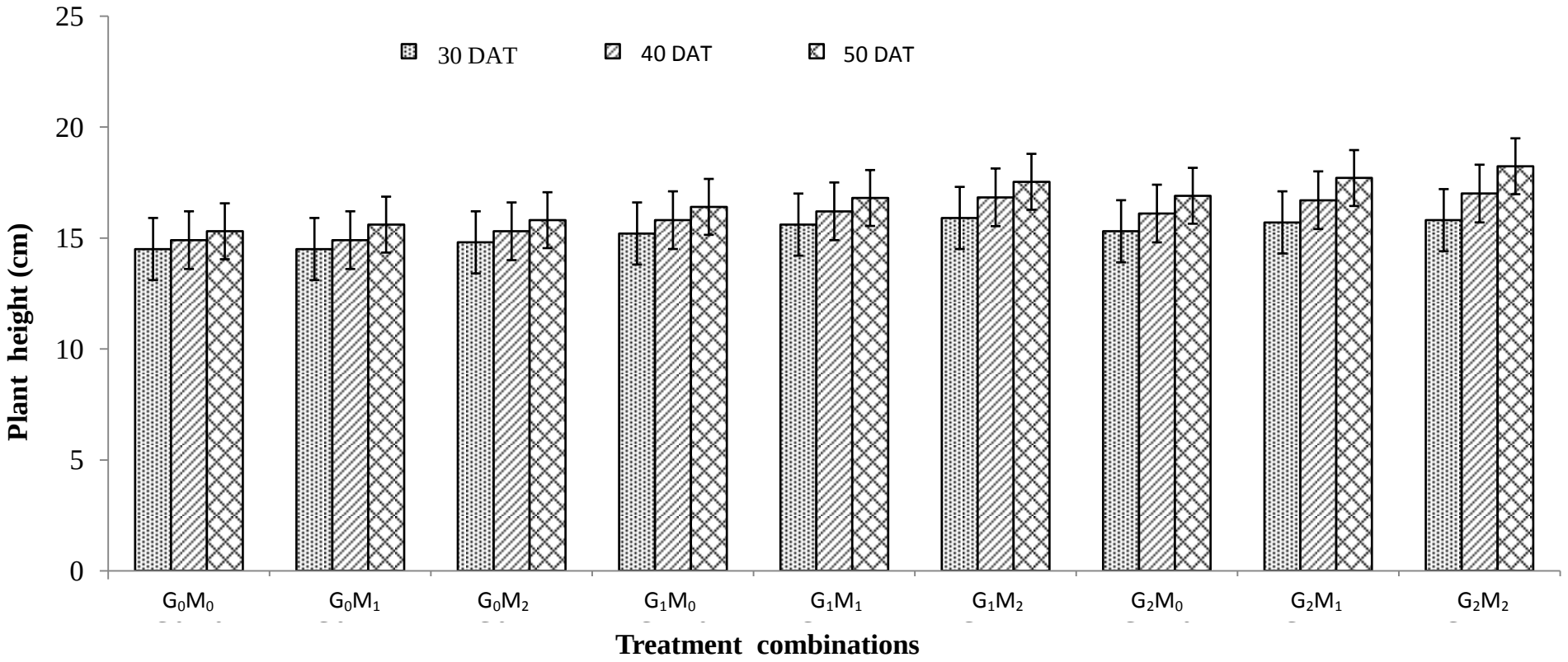

Figure 4. Performance of Treatments combinations on Plant height at different days after transplanting

G_0-Control; G_1-GA_3 single application at 15 DAT; G_2- GA_3 double application at 15 DAT and 30 DAT; M_0-Control, M_1-Foliar application of Iron, M_2- Foliar application of Manganese, Vertical bars represent the $LSD_{0.05}$ value.

4.2 Leaf number

Significant variation was found among the treatments of GA_3 in case of leaf number. (Appendix III). Leaf number showed statistically significant inequality among G_1, G_2 and G_3 at 30, 40 and 50 DAT (Figure 5). The maximum number of leaves was obtained from G_2treatments(8.3) and minimum from G_0 (7.1) at 50DAT of strawberry plantlets (Table 1). This might be due to the rapid increment and expansion of plant cells for proper plant growth by the increased concentrations of GA_3 (Rashid, 2010). Same findings were also found by Rashid (2010); Lolaei *et al*., (2013) and Ayyub *et al*., (2013).

Leaf number was significantly affected by Micronutrient treatments (Appendix III). Leaf number of strawberry exposed statistically significant inequality among control, Iron (150 ppm), and Manganese (150 ppm)at 30, 40 and 50 DAT of strawberry plantlets (Figure 6). The maximum number of leaf was observed in manganese (M_2; 8.1) treated plants while minimum from control (M_0; 7.5) at 50 DAT (Table 2). Study referred that manganese treatment produce maximum number of leaves. Manganese is an essential plant micronutrient. Foliar application increases uptake of this nutrient which including chloroplast formation, photosynthesis, nitrogen metabolism and synthesis of some enzymes. Jabeen and Ahmed (2011); Asadollahi and Mozaffari (2012) found the same findings.

Combined effect of different GA_3 treatments and different Micronutrient treatments in terms of leaf number also exposed significant variation (Appendix III). Leaf number of strawberry treated with GA_3 showed statistically significant inequality among Micronutrient treatments at 30, 40 and 50 DAT (Figure 6). The maximum number of Leaf was observed under the G_2M_2 (8.7) treatment whereas the minimum from G_0M_0 (6.6) treatment (Fig 7).

