PERFORMANCE OF STRAWBERRY GERMPLASM TO NPK BORON AND ZINC

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This is to certify that the thesis entitled **" PERFORMANCE OF STRAWBERRY GERMPLASM TO NPK BORON AND ZINC"** 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. KAMRUL AHSAN**, Registration No. **06-02082** 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.

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ABSTRACT

The study was conducted at Horticulture Farm, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from October 2011 to March 2012. The experiment consisted of two factors. Factor A: Strawberry germplasm (3 types) - V_1: Germplasm 01; V_2: Germplasm 02, V_3: Germplasm 03; and Factor B: Nutrients (4 types) - F_0: No fertilizer i.e. control, F_1: NPK (120 kg N, 60 kg P_2O_5 and 40 kg K_2O/ha), F_2: NPK+B @1.7 kg/ha and F_3: NPK+Zn @ 4.2 kg/ha.The experiment was laid out in Complete Randomized Design with five replications. In case of germplasm, the tallest plants (30.34 cm), highest fruit yield per plant (433.95 g) and highest brix percentage in fruit (12.62%) were recorded from $V_{1,}$ while the lowest value was observed from V_2 at 60 DAT. For nutrients, the tallest plants (32.71 cm), highest fruit yield per plant (486.22 g) and highest brix percentage in fruit (13.07%) were observed from F_3 and the lowest value were recorded from F_0 at 60 DAT. Due to the interaction effect of different germplasm and nutrients, the tallest plants (33.62 cm), highest fruit yield per plant (516.77 g) and highest brix percentage in fruit (13.27%) were observed from V_1F_3, while the lowest value were recorded from V_2F_0 at 60 DAT. So, germplasm 01 and NPK+Zn were more effective for the growth, yield and quality of strawberry.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

CHAPTER I

INTRODUCTION

Strawberry (*Fragaria* × *ananassa* Duch.) is a natural hybrid perennial plant under Rosaceae family and a major fruit of temperate region (Bowling, 2000 and Darnel *et al*., 2003) also grown in the sub-tropical region. Strawberries have traditionally been a popular delicious fruit for its flavour, taste, fresh use, freezing and processing and are highly valued as dessert fruit. It is one of the most fascinating fruits of the world, which is a rich source of vitamins and minerals and has fabulous flavour and stimulating aroma. It contains numerous important dietary components and is a rich source of vitamin C (Riyaphan *et al*., 2005). Strawberries are very popular throughout the world as well as in the people of Bangladesh for its attractive colour and excellent flavour. Different regions of Bangladesh are suitable for strawberry cultivation in terms of photoperiod, temperature and humidity. The incomes per unit area are high in strawberry cultivation (Awal and Khan, 1999, Dziadczyk *et al*., 2005). Due to these advantages, strawberry cultivation in Bangladesh is becoming more popular and total yearly production is increasing gradually, although the farmers of Bangladesh are not well known regarding the procedures of increasing sweetness, shelf life, fruit size etc.

Starting production with healthy, uniform and plentiful plants along with proper supply of macro and micro nutrients gives grower a greater chance of higher yield. The availability of high quality variety and nutrients is most important factors to obtaining high-quality yields. Good quality variety for producing maximum yield plays an important and major role in the growth and development of any crop. Different varieties respond differently to cultivation practices and the prevailing environment condition during the growing season.

Among the production factors affecting crop yield, nutrient is the single most important factor that plays a dominant role in yield increase if other production factors are not limiting. It is reported that chemical fertilizers today hold the key to success of production systems of Bangladesh agriculture being responsible for about 50% of the total crop production (BARC, 1997). Nutrient imbalance can be minimized by judicious application of different fertilizers. Strawberry responds greatly to major essential elements like N, P and K for its growth, yield and quality. Nitrogen, phosphorus and potassium progressively increase the marketable yield (Obreza and Vavrina, 1993) but an adequate supply is essential for vegetative growth, and desirable yield (Yoshizawa *et al*., 1981). Excessive application is not only uneconomical but also induces physiological disorder. Like macro and micro nutrient is an essential mineral element for all plant like strawberry. Zinc is one of the most important micronutrient essential for plant growth especially to fruit crops for sweetness. It is a major component and activator of several enzymes involved in metabolic activities. Among the many factors which influence zinc supply to the plants, pH, concentration of zinc, iron, manganese and phosphorus in soil solution are very important. Boron plays a vital role in the physiological processes of plants such as cell maturation, cell elongation and cell division, sugar transport, hormone development, carbohydrate, protein and nucleic acid metabolisms, cytokinins synthesis and phenol metabolisms (Lewis, 1980).

Considering above mentioned situation the present research work was undertaken with following objectives-

- To determine the performance of strawberry germplasm
- To find out the effect of NPK, B and Zn on growth, yield and quality of strawberry

CHAPTER II

REVIEW OF LITERATURE

Strawberry is a popular delicious fruit for its flavour, taste, fresh use and is highly valued as dessert fruit and its production in Bangladesh is increasing gradually. A very few research works related to strawberry cultivation especially emphasis on germplasm and nutrients have been carried out in Bangladesh. Nevertheless, some of the important and informative works regarding the variety or germplasm and nutrients so far been done at home and abroad of this crop have been reviewed in this chapter under the following headings-

2.1 Review related to varieties of strawberry

Varietal differences of fruit firmness, soluble solids concentration, titratable acidity, anthocyanin concentration and soluble sugar composition as influenced by storage temperature were evaluated by Matsumoto *et al*. (2008) in 4 strawberry cultivars, namely 'Mae-hyang', 'Seol-hyang', 'Keum-hyang' and 'Akihime'. The major soluble sugar in 'Keum-hyang' and 'Mae-hyang' was sucrose whereas 'Seol-hyang' had a higher concentration of reducing sugars such as fructose and glucose as shown in the Japanese cultivar, 'Akihime'. Changes in sugar composition at each storage temperature differed according to the major soluble sugar.

Macit *et al*. (2007) conducted an experiment with five short-day strawberry (*Fragaria ananassa* Duch.) cultivars including ‘Sweet Charlie’, ‘Redlans Hope’, ‘Kabarla’, ‘Festival’ and ‘Camarosa’ were grown to evaluate their yield, quality and nutritional status under organic and conventional growing conditions in 2004-2005 seasons. In the conventional system, plants had early flowering and fruit development and produced higher yield when compared to the organic system. According to total yield of two years, there were significant differences between two growing systems, ranging from 21 (Camarosa) to 29% (Sweet Charlie). There were also significant differences in average fruit weight among cultivars in organic and conventional system. However, difference between growing systems in terms of fruit weight of each cultivar was not significant.

Redlans Hope had the highest average fruit weight under conventional and organic system, followed by ‘Camarosa’ and ‘Kabarla’. Total Soluble Solid (TSS) content of ‘Sweet Charlie’ and ‘Festival’ cultivars had the highest TSS content under conventional system.

After trials for several years by Gao *et al*. (2006) Honglianjia and Camarosa strawberry cultivars are recommended for commercial growing in sunny greenhouse in Shenyang area. The first one is a Japanese cultivar. Its dormancy is short. Berry is large, weighing 29.6 g, having a bright red glossy skin and pretty appearance. Flesh is white, fine, firm, juicy with strong aroma, of very good eating quality. Camarosa is a good shipping cultivar, high production, but the berry flavour is not rich. ‘Beihui’, ‘Earlirite’ and ‘Cal Giant # 2’ are suitable to be grown under cool shed. ‘Beihui’ is a Japanese cultivar; berries are large, firm, juicy, having a pleasant acid sweet flavour, of good eating quality. ‘Earlibrite’ is a higher shipping cultivar, having a short dormancy period.

Plant growth, phenophases and fruit characteristics were studied and evaluated by Liu and Wang (2006) in 11 strawberry cultivars (including ‘Allstar’, ‘Toyonoka’, ‘Tudla’, ‘Darselect’, ‘Guinugan’, ‘Camarosa’, ‘A Huang B1-1’, ‘A Huang B1-2’, ‘B2-2’, ‘Hongbaoshi’ and ‘Dajiangjun’) growing in a sunny greenhouse. All cultivars were better than the existing popular cultivar ‘Allstar’. ‘Camarosa’ was the best cultivar in all aspects, including disease resistance and yields. The berries were large, weighing 50 g on average, but reaching 112 g, with a glossy bright red colour with uniform sunken seeds and a pleasant acid sweet flavour.

Simpson *et al*. (2006) released two new strawberry cultivars from the breeding programme at East Malling Research, one ever bearing and one June-bearing. 'Flamenco' (2002) is an ever bearing type that crops from mid-July to mid-October in the UK, but is most productive in late summer and autumn. It has excellent fruit quality and is suitable for all types of market outlets. The berries are large, firm, sweet and very attractive, with long shelf life. Plants are resistant to *Verticillium dahliae*, and are moderately resistant to *Sphaerotheca macularis*. Runner production is prolific for an everbearing type, and the plants are vigorous.

'Mae' (2003) is an early June-bearer with a season approximately one week in advance of 'Elsanta'. Yield is similar to 'Elsanta' but average fruit size is larger. Both yield and fruit size are maintained on second year plants. The berries are firm with a regular conical shape, strong red colour and pleasant flavour. The plants are compact and well suited to production under tunnels.

Ten cultivars of strawberry (*Fragaria ananassa* Duch.), viz. ‘Florida-90’, ‘Selva’, ‘Belrubi’, ‘Elsanta’, ‘Confictura’, ‘Brighton’, ‘Pajaro’, ‘Redcoat’ and ‘Seascape’ were studied by Ram and Yadav (2006) at Vidya Vatika of the Department of Applied Plant Science (Horticulture), Babasaheb Bhimrao Ambedkar University, Lucknow for their growth and yield characteristics. The maximum number of leaves per plant (15.65) were recorded in ‘Redcoat’, whereas minimum (8.66) in ‘Elsanta’. The maximum plant height (13.97 cm) in Chandler, whereas minimum plant height (7.90 cm) in ‘Confictura’. The maximum number of runners (5.26) were observed in ‘Brighton’, whereas minimum (3.16) in ‘Seascape’. The maximum number of flowers (33.11) in ‘Belrubi’, while minimum (6.44) in ‘Seascape’. The maximum of fruit set per plant (18.0) in ‘Elsanta’, whereas minimum (3.56) in ‘Seascape’. The maximum fruit set (81.44%) in ‘Elsanta’, whereas minimum (26.07%) in ‘Selva’. The maximum number of fruits (16.22%) in ‘Elsanta’, whereas minimum (3.56) in ‘Florida-90’. The minimum days for maturity (140.0) in ‘Elsanta’, while maximum day (169.44) in ‘Florida-90’. The minimum days for flowering (97.56) in ‘Elsanta’, whereas maximum days (142.28) in ‘Florida-90’. The maximum flower size (0.90 cm.) in ‘Confictura’. The maximum fruit length (2.92 cm) in ‘Belrubi’, whereas minimum fruit length (1.69 cm) in ‘Elsanta’. The maximum fruit diameter (2.83 cm) and fruit weight (4.09 g) were obtained from ‘Selva’, whereas cv. ‘Elsanta’ produced the minimum fruit diameter (1.22 cm) and fruit weight (1.11 g), respectively. The cultivar ‘Belrubi’ gave the highest fruit yield (198.34 g/plant) and ‘Florida-90’ lowest (19.67 g/plant). On the basis of these characteristics, the cultivars ‘Selva’, ‘Chandler’, ‘Belrubi’ and ‘Brighton’ are rated suitable for cultivation under Lucknow conditions.

The performance of 7 strawberry cultivars (‘Chandlar’, ‘Confictura’, ‘Elista’, ‘Florida’, ‘Gorella’, ‘Katrain Sweet’ and ‘Pajaro’) grown in a greenhouse was evaluated by Pathak *et al*. (2006). ‘Confictura’ produced the largest fruits (13.80 g) with a TSS content of 10.20 degrees Brix, total sugar content of 5.26%, and TSS:acid ratio of 7.39. The results indicated that this cultivar may be grown under cover in the plains of West Bengal, India.

Biological and economical properties of ten strawberry cultivars (‘Saulene’, ‘Honeoye’, ‘Kent’, ‘Elkat’, ‘Polka’, ‘Dange’, ‘Senga Sengana’, ‘Pegasus’, ‘Bogota’ and ‘Pandora’) were investigated by Uselis (2005) at the Lithuanian Institute of Horticulture during 2003-05. The only cultivars which remained in excellent condition during all the period of three-year growing were ‘Dange’ and ‘Elkat’. When strawberry-canes got older the state of strawberry-canes of cultivars ‘Bogota’ and ‘Kent’ significantly worsened. Strawberry cultivars ‘Saulene’, ‘Honeoye’ and ‘Kent’ started flowering early (15-17 May), ‘Elkat’, ‘Polka’, ‘Dange’, ‘Senga’ ‘Sengana’, ‘Pegasus’ had averagely late flowering (19-20 May), and ‘Bogota’ and ‘Pandora’ had very late flowering (26-31 May). According to the average two-year yield, strawberries of Bogota and Kent are averagely productive (6-7 t/ha), Pegasus was productive (9 t/ha), and ‘Saulene’, ‘Pandora’, ‘Senga Sengana’, ‘Honeoye’, ‘Polka’, ‘Elkat’ and ‘Dange’ were very productive (11-17 t/ha). Up until the full yielding of ‘Senga Sengana’, the early cultivar ‘Saulene’ produced 65%, and averagely early cultivars Honeoye, ‘Elkat’ and ‘Kent’ produced more than 33% of berries. Up until the full yielding of Pandora, the berries of ‘Saulene’ were already gathered, and more than 80% of the berries of ‘Senga’ ‘Sengana’, ‘Polka’, ‘Dange’, ‘Honeoye’, ‘Elkat’ and ‘Kent’ were gathered. At the end of ‘Senga Sengana’ yielding, the strawberries of other cultivars were already harvested 5-8% of the yield of ‘Pegasus’ and ‘Bogota’ was still unripe as well as more than 50% of the yield of Pandora.

It is suggested to grow in business strawberry plantations averagely early cultivars Honeoye and ‘Elkat’, averagely late ‘Polka’, late ‘Senga Sengana’ and very late ‘Pandora’.

Crossing of ‘Zenga’ ‘Zengana’, ‘Red Coat’ and ‘Fairfax’ cultivars was conducted in Russia by Zuboy *et al*. (2005). The cultivars obtained underwent selection for increased winter hardiness, better taste, higher berry density, anthocyanins and vitamin C [ascorbic acid] contents. The cultivars obtained include ‘Prazdnichnaya’, ‘Rubinovyi kulon’, ‘Urozhainaya ‘TsGL’, ‘Yarkaya’, ‘Lakomaya’ and ‘Feierverk’ (productivity, respectively, 12.5, 11.5, 14.2, 11.0, 13.0 and 15.7 t/ha). Short descriptions of each cultivar are provided.

