EFFECTS OF NITROGEN, PHOSPHORUS, POTASSIUM AND SULPHUR ON GROWTH, YIELD AND NUTRIENT CONTENT OF STRAWBERRY (*Fragaria ananassa*)

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CERTIFICATE

This is to certify that the thesis entitled **"EFFECTS OF NITROGEN, PHOSPHORUS, POTASSIUM AND SULPHUR ON GROWTH, YIELD AND NUTRIENT CONTENT OF STRAWBERRY (*Fragaria ananassa*)"** submitted to the Department of **Agricultural Chemistry**, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE in AGRICULTURAL CHEMISTRY**, embodies the result of a piece of bona fide research work carried out by **CHAMON-ARA-AFROZ**, Registration Number: **05-1770** 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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TO

MY BELOVED PARENTS

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ABSTRACT

The experiment was conducted at Horticulture Research Centre, Gazipur, Bangladesh, during the period of November 2011 to April 2012 to study the effects of nitrogen, phosphorus, potassium and sulphur on growth, yield and nutrient content of strawberry. The experiment was laid out in Randomized Complete Block Design (RCBD). There were 4 levels of different nutrients, viz. 0, 90, 115 and 140 kg N ha^{-1}; 0, 20, 40 and 60 kg P ha^{-1}; 0, 85, 110 and 135 kg K ha^{-1}; 0, 15, 25 and 35 kg S ha^{-1}. There was a positive impact of each fertilizer combinations on yield, yield parameters and nutrient contents of BARI Strawberry 1 except control treatment. The highest values of plant height (25.60 cm); number of leaves (21.66), flowers (125.33), fruits (12.35), destroyed fruits (11), fruit weight (215.10 g) $plant^{-1}$ and fruit length (4.16 cm), fruit diameter (3.41cm), individual fruit weight (17.85 g) and fruit yield (11.50 t ha^{-1}) were found in treatment of 115-40-110-25 kg ha^{-1} NPKS, respectively. Among the fertilizers, the single effect of nitrogen (115 kg ha^{-1}), phosphorus (40 kg ha^{-1}), potassium (110 kg ha^{-1}) and sulphur (25 kg ha^{-1}) gave maximum growth and yield of strawberry. The highest concentration of N, P, K and S were found in shoot and fruit of strawberry when N-P-K-S fertilizers were used 140-60-135-35 kg ha^{-1}, respectively.

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ABBREVIATIONS AND ACRONYMS

Full word	Abbreviation
And others (at elli)	*et al.*
Centimeter	cm
Correlation variation	CV
Day after transplanting	DAT
Degree celcius	^{0}C
Hectare	ha
Hydrogen ion conc.	pH
Kilogram	kg
Kilo pascle	kPa
Least significant difference	LSD
Microgram	µg
Milli equivalent	mEq
Milligram	mg
Milliliter	mL
Milli mole	mM
Pars permillion	ppm
Pound	lb
Quintal	q
Square centimeter	cm^2
Square meter	m^2
Total soluble solid	TSS

CHAPTER I

INTRODUCTION

Strawberry (*Fragaria ananassa*) is a new fruit crop in Bangladesh which belongs to the family Rosaceae, is widely grown from the low- latitude tropics and subtropics to the colder high-latitude areas (Darnell *et al.*, 2003). The plant comprises a shorten stem or crown from which arises leaves, runners, roots, auxiliary crowns and inflorescences (Darnell *et al.*, 2003). Strawberries are native to most of the Northern hemisphere, inclusing Europe and Britain. The garden (modern) strawberry is simply a hybrid of North and South American varieties. The cultivated strawberry is an octoploid ($2n = 56$) and though to be an autoployploid. The leaves typically have three leaflets that means trifoliate. Strawberry fruit is non-climactric and ripens rapidly (Wills *et al.*, 1998). During ripening, fruit continue to increase in size, accumulate soluble solid content (SSC) and goes distinct changes on pigmentation and soften (Spayd and Morrus, 1981).

Strawberries have been introduced in Bangladesh recently and getting popularity and cultivated very small scale. Different regions of Bangladesh are suitable to cultivate strawberry in terms of photoperiod, temperature and humidity. It is the time to research for improving strawberry varieties which are cultivated in our environment. Since it is adaptable strawberry has an expand culture in the world. On the other hand since fruits can be obtained early in the seasons where there is no fresh fruit in the market as its marketability is high. Another important aspect is that it can bring back the investment in a short period therefore it is suitable for farming. Apart from these, the income per unit area is high in strawberry cultures. Due to all these advantages in production and marketing strawberry cultivation area is gradually increasing in

Bangladesh. To meet the increasing demand in our local market traders import large amount of strawberry from different foreign countries.

Nitrogen, phosphorus, potassium and sulphur are essential nutrients for strawberry production. Nitrogen is used for proteins, nucleic acids and various co enzymes production. Phosphorus is effective an energy transfer process in strawberry plants. Phosphorus is a major component of the fruit size, colour and acidity of the fruit. It has also a great importance for maximizing quality of the fruit. Sulphur is a constituent of essential amino acids (cysteine, methionine, and cystine) involved in chlorophyll production, plant function and structure.

BARI Strawberry 1 is one of the high yielding varieties which is suitable for cultivation all over the country. The average yield is very low compared to that in other sub-tropical countries. Most of the soils and climatic conditions of Bangladesh are suitable for strawberry production but the crop did not show its potentially due to imbalance fertilization and poor agronomic practices. It is difficult to be specific about fertilizer recommendation because of variation in soil types, soil fertility and system of cultivation. Strawberry responds well to manuring and fertilizer. The application of high input technologies such as chemical fertilizers, pesticides, herbicides improved the production but there is growing concern over the adverse effects of the use of chemicals on soil productivity and environment quality (Prabhu *et al.*, 2006). There is a scope for increasing yield of this crop with combination of N, P, K and S fertilizer under the agro-ecological condition in Bangladesh. Soil fertility and productivity changes overtime and this change towards negative direction because of intensive cropping with modern varieties, improper and imbalance use of fertilizer and manure (BARC, 2005). Usually, farmers use fertilizers based on their own idea that make the soil heterogeneous causing declination of soil fertility in a long run. Farmers also suffer economic loss on the yield. But there is enough scope to increase yield with balanced fertilization. However, research works on nutrient management for strawberry is scanty in Bangladesh.