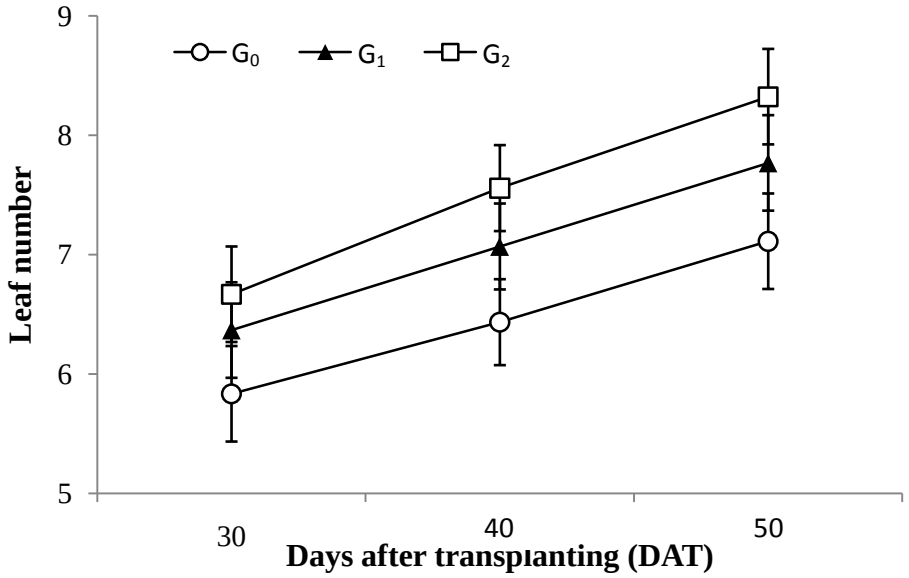

Figure 5. Performance of GA_3 on leaf number at differentdaysafter transplanting

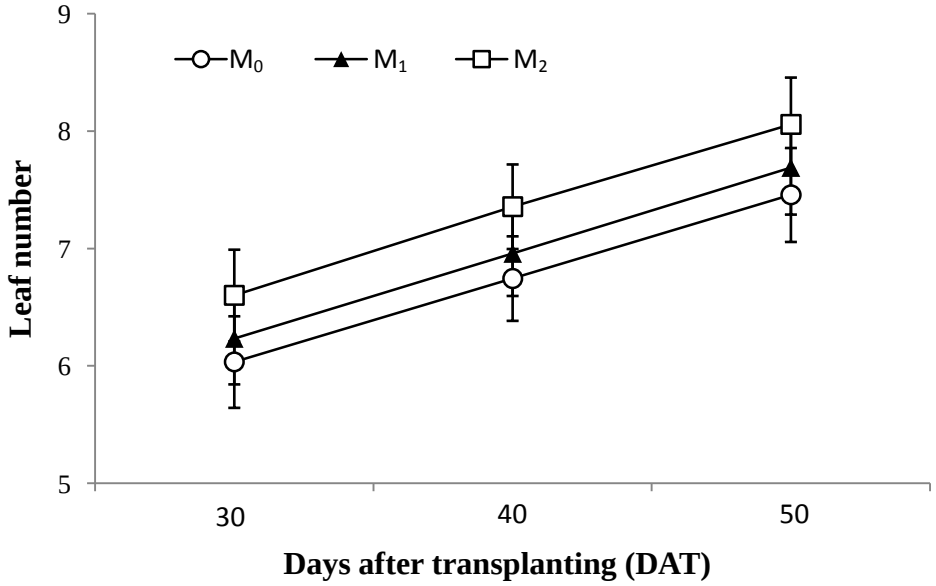

Figure 6. Performance of micronutrients on leaf number at different days after transplanting

G_0-Control; G_1-GA_3 single application at 15 DAT; G_2- GA_3 double application at 15 DAT and 30 DAT; M_0-Control, M_1-Foliar application of Iron, M_2- Foliar application of Manganese, Vertical bars represent the $LSD_{0.05}$ value.

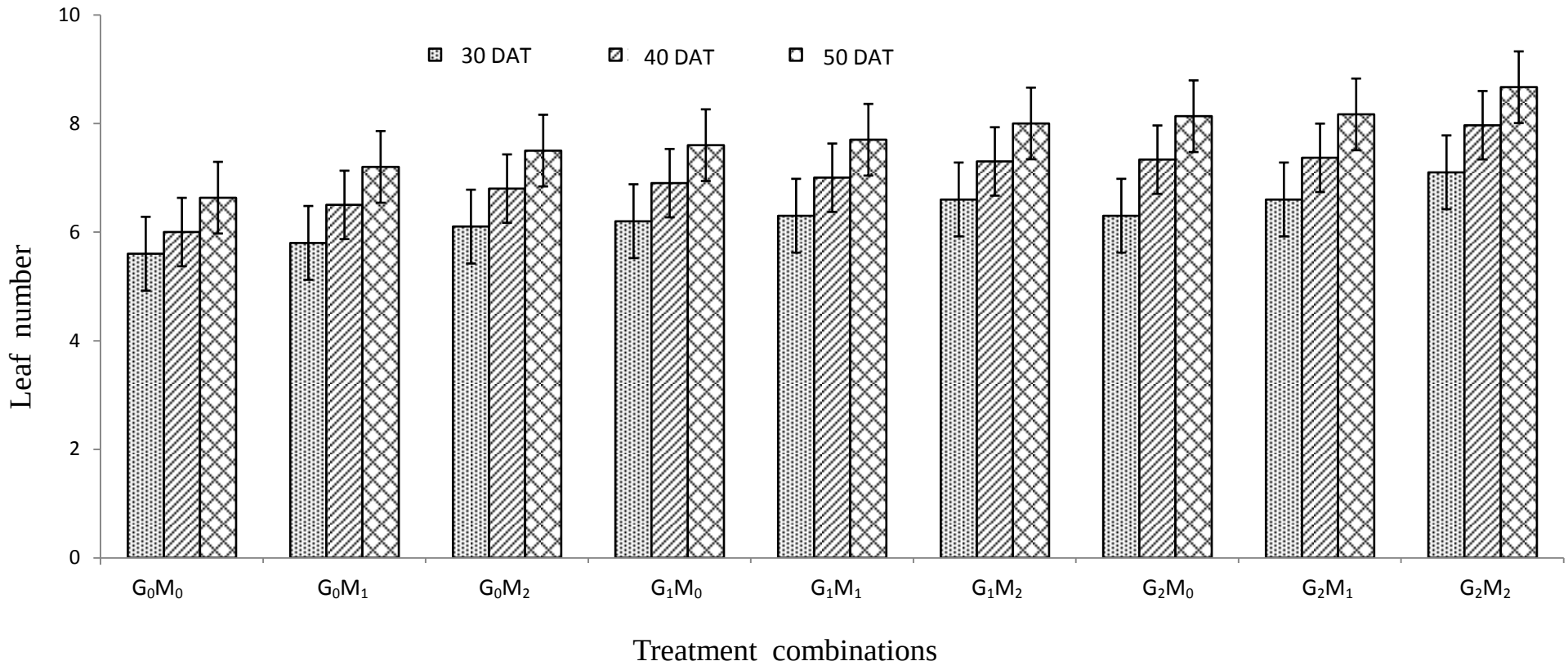

Figure 7. Performance of Treatments combination on leaf number at different days after transplanting

G_0-Control; G_1-GA_3 single application at 15 DAT; G_2- GA_3 double application at 15 DAT and 30 DAT; M_0-Control, M_1-Foliar application of Iron, M_2- Foliar application of Manganese, Vertical bars represent the $LSD_{0.05}$ value.

4.3 Leaf Area (cm^2)

Strawberry plants treated with different GA_3 concentration showed statistically significant difference in case of leaf area (Appendix V). Maximum leaf area was found from G_2 ($83.5cm^2$) treatment and the minimum was G_0 ($54.9cm^2$) (Table 1). It means that plant sprayed with GA_3 twice produce bigger leaf. The increase in the size of leaf area in trees which sprayed with GA_3 may due to the enhancing effect of GA_3 on division of leaves cell, leaves elongation, and finally increasing growth. GA_3 also enhance the osmosis process also increase the extensibility of cell wall thus the cell become expanded and may this is also the reason why leaf become bigger if GA_3 is sprayed. As GA_3 enhances the photosynthesis processby activating the photosynthetic enzymes, which needs more light consumption which may needs an increased leaf surface area. Findings of AL-Rawi (1999); Paroussi *et al.,* (2002) and Abass *et al*., (2011) are similar to these results.

Leaf area significantly differed within the micronutrients(AppendixV). Largest leaf surface was found with the plants in M_2 ($72.9cm^2$). And the smallest leaf was found in M_0 ($64.1cm^2$) (Table: 2). Study referred that Leaf area increased due to application of manganese. Strawberry needs slightly acidic condition for its proper growth and development. Manganese provides the better growth condition for strawberry which leads to better nutrient uptake and finally bigger leaf. The same result was found by Hasani *et al*., (2012) and Eiada and Al-Hadethi(2013).