In the organic production of strawberries, one of the most important factors is the right choice of cultivars reported by Verona *et al*. (2005). The objective of this study was to assess the yield and the susceptibility of the cultivars ‘Tudla’, ‘Tangi’, ‘Camarosa’, ‘Toyonoca’ and ‘Seascape’ to diseases in an organic cultivation. The studied cultivars showed adequate adaptation to the organic cultivation system. The cultivars with the highest productivity were ‘Tudla’, ‘Tangi’ and ‘Camarosa’.

Strawberry cultivars ‘Totem’, ‘Honeoye’, ‘Chandler’ and ‘Senga Sengana’ were evaluated by Han *et al*. (2005) over 4 years in an area with an elevation of 22.3-67.8 m, mean annual temperature of 12.2^0C, mean annual rainfall of 775.6 mm, and a brown loam soil with 0.8% organic matter. Totem produced the best quality fruits which were ideal for processing, but yields were not high. Totem fruits were large, weighing 18.5 g on average, with dark red skin and flesh. The flesh was firm with a soluble solids content of 9.3%.

Ten strawberry cultivars and two hybrid clones were investigated by ‘Rugienius’ and ‘Sasnauskas’ (2005) in 2001-03 in Lithuania. ‘Salwa’, ‘Aga’, ‘Heros’ and ‘Vikat’ were the most winter hardy, while ‘Elsanta’ and ‘Kama’ were the most cold susceptible cultivars.

The highest 2-year (2002-03) average yield was obtained from ‘Salwa ‘(7.8 t/ha) and ‘Filon’ (6.6 t/ha). ‘Vikat’ and K952001 had the biggest berries. The best berry appearance was recorded from ‘Aga’, ‘Elkat’, ‘Luna’ and ‘Salwa’, berry firmness

from ‘Elsanta’, ‘Filon’, ‘Heros’, ‘K952001’ and ‘Salwa’, and best berry taste from ‘Dukat’, ‘B940101’ and ‘K952001’.

The growth and yield of commercial strawberry cultivars Tioga and Tochiotome were measured by Riyaphan *et al*. (2005) under different elevations: Royal Agricultural Research Center (RARC), Royal Phang-da Agricultural Station (RPAS), and Doi Pui Research Station (DPRS) at elevations of 340, 650, and 1300 m, respectively. The vegetative and reproductive growth significantly differed. At RPAS, Tioga had higher fresh and dry weights, and more crowns than ‘Tochiotome’, but it had the longest roots at DPRS. At all three sites, ‘Tochiotome’ flowered for fewer days after transplanting than Tioga. At DPRS, Tioga had the highest number of inflorescences, while ‘Tochiotome’ grown at RPAS had the most runners. Tioga at DPRS produced the largest number of fruits and had the highest yield.

The growth, yield and berry weight of nine June-bearing strawberry (*Fragaria ananassa*) cultivars (‘Allstar’, ‘Cavendish’, ‘Honeoye’, ‘Jewel’, ‘Kent’, ‘Mesabi’, ‘Mira’, ‘Northeaster’ and ‘Winona’) and six floricane fruiting (summer-bearing) raspberry (*Rubus idaeus*) cultivars (‘Algonquin’, ‘K-81-6’, ‘Lauren’, ‘Nova’, ‘Qualicum’ and ‘Reveille’) grown in southern Idaho, USA, were compared during 2000-02 by Robbins (2005). ‘Cavendish’, ‘Mesabi’ and ‘Winona’ established quickly and maintained their spring vigour. Strawberry cultivars grew well during the summer but some cultivars had low spring vigour ratings. The most reliable yielding cultivars were Cavendish and Mesabi in spite of spring frosts, which damaged blossoms. Mesabi yielded best during a season where plants suffered spring freeze injury. Only Mesabi yielded above 13.45 metric ton/ha in 2001. Spring freezing and relatively low yields were the limiting factors in strawberry production in southern Idaho. Berry weight averaged 5.5 to 8.8 g in the second year of the study and may be too small for consumer acceptance and other commercial competition. Cavendish and Mesabi fruited earliest where Honeoye and Winona were latest. Raspberry shoot and cane growth was strong in all years.

Over the course of the study, the highest yielding in 2001 was Nova (17.15 metric ton/ha) and in 2002 was K-81-6 (23.31 metric ton/ha). In the second year of harvest (2002), all cultivars produced greater than the projected commercial production requirement of 6.73 Mg/ha. Raspberry bloom occurred after the spring frosts. Berry weight was the largest in K-81-6 (3.3 and 2.5 g in 2001 and 2002, respectively) and smallest in Algonquin (1.8 and 1.5 g in 2001 and 2002, respectively). The early fruiting cultivars were Nova and Reveille.

The performance of 14 cultivars ('Belrubi', 'Catskill', 'Chandler', 'Dana', 'Elostha', 'Fern', 'Gorella', 'Howard', 'Missionery', 'Selva', 'Shasta', 'Katrainsweet', 'Tioga' and 'Torrey') of strawberry, grown in Bhubaneswar, Orissa, India, was evaluated by Sahoo *et al*. (2005) during 2001-02 in terms of 17 quantitative characters, including 7 biochemical characters. Analysis of variance and F-test revealed highly significant differences among cultivars for all the characters studied. The yield performance of the cultivars varied from 8.56 g/plant in 'Missionery' to 110.58 g/plant in 'Chandler'. 'Chandler' and 'Selva' could produce significantly higher yield than average yield of all the cultivars. The total soluble solids/titratable acidity ratio was highest in 'Selva', followed by 'Chandler', indicating the superiority of these cultivars in fruit quality.

A re-evaluation of 27 strawberry cultivars preserved in the gene bank collections in Pometet ('Copenhagen', 'Denmark') was carried out by Jensen and Toldam (2004) to determine if any long-term trends in quality changes can be detected. The cultivars chosen represent a wide range of cultivars introduced over more than 150 years from Atkinson in 1820 to Dania in 1982 including the Danish cultivars 'Dybdahl' (1909) and 'Zefyr' (1952), which together with 'Senga Sengana' have been the dominating cultivars over the years. The fruits were picked in a 2-year old field planting with each cultivar in small plots of 5 plants. Considerable variation among cultivars was found, but with no documentation for significant or systematic changes over time in neither size, shape, firmness or calyx characters, nor in colour of fruits or achenes. However, the oldest cultivars (before 1900) tend to have the smallest fruits while the newest cultivars (late

1970's-early 1980's) tended to be more constant with firm fruits. Fruits of the first pick were larger than those of the second pick. A trend may exist in the coloration as 7 of the 10 oldest showed uniform colouring, while 8 of the 10 most recent initiated red colours at the calyx end.

Capocasa *et al*. (2004) included information is on genetic improvement programs initiated in Italy at the beginning of the 1980s in various regions of Italy, particularly in the Medium Adriatic region. Objectives of a genetic improvement project initiated in 1994, particularly those related to prohibition of use of bromide starting from 2005 were considered. Data are tabulated on productive and qualitative parameters of ‘Adria’ and ‘Sveva’ obtained in field trials during 2001-03. Descriptions are provided of yield, quality and maturation parameters of ‘Adria’ and ‘Sveva’. Data are tabulated on antioxidant capacity and total polyphenols of ‘Adria’ and ‘Sveva’. Illustrations are included of fruit of ‘Adria’ and ‘Sveva’. It is concluded that the fruit of both cultivars are characterized by relatively late and very late maturation times, and fruit with high antioxidant values.

Fruits of 39 strawberry genotypes were evaluated for their freezing performance based on drip loss percentage by Khanizadeh *et al*. (2004). The amount of juice lost was evaluated for each genotype after 4 months of storage (20^0C) upon thawing at 20^0C for 20 hour. A preliminary selection based on the drip loss method or exudation enabled us to eliminate genotypes that are the least interesting from a freezing standpoint and to focus our efforts on those with a high processing potential. 'NY1529', 'Scott', 'Arking', 'SJ8317-5' and 'SJ83145-1' with less than 30% juice loss seems suitable for jam, yoghurt and frozen food production. On the other hand, with more than 60% juice loss, 'Tenira', 'Primela' and 'Splendida' seemed less desirable for processing.

In 2001 and 2002, agronomic and sensory characterizations of the Spanish strawberry cultivars 'Medina' and 'Marina', compared with 20 other standard cultivars, were carried out by Bartual *et al*. (2004) at 4 different locations within the area of Huelva, Spain. 'Medina' was characterized by high productivity and

early maturity, small proportion of second quality fruit yield and low skin firmness than the standard 'Camarosa'. 'Marina' was characterized by a very good taste and very high colour intensity, indicating its suitability for direct consumption and processing.

Strawberry cultivars ‘Elsanta’, ‘Gerida’, ‘Honeoye’, ‘Kama’, ‘Pandora’, ‘Senga’ ‘Sengana’ and ‘Vega’ were evaluated by Maodobry and Bieniasz (2004) for their yield in a field experiment conducted in Poland during 1998-2000. ‘Honeoye’ recorded the highest whereas ‘Gerida’ recorded the lowest marketable yield (31.7 and 22 kg/30 plants, respectively). On the other hand, ‘Senga Sengana’ recorded the highest, whereas ‘Honeoye’ recorded the lowest unmarketable yield (16.9 and 3.3 kg/30 plants, respectively). ‘Elsanta’ recorded the highest, whereas ‘Kama’ recorded the lowest mean weight of 100 fruits (1369.7 and 868.3 g, respectively).

The effects of physical characteristics (firmness, drip loss and jam cooking) and cell wall enzymatic activities of several strawberry cultivars (‘Siabelle’, ‘J2’, ‘Senga Sengana’ and ‘Darsanga’) were investigated by Lefever *et al*. (2004) for possible industrial use. The enzymes study showed that the softest varieties had the highest pectin methylesterase (PME) and polygalacturonase (PG) activities. Differences in alcohol-insoluble pectin, water-soluble pectin, and parietal residue compositions were observed between ‘Darsanga’ ("firm fruit") and ‘Senga sengana’ ("soft fruit"). Finally, the study of pectin composition of Darsanga and ‘Senga sengana’ indicated that the softest fruit had the highest water-soluble pectin content. The measurement of fruit PME activity permitted a preliminary screening of fruit maturity characteristics.

The need for cultivars adapted to Northern climatic conditions is one of the major problems in the strawberry production in Estonia stated by Kikas and Libek (2004). Therefore new cultivars from several breeding programmes, are being tested in order to fill in the cultivar gap. 13 strawberry cultivars, 'Ducat', 'Feierverk', 'Gea', 'Hella', 'Induka', 'Kent', 'Korona', 'Lina', 'Marmolada', 'Polka', 'Privevyata', 'Sara' and 'Senga Sengana' were evaluated on the experimental field of the Polli Horticultural Institute in 1998-2001. Winter hardiness, phenology,

damage of blossoms by spring frosts and blossom weevil (*Anthonomus rubi*), yield, quality and weight of fruits were investigated. The cultivars 'Polka', 'Korona', 'Induka' (all originating in Holland) and 'Kent' (Canada) appeared to be new possibilities for this crop in Estonia. These cultivars had good yield and firm fruits. 'Lina' and 'Sara' (both originating in Sweden) had very good winter hardiness. 'Lina' had the greatest yield, but the firmness and taste of fruit were not good.

Zurawicz *et al*. (2004) conducted cultivar trials in the frame of the European Network for Strawberry Cultivar Evaluation (‘COST 836’, ‘WG 2’) in two field experiments carried out at two sites: the Research Institute of Pomology and Floriculture in Skierniewice (Central Poland) and the Fruit Research Station in Brzezna (Southern Poland). In the years 2001-2002, 15 cultivars were tested in both sites, while in the years 2002-2003, 31 cultivars were under investigation in Skierniewice and 26 cultivars in Brzezna. The studied cultivars differed in all important traits (productivity, ripening time, fruit size, fruit firmness, fruit susceptibility to grey mould and winterhardiness) with the most promising being 'Rosie', 'Honeoye', 'Elkat', 'Filon', 'Patty', 'Maya', 'Onda', 'Nadina', 'Alice', 'Kimberly', 'Florence', 'Tarda', 'Sophie' and 'Vikat'.

An experiment was conducted by Ylmaz *et al*. (2003) in 2001 in Turkey, to determine the effects of jasmonic acid (JA) concentrations (0, 0.10, 0.25, 0.50, and 1.0 mM) applied on 25 April, at the start of flowering, on fruit ripening and development of strawberry cultivars ‘Tufts’ and ‘Cruz’. The effects of JA on yield components were also studied.

The effect of JA was similar in both cultivars. JA at 0.25, 0.50, and 1.00 mM caused the fruits to ripen approximately one week earlier than the control. In the first week of harvest, there were no ripe fruits from plants treated with 0.10 mM JA or the control, but the mean number of fruits per plant was 1.8, 5.3, and 4.9 for Tufts and 2.7, 6.3, and 5.9 for ‘Cruz’ treated with 0.25, 0.50, and 1.00 mM JA, respectively. In addition, JA increased the total yield per plant by increasing berry size during the first 2 weeks of harvest for both cultivars. The total yield per plant

was highest in 0.50 mM JA-treated plants (299 g/plant for ‘Tufts’ and 377.4 g/plant for Cruz). The differences in total soluble solids content and titratable acidity were not significant.

Handley and Dill (2003) stated that strawberry cultivars can differ in their susceptibility to tarnished plant bug injury, but the mechanisms for such differences have not been determined. Isolating such mechanisms could allow breeders to develop significant insect resistance in commercial strawberry cultivars. Selected vegetative and floral characteristics were measured in six strawberry cultivars grown in a perennial matted row system and compared to the yield data and levels of tarnished plant bug injury. 'Mira' and 'Mesabi' had the highest marketable yields, followed by 'Jewel' and 'Sable'. 'Cabot' and 'Northeaster' had the lowest yields. 'Cabot' had the largest fruit size, followed by 'Jewel', 'Mira', 'Northeaster', 'Sable' and 'Mesabi'. Naturally occurring levels of tarnished plant bug injury were lower than expected, but some significant differences were observed among the 6 cultivars. 'Mira', 'Northeaster' and 'Cabot' had the highest levels of tarnished plant bug injury. 'Jewel', 'Mesabi' and 'Sable' had lower levels of injury. There was no significant correlation between yield and levels of tarnished plant bug injury, reflecting the low levels of injury in this experiment. Of the parameters evaluated, only high pollen levels were significantly correlated with higher levels of tarnished plant bug injury. Flower size, flower number, pedicel length, peduncle length and petiole lengths were not significantly correlated with injury. Primary flower diameter and flower dry weight were positively correlated with average fruit weight.