Hence the present study was, therefore, undertaken to evaluate the response to N, P, K and S and also to find out the optimum fertilizer package for maximizing yield of strawberry in Grey Terrace soil of Joydebpur, Gazipur with following objectives:

1. To determine the optimum fertilizer management package for maximizing growth and yield of strawberry.
2. To observe the N, P, K and S nutrient content in shoot and fruit of strawberry.
3. To find out the economic optimum fertilizer dose for yield of strawberry.

CHAPTER II

REVIEW OF LITERATURE

The significance of macro nutrients such as nitrogen, phosphorus, potassium and sulphur nutrition is well established. Numerous works have been done on the effect of nitrogen, phosphorus, potassium and sulphur. But information concerning their effect on strawberry under the climatic condition of Bangladesh is meager. Nevertheless, some of the important and informative works so far have been done abroad on these aspects have been presented in this chapter.

2.1 Literatures on nitrogen

Albregts and Howard (1980a) conducted a field experiment with different levels of nitrogen rates of 100, 150, or 200 lb acre^{-1} N were applied in 1976-1977 and in the second year 1977-1978. They stated that yields were not affected by N rate in either season or by placement method in the second season. They stated that yield highest in each season with 100 lb acre^{-1} N (2429 and 1976 flats acre^{-1}) placed at bed center, 1 inch below the bed surface.

Yoshida (1992) conducted an experiment with strawberry and found that 100 kg N ha^{-1} increased the number of flowers on first inflorescens. However, fruit malformation occurred more severely than in plants without nitrogen application and the increase in ratio of small fruits (<20 g) resulted in reduced yield.

Kopanski and Kaweci (1994) showed that N application of 90 kg N ha^{-1} increased fruit dry weight and vitamin C content of 'Dukat' and 'Senga Sengana' strawberries. The effect of N on the content of organic acids and total sugars was inconsistent.

Two experiments (E_1 and E_2) were conducted by Miner *et al.* (1997) on a wagram loamy sand (Arenic Kandiudult) in 1992 and on a Norfolk sandy loam (Typic Kandiudult) in 1993 to investigate the effects of fall-applied N and spring-applied N and K on `Chandler' strawberry yield and fruit quality. E_1 treatments included factorial combinations of fall-applied N (0, 34 and 67 kg ha^{-1}) and drip spring-applied N (0, 0.19, 0.37, 0.56 and 0.75 kg ha^{-1} d^{-1} and 0, 0.37, 0.75 and 1.12 kg ha^{-1} d^{-1} in 1992 and 1993, respectively). E_2 treatments included combinations of drip spring-applied N (0.56, 1.12, 1.68 and 2.24 kg ha^{-1} d^{-1}) and K (0.46, 1.39 and 2.32 kg ha^{-1} d^{-1} and 0, 0.75, 1.49 and 2.24 kg ha^{-1} d^{-1} in 1992 and 1993, respectively). There were no significant interactions among main effects for any of the measured variables. Market yield maximized with total N at 120 kg ha^{-1} with one-half banded in the fall and the remainder drip-applied in the spring. Fruit firmness decreased with increasing N rate. Fruit pH and concentrations of total acids and soluble solids were not affected by N treatments, but soluble solids increased as the harvest season progressed. Plant crown number was not affected by N treatment but crown yield increased with N rate similar to market yield.

Nestby (1998) reported that an average of two years, that the content of sucrose, glucose and fructose in the fruits of 'Korona' and 'Bounty' strawberries, increased when N was fertigated as NO_3 with levels of N up to 124 kg ha^{-1}, starting 4 weeks before harvest and ending after 2 weeks in the harvest period. Deng and Woodward (1998) grown Strawberry plants (*Fragaria ananassa* Duchesne var. Elsanta) in pots at two concentrations of carbon dioxide (partial pressures of 39 and 56 Pa) and with three rates of nitrogen supply (0.04, 0.4 and 4 mM as nutrient solution) to study their individual and interactive effects on plant growth and fruit yield. Nitrogen deficiency reduced total dry biomass and relative growth rate (RGR), mainly through reductions in leaf area ratio (LAR) and plant N concentration (PNC), although both the net assimilation rate (NAR) and root weight ratio (RWR) increased. N deficiency increased the proportion of total plant dry biomass allocated to fruits. There were no significant interactions between CO_2 and N supply on yield.

Rauf *et al.* (1998) conducted the trial to investigate an optimum level of NPK for strawberry cv. 'Gorella' grown in containers. Four levels of NPK. i.e. 0, 2, 4, and 6 g plant^{-1} were studied. The data showed that 4 g of NPK plant^{-1} gave maximum number of flowers plant^{-1} (29), maximum number of fruits plant^{-1} (19) and maximum number of runners plant^{-1} (4.5). While minimum number of fruits plant^{-1} (13.25) and minimum number of runners plant^{-1} (1.5) by 2 g NPK plant^{-1} and 6 g NPK plant^{-1}. However larger size fruits were observed in plants which received NPK at the rate of 6 g plant^{-1}.

Chen *et al.* (1999) stated that contents of NPK were maintained at high concentrations in plants during early stages of development, and then began to decline. P concentrations were low in all plant parts, but were higher in fruits than in leaves, roots and stems. N concentrations were higher in leaves than in fruits, stems and roots. Contents of N in stems and roots declined with development; there was a sharp drop in concentration in fruits. K contents were higher in fruits than in leaves, stems and roots, then dropped sharply. Lacertosa *et al.* (1999) conducted an experiment that acid and sugar concentrations were inversely correlated to the content of nitrogen in the fruits, indicating that a proper control of N fertilizers could be effective in improving fruit quality.

Gariglio *et al.* (2000) conducted an experiment on using nitrogen balance to calculate fertilization in strawberries. Using four treatments: control (T_0) = without fertilization; treatment 1 (T_1) = N fertilizer 53 kg ha^{-1}; treatment 2 (T_2) = N fertilizer 66 kg ha^{-1}; treatment 3 (T_3) = N fertilizer 117 kg ha^{-1}. All N treatments significantly increased yields over the control. Yield increased to increasing N rates from 0 to 53 kg ha^{-1}. This response was due to an increase in fruit number but not in fruit weight. High N rates promoted runner growth without increasing fruit yield. The use N balance method for strawberry fertilization showed satisfactory results. Accumulated N balance (T_1), required the least amount of N fertilizer while producing good yield.