The combinations of GA_3 and Micronutrients also showed statistically significant variation in case of leaf area(Appendix V). Combination G_2M_2 ($88.5cm^2$) showed highest leaf area and G_0M_0 ($51.3cm^2$) showed lowest leaf area which is statistically similar to G_0M_1 (Table: 3). GA_3 promotes growth by increasing photosynthesis which may need bigger leaf surface. In other hand manganese provide proper environment for nutrient uptake which boost the uptake of nutrient may help in developing the leaf bigger.

4.4 Chlorophyll percentage

Chlorophyll percentage significantly differed among the plants treated with different doses of GA_3(Appendix V). Where highest chlorophyll percentage was found in case of G_2 (53.2) and lowest was found in case of G_0 (43.9) (Table: 1). From this research we see foliar application of GA_3 twice showed highest chlorophyll percentage. GA_3 boosts the process of photosynthesis which needs more light absorption thus higher chlorophyll content.GA_3 acts to accumulate nutrition elements from plant parts to positions which GA_3accumulated. Some of these nutrition elements became parts of new chlorophyll molecule (Abass*et al*., 2011). The same result was also shown by Turkyilmaz (2012); AL- Rawi (1999) and Abass *et al*., (2011).

Strawberry plants treated with different Micronutrient treatments also showed significant variation (Appendix V). Strawberry plants treated with M_2 (46.8) treatment had highest chlorophyll percentage while plants treated with control (49.7) had the lowest (Table: 2). The study expressed that plants treated with manganese showed higher chlorophyll percentage. Although Mn is not a constituent of chlorophyll, it helps in its formation. The function of Mn at the cellular level of plant is to bind firmly to lamellae of chloroplast, possibly to the outer surface of thylakoid membranes, affecting the chloroplast structure and photosynthesis (Lidon and Teixeira, 2000). A deficiency of Mn causes chlorosis between the veins of leaves. Manganese actively involved in the process of chlorophyll formation and is necessary for building chloroplasts (Lidon*et al*., 2004). Shashi and roy (2011); Eiada*et al*., (2013); Kahramanova *et al*., (2014); Soltangheisi*et al*., (2014) also found the same result.

The combination of GA_3 and micronutrients also showed significant variation in strawberry plants in case of chlorophyll percentage (Appendix V). Combination G_2M_2 (55.5) and G_2M_1 was statistically similar of which G_2M_2 showed the highest amount chlorophyll present in strawberry leaf, while combination G_0M_0 (43.1) showed the lowest amount of chlorophyll present in leaf (Table: 3). From the above study we found that twice spray of GA_3 in combination with manganese increased the amount of chlorophyll present in leaf. GA_3 supplies the required nutrition for chlorophyll formation while manganese activates the enzymes which accelerate the process.

4.5 Days to flower initiation

Significant variation was received among the plants treated with GA_3 in respect of days to first flowering from days after transplantation of strawberry plantlets (Appendix IV). Longest period was required for flowering in G_2 treatment (42.3ays) while shortest period in G_1 treatment (35.1days) (Table 4). The result showed that G_1 treatment had early flowering whereas G_2treatment had late flowering. Early flower initiation leads to an early fruiting, which may reduce the total time needed for crop production, ultimately leads to a higher cropping intensity. According to Phengphachanh *et al.,* (2012) GA_3 seemed to decrease ABA concentration and to boot t-ZR (trans-Zeatin Riboside) up in leaf that might be related to flower buds initiation and early flowering. Four treatments of GA_3 in strawberry was studied by Uddin*et al.,* (2012) reported that the minimum days for flower bud initiation (70.0) at 75ppm, while maximum day (95.6) in control. Paroussi*et al.,* (2002); Jamal Uddin *et al.,* (2012); Hossan (2010) and Naeem, (2004) also found that GA_3 application induces early flowering.

Days to first flowering were significantly affected by micronutrients (Appendix IV). Early flowering was recorded in manganese (M_2 36.6 days) treated plants and delayed in control (M_0: 40.5days) (Table 5). Strawberry plants produced early flowering due to application of manganese. Eleyan *et al*., (2014) showed that plant responses early if sprayed with manganese.

Combination effect of GA_3 and micronutrients affects on days taken to first flowering also varied significantly to from each other (Appendix IV). G_1M_2 (32.3days) treatment required minimum period for flower bud initiation whereas G_2M_0 (44.6 days) took the maximum period for flower bud initiation (Table: 6). From this above study we can conclude that GA_3 single spray in combination with manganese works best.

4.6 Days to fruit setting

Significant variation was received for days to first fruit setting with different treatments of GA_3 (Appendix IV). Longest period was required for fruiting in G_2 (50.3days) treatment whereas, shortest period from G_1 (43.1 days) treatment (Table 4). The result indicated that fruiting of plants treated with GA_3 single spray was early whereas fruiting of plants treated with GA_3 double spray was late. Early fruiting is required to increase cropping intensity. GA_3 causes early flowering which may lead to an early fruit setting. Paroussi *et al*., (2002) and Hossan (2010) found the result similar to this finding.

Days to fruit setting were significantly affected by micronutrient treatments (Appendix: IV). Early fruiting was recorded in manganese (M_2:44.6days) treated plant and delayed in control (M_0: 48.5days) (Table 5). Manganese plays a very important role in several activities during generative stage. That is why higher demand for manganese during the generative growth (flowering and seed set) (Reuter et al., 1988). Due to the availability of proper nutrition influenced by manganese, growth of reproductive parts of flower is very good (Marschner, 1995). This may enhance a better and early fruit setting. Eleyan *et al*., (2014) also found that manganese significantly reduced the period need for fruiting.

GA_3 and micronutrient combinations significantly affected on days taken to first fruit setting (Appendix IV). G_1M_2 treatment was exhibited as superior combination (40.3 days required) for days to fruiting whereas G_2M_0 (52.6 days) performed as inferior combination showed in Table 6. So we find GA_3 single spray in combination with manganese gives the early fruit setting.

4.7 Days to first fruit harvesting

Early flower bud initiation, flowering, fruiting and harvesting is very important for better strawberry production with better quality in Bangladesh. As it grows well under temperate climate, low temperature is required for quality production. Production and quality decrease dramatically with the increase of temperature. In Bangladesh, from month of February temperature increases rapidly and strawberry plants face a major problem on fruit development and ripening. Early flower bud initiation, flowering, fruiting and harvesting can overcome this problem. Significant variation was found on days to first fruit harvesting with GA_3 (Appendix IV). Longest period was required for harvesting in G_2 Treatment (71.8days) whereas shortest period from G_1 Treatment (64.6days) (Table 4). The result showed that single spray of GA_3 had the early harvesting of strawberry plants whereas double spray of GA_3 had the late harvesting. Early fruit harvesting is essential to minimize the cropping period that will increase cropping intensity. Hossan*et al.*, (2013) reported that maximum 129.3 days required for fruit maturity of strawberry plant. Paroussi *et al.*, (2002); Hossan (2010) and Roy and Nasiruddin (2011) reported the result justifies the present findings.

Days to harvesting were significantly affected by micronutrient treatments (Appendix: IV). Early harvesting was performed by the plants treated with manganese which is M_2 (66.1days) and delayed in control (M_0; 70.0 days). Early flowering causes early fruiting and finally minimize the days required for harvesting (Table 5). Eleyan *et al.*, (2014) found earlier harvesting due to application of manganese.