The colour of skin surface and flesh of fruits of 9 strawberry cultivars (‘Camarosa’, ‘Dorit’, ‘Selva’, ‘Sweet Charlie’, ‘Seascape’, ‘Pajora’, ‘Chandler’, ‘Tudla’ and ‘Muir’), grown during the summer on the ‘Amik plain’ (85-m altitude) and at ‘Yayladag’ (450-m altitude), Turkey, was evaluated by Ozdemir *et al*. (2003). Measurements were taken using a Minolta chromometer for L* (lightness), H degrees (hue angle) and C* (chroma). Higher L* values were obtained from the skin and flesh of fruits of the cultivars grown on the Amik

plain. Cultivars grown at this location also showed more intense coloration (low hue angle values). C* values were higher for cultivars grown at Yayladag. Among the cultivars, ‘Dorit’, ‘Seascape’, and ‘Selva’ had the brightest fruit surface skin, while ‘Chandler’ had the darkest red fruit surface skin. The darkest red flesh were recorded in the fruits of ‘Chandler’, ‘Tudla’ and ‘Muir’.

The fruits of the cultivars 'Eros', 'Selena', 'Northaester', 'Fern', 'Simphony', 'Mohawk', 'Elsanta', 'Miss', 'Evita', 'Marmolada', 'Pegasus', 'Kent' and 'Cortina' were chemically analysed by Sturm *et al*. (2003). With the high-performance liquid chromatography (HPLC) method the individual sugars (sucrose, glucose, fructose and xylose) and organic acids (citric, fumaric and shikimic) were estimated in two different stages of ripeness: the stage of technological ripeness and the stage of complete ripeness. Statistical differences among the fruits of the same cultivar and of different maturity stages were established in the contents of glucose, fructose, xylose, fumaric and shikimic acids, but there were no statistical differences in the contents of sucrose and citric acid. Among the fruits in the stage of complete ripeness the cvs. 'Mohawk' and 'Evita' were outranking with regard to the content of sucrose, while the fruits of the cvs. 'Fern' and 'Northaester' attained the highest contents of glucose, fructose and citric acid. During the same time of ripeness the highest content of total soluble solids (TSS) was measured in the cv. 'Mohawk', and the lowest content of TSS was exhibited by the cv. 'Miss'. The results of the analyses conducted during the research confirm that the chemical composition of strawberry fruits significantly varied among the genotype of the plant and on the stage of maturity of fruits.

Therefore harvesting in optimal fruit bearing time is essential for achieving good quality of strawberries, since important changes in the content of individual sugars and acids occur in the last period of maturity as well.

The nutritive value of fruits of strawberry cultivars ‘Pandora’, ‘Elsanta’, ‘Marmolada’, ‘Vicoda’, ‘Kent’ and ‘Senga Sengana’, was determined in an experiment conducted by Skupien (2003) in Poland during 1991-2001. ‘Senga Sengana’ recorded the highest dry matter content (10.2%), titratable acidity

(0.95%), total sugars (7.60%) and saccharose content (1.79%), whereas Kent recorded the highest soluble solid (8.7%) and reducing sugar content (5.99%). Vicoda and Pandora recorded the highest total phenol (295.5 mg/100 g) and ascorbic acid content (83 mg/100 g), respectively.

An experiment were carried out by Ilgin *et al*. (2002) during the second half of 1999 and the first half of 2000 at the K.S.U. and from the experiments, the 25 hybrids of strawberry obtained by Paydas and 10 cultivars (‘Annapolis’, ‘Camarosa’, ‘Delmarvel’, ‘Douglas’, ‘Early Glow’, ‘Northeaster’, ‘Pajaro’, ‘Spadeke’, ‘Sweet Charlie’, ‘Tudla’) were used summer planting method was applied. The frigo plants were planted on a specially prepared beds with mixtures of (1) Sand+Terra Rosa soil+farmyard manure (2) Sand+Terra Rosa soil (Terra rosa is Mediterranean soil type. It is common in all the Mediterranean basin countries). (3) Terra Rosa soil. Fertilization was done by drip irrigation. In the hybrids and cultivars, yield/plant, and some quality characteristics such as fruit size, total soluble solid, flesh firmness, flesh color, fruit color, ease of calix removal and flavour were examined. The aroma and flavour were superior, but yields were low. It was thought that these hybrids could be grown here for the processing industry. The performances of the cultivars were found to be rather satisfactory with the growth and development of the plants quite acceptable.

Maltoni *et al*. (2002) presented results of a 3-year (1999-2001) study of the main chemical and physical characteristics of the fruits of strawberry cultivars grown in the Emilia-Romagna region of Italy and of new selections from the local breeding programme. In the study, 7 cultivars and 7 selections were evaluated over all 3 years, while a further 1 cultivar and 11 selections were evaluated only during 2000-01. Evaluations took place in Cesena, except for 2 selections evaluated in Verona and 1 in Trento. There were marked differences between accessions for quality traits, and significant genotype x year interactions confirmed the influence of environment on the expression of many quality characters.

The majority of cultivars grown in the Cesena area, such as ‘Don’, ‘Maya’, ‘Marmolada’, ‘Miss’, ‘Onda’ and ‘Patty’, had rather basic but satisfactory organoleptic characteristics, but only Idea was distinguished by a high and balanced content of sugars and acids.

The main goal in strawberry breeding program conducted in RIPF is to develop cultivars well adapted to Polish environment conditions particularly to low winter temperatures and with differentiated ripening season reported by Zurawicz and Masny (2002). There are two objectives in the program; one to develop cultivars for processing requirements and the other to develop cultivars for fresh consumption. In both objectives resistance to diseases is the main focus, in particular attention is paid to *Mycosphaerella fragariae*, *Diplocarpon earliana*, *Sphaerotheca macularis* and *Verticilium dahliae*. In the recent past the following cultivars have been released: 'Elkat' (SK 1015), 'Filon' (SK 1476), 'Vikat' (SK 1483) and 'Salut' (SK 1509). All are short day cultivars, highly productive, with large fruit and a high level of resistance to low temperatures as well as foliage and root fungal diseases.

Turemis (2002) conducted an experiment to investigate opportunities of all season strawberry production with day-neutral cultivars for the purpose, the day neutral cultivars ‘Selva’, ‘Muir’, ‘H-1’, ‘Tribute’, ‘Seascape’ and the short day cultivars ‘Camarosa’, ‘Tudla’ and ‘Oso Grande’ were compared cultivars in terms of yield per plant and quality. During the growing period, the highest early yield was taken from ‘Camarosa’ and ‘Selva’, respectively. Similarly, the best results from the point of view of average fruit weight were determined in ‘H-1’, ‘Seascape’ and ‘Camarosa’. Other fruit quality criterias were not found to be important statistically.

A field experiment was conducted by Hassan *et al.* (2001) during 1997/98, at ‘Sharaw’, ‘Hisar’, ‘haryana’, India, to evaluate the yield and quality of different strawberry cultivar, i.e. ‘Chandler’, ‘Oso Grande’ and ‘Ofra’. Yield (g/plant) was recorded at weekly intervals in different months of harvesting and total yield (g/plant) and yield (t/ha) was calculated.

Fruit quality in terms of total soluble solids (TSS), acidity, TSS/acid ratio, juice and pulp percentage was determined in all the three months of harvesting (February, March and April). The cultivar 'Oso Grande' recorded the highest values for TSS (9.87%), ascorbic acid (46.42 mg/100 ml), minimum acidity (1.11%) and yield (30.90 t/ha), whereas 'Ofra' recorded the highest early yield. Fruit quality was highest in all cultivars in March, because the acidity was highest (1.35%) in February and ascorbic acid content was lowest (27.84 mg/100 ml) in April.

A field experiment was conducted by Ozdemir *et al*. (2001) in Turkey, from 2000 to 2001, to study the runner production and quality of the strawberry cultivars 'Seascape', 'Dorit', 'Camarosa', 'Sweet Charlie', 'Pajaro', 'Chandler', 'Tudla', 'Muir' and 'Selva'. The highest number of runners were obtained from 'Seascape' and 'Dorit' (240.25-237.50 number/m^2, respectively), followed by 'Camarosa' (233.25 number/m^2). Selva produced the lowest number of runners (183.50 number/m^2). In terms of runner quality, differences were observed among cultivars. The highest rate of first quality runners was obtained from 'Selva', 'Dorit' and 'Muir'. The lowest number of cull runner was obtained from 'Selva'. When considering the runner production and quality, the best results were obtained from 'Dorit', 'Camarosa' and 'Muir'.

An experiment was conducted by Fazli-Rabi (2001) during 1997-98 in Pakistan on strawberry cultivars 'Chandler', 'Korona', 'Tufts', 'Gorella', 'Tioga' and 'Sequioa'. 'Tioga' had maximum runners survival (75%) while Chandler had minimum survival percentage (40.33%). Maximum days to flowering (131.7) were observed for 'Chandler' while the minimum (126.0) days to flowering were recorded for 'Korona'. 'Korona' exhibited maximum days to last harvest (205.7) while 'Gorella' exhibited minimum days to harvest (185.0). The maximum berries were produced by 'Korona' (7.32) while the minimum was produced by Tioga (5.33). 'Korona' had maximum root length (15.40 cm) whereas 'Chandler' had maximum yield per plant.

The cultivars significantly affected the total yield wherein ‘Chandler’ had the highest yield (34.11 kg/ha). Tabulated data on the runners survival rate (%), days to last harvest, number of berries produced/plant root length, yield per plant (kg) and total yield (kg/ha) of different strawberry cultivars are presented.

Leaf number and leaf area during the vegetative period were studied by Rugienius and Brazaityte (2001) in *Fragaria virginiana glauca* [*F. virginiana* subsp. glauca], *F. chiloensis* (cv. Del Norte), and strawberry cultivars ‘Venta’, ‘Jaune’, ‘Nida’, ‘Krona’, ‘Honeoye’, ‘Dukat’ and ‘Tristar’ grown in Lithuania during 1999-2000. Pigment composition was also studied during the same period in ‘Elsanta’, ‘Venta’, ‘Jaune’, ‘Nida’, ‘Honeoye’, ‘Dukat’, and *F. virginiana glauca*. In 1999-2000, winter was warmer and the minimum temperature in January was -18.8^{0}C. Spring was warm and dry. In August and May, air temperature was higher than the average by 7.6 and 0.6^{0}C, respectively, and precipitation was also less than the average by 21-55%. In May, air temperature dropped to -3.9^{0}C. In June, air temperature was lower than the average by 0.8^{0}C and precipitation was higher than the average by 28%. The beginning of the vegetation stage in the strawberry cultivars was observed on 10-12 August. The meteorological conditions in 2000 facilitated the onset of vegetation, flowering, and fruiting in early spring. Under these conditions, however, a negative correlation between intensive plant growth at the early vegetation stage and early yield was observed. The stable or lower average leaf area, predominance of young leaves, and higher amounts of chlorophyll and carotenoids during September and October compared to early June were indicative of winter hardiness in strawberry plants.

The highest pigment content in autumn was observed in ‘Dukat’, ‘Korona’, and *F. virginiana glauca*, whereas the lowest was observed in ‘Elsanta’ and ‘Del Norte’.

The effects of growing media/soilless system (nutrient film technique or ureaformaldehyde foam) and orientation (north or south) on the yield and quality of three strawberry (*Fragaria ananassa*) cultivars, i.e. ‘Chandler’, ‘OG’ and ‘Silva’, were investigated by El-Behairy *et al*. (2001).

Data were recorded for number of flowers, fruit weight, leaf area, number of fruits per plant and yield per plant. ‘OG’ and ‘Chandler’ both performed well in soilless culture, giving better results than ‘Selva’ in terms of fruit number, fruit weight and total yield.

The performance of 12 strawberry cultivars (‘Punjab’, ‘Torry’, ‘Fern’, ‘Chandler’, ‘Belruby’, ‘Selva’, ‘Catskill’, ‘762 NA-3’, ‘Dana’, ‘Pazaro’, ‘Sastha’ and ‘Blackmore’) were evaluated by Mondal *et al*. (2001) in a field experiment conducted in West Bengal, India during the kharif season of 1998-2000. Pazaro recorded the highest plant height (22 cm) and dry matter weight (28.66%) while Torry exhibited the widest plant spread (46 cm) and highest leaf dry weight (0.88 g). Fern recorded the highest chlorophyll a content (2.52 mg/g) while 763-NA-3 recorded the highest petiole length (9.77 cm), chlorophyll b content (1.68 mg/g), total chlorophyll content (3.88 mg/g) and leaf fresh weight (3.58 g). Highest leaf area (72.79 cm) was recorded by Dana while number of runners (12.75) and leaves per plant (49.30) were recorded by Sastha. Highest stalk length (10.88 cm), days to maturity (29.50 days), number of fruits per plant (66), fruit yield (752) and lowest number of days to flower (4.66) were recorded by ‘Torry’, ‘Sastha’, ‘Catskill’, ‘Chandler’ and ‘Fern’, respectively.

A variety trial comparison was established by Karo (2000) in 1996 at EAU trial garden using meristem plants. The trial included cv. ‘Senga Sengana’ (control), ‘Bounty’, ‘Honeoye’, ‘Jonsok’, ‘Nr. 2179 Bogota’, ‘Korona’, ‘Lina’, ‘Venta’, ‘Elsanta’, ‘Marmolada’, ‘Hella’, ‘Senga Dulcita’ and ‘Hiku’. From results over several years, the most productive variety providing a stable yield for sale is ‘Bounty’. Regardless of different conditions and different years, Bounty gave the highest revenue level per plant.

Field trials were carried out by Faedi *et al*. (2000) over three years in the Cesena area (Po Valley) to evaluate the performance of 10 cultivars and 9 advanced selections obtained by breeding carried out in Cesena. The extent of variability between clones was wide for all traits, in particular yield and fruit quality. Cultivars Idea, MarmoladaReg.

Onebor and Miss, representing the check varieties for this area, confirmed their good characteristics. New Italian strawberry cultivars as Onda and Patty (from Fruit Growing Project), MadeleineReg. CivMad (CIV-Ferrara) and Maya (New Fruits-Cesena) were shown to be well-adapted to the Cesena area. The most promising selections were 89.250.2 and 94.568.2 for good fruit flavour combined with very high fruit firmness.