Darnell and Stutte (2001) grown strawberries (*Fragaria ananassa* Duch. 'Osogrande') hydroponically with three NO_3^- N concentrations (3.75, 7.5, or 15.0 mM) to determine effects of varying concentration on NO_3^- N uptake and reduction rates, and to relate these processes to growth and fruit yield. Plants were grown for 32 weeks, and NO_3^- N uptake and nitrate reductase (NR) activities in roots and shoots were measured during vegetative and reproductive growth. In general, NO_3^- N uptake rates increased as NO_3^- N concentration in the hydroponics system increased. Tissue NO_3^- concentration also increased as external NO_3^- N concentration increased, reflecting the differences in uptake rates. There was no effect of external NO_3^- N concentration on NR activities in leaves or roots during either stage of development. Leaf NR activity averaged approximately 360 mM NO_2 formed g^{-1} fresh weight (FW) h^{-1} over both developmental stages, while NR activity in roots was much lower, averaging approximately 115 mM NO_2 formed g^{-1} FW h^{-1}. Vegetative organ FW, dry weight (DW), and total fruit yield were unaffected by NO_3^- N concentration. These data suggest that the inability of strawberry to increase growth and fruit yield in response to increasing NO_3^- N concentrations is not due to limitations in NO_3^- N uptake rates, but rather to limitations in NO_3^- reduction and/or assimilation in both roots and leaves.

Singh *et al.* (2001) showed the effects of urea at 0, 15, 30, 45, 60 and 75 g m^{-2} on the growth and fruit yield of strawberry cv. Chandler under greenhouse conditions were investigated in 1998-99 and 1999-2000. Urea at 75 g m^{-2} resulted in the highest number of leaves and runners per plant. Urea at 30 g m^{-2} resulted in the highest number of fruits $plant^{-1}$, fruit weight and crop yield. Rates higher than 30 g m^{-2} reduced fruit number and yield.

A field experiment was conducted by Ali *et al.* (2003) in Kashmir, Pakistan during 1999-2001 to determine the effects of single or combined applications of N (150 kg ha^{1}), P (100 kg ha^{-1}) and farmyard manure (FYM; 20 t ha^{-1}) on the yield and yield components of strawberry cv. Tuft. Combined application of 150 kg N ha^{-1}, 100 kg P ha^{-1} and 20 t FYM ha^{-1} resulted in the highest number of flowers plant^{-1} (14.63), fruit set plant^{-1} (9.13), number of fruits retained plant^{-1} (6.40), fruit weight (5.84 g) and yield (7 t ha^{-1}).

Gaur and Gangwar (2003) showed the effects of N rate (50, 100, 150 or 200 kg ha^{-1}) on the growth, yield and quality of strawberry cv. Seascape which were studied in Kanpur, Uttar Pradesh, India during 1997/98. The application of 200 kg N ha^{-1} resulted in the greatest number of leaves plant^{-1} (23.15) and plant height (19.90 cm). N at 150 kg/ha gave the highest number of flowers plant^{-1} (3.95), fruit set (68.35%), fruit length (2.56 cm) and width (2.04 cm), number of fruits plant^{-1} (16.7), average fruit weight (7.90 g), and total fruit yield plant^{-1} (137.75 g). The N rate did not significantly affect the ascorbic acid content of fruits and acidity of fruit juice.

Rana and Chandel (2003) conducted an experiment on strawberry cv. Chandler in Himachal Pradesh, India, during 1999-2000 to determine the effect of nitrogen (0, 60, 80 and 100 kg N ha^{-1}) and biofertilizers (Azotobacter, Azospirillum and Azotobacter + Azospirillum) on strawberry production. The maximum plant height (24.51 cm), number of leaves (26.20), leaf area (92.66 cm^{2}), fruit length (35.80 mm), fruit breadth (23.24 mm), fruit weight (9.17 g), TSS (8.60 degrees Brix) and total sugars (7.58%) were recorded with 100 kg N ha^{-1}. However, the maximum yield (74.81 qha^{-1}) and number of runners plant^{-1} (18.69) were obtained with 80 kg N ha^{-1}. Azotobacter inoculated plants attained maximum plant height (24.92 cm), number of leaves plant^{-1} (26.29), leaf area (96.12 cm^{2}), fruit length (35.94 mm), fruit diameter (22.91 mm), fruit weight (9.11 g), total soluble solid (8.64 degrees Brix) and total sugars (7.65%). The maximum yield (73.60 q ha^{-1}) and the number of runners plant^{-1} (18.70) was also recorded in Azotobacter inoculated plants. The maximum leaf area (102.50 cm^2), yield (79.12 q ha^{-1}), fruit length (37.32 mm), fruit diameter (23.65 mm), and fruit weight (10.02 g) were recorded with Azotobacter inoculation combined with 60 kg N ha^{-1}. However, the maximum total soluble solid (8.78 degrees Brix) content was recorded with Azotobacter combined with 80 kg N ha^{-1}.

Neuweiler (2004) conducted a great deal of research into the fertigation of strawberry plants cultivated in peat bags. In comparison there is very little scientific data from field-trials on the nutrition of outdoor plantings. Central interests are concentrated on nitrogen, which is easily leached out by rainfall. Modern strawberry cultivars may demand less nitrogen than traditional ones. Compared with other field-crops strawberry plants have a limited root-system, concentrated in the upper soil layer. The use of split applications of the annual nitrogen input by means of row applications at different times is important. In trials foliar applications of urea (0.3%) had a positive effect on the development of strawberry plants on poor soils. Nitrogen fertilizing did not increase the fruit yield of June-bearing cultivars on soils with medium nutrient reserves. Firmness and shelf-life of strawberry fruit decreased with increasing nitrogen supply.

Gutal *et al.* (2005) conducted a study from 1996 to 1999 in Maharashtra, India, to determine the effects of fertilizer rates of N with splits through drip irrigation on the growth and yield of strawberries. Four levels of recommended dose of nitrogen (50, 75, 100 and 125 kg ha^{-1}) through drip were given and compared with the recommended dose of nitrogen applied as band placement. The recommended dose of NPK was 120: 60: 60 kg ha^{-1}. The yields from 75 and 100 kg ha^{-1} were at par with each other, and both were superior to all other treatments. However, in terms of fertilizer savings (25%) and yield increase (15.6%), 75 kg ha^{-1} was the best treatment.

Faedi *et al.* (2006) carried out a two years experiment on strawberry plants (cv. Idea and Onda) grown in Cesena area (Italy) was performed in order to evaluate the effects of rate and timing of nitrogen and potassium application on yield and fruit quality. Increasing N supply (0-55-110 kg N ha^{-1}) in spring increased N- availability in the soil, leaf N, vegetative growth and fruit solid soluble content, but decreased fruit firmness without affecting plant yield.