GA_3 treatments in combination with micronutrient treatments affected significantly on days taken to harvest fruit (Appendix IV). In this case, G_1M_2 imparted the best result by taking earlier harvesting period (61.8 days) whereasG_2M_0 took the longest period to harvest (74.1days of harvesting period)(Table: 6).

Table 1. Effect of GA_3 on strawberry plants related to quality attributes[Y]

Treatments[x]	Leaf area (cm^2)	Chlorophyll (%)	Days to flower initiation	Days to fruit setting	Days to harvesting
G_0	54.9 c	43.9 c	38.8 b	46.8 b	68.3 b
G_1	66.5 b	47.7 b	35.1 c	43.1 c	64.6 c
G_2	83.5 a	53.2 a	42.3 a	50.3 a	71.8 a
CV (%)	3.7	4.1	7.8	6.4	4.4
LSD (0.05)	2.5	2	3	3	3

[X] G_0-Control, G_1- GA_3once spray at 15 DAT, G_2- GA_3 twice spray at 15 DAT and 30 DAT,

[Y] In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Table 2. Effect of micronutriuents on strawberry plants related to quality attributes[Y]

Treatments[x]	Leaf area (cm^2)	Chlorophyll (%)	Days to flower initiation	Days to fruit setting	Days to harvesting
M_0	64.1 c	46.8 b	40.5 a	48.5 a	70 a
M_1	67.9 b	48.2 ab	39 ab	47 ab	68.5 ab
M_2	72.9 a	49.7 a	36.6 b	44.6 b	66.1 b
CV (%)	3.7	4.1	7.8	6.4	4.4
LSD (0.05)	2.5	2	3	3	3

[X] M_0-Control, M_1-Foliar application of Iron, M_2- Foliar application of Manganese

[Y] In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Table 3. Effect of treatments combinations on strawberry plants related to quality attributes[Y]

Treatments[x]	Leaf area (cm)	Chlorophyll (%)	Days to flower initiation	Days to fruit setting	Days to harvesting
G_0M_0	51.3 h	43.1 f	39.8 abc	47.8 abc	69.3 abc
G_0M_1	55.1 gh	44.1 ef	39.5 abc	47.5 abc	69 abc
G_0M_2	58.3 fg	44.5 ef	37 bcd	45 bcd	66.5 bcd
G_1M_0	62.5 ef	46.3 def	37.2 bcd	45.2 bcd	66.7 bcd
G_1M_1	65 e	47.5 de	35.7 cd	43.7 cd	65.2 cd
G_1M_2	72 d	49.2 cd	32.3 d	40.3 d	61.8 d
G_2M_0	78.5 c	51 bc	44.6 a	52.6 a	74.1 a
G_2M_1	83.5 b	53.1 ab	41.7 ab	49.7 abc	71.2 ab
G_2M_2	88.5 a	55.5 a	40.5 abc	48.5 abc	70 abc
CV (%)	3.7	4.1	7.8	6.4	4.4
$LSD_{(0.05)}$	4.3	3.4	5.1	5.1	5.1

[X] G_0-Control, G_1- GA_3 single application at 15 DAT, G_2- GA_3 double application at 15 DAT and 30 DAT, M_0-Control, M_1-Foliar application of Iron, M_2-Foliar application of Manganese

[Y] In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

4.8 Number of flower bud per plant

Significant variation was received among the plants treated with GA_3 in respect of number of flower bud per plant (Appendix V). Highest flower bud initiation was found in G_1 treatment (27.4) while G_0 (22.2) showed the minimum number (Table 5). GA_3 induced highest amount of flower bud initiation. GA_3 boosts the plant growth which may lead to proper development of the plant for flowering. GA_3 had stimulatory effect on floral stem length and number of flower (Awan *et al*., 1999) which may increase the number of flower bud. These findings are supported by Paroussi *et al.,* (2002); Jamal Uddin *et al.*, (2012) and Asadi *et al.*, (2013).

Number of flower bud was significantly affected by micronutrients (Appendix V). There was significant variation among micronutrient treated strawberry plants. Highest flower bud initiation was recorded in manganese (M_2: 27.3) treated plants and delayed in M_0 (22.5) which is control (Table 5). Initiation of higher amount of flower may lead to a higher flowering and followed by higher fruiting. Yadegari (2013) also found the same result.

Combination of GA_3 and micronutrients affect significantly on number of flower bud (Appendix: V). G_1M_2 (30.1) treatment showed highest flower bud initiation whereas G_0M_0 (20.5) showed the minimum (Table: 6). From this study we see GA_3once spray at 15 DAT in combination with manganese showed highest number of flower bud.

4.9 Number of flower per plant

Significant variation was found among the treatments of GA_3 in case of number of flower. (Appendix V). Number of flower showed statistically significant difference among G_0, G_1 and G_2 (table 4). Maximum number of flower was obtained from G_1 (24.0) treatment whereas G_0 (20.3) showed no minimum no of flower (Table 5). This might be due to the positive stimuli of GA_3 for flowering.GA_3 provides the necessary nutrition and food materials needed for the buds to be transformed into a flower and also restrict the bud from drying (Monselise, 1979). Lee *et al.,* (1999) reported that GA_3 increased and number of flower per plant. Which was also supported by Paroussi *et al,* (2002); Jamal Uddin *et al.,* (2012) and Kazemi (2014).

No of flower was significantly affected by micronutrient treatments (Appendix V). Leaf number of strawberry exposed statistically significant inequality among control, Iron, and Manganese (table 5). Maximum number of flower was observed in manganese (24.0) treated plants while minimum from control (20.5) (Table 2). Study referred that manganese treatment produce maximum number of flower. Manganese deficiency causes low pollen fertility (Sharma *et al*., 1991). Foliar application of Mn is used to correct Mn deficiency at reproductive growth (Bergmann, 1992) may lead to higher number of flower. Yadegari (2013) also found the same result.

Combined effect of different GA_3 treatments and different micronutrients in terms of number of flower also exposed significant variation (Appendix: V). Number of flower of strawberry treated with GA_3 showed statistically significant inequality among micronutrients (table 6). Maximum number of flower was observed under the G_1M_2 (26.6) treatment whereas minimum from G_0M_0 (19.1) treatment. From the above discussion we can say GA_3 single spray in combination with manganese produces highest number of flowers among the treatments.

4.10 Number of fruit per plant

No of fruit per plant in strawberry significantly differed among the GA_3 treatments (Appendix: V). Maximum number of fruit was found in G_1 (21.5) treatment. G_0 (18.4) produced minimum number of fruit (Table: 4).So from this study we see that GA_3 single spray induced the highest amount of fruit, where the control produced lowest amount of fruit. Monselise, 1979 reported that GA_3 retarded the abscission of reproductive structures and increased the percentage of organs reaching the fruitlet stage. Sharma and Singh (2009); Rasheed (2010) and Kazemi (2014) showed that spraying of GA_3 increases the number of fruit.

Micronutrient treatments also showed significant variation in case of no of fruit per plant (Appendix: V). Maximum no of fruit per plant was observed in treatment M_2(21.6), and minimum in M_0 (18.4) (Table: 5). From the above study we see that no of fruit per plant was increased by the application of manganese. Manganese plays a very important role in fruit setting by increasing viability of pollen. If manganese is deficient fruit setting reduces and causes shortage of carbohydrates supply for fruit and seed development (Sharma *et al*., 1991). El-Seginy *et al.*, (2003); Hassan *et al.*, (2010) and Eiada *et al.*, (2013) also found the similar result.