The research was conducted by Radajewska (2000) from 1997 to 1998 in the western region of Poland called Wielkopolska, on loessial, clay-based soil, valuation class III. The subject of investigation were 9 strawberry cultivars: 'Kent', 'Elsanta', 'Gerida', 'Senga Sengana', 'Marmolada', 'Vicoda' and 'Pandora', and 2 cultivars of Polish origin: 'Elkat' and 'Seal'. Several biological features were evaluated, such as the growth of plants, their expansion, crown and runner production, flowering, fruit-ripening dates, crop yields and mean fruit mass were assessed in each harvest period. The cultivars 'Marmolada', 'Vicoda', and 'Gerida' were distinguished by stronger growth and a spreading plant shape. 'Elsanta', 'Senga Sengana', and 'Pandora' grew more weakly. One-year-old plants of 'Senga Sengana' and 'Elkat' had the most crowns, while plants of Seal had the fewest crowns, followed by 'Vicoda' and 'Elsanta'. Elkat had the most runners (with an average of 23 per plant). Similarly, the plants of 'Pandora', 'Gerida', 'Senga Sengana' and 'Marmolada' produced numerous runners. 'Elsanta' had the fewest runners. 'Senga Sengana' had the most inflorescences and flowers, while Pandora and 'Elsanta' had the fewest inflorescences, and 'Seal' and 'Elsanta' the fewest flowers. Kent had the earliest fruits of all cultivars each year, with Elsanta closely following, while 'Pandora' and 'Vicoda' gave the latest ripe fruit. In the 3-year period 'Kent' had the highest yields, with a total of 445 kg/100 m^2 and a commercial yield of 335 kg, the second was 'Vicoda' (441 and 337 kg, respectively), 'Pandora' (with 439 and 329 kg), and 'Marmolada' (426 and 340 kg). Each year the lowest yields were obtained from 'Elsanta' (198 and 165 kg), followed by Seal (225 and 188 kg) and finally 'Senga Sengana' (287 and 186 kg).

On the other hand, ‘Vicoda’ and ‘Marmolada’ were characterized by large berries with the highest mass, whereas the smallest fruits were produced by ‘Senga Sengana’, followed by ‘Seal’, ‘Elsanat’ and ‘Elkat’.

2.2 Review related to plant nutrients

Effect of foliar application of iron, calcium and zinc sulfate reproductive growth, yield and some qualitative characteristics of strawberry fruit were investigated by Kazemi (2014). The treatments included zinc sulfate at three levels (50, 100 and 150 mgl^{-1}), iron at three levels (250, 500 and 1000mgl^{-1}), calcium at two levels (5 and 10 mM) and distilled water as a control. As result has shown iron, calcium and zinc sulfate increased dry weight, leaf area, length of roots of strawberry. Foliar application of 150 mgl^{-1} zinc sulfate provided 5.1 number of runner, 46.3 cm^2 leaf area, 15.7 flowers, 18.3 primary fruit and 16.3 secondary fruit. Sprays of zinc sulfate at 150 mgl^{-1}, iron at 1000 mgl^{-1} and calcium at 10 mM improved number of flowers, weight of primary and secondary fruit. The highest percentage of total soluble solids, titratable acidity and ascorbic acid was attained in fruits treated with zinc sulfate at 150 mgl^{-1} and the lowest was achieved in control. In general, spraying zinc sulfate at 150 mgl^{-1}, iron at 1000 mgl^{-1} and calcium at 10 mM concentration is recommended for increasing the strawberry yield.

Proper nutrient at the right time increases fruit quality, and yield of strawberry plants. An experiment was conducted with the aim of reducing vegetative growth and increasing yield and fruit quality of Selva strawberry cultivar using paclobutrazol (0, 100 mgl^{-1}), boric acid (0, 150, 300 mgl^{-1}) and zinc sulfate (0, 100, 200 mgl^{-1}). Leaf number, leaf area, length and diameter of petiole, fresh and dry shoot root ratio, yield, total soluble solid, acidity and vitamin C were considered under evaluation. Results indicated that vegetative growth was reduced with PP333. Zinc ($ZnSO_4$) had positive effect on criteria measured. However, combined PP333×B decreased total soluble solid in fruits. Highest vitamin C was obtained at concentration of (0-300 mgl^{-1} PP333- B). Foliar application of $ZnSO_4$ prior to flowering was recommend to increase fruit quality and yield of strawberry.

The effects of bark mulch and NPK fertilizers on yield and leaf and soil nutrient status of 'Korona' strawberry plants (Fragaria x ananassa), were studied by Sonsteby *et al* (2004) over a period of three years. A significant effect of mulching was found in the first harvest year, but additional fertilizer did not affect total yield. Bark mulch slightly decreased the level of leaf nitrogen, but increased the level of leaf phosphorus and potassium in all years. Bark had a significant, negative effect on soil nitrate and ammonium content in the two first seasons. Mulching increased the soil moisture content in all years.

Strawberry cultivars Jonsok and Bounty were supplied with 250 or 500 kg Kemira Horti/ha, or 300 or 600 kg complex fertilizer taru/ha in a field experiment conducted by Klaas (2001) in Estonia during 1998. In 1999, old leaves were removed and the cultivars were top-dressed with 1% Kemira Hydro (6:5:26 NPK + microelements) or 1% Kemira Hydro followed by 1% calcium nitrate treatment. All variants of Jonsok supplied with additional mineral fertilizers recorded higher yield than the control. Application of Kemira Horti2 and 1% Kemira Hydro resulted in the highest yield of 440 g per plant (14.5 t/ha) in Jonsok. In Bounty, 500 kg Kemira Horti2/ha + top dressing with calcium nitrate 1%, resulted in a yield of 426 g per plant (t/ha), which was greater than that of the control, 408 g per plant (13.5 t/ha).

A study was conducted by Erdal *et al*. (2004) to investigate the effect of foliar Fe applications on leaf Fe and some nutrient (P, Ca, Mg, K, Mn and Zn) concentrations in strawberry (*Fragaria vesca*) cultivars Addie, Dorit, Camarosa (Fe-sensitive), Selva (Fe-semi-sensitive) and Delmarval (Fe-resistant).

For this purpose, 2 forms of Fe solutions ($FeSO_4.7_2O$ and Fe-EDTA) containing 0.28% Fe were sprayed onto the strawberry leaves at 3 growth stages (before flowering, first flowering and full flowering). Depending on the Fe sources, Fe concentration increased after each application. Before flowering, leaf Fe concentration increased from 60 mg kg^{-1} (control) to 127 and 105 mg kg-1 with Fe-EDTA and $FeSO_4.7_2O$, respectively. During the first flowering, leaf Fe concentration continued to increase to 139 mg kg-1 with both Fe sources.

While Fe concentration was 87 mg kg^{-1} with the control treatment, it reached 184 mg kg-1 with Fe-EDTA and 238 mg kg-1 with $FeSO_4.7_2O$ application after the full flowering. While the leaf Fe and Zn concentrations increased with foliar Fe applications, leaf P, Mg and K concentrations were not affected, but Ca and Mn concentrations decreased. This indicated that the leaf Fe concentration of strawberry increased continuously with repeated foliar Fe application from both sources. The effect of $FeSO_4.7_2O$ on leaf Fe concentrations was higher than that of Fe-EDTA.

The effects of various concentrations of nitrate-nitrogen, potassium and calcium, and nutrient solution temperatures on the growth and yield of strawberry cv. Redgauntlet grown in a nutrient film hydroponic system were studied by Chow *et al*. (2004) over a 106-day period. The treatments consisted of solutions with high nutrient content (14.9:8.5:4.2 mM N:K:Ca, respectively) and low (18.5-31.0 degrees C) or high (22.5-36.0 degrees C) temperature, and solutions with low nutrient content (7.1:4.6:2.3 mM) and low or high temperature. At 35 days after transplanting (DAT), plant height, area and total leaf area of bare-rooted plants grown under low nutrition/high solution temperature were significantly greater than those of plants grown under high nutrition/low solution temperature. These differences were not significant at 50 DAT. At 35 DAT, plants were taller under high solution temperatures, and the number of trifoliate leaves was highest under high nutrition/high solution temperature. The number of trusses, fruit size, fruit weight, and number of fruits were lowest in plants grown under high nutrition/high solution temperature.

Flowering was initially observed at 27 DAT in plants grown under high nutrition/high solution temperature. Bare-rooted plants grown under high solution temperatures produced fruits 39 DAT. The treatments had no effect on N, K or Ca uptake. Fruit production was dependent on plant size and number of trusses. Ca deficiency in young leaves was associated with high solution temperatures and not with the level of Ca in the nutrient solution.

An experiment was conducted to study the effects of nitrate (NO_3-) and ammonium (NH_4+) ratios in nutrient solutions on the growth and production of fruits, runners, and daughter plants of strawberry Fragaria x ananassa Duch., grown in a hydroponic system. Five treatments were applied, consisting of different proportions of NH_4+ and NO_3- in the nutrient solution. The NH_4+:NO_3- ratios were: T_0 = 0:4, T_1 = 1:3, T_2 = 2:2, T_3 = 3:1, and T_4 = 4:0, at a constant nitrogen (N) concentration of 4 mol m-3. Growth and morphogenesis were characterized by monitoring leaf-area increase, number of flowers and fruits per plant, and number of daughter plants of first and second generations. Nitrogen and carbon (C) content were measured at the end of the experiment in the organs of both mother and daughter plants. None of the variables related to the growth of the mother plant was affected by the treatments. However, the number of fruits increased with the proportion of NH4+ in the nutrient solution. The number of daughter plants produced was affected only at high NH4+ proportions, and their size (dry matter per daughter plant) and fertility (number of second-generation plants per first-generation plants) were reduced. The N or C content of the plants was not significantly affected by the treatments, but the C/N ratio in the crowns of mother plants was higher in treatments with 25% and 50% NH4+ in the nutrient solution.

CHAPTER III

MATERIALS AND METHODS

A pot experiment was conducted in the Field of Horticulture Farm, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from October 2011 to March 2012 to study the performance of strawberry germplasm to NPK Boron and Zinc. The materials and methods that were used and followed for conducting the experiment presented under the following headings-

3.1 Experimental site

The study was conducted in the Horticulture Farm, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh to find out the performance of strawberry germplasm to NPK Boron and Zinc. The location of the experimental site is $23^0 74^/$N latitude and $90^0 35^/$E longitude and at an elevation of 8.2 m from sea level (Anon., 1989).

3.2 Characteristics of soil

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

3.3 Climatic condition

Experimental field is situated in the sub-tropical climate zone, which is characterized by heavy rainfall during the months of April to September and scanty rainfall during the rest period of the year. Details of the meteorological data during the period of the experiment was collected from the Bangladesh Meteorological Department, Agargoan, Dhaka and presented in Appendix II.

3.4 Planting materials

Fifteen days old stolon emerged from runners of strawberry as Germplasm 01, Germplasm 02 and Germplasm 03 was used as test crop in this experiment. The germplasm were collected from the project of "Varietals Trial and Sustainable Technology Development for The Commercial Production of Strawberry in Bangladesh" financed by The Sher-e-Bangla Agricultural University Research System (SAURES). Saplings were planted in such a way that the crown did not go much under the soil or did not remain in shallow.

3.5 Treatment(s) of the experiment

The experiment was designed to study the performance of strawberry germplasm to NPK Boron and Zinc. The experiment consisted of two factors. Details were presented below:

Factor A: Strawberry germplasm

i. V_1: Germplasm 01
ii. V_2: Germplasm 02
iii. V_3: Germplasm 03

Factor B: Nutrients

i. F_0: No fertilizer i.e. control
ii. F_1: NPK (120 kg N, 60 kg P_2O_5 and 40 kg K_2O/ha)
iii. F_2: NPK+B (Boron) @ 1.7 kg/ha
iv. F_3: NPK+Zn (Zinc) @ 4.2 kg/ha

There were a total of 12 (3 × 4) treatment combinations such as V_1F_0, V_1F_1, V_1F_2, V_1F_3, V_2F_0, V_2F_1, V_2F_2, V_2F_3, V_3F_0, V_3F_1, V_3F_2 and V_3F_3.

Boron was applied in Boric Acid (H_3BO_3) form, which contained 17% Boron on the other hand Zinc was applied in Zinc Sulphate ($ZnSO_4$) form, which contained 21% Zinc.

3.6 Design of the experiment

The two factors experiment was laid out in Complete Randomized Design (CRD) with five replications. There were 60 unit pots altogether in the experiment. Two saplings were planted in each unit pot.

3.7 Production methodology

3.7.1 Pot preparation

The experimental pots were first filled at 2nd October, 2011. Potted soil was brought into desirable fine tilt by hand mixing. The stubble and weeds were removed form the soil. The final pot preparation was done on5th October, 2011.

3.7.2 Transplanting of seedlings:

Seedlings were transplanted in such a way that the crown does not go much under the soil or does not remain in shallow. On an average runners were planted at 7 cm depth in pot on 12th October, 2011. Total numbers of Pots were used in 36 and 12 from the each germplasm

3.7.3 Fertilizers and their application methods

Fertilizers were applied at the rate of N-120kg/ha (i.e., 0.5g/pot), P-60kg/ha (i.e., 0.25g/pot), K-40kg/ha (i.e., 20g/pot), B-1.7kg/ha (i.e., 2mg/pot) and Zn-4.2kg/ha (i.e., 4mg/pot). The whole amount of P, K, B and Zn were applied during final pot preparation. Urea were applied in 3 equal installments 30, 45 and 60 days after transplanting.

3.7.4 Irrigation

Light over-head irrigation was provided through a pipe to the plots immediately after transplanting of strawberry saplings. The experimental plots were irrigated as and when necessary during the crop period.

3.7.5 Weeding

Weeding was done two times at 20 and 40 days after sapling transplanting in the plots considering the optimum time for removal of weed.

3.7.6 Mulching

The pot soil was mulched after irrigation by breaking the crust for easy aeration and to conserve soil moisture.

3.7.7 Protection

During fruit ripening time the plot were covered with net to protect the fruit from bird, squirrel and rat.

3.7.8 Disease and pest control

Experimental crop was infected by gray mold during the flowering stage. Disease was controlled by spraying Diathene M-45. Fungicide was sprayed two times at 15 days interval. Crop was also attacked by leaf feeder during the growing stage and flowering stage. The larvae were controlled by Pyrithrum @ 1.5 ml/l. The insecticides were sprayed one time after 7 days of planting of suckers.

3.7.9 Harvesting of fruits

Fruits were harvested depending upon the attaining ripening condition of the maximum fruits and the harvesting was done manually. In harvesting period the fruits turn red in color with waxy layer. Enough care was taken during harvesting period to prevent damage of fruit.

3.8 Data collection

The data were collected from each treatment and in each unit pot. Data were collected in respect of the plant growth characters, yield contributing characters, yield of strawberry and also some chemical composition.

3.8.1 Plant height

The height of plant was recorded at 30, 40, 50 and 60 days after transplanting (DAT) using a meter scale and expressed in centimeter. The height was measured from the ground level to the tip of the leaf of an individual plant.

3.8.2 Number of leaves per plant

Number of leaves per plant was counted and the data were recorded at 30, 40, 50 and 60 days after transplanting (DAT) and mean values were calculated.

3.8.3 Number of runners per plant

Number of runners per plant was counted and the data were recorded at 30, 40, 50 and 60 days after transplanting (DAT) and mean values were calculated.

3.8.4 Number of stolons per plant

Number of stolon per plant was counted and the data were recorded at 30, 40, 50 and 60 days after transplanting (DAT) and mean values were calculated.