Karlidag and Yildirim (2007) conducted field study for three years to determine different aspects of intercropping strawberry (*Fragaria ananassa* L. Duch.) with broad bean (*Vicia faba* L. cv. Lara) and their similarities to different nitrogen concentrations. Nitrogen was applied at three different rates (0, 80 and 160 kg ha^{-1}) in both sole and intercrop plots of strawberry. Sole cropping grown with no fertilizer-N application was considered the control. As a result of these studies, it was reported that the chemical characteristics such as ascorbic acid, total soluble solid, and titratable acidity of strawberry fruits were not significantly affected by either intercropping or nitrogen fertilization. While cropping system did not have any negative effects on fruit weight, fruit weight per plant, and yield of strawberry, nitrogen application rate did significantly affect these parameters. The 80 kg ha^{-1} nitrogen application gave maximum amount of marketable fruits for strawberry in both sole cropping and intercropping. Cropping system interaction with nitrogen application showed significant differences in fruit weight per plant and total fruit weight of strawberry. Strawberry intercropping might be more productive than sole cropping especially in case of 80 kg ha^{-1} nitrogen application.

The effects of increasing rates of N (as urea) and K on vegetative growth, nutrient uptake, fruit yield and quality of strawberries (*Fragaria anassa* Duch.) was investigated by Haynes and Goh (2008) in a field trial. In the first and second seasons there were small increases in plant growth and yields with the low rate of N but higher rates caused marked reductions in both growth and yields. However, increasing rates of N raised concentrations of α amino acid N and applied N tended to raise concentrations of polyphenols and reduce those of ascorbic acid. Applications of N had variable effects on titratable acidity and sugar contents of fruit and year to year differences in quality parameters were generally greater than those caused by N additions. With the high N rates accumulation of high levels of ammonium and soluble salts in the soil during spring of the first season was thought to have initially inhibited plant growth. Following nitrification of the accumulated ammonium, soil acidification occurred and consequently toxicities of Al and Mn limited strawberry growth at high N rates.

Human and Kotze (2008) field trial was conducted on the youngest fully expanded mature leaf of each plant was sampled from a factorial N and K fertilization on July 4, August 22, October 27 and December 4. Nutrient uptake was not very active during the late autumn and winter. On the first sampling date no differences in leaf N content were observed among the different fertilization treatments. During the remainder of the growing season, N fertilization generally affected leaf nutrient values. Nitrogen content decreased during the harvesting season to levels of about 1%, for both fertilized plants and unfertilized controls, indicating that either no uptake was taking place during the late harvesting period, or that all N was being transported to fruit.

Kim (2009) conducted the experiment to investigate the effect of nitrogen and potassium sources on growth and yield of strawberry 'Seolhyang' and 'Maehyang' in fertigation culture. The plant fresh and dry weight was higher in urea + potassium sulfate and ammonium sulfate + potassium sulfate as nitrogen and potassium sources than others in both varieties. But there were no significant difference among nitrogen and potassium sources in other growth characteristics, such as plant height, no. of leaf, crown diameter etc. Also, the marketable yield of fruit was higher in urea + potassium sulfate and ammonium sulfate + potassium sulfate. The fruit qualities, such as total soluble solid, hardness, acidity, vitamin C content were not significant difference among the treatments.

Dar *et al.* (2010) was conducted an field experiment to study the effect of various organic fertilizer combinations on growth, yield and quality of strawberry (*Fragaria ananassa* Duch) cv. Sweet Charlie comprising eight inorganic fertilizer treatment combinations including the control. Here authors used different combinations of NPK fertilizers. The treatment nitrogen 100 kg ha^{-1} recorded maximum no. of leaves (8.34), plant spread (27.52 cm), petiole length (6.14 cm), plant height (11.50 cm), number of flowers $plant^{-1}$ (4.45), fruit length (1.40 cm), specific gravity (1.20), ascorbic acid (55.85 mg 100 g^{-1}), pH (3.15) and yield $plant^{-1}$ (367.60 g).

Chepinski *et al.* (2010) carried out an experiment in 2006-2007, influence of different fertilizers on yield and quality of cv. Kent strawberry. Two combinations were tested, each consisting of 3 types of fertilizers. The control plants remained unfertilized. In both combinations, two types of multi-component fertilizers were used (T - 5% N, 5% P_2O_5, 15% K_2O and O - 10% N, 5% P_2O_5, 10% K_2O) as well as one rate of ammonium nitrate to provide 50 kg N ha^{-1} in the first combination and 70 kg N ha^{-1} in the second one. The treatment with multi-component fertilizers enhanced firmness as well as calciam, phosphorus and potassium content in fruit. Strawberry fertilized with higher rate of T fertilizer contained more soluble solids, total sugar and reducing sugar. Neither the type of fertilizers, nor their rate affected acidity, vitamin C, total phenol and magnesium content in berries. The lowest nitrogen content was observed for control berries. Practically, the differences regarding nitrogen content between the fruits of the first (50 kg N ha-1) and second combination (70 kg N ha-1) were negligible. The usage of multi-component fertilizers, especially O type resulted in an increase of cv. Kent strawberry yield.

Jarosz and Konopinska (2010) carried out an experiment to determine the quantity and quality of the yield of plants grown in the soilless system is the kind of cultivation substrate used and the level of supplying the plants with nutrients. Studies conducted in the years 2005-2006 were aimed at determining the effect of differentiated nitrogen dose (140 and 210 mg N dm^{-3}) upon yielding, chemical composition of strawberry (*Fragaria ananasa* Duch.) leaves and fruit, cultivar "Elsanta", grown in unheated foil tunnel. In the leaves of strawberries fertilized with nitrogen in the dose of 210 mg N dm^{-3} we found significantly more nitrogen and phosphorus, as well as less calcium and magnesium, as compared to plants fertilized with smaller doses of this nutrient. The fruit of strawberries fertilized with a higher nitrogen dose contained significantly more nitrogen and potassium, as well as less vitamin C and soluble solids, as compared to the fruit collected from plants fertilized with nitrogen in the dose of 140 mg N dm^{-3}. In our studies no significant effect of differentiated nitrogen fertilization upon strawberry yielding was demonstrated.