Significant variation was found among the treatment combinations of GA_3 and micronutrients in case of no of fruit per plant (Appendix: V). G_1M_2 (23.7) gave the maximum no of fruit per plant and G_0M_0 (17.3) showed the minimum (Table: 6). From this study we see GA_3 single spray in combination with manganese increased the no fruit per plant.

4.11 Degree of brix (%)

Degree of brix was significantly affected by GA_3 treatments (Appendix V). Sweetness of strawberry exposed statistically significant inequality among treatments. The maximum brix percentage was observed in G_1 (5.5) treated plants while minimum from control (3.4) (Table: 7). Study referred that GA_3 single spray produces sweetest fruit. GA_3 influences the process of movement of produce food as sugars. It enhances the accumulation of sugar within the fruit. May this is why GA_3 treated plants produce sweet fruit. Singh and Singh (1979); Kazemi (2014) showed the same result.

There was significant variation among the different micronutrient treated plants in case of degree of brix (Appendix V). The maximum degree of brix was observed from plant treated with M_2 (5.5) and the minimum degree of brix was found from M_0 (4.0) (Table: 8). The cause for increasing the percentage of total soluble solids when spraying these elements, it may be due to the role of these elements in increasing activities of the vegetative growth, then absorb nutrients (Al-Rawi *et al.,* 2012). Also due to its role in the efficiency of the process of photosynthesis, thereby increasing manufactured materials in the leaves and moving to the fruit increases the components and their properties (Al-Rawi *et al.,* 2012). The same result was also studied by Al-Hawezi (2008); Hassan *et al.,* (2010) and Hasani *et al.,* (2012).

Significant variation was also found among the combinations of GA_3 and micronutrients in case of brix percentage (Appendix V). Degree of brix was maximum in G_1M_2 (6.8) and minimum in G_0M_0 (3.0) (Table: 9). From this study we see GA_3 single spray in combination with manganese increased the degree of brix.

Table 4. Effect of GA_3 on strawberry plants related to quality attributes[Y]

Treatments[x]	No. of flower bud/plant	No. of flower/plant	No. of fruit/plant	Degree of brix (%)
G_0	22.2 c	20.3 c	18.4 c	3.4 c
G_1	27.4 a	24.0 a	21.5 a	5.5 a
G_2	24.9 b	21.9 b	19.7 b	5.1 b
CV (%)	5.3	5.4	6.7	6.4
LSD $_{(0.05)}$	1.1	1.0	0.9	0.3

[X] G_0-Control, G_1- GA_3 single application at 15 DAT, G_2- GA_3 double application at 15 DAT and 30 DAT,

[Y] In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Table 5. Effect of micronutrients on strawberry plants related to quality attributes[Y]

Treatments[x]	No. of flower bud/plant	No. of flower/plant	No. of fruit/plant	Degree of brix (%)
M_0	22.5 c	20.5 c	18.4 c	4.0 c
M_1	24.7 b	21.9 b	19.7 b	4.6 b
M_2	27.3 a	24.0 a	21.6 a	5.5 a
CV (%)	5.3	5.4	6.7	6.4
$LSD_{(0.05)}$	1.1	1.0	0.9	0.3

[X] M_0-Control, M_1-Foliar application of Iron, M_2- Foliar application of Manganese

[Y] In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Table 6. Effect of treatments combination on strawberry plants related to quality attributes[Y]

Treatments[X]	No. of flower bud	No. of flower	No. of fruit	Degree of brix (%)
G_0M_0	20.5 f	19.1 d	17.3 d	3.0 f
G_0M_1	22.1 ef	20.2 cd	18.4 cd	3.5 ef
G_0M_2	24.1 cd	21.7 c	19.4 c	3.8 ef
G_1M_0	24.5 c	21.7 c	19.5 c	4.5 d
G_1M_1	27.6 b	23.7 b	21.4 b	5.3 bc
G_1M_2	30.1 a	26.6 a	23.7 a	6.8 a
G_2M_0	22.6 de	20.3 cd	18.5 cd	4.5 d
G_2M_1	24.5 c	21.7 c	19.2 c	5.0 cd
G_2M_2	27.6 b	23.8 b	21.3 b	5.8 b
CV (%)	5.3	5.4	6.7	6.4
$LSD_{(0.05)}$	1.9	1.7	5.1	0.5

[X] G_0-Control, G_1- GA_3 single application at 15 DAT, G_2- GA_3 double application at 15 DAT and 30 DAT, M_0-Control, M_1-Foliar application of Iron, M_2- Foliar application of Manganese

[Y] In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

4.12 Fruit length (cm)

Significant variation was found among the GA_3 treatments in case of fruit length of strawberry (Appendix V). The maximum fruit length was found in G_1 (43.7 mm) which is GA_3 single spray. The minimum fruit length is given by G_0(24.5 mm) (Table 7).According to Morgan, (2006) the final size and shape of the berry dependent on the number of achene's formed, which is determined by pollination and fertilization at the time of blooming. GA_3 induces production of healthy reproductive organs and increase the viability of pollen which helps to a proper fertilization. Also GA_3 can increase the leaf area of strawberry. Maximum leaf area enables to enhance CHO concentration in crown and roots at the time of fruiting, these increased CHO concentration was helped to produce larger fruit. May this is why fruit from the plant sprayed with GA_3 produced biggest fruit. Rasheed (2010) also found that GA_3 induced bigger fruit in strawberry.

Length of strawberry fruit from the plants treated with different micronutrients varied significantly (Appendix V). Fruits from the plant treated with M_2 (37.6 mm) treatment had the maximum fruit length and fruits from M_0 (29.7 mm) treatment had minimum fruit length (Table: 8). From this result we see manganese application increased the fruit length of strawberry. Manganese may cause higher pollen fertility and sufficient carbohydrates supply for fruit and seed development (Sharma *et al*., 1991). Analogous outcome was traced in case of peach (El-Sheikh *et al*., 2007); pear (Naiema, 2008); and in peach (Ali *et al.,* 2014) also found that Manganese increased the size of fruit.

Strawberry fruit length also significantly varied among the different treatments combinations of GA_3 and micronutrients (Appendix V). Maximum fruit length was found from G_1M_2 (50.4 mm) and the minimum from G_0M_0 (22.4 mm) and G_0M_1 (23.8 mm) (Table: 9). So we see GA_3 single spray in combination with manganese enhances bigger fruit.

4.13 Fruit diameter

Fruit diameter was significantly affected by GA_3 treatments (Appendix V). Fruit diameter of strawberry exposed statistically significant inequality among treatments. The maximum fruit diameter was observed in G_1 (33.0 mm) treated plants while the minimum from control (G_0:18.6 mm) (Table: 7). Study referred that GA_3 single spray produces maximum fruit diameter. GA_3 induces better vegetative growth so that plant can uptake more nutrient and produce more food which in reproductive stage helps to produce better quality and bigger sized fruit (Takei *et al*., 2002). Asghar *et al.*, (1997) and Khunte *et al.*, (2014) noticed that GA_3 increases the fruit size.