3.8.5 Days to 1st flower bud emergence

Days to 1st flower bud emergence was recorded by calculating the number of days required from transplanting to 1st flower bud emergence (Visual observation).

3.8.6 Days to 1st flowering

Days to 1st flowering was recorded by calculating the number of days required from transplanting to 1st open of flower.

3.8.7 Days to fruit setting

Days to fruit setting was recorded by calculating the number of days required from transplanting to 1st fruit setting.

3.8.8 Days to harvesting of fruits

Days to harvesting of fruits were recorded by calculating the number of days required from transplanting to 1st harvesting of fruits.

3.8.9 Leaf area

Leaf area was measured by using CL-202 leaf area meter in non destructive method from sample leaves and expressed in cm^2. Leaf area was recorded at 30, 40, 50 and 60 days after transplanting (DAT).

3.8.10 Number of fruits per plant

Number of fruits per plant was counted and the data were recorded from selected plants and mean values were recorded.

3.8.11 Weight of individual fruit

Fruit weight was measured by Electric balance in gram. Total fruit weight of each pot was obtained by addition the weight of total fruit and average fruit weight was obtained from division of the total fruit weight by total number of fruit.

3.8.12 Length of fruit

Fruit length were measured using Digital Caliper-515 (DC-515) in millimeter (mm). Mean was calculated for each treatment.

3.8.13 Diameter of fruit

Fruit diameter were measured using Digital Caliper-515 (DC-515) in millimeter (mm). Mean was calculated for each treatment.

3.8.14 Yield per plant

The weight of all fruits from individual plant was weighted using an electric balance and total fruit weight of strawberry from each plant was recorded and was expressed in gram.

3.8.15 Brix percentage (%)

The brix percentage was measured by portable refractometer (ERMA, Tokyo-Japan). To measure the brix percentage whole fruits were smashed and collected the juice. Then a drop of juice was taken to portable refractometer and data were recorded.

3.9 Statistical analysis

The data obtained for different characters were statistically analyzed to find out differences among the treatments on strawberry. The mean values of all the characters were evaluated and analysis of variance was performed by the 'F' (variance ratio) test following MSTAT-C software. The significance of the difference among the treatment means was estimated by the Duncan's Multiple Range Test (DMRT) at 5% level of significance (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

The study was conducted to find out the performance of strawberry germplasm to NPK Boron and Zinc. Data on growth, yield contributing characters, yield and quality attributes were recorded. A summary of the analysis of variance (ANOVA) of the data on different characters have been presented in Appendix III-VIII. The results have been discussed and possible interpretations are given under the following headings:

4.1 Plant heigh

Plant height of strawberry showed statistically significant variation due to different germplasm at 30, 40, 50 and 60 DAT under the present trial (Appendix III). At 30, 40, 50 and 60 DAT, the tallest plant (12.69 cm, 19.76 cm, 27.35 cm and 30.34 cm) was recorded from V_1 (Germplasm 01), which was closely followed (11.57 cm and 24.64 cm) for 30 and 50 DAT and statistically similar (19.70 cm and 29.48 cm) for 40 and 60 DAT with V_3 (Germplasm 03), while the shortest plant (11.57 cm, 18.79 cm, 24.64 cm and 27.53 cm) was observed from V_2 (Germplasm 02) (Figure 1). Plant height is a genetical character and different germplasm produced different plant height on the basis of their characters and an improved germplasm is the first and foremost requirement for initiation and accelerated production program of any crop. Although, different germplasm respond differently due to cultivation practices and the prevailing environment condition during the growing season. Ram and Yadav (2006) and reported the maximum plant height (13.97 cm) in ‘Chandler’, whereas minimum plant height (7.90 cm) in ‘Confictura’ when conducted an experiment with ten cultivars of strawberry (*Fragaria ananassa* Duch.) viz. ‘Florida-90’, ‘Selva’, ‘Belrubi’, ‘Elsanta’, ‘Confictura’, ‘Brighton’, ‘Pajaro’, ‘Redcoat’ and ‘Seascape’.

Statistically significant variation was recorded in terms of plant height of strawberry at 30, 40, 50 and 60 DAT due to different nutrients (Appendix III). The tallest plant (13.42 cm, 20.65 cm, 29.41 cm and 32.71 cm) was observed from F_3 (NPK + Zn), which was statistically similar with F_2 (NPK + B) and F_1 (NPK) at 30, 40, 50 and 60 DAT. On the other hand, the shortest plant (10.55 cm, 17.98 cm, 22.25 cm and 24.67 cm) was recorded from F_0 (no fertilizer, i.e. control condition) (Figure 2). Data revealed that dose of NPK with Zn ensured favorable condition for the growth of strawberry plant with tallest plant.

Interaction effect of different germplasm and nutrients showed significant differences on plant height of strawberry at 30, 40, 50 and 60 DAT (Appendix III). At 30, 40, 50 and 60 DAT, the tallest plant (14.30 cm, 21.00 cm, 29.53 cm and 33.62 cm) was observed from V_1F_3 (Germplasm 01 and NPK + Zn), while the shortest (10.38 cm, 17.08 cm, 19.53 cm and 21.22 cm) was recorded from V_2F_0 (Germplasm 02 and no fertilizer) (Table 1).

4.2 Number of leaves per plant

Statistically significant variation was recorded for number of leaves per plant of strawberry due to different germplasm at 30, 40, 50 and 60 DAT (Appendix IV). The maximum number of leaves per plant was recorded from V_1 (4.47, 6.05, 8.18 and 11.00 at 30, 40, 50 and 60 DAT respectively) while the minimum number from V_2 (3.95, 5.55, 7.32 and 9.40 at 30, 40, 50 and 60 DAT respectively) (Figure 3). Ram and Yadav (2006) reported the maximum number of leaves per plant (15.65) recorded in Redcoa.

Number of leaves per plant of strawberry showed statistically significant variation at 30, 40, 50 and 60 DAT for different nutrients (Appendix III). At 30, 40, 50 and 60 DAT, the maximum number of leaves per plant (4.63, 6.87, 8.60 and 11.40) was observed from F_3, which was statistically similar (4.60, 6.53, 8.27 and 11.00) with F_2 whereas minimum number (3.33, 4.73, 6.53 and 8.20) was recorded from F_0 (Figure 4).

Table 1. Interaction effect of different germplasm and nutrients on plant height of strawberry

Germplasm × Nutrients	Plant height (cm) at			
	30 DAT	40 DAT	50 DAT	60 DAT
V_1F_0	10.40 g	18.04 cd	24.81 de	27.72 d
V_1F_1	12.76 bcd	19.86 ab	29.23 ab	33.54 a
V_1F_2	13.27 abc	20.12 ab	25.83 cd	28.06 d
V_1F_3	14.30 a	21.00 a	29.53 a	33.62 a
V_2F_0	10.38 g	17.08 d	19.53 f	21.22 f
V_2F_1	11.37 efg	17.26 d	21.69 f	24.24 e
V_2F_2	12.37 cde	20.36 a	27.49 abcd	32.06 ab
V_2F_3	12.18 cde	20.46 a	29.85 a	32.60 ab
V_3F_0	10.87 fg	18.82 bc	22.41 ef	25.06 e
V_3F_1	11.32 efg	19.94 ab	25.05 de	30.50 bc
V_3F_2	11.69 def	19.54 ab	26.31 bcd	28.82 cd
V_3F_3	13.79 ab	20.50 a	28.85 abc	31.98 ab
$LSD_{(0.05)}$	1.159	1.339	2.792	2.119
CV(%)	7.56	5.42	8.48	5.72

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

V_1: Germplasm 01
V_2: Germplasm 02
V_3: Germplasm 03

F_0: No fertilizer i.e. control condition
F_1: NPK
F_2: NPK+B
F_3: NPK+Zn

Different germplasm and nutrients showed significant differences on number of leaves per plant of strawberry at 30, 40, 50 and 60 DAT due to interaction effect (Appendix IV). At 30, 40, 50 and 60 DAT, the maximum number of leaves per plant (5.00, 6.60, 9.00 and 12.20) was observed from V_1F_3 and the minimum number (3.20, 4.20, 6.40 and 7.60) was recorded from V_2F_0 (Table 2).

4.3 Number of runners per plant

Number of runners per plant of strawberry showed statistically significant variation due to different germplasm at 30, 40, 50 and 60 DAT (Appendix V). At 30, 40, 50 and 60 DAT, the maximum number of runners per plant (1.32, 1.95, 2.45 and 3.40) was recorded from V_2, while the minimum number (0.72, 1.35, 1.65 and 2.70) was observed from V_1 (Figure 5). Tessarioli *et al*. (2003) reported significant differences for the number of runners produced per square meter for the different cultivars. Ten cultivars of strawberry (*Fragaria ananassa* Duch.) viz. Florida-90, Selva, Belrubi, Elsanta, Confictura, Brighton, Pajaro, Redcoat and Seascape were studied by Ram and Yadav (2006) and reported the maximum number of runners (5.26) were observed in Brighton, whereas minimum (3.16) in Seascape.

Statistically significant variation was recorded in terms of number of runners per plant of strawberry at 30, 40, 50 and 60 DAT due to different nutrients (Appendix V). At 30, 40, 50 and 60 DAT, the maximum number of runners per plant (1.27, 2.07, 2.67and 3.87) was observed from F_3, which was closely followed (1.08, 1.73, 2.33 and 3.13) by F_2, whereas the minimum number (0.73, 1.20, 1.47 and 2.40) was recorded from F_0 (Figure 6).

Interaction effect of different germplasm and nutrients showed significant differences on number of runners per plant of strawberry at 30, 40, 50 and 60 DAT (Appendix V). At 30, 40, 50 and 60 DAT, the maximum number of runners per plant (1.80, 2.40, 3.20 and 4.60) was observed from V_2F_3 and the minimum number (0.60, 0.80, 0.84 and 2.20) was recorded from V_1F_0 (Table 3).

Table 2. Interaction effect of different germplasm and nutrients on number of leaves per plant of strawberry

Germplasm × Nutrients	Number of leaves per plant at			
	30 DAT	40 DAT	50 DAT	60 DAT
V_1F_0	3.60 de	4.80 b	6.60 e	8.60 fg
V_1F_1	4.46 ab	6.40 a	8.30 abc	11.40 abc
V_1F_2	4.80 a	6.40 a	8.80 a	11.80 ab
V_1F_3	5.00 a	6.60 a	9.00 a	12.20 a
V_2F_0	3.20 e	4.20 b	6.40 e	7.60 g
V_2F_1	3.70 cde	4.80 b	7.10 de	9.60 ef
V_2F_2	4.40 abc	6.40 a	7.60 cd	10.40 cde
V_2F_3	4.60 ab	6.80 a	8.20 abc	10.00 de
V_3F_0	3.26 e	5.20 b	6.60 e	8.40 g
V_3F_1	3.90 bcd	6.20 a	7.70 bcd	10.40 cde
V_3F_2	4.40 abc	6.80 a	8.40 abc	10.80 bcd
V_3F_3	4.40 abc	7.20 a	8.60 ab	12.00 a
$LSD_{(0.05)}$	0.635	0.921	0.812	1.019
CV(%)	12.05	6.11	8.22	7.80

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

V_1: Germplasm 01 F_0: No fertilizer i.e. control

V_2: Germplasm 02 F_1: NPK

V_3: Germplasm 03 F_2: NPK+B

F_3: NPK+Zn

Table 3. Interaction effect of different germplasm and nutrients on number of runners per plant

Germplasm × Nutrients	Number of runners per plant at			
	30 DAT	40 DAT	50 DAT	60 DAT
V_1F_0	0.60 f	0.80 d	0.84 d	2.20 e
V_1F_1	0.80 def	1.40 c	1.60 c	2.80 cd
V_1F_2	0.68 ef	1.40 c	2.20 bc	2.80 cd
V_1F_3	0.80 def	1.80 bc	2.00 c	3.00 c
V_2F_0	0.80 def	1.40 c	1.80 c	2.40 de
V_2F_1	1.20 bc	1.60 bc	2.00 c	3.00 c
V_2F_2	1.48 b	2.40 a	2.80 ab	3.60 b
V_2F_3	1.80 a	2.40 a	3.20 a	4.60 a
V_3F_0	0.80 def	1.40 c	1.80 c	2.60 cde
V_3F_1	1.00 cde	1.40 c	2.20 bc	2.40 de
V_3F_2	1.08 cd	1.40 c	2.00 c	3.00 c
V_3F_3	1.20 bc	2.00 ab	2.80 ab	4.00 b
$LSD_{(0.05)}$	0.314	0.453	0.610	0.496
CV(%)	14.28	10.01	12.84	7.81

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

V_1: Germplasm 01 F_0: No fertilizer i.e. control

V_2: Germplasm 02 F_1: NPK

V_3: Germplasm 03 F_2: NPK+B

F_3: NPK+Zn

4.4 Number of stolons per plant

Number of stolon per plant of strawberry showed statistically significant variation due to different germplasm at 30, 40, 50 and 60 DAT (Appendix VI). At 30, 40, 50 and 60 DAT, the maximum number of stolon per plant (2.53, 2.95, 3.34 and 4.92) was recorded from V_1, while the minimum number (2.05, 2.48, 2.96 and 4.47) was observed from V_2 (Figure 7).

Statistically significant variation was recorded in terms of number of stolon per plant of strawberry at 30, 40, 50 and 60 DAT due to different nutrients (Appendix VI). At 30, 40, 50 and 60 DAT, the maximum number of stolon per plant (2.84, 3.37, 3.75 and 5.20) was observed from F_3, which was closely followed (2.47, 2.89, 3.33 and 4.96) by F_2, whereas the minimum number (1.60, 1.97, 2.49 and 4.09) was recorded from F_0 (Figure 8).

Interaction effect of different germplasm and nutrients showed significant differences on number of stolon per plant of strawberry at 30, 40, 50 and 60 DAT (Appendix VI). At 30, 40, 50 and 60 DAT, the maximum number of stolon per plant (3.04, 3.48, 3.80 and 5.40) was observed from V_1F_3 and the minimum number (1.16, 1.48, 2.16 and 3.88) was recorded from V_2F_0 (Table 4)

4.5 Days to 1st flower bud emergence

Days to 1st flower bud emergence of strawberry showed statistically significant variation due to different germplasm (Appendix VII). The highest days to 1st flower bud emergence (63.95) was recorded from V_3 which was statistically similar (62.65) with V_2, whereas the minimum days (60.45) from V_1 (Table 5).

Statistically significant variation was recorded in terms of days to 1st flower bud emergence due to different nutrients (Appendix VII). The highest days to 1st flower bud emergence (65.40) was observed from F_0, whereas the minimum days (60.60) from F_2 which was statistically similar (61.60 and 62.40) with F_3 and F_1 (Table 5).