2.2 Literatures on phosphorus

Albregts and Howard (1979, 1980b, 1981) conducted field investigation on strawberry for maximum fruit yields, nutrients must be present in the greatest quantities during the second half of the season (January through April) to sustain fruiting. Nutrient analyses of dried strawberry plants sampled through the season revealed consistent nutrient accumulation trends among three sampled cultivars. The average P in the plant at midseason and end-of-season samplings was 3.4 and 3.4 lb $acre^{-1}$ P. While accumulation of these nutrients in the plant was nearly unchanged during this period, nutrient accumulation in the fruit significantly increased from 1.8 to 5.0 lb $acre^{-1}$ P at mid and end of season sampling. Accumulation of P by the fruit represented 60% of the total plant plus fruit accumulation of these nutrients by the end of the season. Researchers noted, however, that only small nutrient quantities were needed late in the season to replace those nutrients removed with the fruit. Excessive nutrient application late in the season is often unused by the plant and prone to buildup or leaching from the soil.

May and Marvin (1993) showed the main effects and interactions of soil-applied P, B and Zn on yield and its components were examined in the field at two pH levels with 'Earliglow' strawberries (*Fragaria ananassa* Duch.). Applied nutrients had significant effects on several yield components, but responses depended on the levels of other nutrients or the soil pH at a soil pH of 5.5, yield responded linearly to B and quadratically to P. At pH 6.5, P interacted with B and Zn. Fruit count per inflorescence was the yield component most strongly associated with yield followed by individual fruit weight. However, these two yield components responded differently to soil-applied nutrients. Foliar nutrient levels generally did not increase with the amount of applied nutrient, but often an applied nutrient had a strong effect on the level of another nutrient. Leaf nutrient levels were often correlated with fruit levels, but foliar and fruit levels at harvest were not related to reproductive performance.

Suckkee *et al.* (2002) were carried out this research to describe deficiency symptoms and to determine critical concentrations of plant and soil phosphorus when strawberry plants reveal phosphorus deficiency. Phosphorus deficiency developed first at old leaves. Dry weight began to lessen when tissue phosphorus concentration in dry matter was below 0.3%, and fresh weight began to lessen when phosphorus concentration in plant sap was about 520 mg kg^{-1} indicating those were the critical concentrations. Phosphorus concentrations in soil were 94 and 100 mg L^{-1}, respectively, in the 0.75 and 1 mM treatments. Considering the change of fresh weight, the maximum fresh weight production seems to be possible when phosphorus concentration in soil solution was around 90 mg L^{-1}.

Singh *et al.* (2003) focuses on this paper the phosphorus physiology of the strawberry plants and explores certain aspects of fruit quality that are affected by the level of phosphorus in the plant. In particular, the role of phosphorus in plant growth, metabolism, leaf gas exchange, chlorophyll fluorescence, dry matter accumulation and distribution, fruit quality and carbon and starch accumulation and distribution, are discussed

Strawberries (*Fragaria ananassa*) grown in alfisols of semiarid areas in India at low organic carbon and low phosphorus (P) availability, in addition to high P fixation, affects P availability drastically by Sharma and Adholeya (2004) to show the benefit of the yield of micropropagated strawberry *Fragaria ananassa* through inoculation with arbuscular mycorrhizal (AM) fungi and P application was examined in a field experiment conducted in early November 1998 in Haryana, India. AM response was evaluated at 4 doses of P (50, 100, 150 and 200 kg P ha^{-1}) in a high P-fixing capacity and P-deficient alfisol. At harvest, all inoculated plants, except those at the highest level of applied P (200 kg ha^{-1}), had larger fruit yields per plant, unit mass, number of runners, higher shoot dry matter and shoot P content. However, the AM response, as measured by yield, varied with P concentration. Inoculated plants had a significantly greater fruit yield when grown at 150 kg P ha^{-1}, and the yield was comparable with uninoculated plants grown at 200 kg P ha^{-1}. The external P requirements were 71 kg ha-1 for mycorrhizal and 106 kg ha^{-1} for non mycorrhizal strawberry plants to obtain 90% of the maximum fruit yield. In terms of P application, this corresponds to a savings of 35 kg ha^{-1}. The percent mycorrhizal root length colonization, both in inoculated and uninoculated plants, was not found to differ significantly with P application.

This study was carried out by Odongo (2007) to determine the influence of cattle manure and triple super phosphate on growth, yield and quality of strawberry cultivar. The experiment was carried out in the horticultural research field at Egerton University, Njoro, Kenya. The study was conducted in three seasons from August 2003 to July 2004, February 2004 to February 2005, and July 2005 to June 2006, each in new plots. Cattle manure was applied at the rates of 0, 18, 36 and 54 t ha^{-1} singly or in combination with triple super phosphate (TSP), corresponding to 0, 17, 34 and 68 kg ha^{-1} phosphorus was applied to the soil before planting. Leaf number and biomass, runner number and biomass, leaf chlorophyll content, shoot and root biomasses, and root to shoot ratio, fruit number, weight, size, storage life and brix index, were determined at various weeks after planting (WAP) to monitor performance over time. The combination of 68 kg ha^{-1} P and 18 t ha^{-1} FYM in season 1 resulted in the lowest economic returns whereas 68 kg ha^{-1} P and 18 t ha^{-1} FYM in season 2 resulted in the highest economic returns. High fertilizer doses do not always result in high economic returns, and under similar conditions, 68 kg ha^{-1} P and 18 t ha^{-1} FYM combination is recommended for enhancing strawberry yields.

Zargar (2008) carried out a pot experiment at Indian during 2004-05 to evaluate the interaction effect of inoculation of three levels of each bio-fertilizers (Azotobacter, PSB, VAM), nitrogen, (50, 100, 225 kg ha^{-1}) and phosphorus (50, 75, 150 kg ha^{-1}) on the soil physio-chemical properties and yield attributing parameters of strawberry plant. Each treatment combination has shown significant effects on most of the parameters, but the combination of nitrogen (225 kg ha^{-1}), phosphorus (150 kg ha^{-1}) and bio-fertilizer (Azotobacter) showed highest values of average fruit weight (19 g), plant height (40.66 cm), leaf nitrogen (2.50%), calcium (1.62%), magnesium (0.32%), sulphur (0.68%) and available nitrogen (220 kg ha^{-1}), calcium (3985 kg ha^{-1}), magnesium (184.37 kg ha^{-1}) and sulphur (13.60 kg ha^{-1}). Similarly, the treatment combination of nitrogen (225 kg ha^{-1}), phosphorus (150 kg ha^{-1}) and bio-fertilizers (PSB) significantly affected number of primary flowers (8.0), number of secondary flowers (10.00), total number of flowers $plant^{-1}$ (18.00), number of primary fruits $plant^{-1}$ (7.00), number of secondary fruits (10.00), total number of fruits (17.00), available phosphorus (11 kg ha^{-1}), leaf phosphorus (0.30%).