There was significant variation among the different micronutrient treated plants in case of fruit diameter (Appendix V). The maximum fruit diameter was observed from M_2 (28.4 mm) which is manganese and the minimum fruit diameter was found from M_0 (22.4 mm) which is control (Table: 8). Manganese has important role on activating several enzymes which involve to oxidation reactions, carboxylation, carbohydrates metabolism, phosphorus reactions and citric acid cycle (Millaleo *et al*., 2010) Sufficient amount of manganese may leads to a better plant growth which may result to produce bigger sized fruits. Manganese causes bigger sized fruit was confirmed by El-Sheikh *et al.*, (2007); Hasani *et al.*, (2012) and Ali *et al.*, (2014).

Significant variation was also found among the combinations of GA_3 and micronutrients in case of fruit diameter (Appendix: V). Fruit diameter was maximum in G_1M_2 (38.1 mm) and minimum in G_0M_0 (16.9 mm) and G_0M_1 (18.0 mm) (Table: 9). From this study we see GA_3 single spray in combination with manganese increased the fruit diameter.

4.14 Single fruit weight (g)

Significant variation was received for Single fruit weight with different treatments of GA_3 (Appendix V).The heaviest fruit was foundinG_1(15.6 g) treatment whereas lightest fruit from G_0 (13.5 g) treatment (Table 7). The result indicated that weight of Single fruit is highest in the plants treated with GA_3 single spray whereas weight of Single fruit is lowest in plants treated with none. GA_3 activates the enzymes and facilitates the photosynthetic environment thus increases photosynthesis (lolaei *et al*., 2013). When photosynthesis is increased more food is produced. GA_3 also helps in relocation of food materials from source to sink. GA_3 also increase nutrient use efficiency by activating the proper enzyme function which supply the nutrients needed for the increasing fruit weight. Jamal Uddin *et al.*, (2012); Lolaei *et al.*, (2013) and Kazemi (2014) showed that due to application of GA_3 fruit weight increased over control.

Strawberry plants treated with different micronutrients showed statistically significant difference in case of Single fruit weight (Appendix V). The maximum fruit weight area was found from M_2(15.7g) treatment and the minimum was M_0 (13.5g) (Table: 8). Manganese activates the enzymes induce more photosynthesis and food accumulation and thus enhance growth rate of cells (Cramer and Nowak, 1992). This may cause in this may increase in the weight of fruit. Rasheed (2010) and Eiada *et al.*, (2013) also found the same result.

The combinations of GA_3 and micronutrients also showed statistically significant variation in case of Single fruit weight (Appendix V). Combination G_1M_2 (16.7 g) showed highest weight of single fruit and G_0M_0 (11.9 g) showed lowest weight of single fruit (Table: 9). From this study we find that GA_3 single spray in combination with manganese increases the single fruit weight of strawberry.

4.15 Total fruit weight

Total fruit weight per plant was significantly affected by GA_3 treatments. (Appendix V). Plants treated with G_1(337.3 g/plant) treatment gave highest total fruit weigh tand plants treated with G_0(248.7 g/plant) gave lowest total fruit weight (Table: 7).GA_3 promotes cell division and a number of plant development mechanisms and encourages numerous desirable effects such as uniform growth and flowering, reduced time to flowering and increased flower number and size (Srivastava and Srivastava, 2007) Also GA_3 produces bigger size leaves which enhances the rate of photosynthesis this may lead to a higher amount of total fruit weight per plant. Kazemi (2014); Roy and Nasiruddin (2011); Asadi *et al.*, (2013) and Jamal Uddin *et a.l*, (2012) also observed that application of GA_3 increases fruit yield.

Significant variation was also found among the micronutrienttreated plants in case of total fruit weight(Appendix V). M_2(338.2 g/plant) gave the best result and M_0(249.6 g/plant) gave the lowest result in case of total fruit weight(Table: 8).Manganese plays an important role in chlorophyll production (Mousavi *et al*., 2011).The enzymes activated by manganese also regulate food to be store from source to sink. Manganese has important role on activates several enzymes which involve in different biochemical reactions which are very important for production (Mukhopadhyay and Sharma, 1991; Jackson et al., 1978).All this matters may helped in the increasing of total fruit weight. The same result was also observed by Yousefi and Zandi (2012) and Hasani *et al.*, (2012).

Treatment combinations of GA_3 and micronutrients also showed significant variation in case of total fruit weight per plant of strawberry plants (Appendix V). G_1M_2 (396.2 g/plant) showed the maximum result and G_0M_0 (206.3 g/plant) showed the minimum (Table: 9). From this study we see that GA_3 single spray in combination with manganese increases the total fruit weight per plant.

Table 7. Effect of GA_3 on strawberry plants related to quality attributes[Y]

Treatments[x]	Fruit length (cm)	Fruit diameter (cm)	Single fruit weight (g)	Total fruit weight (g/plant)
G_0	24.5 c	18.6 c	13.5 c	248.7 c
G_1	43.7 a	33.0 a	15.6 a	337.3 a
G_2	31.6 b	23.9 b	14.8 b	292.3 b
CV (%)	4.3	4.3	4.8	7.3
LSD $_{(0.05)}$	1.4	1.1	0.7	11.6

[X] G_0-Control, G_1- GA_3 single application at 15 DAT, G_2- GA_3 double application at 15 DAT and 30 DAT

[Y] In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Table 8. Effect of micronutrients on strawberry plants related to quality attributes[Y]

Treatments[x]	Fruit length (cm)	Fruit diameter (cm)	Single fruit weight (g)	Total fruit weight (g/plant)
M_0	29.7 c	22.4 c	13.5 c	249.6 c
M_1	32.6 b	24.6 b	14.7 b	290.5 b
M_2	37.6 a	28.4 a	15.7 a	338.2 a
CV (%)	4.3	4.3	4.8	7.3
LSD$_{(0.05)}$	1.4	1.1	0.7	11.6

[X] M_0-Control, M_1-Foliar application of Iron, M_2- Foliar application of Manganese

[Y] In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Table 9. Effect of treatments combinations on strawberry plants related to quality attributes[Y]

Treatments[x]	Fruit length (cm)	Fruit diameter (cm)	Single fruit weight (g)	Total fruit weight (g/plant)
G_0M_0	22.4 f	16.9 f	11.9 d	206.3 f
G_0M_1	23.8 f	18.0 f	13.9 c	256.2 e
G_0M_2	27.4 e	20.7 e	14.6 bc	283.7 c
G_1M_0	37.2 c	28.2 c	14.3 c	279.3 cd
G_1M_1	43.4 b	32.8 b	15.7 ab	336.4 b
G_1M_2	50.4 a	38.1 a	16.7 a	396.2 a
G_2M_0	29.4 de	22.2 de	14.2 c	263.1 de
G_2M_1	30.5 d	23.1 d	14.5 bc	278.8 cd
G_2M_2	35.0 c	26.5 c	15.7 ab	334.8 b
CV (%)	4.3	4.3	4.8	7.3
$LSD_{(0.05)}$	2.5	1.9	1.2	20.1

[X] G_0-Control, G_1- GA_3 single application at 15 DAT, G_2- GA_3 double application at 15 DAT and 30 DAT, M_0-Control, M_1-Foliar application of Iron, M_2- Foliar application of Manganese