Table 4. Interaction effect of different germplasm and nutrients on number of stolon per plant of strawberry

Germplasm × Nutrients	Number of stolon per plant at			
	30 DAT	40 DAT	50 DAT	60 DAT
V_1F_0	1.80 e	2.32 d	2.72 ef	4.08 ef
V_1F_1	2.92 ab	3.32 ab	3.56 abc	5.04 bcd
V_1F_2	2.36 cd	2.80 c	3.28 bcd	5.16 abc
V_1F_3	3.04 a	3.48 a	3.80 a	5.40 a
V_2F_0	1.16 f	1.48 e	2.16 g	3.88 f
V_2F_1	1.64 e	2.04 d	2.52 fg	4.28 e
V_2F_2	2.76 ab	3.12 abc	3.48 abc	4.88 cd
V_2F_3	2.64 bc	3.28 ab	3.68 abc	4.84 cd
V_3F_0	1.84 e	2.12 d	2.60 efg	4.32 e
V_3F_1	2.28 d	3.04 bc	3.00 de	4.76 d
V_3F_2	2.28 d	2.76 c	3.24 cd	4.84 cd
V_3F_3	2.96 ab	3.36 ab	3.76 ab	5.36 ab
$LSD_{(0.05)}$	0.324	0.344	0.439	0.322
CV(%)	11.05	9.79	10.97	5.34

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

V_1: Germplasm 01 F_0: No fertilizer i.e. control

V_2: Germplasm 02 F_1: NPK

V_3: Germplasm 03 F_2: NPK+B

F_3: NPK+Zn

Table 5. Effect of different germplasm and nutrients on yield contributing characters of strawberry

Treatments	Days to 1st flower bud emergence	Days to 1st flowering	Days to 1st fruit setting	Days to harvesting of fruits	Leaf area (cm^2)
Germplasm					
V_1	60.45 b	66.05 b	73.65 b	105.55 b	71.16 a
V_2	62.65 a	67.75 ab	74.60 b	107.10 b	68.27 b
V_3	63.95 a	69.00 a	76.90 a	109.85 a	66.86 b
$LSD_{(0.05)}$	2.041	1.951	1.830	2.356	2.354
Nutrients					
F_0	65.40 a	70.33 a	77.60 a	109.80 a	62.02 c
F_1	62.40 b	67.93 b	75.67 a	107.27 ab	68.87 b
F_2	60.60 b	66.27 b	73.53 b	105.87 b	69.71 b
F_3	61.00 b	65.87 b	73.40 b	107.07 ab	74.46 a
$LSD_{(0.05)}$	2.356	2.253	2.113	2.721	2.718
CV(%)	5.15	4.54	3.83	5.45	5.38

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

V_1: Germplasm 01
V_2: Germplasm 02
V_3: Germplasm 03

F_0: No fertilizer i.e. control
F_1: NPK
F_2: NPK+B
F_3: NPK+Zn

Interaction effect of different germplasm and nutrients showed significant differences on days to 1st flower bud emergence (Appendix VII). The highest days to 1st flower bud emergence (66.40) was observed from V_2F_0 and the lowest days (56.60) from V_1F_2 (Table 6).

4.6 Days to 1st flowering

Days to 1st flowering of strawberry showed statistically significant variation due to different germplasm (Appendix VII). The highest days to 1st flowering (69.00) was recorded from V_3 which was statistically similar (67.75) with V_2, whereas the minimum days (66.05) from V_1 (Table 5).

Statistically significant variation was recorded in terms of days to 1st flowering due to different nutrients (Appendix VII). The highest days to 1st flowering (70.33) was observed from F_0, whereas the minimum days (65.87) from F_3 which was statistically similar (66.27 and 67.93) with F_2 and F_1 (Table 5).

Interaction effect of different germplasm and nutrients showed significant differences on days to 1st flowering (Appendix VII). The highest days to 1st flowering (71.00) was observed from V_2F_0 and the lowest days (62.40) from V_1F_2 (Table 6)

4.7 Days to 1st fruit setting

Days to 1st fruit setting of strawberry showed statistically significant variation due to different germplasm (Appendix VII). The highest days to 1st fruit setting (76.90) was recorded from V_3 while the minimum days (73.65) from V_1 which was statistically similar (74.60) with V_2 (Table 5).

Statistically significant variation was recorded in terms of days to 1st fruit setting due to different nutrients (Appendix VII). The highest days to 1st fruit setting (77.60) was observed from F_0 which was statistically similar (75.67) with F_1 again the minimum days (73.40) was recorded from F_3 which was statistically similar (73.53) with F_2 (Table 5).

Table 6. Interaction effect of different germplasm and nutrients on yield contributing characters of strawberry

Germplasm × Nutrients	Days to 1st flower bud emergence	Days to 1st flowering	Days to 1st fruit setting	Days to harvesting of fruits	Leaf area (cm^2)
V_1F_0	64.00 abc	69.20 abc	76.20 abc	107.00 ab	62.60 ef
V_1F_1	63.00 abc	69.20 abc	76.80 ab	109.20 ab	76.37 a
V_1F_2	56.60 e	62.40 d	70.20 e	100.80 c	70.01 bc
V_1F_3	58.20 de	63.40 d	71.40 de	105.20 bc	75.67 a
V_2F_0	66.40 a	71.00 a	77.80 ab	111.40 a	65.43 cde
V_2F_1	61.20 bcd	66.60 abcd	74.20 bcde	105.00 bc	66.01 bcde
V_2F_2	60.00 cde	65.60 cd	72.20 cde	104.80 bc	70.91 b
V_2F_3	63.00 abc	67.80 abc	74.20 bcde	107.20 ab	70.74 b
V_3F_0	65.80 ab	70.80 ab	78.80 a	111.00 a	58.05 f
V_3F_1	63.00 abc	68.00 abc	76.00 abc	107.60 ab	64.23 de
V_3F_2	65.20 ab	70.80 ab	78.20 ab	112.00 a	68.20 bcd
V_3F_3	61.80 abcd	66.40 bcd	74.60 bcd	108.80 ab	76.97 a
$LSD_{(0.05)}$	4.081	3.902	3.660	4.712	4.708
CV(%)	5.15	4.54	3.83	5.45	5.38

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

V_1: Germplasm 01 F_0: No fertilizer i.e. control

V_2: Germplasm 02 F_1: NPK

V_3: Germplasm 03 F_2: NPK+B

F_3: NPK+Zn

Interaction effect of different germplasm and nutrients showed significant differences on days to 1st fruit setting (Appendix VII). The highest days to 1st fruit setting (78.80) was observed from V_3F_0 and the lowest days (70.20) from V_1F_2 (Table 6).

4.8 Days to harvesting of fruits

Days to harvesting of fruits of strawberry showed statistically significant variation due to different germplasm (Appendix VII). The highest days to harvesting of

fruits (109.85) was recorded from V_3 while the minimum days (105.55) from V_1 which was statistically similar (107.10) with V_2 (Table 5). Ten cultivars of strawberry (*Fragaria ananassa* Duch.) were studied by Ram and Yadav (2006) and reported the minimum days for maturity (140.0) in Elsanta, while maximum day (169.44) in Florida-90 which was support the present findings.

Statistically significant variation was recorded in terms of days to harvesting of fruits due to different nutrients (Appendix VII). The highest days to harvesting of fruits (109.80) was observed from F_0 which was statistically similar (107.27 and 107.07) with F_1 and F_3 whereas minimum days (105.87) were recorded from F_2 (Table 5).

Interaction effect of different germplasm and nutrients showed significant differences on days to harvesting of fruits (Appendix VII). The highest days to harvesting of fruits (112.00) was observed from V_3F_2 and the lowest days (100.80) from V_1F_2(Table 6).

4.9 Leaf area

Leaf area of strawberry showed statistically significant variation due to different germplasm (Appendix VII). The highest leaf area (71.16 cm^2) was recorded from V_1, whereas the lowest leaf area (66.86 cm^2) from V_3 which was statistically similar (68.27 cm^2) with V_2 (Table 5).

Statistically significant variation was recorded in terms of leaf area due to different nutrients (Appendix VII). The highest leaf area (74.46 cm^2) was observed from F_3which was closely followed (69.71 cm^2 and 68.87 cm^2) with F_2 and F_1, whereas the lowest leaf area (62.02 cm^2) was recorded from F_0 (Table 5). Kazemi (2014) and Mahnaz *et al.* (2010) stated that leaf area of strawberry plants were increased when the plants sprayed with zinc sulfate @ 150 mgl^{-1} i.e., Zinc increases the plant growth.

Interaction effect of different germplasm and nutrients showed significant differences on leaf area (Appendix VII). The highest leaf area (76.97 cm^2) was observed from V_3F_3 and the lowest leaf area (58.05 cm^2) from V_3F_0(Table 6).

4.10 Number of fruits per plant

Number of fruits per plant of strawberry showed statistically significant variation due to different germplasm (Appendix VIII). The maximum number of fruits per plant (29.85) was recorded from V_1, whereas the minimum number (26.85) from V_3 which was statistically similar (27.85) with V_2 (Table 7). Ram and Yadav (2006) also reported different number of fruits per plant for different genotypes.

Statistically significant variation was recorded in terms of number of fruits per plant due to different nutrients (Appendix VIII). The maximum number of fruits per plant (31.87) was observed from F_3 which was closely followed (30.40) with F_2, while the minimum number (22.27) was recorded from F_0 (Table 7).

Interaction effect of different germplasm and nutrients showed significant differences on number of fruits per plant (Appendix VIII). The maximum number of fruits per plant (32.40) was observed from V_1F_3 and the minimum number (19.40) from V_3F_0 (Table 8).

4.11 Weight of individual fruit

Weight of individual fruit of strawberry showed statistically significant variation due to different germplasm (Appendix VIII). The highest weight of individual fruit (14.27 g) was recorded from V_1, whereas the lowest weight (13.09 g) from V_2 which was statistically similar (13.45 g) with V_3. Ram and Yadav (2006) and reported the maximum fruit weight (4.09 g) were obtained from Selva, whereas cv. Elsanta produced the minimum fruit diameter (1.22 cm) (Table 7).

Table 7. Effect of different germplasm and nutrients on yield contributing characters and yield of strawberry

Treatments	Number of fruits per plant	Weight of individual fruit (g)	Length of fruit (mm)	Diameter of fruit (mm)	Fruit yield (g/plant)
Germplasm					
V_1	29.85 a	14.27 a	30.07 a	19.27 a	433.95 a
V_2	27.85 b	13.09 b	28.74 b	18.44 b	368.22 b
V_3	26.85 b	13.45 b	27.82 c	17.27 c	368.74 b
$LSD_{(0.05)}$	1.127	0.787	0.752	0.566	34.41
Nutrients					
F_0	22.27 d	11.26 c	22.89 d	14.44 d	250.88 c
F_1	28.20 c	13.98 b	29.48 c	18.74 c	397.82 b
F_2	30.40 b	14.00 b	30.99 b	19.51 b	426.31 b
F_3	31.87 a	15.17 a	32.15 a	20.61 a	486.22 a
$LSD_{(0.05)}$	1.301	0.909	0.868	0.653	39.74
CV(%)	6.29	9.10	4.10	4.85	13.87

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

V_1: Germplasm 01
V_2: Germplasm 02
V_3: Germplasm 03

F_0: No fertilizer i.e. control
F_1: NPK
F_2: NPK+B
F_3: NPK+Zn

Table 8. Interaction effect of different germplasm and nutrients on yield contributing characters and yield of strawberry

Germplasm × Nutrients	Number of fruits per plant	Weight of individual fruit (g)	Length of fruit (mm)	Diameter of fruit (mm)	Fruit yield (g/plant)
V_1F_0	23.40 e	11.30 de	24.12 f	14.90 f	256.86 f
V_1F_1	31.60 a	15.95 a	31.57 abc	20.32 abc	506.88 ab
V_1F_2	32.20 a	14.16 bc	31.91 abc	20.62 ab	455.30 abc
V_1F_3	32.40 a	16.03 a	32.67 a	21.23 a	516.77 a
V_2F_0	24.00 e	11.54 de	23.26 f	15.28 f	276.80 ef
V_2F_1	27.40 cd	13.01 cd	29.04 de	18.50 de	355.87 d
V_2F_2	29.00 bc	13.34 c	30.47 cd	19.23 cd	388.42 cd
V_2F_3	31.00 ab	14.48 abc	32.19 ab	20.74 ab	451.80 abc
V_3F_0	19.40 f	10.95 e	21.28 g	13.14 g	218.99 f
V_3F_1	25.60 de	12.91 cd	27.83 e	17.39 e	330.71 de
V_3F_2	30.00 ab	14.51 abc	30.58 bcd	18.68 d	435.19 bc
V_3F_3	32.20 a	15.09 ab	31.59 abc	19.87 bc	490.09 ab
$LSD_{(0.05)}$	2.254	1.574	1.504	1.131	68.83
CV(%)	6.29	9.10	4.10	4.85	13.87

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

V_1: Germplasm 01
V_2: Germplasm 02
V_3: Germplasm 03

F_0: No fertilizer i.e. control
F_1: NPK
F_2: NPK+B
F_3: NPK+Zn

Statistically significant variation was recorded in terms of weight of individual fruit due to different nutrients (Appendix VIII). The highest weight of individual fruit (15.17 g) was observed from F_3 which was closely followed by F_2 and F_1 (14.00 g and 13.98 g respectively) whereas lowest weight (11.26 g) was recorded from F_0 (Table 7).

Interaction effect of different germplasm and nutrients showed significant differences on weight of individual fruit (Appendix VIII). The highest weight of individual fruit (16.03 g) was observed from V_1F_3 and the lowest weight (10.95 g) from V_3F_0 (Table 8).

4.12 Length of fruit

Length of fruit of strawberry showed statistically significant variation due to different germplasm (Appendix VIII). The highest length of fruit (30.07 cm) was recorded from V_1, whereas the lowest length (27.82 cm) from V_3 which was closely followed (28.74 cm) by V_2 (Table 7). Ram and Yadav (2006) reported maximum fruit length (2.92 cm) in Belrubi and minimum fruit length (1.69 cm) in Elsanta.

Statistically significant variation was recorded in terms of length of fruit due to different nutrients (Appendix VIII). The highest length of fruit (32.15 cm) was observed from F_3 which was closely followed (30.99 cm) with F_2, whereas the lowest length (22.89 cm) was recorded from F_0 (Table 7).

Interaction effect of different germplasm and nutrients showed significant differences on length of fruit (Appendix VIII). The highest length of fruit (32.67 cm) was observed from V_1F_3 and the lowest length (21.28 cm) from V_3F_0 (Table 8).