Hong *et al.* (2008) stated that optimizing plant nitrogen (N) and phosphorus (P) nutrition is required in healthy propagation of strawberry nursery plants for fruit production. Strawberry (*Fragaria ananassa* Duch.) nutrient NPK supply was respectively at the rates of 105, 145 and 165 kg ha^{-1}, based on soil testing and regional recommendation. Results showed that strawberry nursery plant propagation and productivity expressed using runner and daughter-plant variables were significantly different among the seven cultivars ($P < 0.05$). Total nitrogen uptake (mean ±SD) varied between 2.96±0.91 g $plant^{-1}$ and total P uptake was 0.29±0.06 g $plant^{-1}$ among the seven cultivars. Whole plant P accumulation increased with increasing of N accumulation (up to 4.7 g $plant^{-1}$, $R2 = 0.76$, $P < 0.01$). It was suggested that strawberry nursery plant propagation could be enhanced with nutrition accumulation ranges of 2.47-3.26 g N $plant^{-1}$ and 0.25-0.34 g P $plant^{-1}$. Runner thinning would be an option for regulating strawberry plant N and P nutrition and nursery plant productivity.

2.3 Literatures on potassium

Locascio and Saxena (1967) grown strawberries during three sea sons on Ona and Kanapaha fine sands to evaluate their response to N and K rates and sources of K. Fruit yields were not significantly influenced by N rates from 46 to 180 lb $acre^{-1}$. Increased rates of K from 35 to 180 lb $acre^{-1}$ had no significant effect on total yield during two seasons. In the third season, a significant reduction in total yield occurred as the rate of applied K was increased from 0 to 130 lb $acre^{-1}$. This yield reduction was associated possibly with a K-Mg antagonism. The N and K composition of leaf tissue was increased by increased rates of applied N and K, respectively. Sulfate, chloride and nitrate sources of K produced the same leaf tissue composition and total fruit yields.

Edward *et al.* (1975) conducted an experiment on strawberry plants, cv. Cambridge was grown (a) with 5 different levels of potassium from planting to dormancy, followed by a constant level of K in the flowering and fruiting phase; or (b) with a constant level of K from planting to dormancy, followed by 4 different levels of K during the flowering and fruiting phase. Application of K ranging from 0.125 to 2 mEq L^{-1} in the nutrient solution over the period from planting to dormancy had no significant effect on any of the components of yield subsequently measured. Application of K ranging from 0.25 to 2 mEq L^{-1} over the flowering and fruiting period produced significant effects on yield, mainly because of increased flower production. Yields for different rooting media, and even between plants grown in the same medium, varied considerably due to factors other than potassium nutrition, but the leaf potassium concentration at the fruit ripening stage associated with maximum yield of fruit (>7 g per berry) was constant at about 1.2% K, irrespective of the actual yield.

Albregts *et al.* (1991) carried out an experiment on variations in yield, average fruit weight, and leaf-tissue K concentration were evaluated for 'Dover' and 'Chandler' strawberry cultivars grown with K rates from 0 to 240 lb $acre^{-1}$ K_2O. Potassium (KCl) was applied at 0, 60, 120, 180 and 240 lb $acre^{-1}$ K_2O with 200 lb $acre^{-1}$ N and 40 lb $acre^{-1}$ P_2O_5. Yields of the Florida cultivar 'Dover' increased linearly with increasing K rates in both seasons, while yields of the California cultivar 'Chandler' were not affected by K fertilization.

Albregts and Sutton (1991) conducted a field experiment on strawberry (*Fragaria ananassa* Duch.) for two seasons on a fine sand soil to study the plant and fruiting response of three cultivars to K rates of 0, 56, 112, 168 and 224 kg ha^{-1}. 'Dover' total fruit yields increased linearly with rate both seasons while the maximum March yield the first season was with 170 kg K ha^{-1}. April yields increased linearly with K rate the first season. The average fruit weight of 'Dover' and 'Tufts' decreased linearly with increasing K rate for March and for the season in 1984, while 'Dover' gave a positive linear average fruit weight response to K rate during Apr. 1986.

Albregts and Chandler (1993) showed that high yields occurred with saturated-water-extracted K concentrations from soil samples from 1990-1993 taken in February each year. Researchers concluded that 70 ppm of saturated-water-extracted K was sufficient for high yields. Soil K concentrations in saturated-water extracts increased linearly through 252 and 275 ppm each year with increasing rates of applied K. Yields were unaffected by the increased soil K concentrations either year.

Albregts *et al.* (1996) conducted a field experiment on `Oso Grande' and `Seascape'. In 1993-94 `Oso Grande' and `Seascape' were grown in a K fertilization study using polyethylene-mulched and fumigated bed at 0.28, 0.56, 0.84, 1.12 and 1.40 kg K ha^{-1} d^{-1}. Early, March, and total-season marketable fruit yields were not affected by K rate during either season. The average fruit weight of `Oso Grande' for the early, March, and total-season harvest periods in the 1992-93 season decreased with increased K rate. For the same harvest periods, `Seascape' average fruit weight increased, decreased, and did not change, respectively, with increased K rate. Petiole sap, whole leaf, and leaf blade K concentrations increased with increasing K rates on most sampling dates during both seasons. `Oso Grande' and `Sweet Charlie' produced similar total marketable fruit yields the first season, but `Oso Grande' produced higher total yields than `Seascape' during all harvest periods of the second season. Fruit yield during both seasons and fruit firmness during both season were not affected by K rate. Petiole sap, whole leaf, and leaf blade K concentrations increased with increasing K rates on most sampling dates during both seasons. `Oso Grande' and `Sweet Charlie' produced similar total marketable fruit yields the first season, but `Oso Grande' produced higher total yields than `Seascape' during all harvest periods of the second season.

Eckstein and Blanke (2000) showed that potted plants of the ever-bearing strawberry cv. Rapella were greenhouse-grown in spring either with or without K nutrient supply. K-deficient strawberry showed reduced leaf growth and reduced uptake of K and N but increased P and Mg uptake relative to K sufficient plants.

Faedi *et al.* (2006) were carried out a two years experiment on strawberry plants (cv. Idea and Onda) grown in Cesena area (Italy) was performed in order to evaluate the effects of rate and timing of nitrogen and potassium application on yield and fruit quality. Potassium applications (60 or 120 kg K ha^{-1}) did not affect leaf mineral concentrations, fruit quality and yield of strawberry plants, likely as a consequence of a high K fertility of the original soil.