[Y] In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

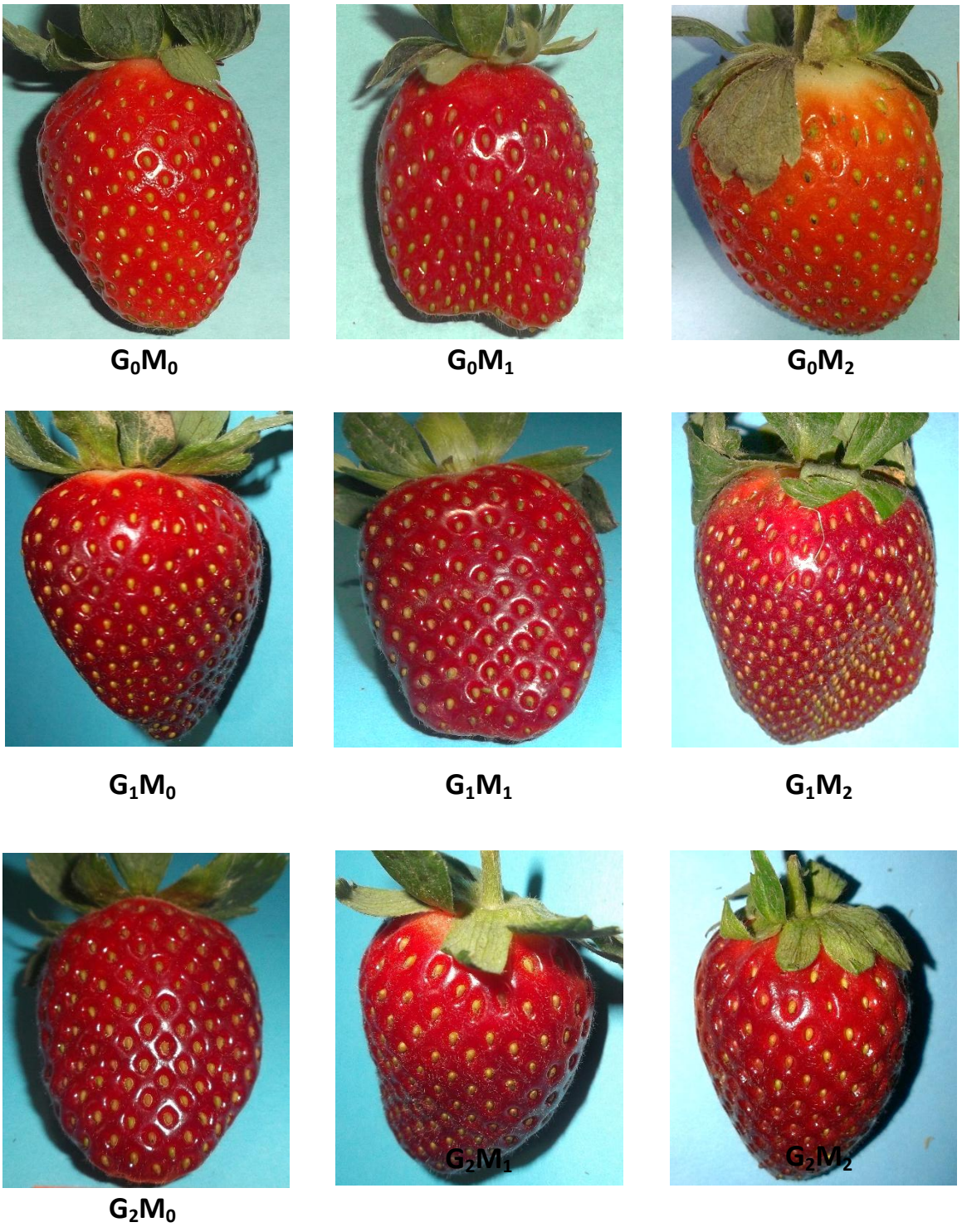

Plate 2: Showing the Influence of GA_3 and micronutrients on size and shape of strawberry fruit

CHAPTER V

SUMMARY AND CONCLUSION

5.1 Summary

Strawberry is a sweet, fleshy and extremely delicious and nutritious berry. In climate like Bangladesh strawberry is well adapted but production is low. Strawberry needs cooler temperature for better yield and quality. In Bangladesh as winter is very short. That's why strawberry plant do not get the appropriate duration for better production. Higher temperature denatures the pollen grain and reduces fruit setting. Higher temperature also induces deformed fruit.

GA_3 can accelerate the vegetative and reproductive growth by reducing the temperature effect. Manganese and iron are two very important micronutrients which also promote growth and development. By using GA_3 and micronutrients strawberry growth and yield may be stimulated.

In order to observe the effects of GA_3 and micronutrients on strawberry, a research was conducted to inspect the growth and yield of strawberry at Horticultural farm, Sher-e-Bangla Agricultural University, Dhaka during period from June 2014 to March 2014. Two factorial experiment included Application of GA_3 viz. G_0 (Control) G_1 (Once spray at 15 DAT), G_2 (Twice spray at 15 DAT and 30 DAT) and Micronutrients viz. M_0 (Control), M_1 (Iron), M_2 (Manganese) was outlined in Complete Randomized Design (CRD) with three replications.

Collected data were statistically analyzed for the evaluation of treatments for the detection of the best treatment of GA_3, micronutrient and the best amalgamation. Summery of the results and conclusion have been described in this chapter.

Looking upon the Plant height of strawberry in treatments in case of GA_3 of Once spray (17.6 cm) showed the tallest plant, whereas G_0 (15.6 cm) showed the shortest plant. On the other hand, observing the micronutrient treated plants, at mature stage manganese (17.2cm) showed highest plant height and control (16.3cm) showed the lowest plant height. In case of combined effects G_2M_2 produced the tallest plant and G_0M_0 produced the shortest plant.

In case of Leaf number GA_3 spraying twice produced the highest number of leaves (8.3) and control produced the lowest number of leaves (7.1), on the other hand among the micronutrients, manganese (M_2) produced the highest (8.1) and control (M_0) produced the lowest (7.5) number of leaves. In case of combined effects G_2M_2 (8.7) provided Maximum number of leaves and G_0M_0 (6.6) provided the minimum.

Monitoring leaf area among GA_3 treatments maximum leaf area (83.5 cm^2) was found in G_2 (Ga_3 spraying once) whereas minimum (54.9 cm^2) from G_0 (Control) at mature stage. In case of micronutrients, manganese provided maximum leaf area (72.9) whereas minimum from control (64.1 cm^2) at mature stage. In amalgamation, G_2M_2 provided maximum leaf area (88.5 cm^2) while minimum from G_0M_0 (51.3 cm^2) at mature stage.

In case of chlorophyll percentage of strawberry leaves G_2 (GA_3 double spray) showed the maximum chlorophyll percentage (53.2) whereas G_0 showed the Minimum (43.9). Regarding the effects of micronutrients, manganese showed the maximum (49.7) chlorophyll and control (M_0) showed the minimum (46.8). In case of combined effects G_2M_2 (55.5) provided Maximum chlorophyll percentage and G_0M_0 (43.1) provided the minimum.

In case of GA_3 treatments GA_3 once spray (G_1) had taken shortest period for first flower initiation (35.1 days), fruit set (43.1 days) and fruit harvesting (64.6 days) whereas GA_3 twice spray (G_2) had taken longest period for first flower initiation

(42.3 days), fruit set (50.3 days) and fruit harvesting (71.8 days). Regarding on micronutrients, manganese treated strawberry plants had taken less time for first flower initiation (36.6 days), fruit set (44.6 days) and fruit harvesting (66.1 days) whereas longest period from control for first flower initiation (40.5 days), fruit set (48.5 days) and fruit harvesting (70 days). In amalgamation, G_1M_2 was taken earliest period for first flower initiation (32.3 days), fruit set (40.3 days) and fruit harvesting (61.8 days) whilst G_2M_0 had taken delayed periodfor first flower initiation (44.6 days), fruit set (52.6.0 days) and fruit harvesting (74.1 days).