4.13 Diameter of fruit

Diameter of fruit of strawberry showed statistically significant variation due to different germplasm (Appendix VIII). The highest diameter of fruit (19.27 mm) was recorded from V_1, whereas the lowest diameter (17.27 mm) from V_3 which was closely followed (18.44 mm) by V_2 (Table 7). Ram and Yadav (2006) and

reported the maximum fruit diameter (2.83 cm) were obtained from Selva, whereas cv. Elsanta produced the minimum fruit diameter (1.22 cm)

Statistically significant variation was recorded in terms of diameter of fruit due to different nutrients (Appendix VIII). The highest diameter of fruit (20.61 mm) was observed from F_3 which was closely followed (19.51 mm) with F_2, whereas the lowest diameter (14.44 mm) was recorded from F_0 (Table 7).

Interaction effect of different germplasm and nutrients showed significant differences on diameter of fruit (Appendix VIII). The highest diameter of fruit (21.23 mm) was observed from V_1F_3 and the lowest diameter (13.14 mm) from V_3F_0 (Table 8).

4.14 Fruit yield per plant

Fruit yield per plant of strawberry showed statistically significant variation due to different germplasm (Appedix VIII). The highest fruit yield per plant was recorded from V_1 (433.95 g) whereas the lowest yield per plant from V_2 (368.22 g) which was statistically similar with V_3 (368.22 g) (Table 7). Ylmaz *et al.* (2003) reported yields per plants (299.0 g/plant for Tufts and 377.4 g/plant for Cruz which support the present investigation.

Statistically significant variation was recorded in terms of fruit yield per plant due to different nutrients (Appendix VIII). The highest fruit yield per plant (486.22 g) was observed from F_3 which was closely followed (426.31 g and 397.82 g) with F_2 and F_1 while the lowest fruit yield per plant (250.88 g) was recorded from F_0 (Table 7). Obreza and Vavrina (1993) reported that nitrogen, phosphorus and potassium progressively increase the marketable yield. Data revealed that doses of NPK with Zn ensured favorable condition for the growth of strawberry plant with optimum vegetative growth and the ultimate results was the highest yield. Kazemi (2014) reported that spraying zinc sulfate at 150 mgl^{-1} increased the strawberry yield. Mahnaz *et al.* (2010) also reported that foliar application of zinc increases the yile of strawberry. So it would be stated that zinc play a major role for the enhancement of strawberry yield.

Interaction effect of different germplasm and nutrients showed significant differences on fruit yield per plant (Appendix VIII). The highest fruit yield per plant (516.77 g) was observed from V_1F_3 and the lowest fruit yield per plant (218.99 g) from V_3F_0 (Table 8).

4.15 Brix percentage in fruits

Brix percentage in fruit of strawberry showed statistically significant variation due to different germplasm (Appendix VIII). The highest brix percentage in fruit (12.62%) was recorded from V_1, whereas the lowest brix percentage in fruit (11.94%) from V_2 which was similar (12.09%) with V_3 (Figure 9). Radajewska (2000) recorded the highest soluble solid (8.70%) from earlier experiment by evaluating nine strawberry cultivars.

Statistically significant variation was recorded in terms of brix percentage in fruit due to different nutrients (Appendix VIII). The highest brix percentage in fruit (13.07%) was observed from F_3 which was closely followed (12.54%) with F_2 and F_1, while the lowest brix percentage in fruit (11.03%) from F_0 (Figure 10). Kazemi (2014) and Mahnaz *et al.* (2010) found that the percentage of total soluble solids, titratable acidity and ascorbic acid in strawberry fruits were increased when the plants treated with zinc sulfate at 150 mgl^{-1}. Application of zinc for the strawberry cultivation may help for the better quality strawberry production.

Interaction effect of different germplasm and nutrients showed significant differences on brix percentage in fruit (Appendix VIII). The highest brix percentage in fruit (13.27%) was observed from V_1F_3 and the lowest brix percentagein fruit (10.50%) from V_3F_0(Figure 11).

CHAPTER V

SUMMARY AND CONCLUSION

The study was conducted in the Field of Horticulture Farm, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh during the period from October 2011 to March 2012 to find out the performance of strawberry germplasm to NPK Boron and Zinc. Runners of strawberry were used as test crop in this experiment. The experiment consisted of two factors. Factor A: Strawberry germplasm (3 types)- V_1: Germplasm 01; V_2: Germplasm 02, V_3: Germplasm 03; and Factor B: Nutrients (4 types)- F_0: No fertilizer i.e. control, F_1: NPK (120 kg N, 60 kg P_2O_5 and 40 kg K_2O/ha), F_2: NPK+B @ 1.7 kg/ha and F_3: NPK+Zn @ 4.2 kg/ha. The two factors experiment was laid out in Complete Randomized Design (CRD) with five replications.

In case of germplasm, At 30, 40, 50 and 60 DAT, the tallest plant (12.69 cm, 19.76 cm, 27.35 cm and 30.34 cm) was recorded from V_1 (Germplasm 01), while the shortest plant (11.57 cm, 18.79 cm, 24.64 cm and 27.53 cm) was observed from V_2. At 30, 40, 50 and 60 DAT, the maximum number of leaves per plant (4.47, 6.05, 8.18 and 11.00) was recorded from V_1, while the minimum number (3.95, 5.55, 7.32 and 9.40) was observed from V_2. At 30, 40, 50 and 60 DAT, the maximum number of runners per plant (1.32, 1.95, 2.45 and 3.40) was recorded from V_2, while the minimum number (0.72, 1.35, 1.65 and 2.70) was observed from V_1. At 30, 40, 50 and 60 DAT, the maximum number of Stolon per plant (2.53, 2.95, 3.34 and 4.92) was recorded from V_1, while the minimum number (2.05, 2.48, 2.96 and 4.47) was observed from V_2. The highest days to 1^{st} flower bud emergence (63.95) was recorded from V_3, whereas the minimum days (60.45) from V_1. The highest days to 1^{st} flowering (69.00) was recorded from V_3, whereas the minimum days (66.05) from V_1. The highest days to 1^{st} fruit setting (76.90) was recorded from V_3 while the minimum days (73.65) from V_1. The highest days to harvesting of fruits (109.85) was recorded from V_3 while the minimum days (105.55) from V_1. The highest leaf

area (71.16 cm^2) was recorded from V_1, whereas the lowest leaf area (66.86 cm^2) from V_3. The maximum number of fruits per plant (29.85) was recorded from V_1, whereas the minimum number (26.85) from V_3. The highest weight of individual fruit (14.27 g) was recorded from V_1, whereas the lowest weight (13.09 g) from V_2. The highest length of fruit (30.07 cm) was recorded from V_1, whereas the lowest length (27.82 cm) from V_3. The highest diameter of fruit (19.27 mm) was recorded from V_1, whereas the lowest diameter (17.27 mm) from V_3. The highest fruit yield per plant (433.95 g) was recorded from V_1, whereas the lowest yield per plant (368.22 g) from V_2. The highest brix percentage in fruit (12.62%) was recorded from V_1, whereas the lowest brix percentage in fruit (11.94%) from V_2.

For nutrients, at 30, 40, 50 and 60 DAT, the tallest plant (13.42 cm, 20.65 cm, 29.41 cm and 32.71 cm) was observed from F_3 and the shortest plant (10.55 cm, 17.98 cm, 22.25 cm and 24.67 cm) was recorded from F_0. At 30, 40, 50 and 60 DAT, the maximum number of leaves per plant (4.63, 6.87, 8.60 and 11.40) was observed from F_3, whereas the minimum number (3.33, 4.73, 6.53 and 8.20) was recorded from F_0. At 30, 40, 50 and 60 DAT, the maximum number of runners per plant (1.27, 2.07, 2.67and 3.87) was observed from F_3, whereas the minimum number (0.73, 1.20, 1.47 and 2.40) was recorded from F_0. At 30, 40, 50 and 60 DAT, the maximum number of stolon per plant (2.84, 3.37, 3.75 and 5.20) was observed from F_3, whereas the minimum number (1.60, 1.97, 2.49 and 4.09) was recorded from F_0. The highest days to 1^{st} flower bud emergence (65.40) was observed from F_0, whereas the minimum days (60.60) from F_2. The highest days to 1^{st} flowering (70.33) was observed from F_0, whereas the minimum days (65.87) from F_3. The highest days to 1^{st} fruit setting (77.60) was observed from F_0 again the minimum days (73.40) was recorded from F_3. The highest days to harvesting of fruits (109.80) was observed from F_0, whereas the minimum days (105.87) was recorded from F_2. The highest leaf area (74.46 cm^2) was observed from F_3, whereas the lowest leaf area (62.02 cm^2) was recorded from F_0. The maximum number of fruits per plant (31.87) was observed from F_3, while the minimum number (22.27) was recorded from F_0. The highest weight of individual fruit (15.17 g) was observed from F_3, whereas the lowest weight

(11.26 g) was recorded from F_0. The highest length of fruit (32.15 cm) was observed from F_3, whereas the lowest length (22.89 cm) was recorded from F_0. The highest diameter of fruit (20.61 mm) was observed from F_3, whereas the lowest diameter (14.44 mm) was recorded from F_0. The highest fruit yield per plant (486.22 g) was observed from F_3, while the lowest fruit yield per plant (250.88 g) was recorded from F_0. The highest brix percentage in fruit (13.07%) was observed from F_3, while the lowest brix percentage in fruit (11.03%) from F_0.

Due to the interaction effect of different germplasm and nutrients at 30, 40, 50 and 60 DAT, the tallest plant (14.30 cm, 21.00 cm, 29.53 cm and 33.62 cm) was observed from V_1F_3, while the shortest (10.38 cm, 17.08 cm, 19.53 cm and 21.22 cm) was recorded from V_2F_0. At 30, 40, 50 and 60 DAT, the maximum number of leaves per plant (5.00, 6.60, 9.00 and 12.20) was observed from V_1F_3 and the minimum number (3.20, 4.20, 6.40 and 7.60) was recorded from V_2F_0. At 30, 40, 50 and 60 DAT, the maximum number of runners per plant (1.80, 2.40, 3.20 and 4.60) was observed from V_2F_3 and the minimum number (0.60, 0.80, 0.84 and 2.20) was recorded from V_1F_0. At 30, 40, 50 and 60 DAT, the maximum number of Stolon per plant (3.04, 3.48, 3.80 and 5.40) was observed from V_1F_3 and the minimum number (1.16, 1.48, 2.16 and 3.88) was recorded from V_2F_0. The highest days to 1st flower bud emergence (66.40) was observed from V_2F_0 and the lowest days (56.60) from V_1F_2. The highest days to 1st flowering (71.00) was observed from V_2F_0 and the lowest days (62.40) from V_1F_2. The highest days to 1st fruit setting (78.80) was observed from V_3F_0 and the lowest days (70.20) from V_1F_2. The highest days to harvesting of fruits (112.00) was observed from V_3F_2 and the lowest days (100.80) from V_1F_2. The highest leaf area (76.97 cm^2) was observed from V_3F_3 and the lowest leaf area (58.05 cm^2) from V_3F_0. The maximum number of fruits per plant (32.40) was observed from V_1F_3 and the minimum number (19.40) from V_3F_0. The highest weight of individual fruit (16.03 g) was observed from V_1F_3 and the lowest weight (10.95 g) from V_3F_0.

The highest length of fruit (32.67 cm) was observed from V_1F_3 and the lowest length (21.28 cm) from V_3F_0. The highest diameter of fruit (21.23 mm) was observed from V_1F_3 and the lowest diameter (13.14 mm) from V_3F_0. The highest fruit yield per plant (516.77 g) was observed from V_1F_3 and the lowest fruit yield per plant (218.99 g) from V_3F_0. The highest brix percentage in fruit (13.27%) was observed from V_1F_3 and the lowest brix percentage in fruit (10.50) from V_3F_0.

Conclusion

From the above findings it was revealed that Germplasm 01 and NPK+Zn were more effective for the growth, yield and quality of strawberry.

Recommendations

Considering the findings of the present experiment, further studies in the following areas may be suggested:

1. Another strawberry germplasm may be included for further study.
2. Other macro and micro nutrients with different level may be included for future study.

REFERENCE

Anonymous. (1989). Annual Report 1987-88. Bangladesh Agricultural Research Institute. Joydebpur, Gazipur. p. 133.

BARC (Bangladesh Agricultural Research Council). (1997). Crop production. In: Agriculture in Bangladesh. Farm Gate, Dhaka. pp. 8-12.

Bartual, R., Marsal, J. I., Medina, J. J., Miranda, L., Soria, C., Sanchez, J. F., Galvez, J., Clavero, I., Lopez, J. M., Arjona, A. and Bardon, E. (2004). Quantitative and qualitative traits of two new Spanish strawberry cultivars. *Acta Hort*., 649: 77-80.

Capocasa, F., Scalzo, J., Murri, G. and Mezzetti, B. (2004). Adria and Sveva, new late maturing strawberry cultivars. *Inform. Agric*., **60**(27): 51-52.

Cardenas, N., Lopez, P. L., Lobit, P., Ruiz-Corro, R. and Castellanos, M. V. C. (2006). Effects of Nitrogen Source on Growth and Development of Strawberry Plants. J. plant nutrition. 29(9): 1699-1707.

Chow, K.K., Price, T.V., and Hanger, B.C. (2004). Effects of nitrogen, potassium, calcium concentrations and solution temperatures on the growth and yield of strawberry cv. Redgauntlet in a nutrient film (NFT) hydroponic system. *Acta Hort*. **633**: 315-327.

Dziadczyk, P., Kiszczak, W., Tyrka, M. M. and Daiufer, K. (2005). Evaluation of strawberry (*Fragaria ananassa* Duch.) cultivar's salt stress tolerance. *J. Food Agric. Envir*., **3**(2): 275-281.

El-Behairy, U. A., Abou-Hadid, A. F., Medany, M. A. and Awad, M. M. (2001). The effect of different cultivars, orientation and soilless culture systems on production and quality of strawberry. *Acta Hort.,* **548**: 59-64.

Erdal, I., Kepenek, K. and Kzlgoz, I. (2004). Effect of foliar iron applications at different growth stages on iron and some nutrient concentrations in strawberry cultivars. Turkish J. Agric. and Forestry. **28**(6): 421-427.

Faedi, W., Baruzzi, G., Carloni, A., Lucchi, P., Sbrighi, P. and Turci, P. (2000). Performance of new strawberry cultivars and advanced selections in north Italy. *Rivista Frut. Ort.,* **62**(12): 5, 26-34.

FAO. (1988). Production Year Book. Food and Agricultural Organizations of the United Nations. Rome, Italy. **42**: 190-193.

Fazli, R., Muhammad, I., Muhammad, A. and Rahman, K. (2001). Performance of some commercial and non-commercial strawberry cultivars under the agroclimatic conditions of Mingora, Swat. *Sarhad J. Agric*., **17**(1): 65-67.

Gao, X. Y., Zhang, Z. H., Du, G. D., Li, H. and Liu, F. J. (2006). The performance of 5 strawberry cultivars grown under protected conditions in Shenyang area. *China Fruits*., **5**: 24-26.