Khayyat *et al.* (2007) showed fruit set and quality in strawberry cv. Selva were influenced by salinity (NaCl) and supplementary calcium and potassium. Treatments applied to the root medium of plants growing in soilless culture under heated greenhouse conditions. Yield components such as primary fruit weight and fresh fruit weight (at harvest time) and fruit number were higher in control and there was no significant difference between control and NaCl (35 mM) + $CaSO_4$ (10 mM). Primary fruit weight and fresh fruit weight (at harvest time) were decreased by salinity. Their results suggest that in saline conditions, $CaSO_4$ application cause increase in fruit yield and quality of strawberry.

The effects of increasing rates of N (as urea) and K on vegetative growth, nutrient uptake, fruit yield and quality of strawberries (*Fragaria ananassa* Duch.) was investigated by Haynes and Goh (2008) in a field trial. There was a positive growth and yield response to the addition of K in the no-N and low-N treatments although rate of K had no influence. Increasing rates of K generally increased concentrations of leaf K and decreased those of Mg and Ca. Additions of K had no effect on chemical parameters of fruit quality.

Human and Kotze (2008) conducted a field trial on the youngest fully expanded mature leaf of each plant was sampled from a factorial N and K fertilization on July 4, August 22, October 27 and December 4. Nutrient uptake was not very active during the late autumn and winter. Leaf K levels should not be higher than about 1.65% at the beginning of the harvesting season, as leaf levels of 1.80% were associated with soil K levels of 80 ppm, which resulted in decreased yield and fruit size. There is no single time at which leaves should be sampled for diagnostic purposes, and different standards for leave analyses should be developed for different periods during the growing season.

Kim (2009) conducted the experiment to investigate the effect of nitrogen and potassium sources on growth and yield of strawberry 'Seolhyang' and 'Maehyang' in fertigation culture. The plant fresh and dry weight was higher in urea + potassium sulfate and ammonium sulfate + potassium sulfate as nitrogen and potassium sources than others in both varieties. But there were no significant difference among nitrogen and potassium sources in other growth characteristics, such as plant height, no. of leaf, crown diameter etc. Also, the marketable yield of fruit was higher in urea + potassium sulfate and ammonium sulfate + potassium sulfate. The fruit qualities, such as total soluble solid, hardness, acidity, vitamin C content were not significant difference among the treatments.

Khayyat *et al.* (2009) an experiment was carried out on strawberry plants which were grown in soilless culture under greenhouse conditions to investigate the effect of supplementary potassium fertilization on growth and development of plants exposed to high NaCl concentration (35 mM L^{-1}). Treatments included: 1) nutrient solution alone (N); 2) N + 35 m L^{-1} NaCl (NS); 3) NS + 5 mM L^{-1} K_2SO_4 (NSK1); 4) NS + 10 mM L^{-1} K_2SO_4 (NSK2). Results showed that leaf area, ion leakage (EC), chlorophyll contents, biomass production and water usage were negatively affected by NaCl stress. Moreover, fruit set and fruit number decreased under stress condition. Mineral content

(Na, Cl, Ca and K) in various plant parts increased upon NaCl stress. Although supplementary potassium fertilization positively influenced the leaf area development, chlorophyll contents and reproductive parameters, it had a negative effect on biomass production. On the other hand, in addition to K and Ca supplementary potassium increased Na and Cl content. These results showed that potassium reduces some negative effects of NaCl stress in strawberry.

Andriolo and Luiz (2010) conducted an experiment in order to evaluate the effect of potassium doses supplied by fertigation and of calcium by foliar spray on plant growth, fruit yield and quality of soilless grown strawberries, plants were supplied with nutrient solutions at K^+ concentrations of 9 (T_1); 6 (T_2, control) and 4.28 mM L^{-1} (T_3) and with the control nutrient solution (T_2) supplemented once a week by spraying $CaCl_2$ on shoot at concentrations of 2.5 (T_4) and 5g L^{-1} (T_5). Plant growth was lower in the higher potassium concentration (T_1) and the highest LAI was recorded in the higher $CaCl_2$ dose (T_5). Fruit yield was higher in T_2 and T_3, the titratable acidity (TA) was higher in T_1, while total soluble solids (TSS) and the ratio TTS/TA did not differ among treatments. It was concluded that high potassium concentration in the nutrient solution reduces plant growth, fruit yield and quality and that calcium supplied on shoot by $CaCl_2$ reduces fruit production.

Dar *et al.* (2010) conducted a field experiment to study the effect of various organic fertilizer combinations on growth, yield and quality of strawberry (*Fragaria ananassa* Duch) cv. Sweet Charlie comprising eight inorganic fertilizer treatment combinations including the control. Here author used different combinations of NPK fertilizers. The treatment potassium 80 kg ha^{-1} recorded maximum no. of leaves (8.34), plant spread (27.52 cm), petiole length (6.14 cm), plant height (11.50 cm), no. of flowers $plant^{-1}$ (4.45), fruit length (1.40 cm), specific gravity (1.20), ascorbic acid (55.85 mg 100 g^{-1}), pH (3.15) and yield $plant^{-1}$ (367.60 g).

Ebrahimi *et al.* (2012) conducted this study to evaluate the effect of different types of substrate, concentrations of potassium and cultivars were evaluated on yield and quality parameters of strawberry in hydroponic system. The factors were three strawberry cultivars under three potassium concentrations (200, 300 and 400 ppm) of nutrient solution of KH_2PO_4, KNO_3 and K_2SO_4 and three different substrates (peat + sand + perlite, cocopeat + perlite and sand + perlite). Results showed that increasing the concentration of potassium to 300 ppm in nutrient solution increased vitaminC content, TSS, fruit number, fruit weight, yield of plant, root weight, root dry weight and length of root. The highest total yield was obtained from Parus with 300 ppm potassium in cocopeat + perlite substrate (921.84 g $plant^{-1}$).

Souri and Eskandarpor (2012) conducted an experiment to investigate the response of three strawberry cultivars to different potassium to calcium ratios of nutrient solution, this study was conducted as factorial based on completely randomised design with 4 replicates under greenhouse conditions. Three potassium to calcium ratios of 200:200, 400:200 and 600:200 mg L^{-1} on three strawberry cultivars (Camaraso, Silva and Parus) were applied under soilless culture system. The results however, showed that there was a significant increase on growth and physiological parameters, including root dry weight, pH and total acidity of fruit juice, the index of fruit flavor, fruit length, the number of fruits per plant, yield and fruit dry matter with increasing the potassium to calcium ratio in nutrient solution.