Considering the application of GA_3 single spray produced maximum number of flower bud (27.4/plant), flowers (24/plant) and fruits (21.5/plant) while minimum number of flower bud (22.2/plant), flowers (20.3/plant) and fruit (18.4/plant) were produced by G_0 (control). Monitoring micronutrients, manganese provided highest number of flower bud (27.3/plant) flowers (24/plant) and fruits (21.6/plant) even as minimum flower bud (22.5/plant) flowers (20.5/plant) and fruits (18.4/plant) from control. Conversely, best combination was G_1M_2 (as it produced 30.1 flower bud, 26.6 flowers/plant and 23.7 fruits/plant) and worst combination was G_0M_0 (as it generated 20.5 flower bud/plant 19.1 flowers/plant and 17.3 fruits/plant).

Among the GA_3 treatments, G_1 (Once spray) had the maximum brix (5.5%) and minimum in G_0 (Control) (3.4%). Regarding micronutrients, maximum brix was in manganese (M_0) (5.5%) and minimum in control (4.0%). Conversely, in combination of GA_3 single spray with manganese, maximum brix was put forwarded by G_1M_2 (6.8%) while minimum from G_0M_0 (3.0%).

Regarding GA_3 treatments, G_1 (GA_3 once spray) provided the biggest fruit (Length: 43.7 cm and diameter: 33 cm) fruit whereas G_0 (control) provided smallest fruit (Length: 24.5cm and diameter: 18.6cm). Concerning micronutrients, manganese (M_2) put forwarded biggest fruit (Length: 37.6cm and diameter: 28.4 cm) fruit whereas M_0 (control) provided smallest fruit (Length: 29.7cm and

diameter: 22.4cm). In amalgamation of GA_3 with micronutrients G_1M_2 produced biggest (Length: 50.4cm and diameter: 38.1cm) fruit and G_0M_0 brought into being smallest fruit (Length: 22.4cm and diameter: 16.9cm).

Among the GA_3 treatments premier fruit weight (15.6 g of a single fruit) and total fruit weight (337.3 g/plant) were achieved from G_1 (GA_3 once spray) as lesser amount of fruit weight (13.5 g of a single fruit) and total fruit weight (248.7 g/plant) were got from G_0 (Control). Among the micronutrients Manganese stood for highest fruit weight (15.7 g of a single fruit) and total fruit weight (338.2 g/plant) conversely control represented for least fruit weight (13.5 g of a single fruit) and total fruit weight (249.6 g/plant). In case of combination, G_1M_2 corresponded to top most results in terms of fruit weight (16.7 g of a single fruit) and total fruit weight (396.2 g/plant) whereas lowest results were acquired from G_0M_0 (11.9 g of a single fruit and total fruit weight 206.3 g/plant).

5.2 Conclusion

Regard as the above results it can be concluded that G_2 (GA_3 twice spray at 15 and 30 DAT) performed best in case of vegetative characteristics like plant height, leaf number, leaf area and chlorophyll percentage. On the other hand G_1 (GA_3 once spray) stood for early bud initiation, flowering, fruiting and harvesting also utmost number of flowers and fruits, fruit length, fruit diameter and percentage of brix, weight of fruit, total fruit weight per plant. It can be concluded that though G_2 performed best in case of vegetative characteristics meanwhile G_1 improved the reproductive characters. So G_1 stands for the best treatments to earn better yield. On the other hand, manganese performs as excellent among the micronutrients used in terms of all parameters. Besides the combination, GA_3 Once spray at 15 DAT with manganese performed as the best combination.

5.3 Suggestions

Further research in the subsequent areas may be suggested:

- ® Scope to improve seedling production (through tissue culture) and management
- ® Solve short low temperature period and rapid high temperature during fruit ripening

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APPENDICES

Appendix I. Monthly record of air temperature, relative humidity, rainfall and sunshine hour at experimental site during the period of experiment in field

Month	*Air temperature (^{o}c)		*Relative Humidity (%)	Total Rainfall (mm)	*Sunshine (hr)
	Maximum	Minimum			
October, 2014	26.5	19.4	81	22	6.9
November, 2014	25.8	16.0	78	00	6.8
December, 2014	22.4	13.5	74	00	6.3
January, 2015	24.5	12.4	68	00	5.7
February, 2015	27.1	16.7	67	30	6.7
March, 2015	31.4	19.6	54	11	8.2

* Monthly average

Source: Bangladesh Meteorological Department (Climate & Weather Division) Agargoan, Dhaka – 1212

Appendix II. Analysis of variance on the plant height of strawberry at different days after transplanting

Source of Variation	Degrees of freedom (df)	Mean Square for plant height		
		30DAT	37DAT	44DAT
Factor A	2	2.903*	6.160**	9.603**
Factor B	2	0.563	1.370*	1.801*
Interaction (A x B)	4	0.053	0.117	0.368*
Error	18	0.640	0.588	0.546

*: Significant at 0.05 level of probability

**: Significant at 0.01 level of probability

Appendix III. Analysis of variance on the leaf number of strawberry at different days after transplanting

Source of Variation	Degrees of freedom (df)	Mean Square for leaf number		
		30DAT	37DAT	44DAT
Factor A	2	1.603*	2.849**	3.308**
Factor B	2	0.743	0.867*	0.823*
Interaction (A x B)	4	0.033	0.067	0.078*
Error	18	0.160	0.138	0.149

*: Significant at 0.05 level of probability

**: Significant at 0.01 level of probability

Appendix IV. Analysis of variances of the data on crop duration related attributes of strawberry

Source of variation	Degrees of freedom (df)	Mean square for crop duration		
		Days to flowering	Days to fruit setting	Days to harvesting
Factor A	2	116.670**	116.670**	116.670**
Factor B	2	35.290**	35.290**	35.290**
Interaction(A×B)	4	2.020*	2.020*	2.020*
Error	18	9.045	9.036	9.004

*****: Significant at 0.05 level of probability

******: Significant at 0.01 level of probability

Appendix V. Analysis of variances of the data on growth and yield related attributes of strawberry

Source of variation	Degrees of freedom (df)	Mean square for growth and yield of strawberry									
		Chlorophyll	Leaf area	Number of flower buds/plant	Number of flowers/plant	Number of fruits/plant	Fruit length	Fruit diameter	Brix	Single fruit weight	Total fruit weight
Factor A	2	196.943**	1862.280**	60.083**	30.413**	22.803**	841.943**	482.129**	11.063**	10.163**	17657.433**
Factor B	2	19.363**	176.830**	50.493**	30.583**	20.943**	145.023**	82.647 **	4.893*	10.943**	17726.953**
Interaction(A×B)	4	1.888*	3.880*	0.993*	1.023*	1.003*	16.093*	9.029**	0.488*	0.598*	704.585**
Error	18	4.000	6.250	1.210	1.000	0.810	2.063	1.180	0.090	0.490	737.573

*****: Significant at 0.05 level of probability

******: Significant at 0.01 level of probabilit