Gomez, K. A. and Gomez, A. A. (1984). Statistical procedures for Agricultural Research. Jhon Wiley and Sons, New York.

Han, M. S., Yang, X. H., Sun, Z. F., Wang, J. and Wang, Z. Y. (2005). The performance of 4 strawberry cultivars in Qingdao area. *China Fruits*., **6**: 17-19.

Handley, D. T. and Dill, J. F. (2003). Vegetative and floral characteristics of six strawberry cultivars associated with fruit size, yield and susceptibility to tarnished plant bug injury. *Acta Hort.,* **626**: 161-167.

Hassan, G. I., Godara, A. K., Jitender, K. and Huchche, A. D. (2001). Evaluation of different strawberry (*Fragaria ananassa* Duch.) cultivars under Haryana conditions. *Haryana J. Hort. Sci*., **30**(1/2): 41-43.

Ilgin, M., Kaska, N. and Colak, A. (2002). Yield and quality performances of some strawberry hybrids and cultivars grown in K. Maras, Turkey. *Acta Hort.*, **567**(1): 195-197.

Islam, M. M. (2003). Response of different nutrient to the plant growing. *Indian J. Agric. Sci*., **65**(11): 818-820.

Jensen, S. L. and Toldam A.T. B. (2004). Evaluation of 27 strawberry cultivars grown in Denmark over more than 150 years. External qualities. *Acta Hort.* **649**: 151-155.

Karp, K., Starast, M. and Varnik, R. (2000). Yield and income of different strawberry varieties. *Transactions of the Estonian Agricultural University, Agronomy*. **208**: 56-59.

Kazemi, M. (2014). Influence of foliar application of iron, calcium and zinc sulfate on vegetative growth and reproductive characteristics of strawberry cv. Pajaro. *Trakia J. of Sciences*, **12**(1): 21-26.

Khanizadeh, S., Gauthier, M., Rekika, D. and Deschenes, M. (2005). Evaluation of the drip loss of 30 cultivars and 9 advanced selections from Agriculture and Agri-Food Canada National Strawberry Breeding Program. *Small Fruits Review*., **4**(2): 35-40.

Kikas, A. and Libek, A. (2004). Evaluation of strawberry cultivars at the Polli Horticultural Institute (Estonia). *Acta Hort*., **663**(2): 915-918.

Klaas, L. (2001) Fertilization of strawberry cultivars Jonsok and Bounty. *Sodininkysteir Darzininkyste*. 20(3/2): 32-37.

Lefever, G., Vieuille, M., Delage, N., Harlingue, A., Monteclerc, J. and Bompeix, G. (2004). Characterization of cell wall enzyme activities, pectin composition, and technological criteria of strawberry cultivars (*Fragaria ananassa* Duch). *J. Food Sci*., **69**(4): 221-226.

Lewis, Y. (1980). Effects of boron on leaf area and dry matter production in strawberry. *J. Maharastra Agril. Univ.* **19**(2):211-213.

Liu, R. M. and Wang, K. (2006). Cultural comparison of strawberry cultivars grown under semi-forced culture. *South China Fruits*., **3**: 64-65.

Macit, I., Koc, A., Guler, S. and Deligoz, I. (2007). Yield quality and nutritional status of organically and conventionally-grown strawberry cultivars. *Asian J. Plant Sci*., **6**(7): 1131-1136.

Mahnaz, A., Saeid, E. and Tafazoli, E. (2010). Interaction of Paclobutrazol, Boron and Zinc on Vegetative Growth, Yield and Fruit Quality of Strawberry (*Fragaria* × *Ananassa* Duch. Cv. Selva). *J. Biol. Environ. Sci.*, **4**(11): 67-75.

Maltoni, M. L., Magnani, S., Bonoli, M., Manucci, C. and Baruzzi, G. (2002). Evaluation of quality of strawberry cultivars. *Informatore Agrario*., **58**(37): 35-41.

Maodobry, M. and Bieniasz, M. (2004). Yield structure of seven strawberry cultivars. *Folia Hort.*, **16**(1): 79-85.

Matsumoto, K., Lee, C. H., Chun, J. P., Kim, T., Tamura, F., Tanabe, K. and Hwang, Y. S. (2008). Varietal differences of fruit quality and shelf life in strawberry cultivars developed in Korea. *Hort. Res. Japan*., **7**(2): 293-297.

Mondal, K. K., Bhattacharya, B. and Ghosh, S. K. (2001). Introduction of some promising cultivars of strawberry to study their performance under Terai agro-climatic region of West Bengal. *Environ. Ecol*., **19**(2): 275-278.

Munbodh, R. S. and Goburdhun, S. (2001). Effect of temperature and packaging on shelf life of two strawberry cultivars (Marquise and Tiobelle). *Res. Agric*., **80**(3): 171-178.

Obreza, T. A. and Vavrina, C. S. (1993). Production of strawberry in relation to nitrogen Source, Rate and Leaf nutrient concentration in Soil Science and Plant Analysis. **24**: 13-14.

Ozdemir, E., Bayazit, S. and Gunduz, K. (2001). The runner production and quality of some important strawberry cultivars grown in Amik Plain. *Ziraat Fakultesi Dergisi*., **6**(1/2): 23-28.

Ozdemir, E., Gunduz, K., Gidemen, F. and Sehitoglu, M. (2003). Coloring of some strawberry cultivars grown in Amik plain and Yayladag (Hatay). *Bahce*., **32**(1/2): 45-51.

Pathak, P. K. Gurung, M. R. and Mitra, S. K. (2006). Performance of strawberry cultivars under cover in the plains of West Bengal. *Orissa J. Hort*., **34**(2): 35-37.

Radajewska, B. (2000). Some biological characteristics and productive value of nine strawberry cultivars. *Folia Hort.*, **12**(1): 13-28.

Ram, R. B. and Yadav, A. K. (2006). Introduction and evaluation of some strawberry (*Fragaria ananassa* Duch) cultivars under Lucknow conditions. *Plant Archives*., **6**(2): 529-531.

Riyaphan, P., Pipattanawong, N. and Subhadrabandu, S. (2005). Influence of different climatic conditions on growth and yield of strawberry plants in Thailand. *Technical Reports Series*., **61**: 65-72.

Robbins, J. A. (2005). Evaluation of selected raspberry and strawberry cultivars in Southern Indho. *Hort. Tech.*, **15**(4): 900-903.

Rugienius, R. and Brazaityte, A. (2001). Investigations of leaf number, leaf area and pigments amount of different strawberry cultivars during vegetation. *Sodininkysteir Darzininkyste*., **20**(3(1)): 154-163.

Rugienius, R. and Sasnauskas, A. (2005). Investigation of strawberry cultivars and hybrid clones. *Sodininkyste Darzininkyste*., **24**(1): 34-41.

Sahoo, R. K., Das, A. K., Singh, B. and Satpathy, S. K. (2005). Performance of some strawberry (*Fragaria ananassa* Duch.) cultivars in the coastal zone of Orissa. *Orissa J. Hort.*, **33**(2): 50-52.

Simpson, D., Hammond, K. and Whitehouse, A. (2006). Two new strawberry cultivars from East Malling Research. *Acta Hort.*, **708**: 565-567.

Skupien, K. (2003). Biological value of selected cultivars of strawberry fruit (*Fragaria ananassa* Duch.). *Folia Hort.*, **15**(2): 167-172.

Sonsteby, A., Nes, A. and Mage, (2004). F Effects of bark mulch and NPK fertilizer on yield, leaf nutrient status and soil mineral nitrogen during three years of strawberry production. *Acta Agril. Soil Plant Sci*. **54**(3): 128-134

Sturm, K., Koron, D. and Stampar, F. (2003). The composition of fruit of different strawberry varieties depending on maturity stage. *Food Chemistry*., **83**(3): 417-422.

Tessarioli, Y. K., Jitender, K. and Huchche, A. D. (2003). Runner types and quality of runner production of strawberry. *J. American Pomol. Soc*.. **57**(1): 12-16.

Turemis, N. (2002). All season strawberry growing with day-neutral cultivars. *Acta Hort.*, **567**(1): 199-202.

UNDP. (1988). Land Resources Appraisal of Bangladesh for Agricultural Development. Report 2: Agro-ecological Regions of Bangladesh, FAO, Rome. pp. 212.

Uselis, N. (2005). Evaluation of biological and economical properties of strawberry cultivars. *Sodininkyste Darzininkyste*.. **24**(4): 72-80.

Verona, L. A. F., Nesi, C. N., Scherer, E. E., Gheller, C. and Grossi, R. (2005). Strawberry cultivars for organic cultivation system. *Agropecuaria Catarinense*., **18**(2): 90-92.

Ylmaz, H., Yldz, K. and Muradoglu, F. (2003). Effect of jasmonic acid on yield and quality of two strawberry cultivars. *J. American Pomol. Soy*., **57**(1): 32-35.

Yoshizawa, T. Ma, C. H. and Roan, Y. C. (1981). Management of nutrients for crop cultivation. AVRDC, Shanhua, Taiwan. p. 12.

Yusuf, A., Masood, I., Shah, S. Z. A. and Ahmed, M. J. (2003). Effect of different combinations of nitrogen, phosphorous and farm yard manure on yield and quality of strawberry. *Sarhad J. Agric*., **19**(2): 185-188.

Zubov, A. A., Lukyanchuk, I. V. and Zhbanova, E. V. (2005). New strawberry cultivars. *Sadovodstvo Vinogradarstvo*., **4**: 21-22.

Zurawicz, E. and Masny, A. (2002). New strawberry cultivars from the breeding project of Research Institute of Pomology and Floriculture (RIPF), Skierniewice Poland. *Acta Hort*., **567**(1): 179-181.

Zurawicz, E., Kruczynska, D. Masny, A. and Pierzga, K. (2004). Field performance of selected domestic and foreign strawberry cultivars grown at two sites of Poland. *Acta Hort*., **663**(2): 919-922.

APPENDICES

Appendix I. Characteristics of field soil analyzed in Soil Resources Development Institute (SRDI) laboratory, Khamarbari, Farmgate, Dhaka

A. Morphological characteristics of the experimental field

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

B. Physical and chemical properties of the initial soil

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

Source: Soil Resources Development Institute (SRDI)

Appendix II. Monthly record of air temperature, relative humidity, rainfall, and sunshine (average) of the experimental site during the period from October 2011 to March 2012

Month	Air temperature (^{0}c)		Relative humidity (%)	Rainfall (mm)	Sunshine (hr)
	Maximum	Minimum			
October, 2011	26.5	19.4	81	22	6.9
November, 2011	25.8	16.0	78	00	6.8
December, 2011	22.4	13.5	74	00	6.3
January, 2012	24.5	12.4	68	00	5.7
February, 2012	27.1	16.7	67	30	6.7
March, 2012	31.4	19.6	54	11	8.2

Source: Bangladesh Meteorological Department (Climate & weather division) Agargoan, Dhaka–1212

Appendix III. Analysis of variance of the data on plant height at different days after transplanting (DAT) of strawberry as influenced by different germplasm and nutrients

Source of variation	Degrees of freedom	Mean square			
		Plant height (cm) at DAT			
		30	40	50	60
Germplasm (A)	2	6.492**	5.868**	37.472**	41.590**
Nutrients (B)	3	21.690**	20.497**	131.912**	165.439**
Interaction (A×B)	6	2.197*	3.633**	24.589**	50.519**
Error	48	0.830	1.109	4.821	2.776

**: Significant at 0.01 level of probability; *: Significant at 0.05 level of probability

Appendix IV. Analysis of variance of the data on number of leaves per plant at different days after transplanting (DAT) of strawberry as influenced by different germplasm and nutrients

Source of variation	Degrees of freedom	Mean square			
		Number of leaves per plant at DAT			
		30	40	50	60
Germplasm (A)	2	1.601**	3.267**	3.650**	13.067**
Nutrients (B)	3	5.442**	13.394**	12.349**	30.667**
Interaction (A×B)	6	0.081*	0.844*	0.294**	0.800*
Error	48	0.249	0.525	0.408	0.642

**: Significant at 0.01 level of probability; *: Significant at 0.05 level of probability

Appendix V. Analysis of variance of the data on number of runners per plant at different days after transplanting (DAT) of strawberry as influenced by different germplasm and nutrients

Source of variation	Degrees of freedom	Mean square			
		Number of runners per plant at DAT			
		30	40	50	60
Germplasm (A)	2	1.800**	1.867**	3.350**	2.467**
Nutrient (B)	3	0.735**	2.061**	4.022**	5.978**
Interaction (A×B)	6	0.178**	0.311*	0.506*	0.778**
Error	48	0.061	0.127	0.230	0.152

**: Significant at 0.01 level of probability; *: Significant at 0.05 level of probability

Appendix VI. Analysis of variance of the data on number of stolen per plant at different days after transplanting (DAT) of strawberry as influenced by different germplasm and nutrients

Source of variation	Degrees of freedom	Mean square			
		Number of stolon per plant at DAT			
		30	40	50	60
Germplasm (A)	2	1.169**	1.226**	0.720**	1.116**
Nutrients (B)	3	4.048**	5.072**	4.180**	3.401**
Interaction (A×B)	6	0.833**	0.749**	0.389**	0.168*
Error	48	0.065	0.073	0.119	0.064

**: Significant at 0.01 level of probability; *: Significant at 0.05 level of probability

Appendix VII. Analysis of variance of the data on yield contributing characters of strawberry as influenced by different germplasm and nutrients

Source of variation	Degrees of freedom	Mean square				
		Days to 1st flower bud emergence	Days to 1st flowering	Days to 1st fruit setting	Days to harvesting of fruits	Leaf area (cm^2)
Germplasm (A)	2	62.600**	43.850**	55.850**	94.860**	96.172**
Nutrients (B)	3	70.950**	61.822**	59.528**	40.999*	393.763**
Interaction (A×B)	6	25.201*	28.206**	21.161*	44.849**	83.924**
Error	48	10.300	9.417	8.283	13.733	13.706

**: Significant at 0.01 level of probability; *: Significant at 0.05 level of probability

Appendix VIII. Analysis of variance of the data on yield contributing characters and yield of strawberry as influenced by different germplasm and nutrients

Source of variation	Degrees of freedom	Mean square					
		Number of fruits per plant	Weight of individual fruit (g)	Length of fruit (mm)	Diameter of fruit (mm)	Fruit yield (g/plant)	Brix percentage (%)
Germplasm (A)	2	46.667**	7.327**	25.53**	20.124**	28576.10**	2.587**
Nutrients (B)	3	267.44**	41.195**	257.00**	109.49**	149957.09**	11.225**
Interaction (A×B)	6	16.089**	4.460**	2.657*	1.566*	10783.09**	0.584**
Error	48	3.142	1.533	1.398	0.791	2920.640	0.173

**: Significant at 0.01 level of probability; *: Significant at 0.05 level of probability