2.4 Literatures on sulphur

Erdal *et al.* (2006) carried out this study in a calcareous soil in Turkey to investigate the effects of different sulfur (S) and iron (Fe) sources on Fe nutrition of strawberry plants (*Fragaria vesca*). Elemental S and S-containing waste from S factory (500 and 1000 kg S ha^{-1}) as well as $FeSO_4$ and Sequestrene Fe-138 (Fe-chelate) (20 kg Fe ha^{-1}) were applied to the soil. Soil pH decreased from 8.3 (without S application) to 7.7-7.9 with the application of the S sources. The leaf Fe concentration, chlorophyll content, green colour intensity and fruit yield increased with single and/or combined applications of S and Fe. Both S sources showed similar effects regarding parameters mentioned above. The results showed that S containing waste could be used as an alternative to elemental S for improvement of Fe nutrition in calcareous soils under similar conditions.

Bielinski and Santos (2010) field studies were conducted to determine effects of pre-plant nitrogen (N) and sulfur (S) sources on 'Strawberry Festival' strawberry (*Fragaria ananassa*) growth and yield. Six treatments resulted from the pre-plant application of ammonium nitrate [AN (34% N)], ammonium sulfate [AS (21% N and 24% S)], ammonium sulfate nitrate [ASN (26% N and 14% S)], polymer-coated AS [PCAS (20% N and 23% S)] and elemental S (90% S). A non treated control was added. The N was fixed at 50 lb acre^{-1} for AN, AS, ASN and PCAS, which resulted in S rates of 0, 57, 27 and 57 lb acre^{-1} respectively. The S rate of the elemental S treatment was set at 57 lb acre^{-1}. For early fruit number, the highest values were found in plots treated with AS and elemental S, while the highest total fruit numbers were obtained in plots treated with AS, ASN, PCAS and elemental S. There was no difference in total fruit numbers between the non treated control and AN. Plots treated with elemental S, PCAS, ASN and AS had the highest early marketable fruit weights, whereas the lowest early marketable fruit weight was found in the non treated plots. In comparison with the non treated control plots, all the pre-plant fertilization programs improved early marketable fruit weight, with AN, AS, ASN, PCAS and elemental S. Total marketable fruit weights were maximized in plots treated with pre-plant AS, ASN, PCAS or elemental S. There was no difference between the total fruit weights obtained in the control and AN-treated plots. The data indicated that the strawberry total yield increases can be attributed to the use of pre-plant fertilizer sources containing S.

CHAPTER III

MATERIALS AND METHODS

This chapter deals with the experimental aspect of the work followed in the study containing a brief description of site, soil, climate, crop treatment, land preparation, experimental design, transplanting of seedlings, fertilizer application, intercultural operations, harvesting, data recording and soil and plant analyses.

3.1 Description of the experimental site

3.1.1 Location of the experimental field

The experiment was conducted at the Horticultural Research Farm, BARI, Joydebpur, Gazipur during robi season of 2011-2012.

3.1.2 Characteristics of the soil

The soil of the experimental field was silt loam in texture belonging to the agro-ecological zone of the Madhupur Tract (AEZ-28). The selected plot was medium high land that remained fallow during the previous winter. The physical and chemical characteristics of the soil were determined at the laboratory of Horticultural Research Farm, BARI, Joydebpur Gazipur. The characteristics of the soil are shown in Table 3.1 and 3.2.

3.1.3 Climate

The climate of the experimental site is subtropical in nature, characterized by three distinct seasons. The monsoon, popularly known as rainy seasons which extends from May to October, the pre-monsoon period or hot season extends from March to April and the winter season from November to February. The experiment was carried out from November to April. Details of the meteorological data in respect of temperature, rainfall, relative humidity during the period of the experiment have been given in (Appendix I).

Table 3.1 Morphological, physiological and mechanical characteristics of the soil of the experimental area

a) Morphological characteristics

Locality	Horticultural Research Farm, BARI, Joydebpur, Gazipur
General Soil type	Calcarious Dark Grey Flood Plain
Physiographic unit	Madhupur Tract
Topography	Medium High Land
Drainage	Adequate
Flood level	Above flood level
Climate	Humid, Sub-tropical
Vegetation	Cropped with strawberry, tomato, brinjal vegetation

b) Physical characteristics

Depth in cm	Description
0-15 cm	The soil is soft and feels floury. It appears cloddy but readily broken. When pulverized the soil is light brownish in color when pulverized. The soil is light brownish in color when wet, it shows finger print when pressed with thumb.

c) **Mechanical composition of soil**

Constitutents	Percent
Sand	30.56
Silt	37.26
Clay	32.15
Textural class	Silt loam

Table 3.2 Initial soil nutrient status of the experimental site of HRC Farm, Joydebpur, Gazipur

Nutrient	Soil test value
pH	6.2
Organic matter (%)	0.95
Ca (mEq/100 g soil)	1.12
Mg (mEq/100 g soil)	0.60
Total N (%)	0.15
Available P (ppm)	9
K (mEq/100 g soil)	0.17
S (ppm)	15
Zn (ppm)	1.4
B(ppm)	0.10

3.1.4 Test crop

The variety 'BARI strawberry 1' was used as the test crop. This variety was developed by Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur. This is a popular variety.

3.1.5 Land preparation

The land preparation was started one month prior to transplant of the seedlings. The land was thoroughly prepared with the help of a power tiller. Subsequently the land was sufficiently irrigated and ploughed and crops ploughed three times with country plough followed by laddering to have a good tilt. All kinds of weed, stubbles and residues of previous crop were removed from the field. After uniformly leveling, the experimental plots were laid out according to the requirement of the treatments and statistical design.

3.1.6 Experimental design

The field experiment was set up in a Completely Randomized Block Design (RCBD) with three replications having 14 treatment combinations. Thus the total number of unit plots was 42. The unit plot size was 2 m x 1 m. The plot to plot distance was 50 cm x 50 cm. The treatments were randomly distributed to the plots with proper fertilization. The bunds around individual plots were sufficiently strong to control water movement between plots. A drain of 50 cm wide was provided between the unit plots. 2.5 m wide drain was provided around the whole experimental plot.

3.1.7 Treatments

There were altogether 14 treatments consisting of nitrogen, potassium, phosphorus and sulfur including control (Table 3.3). The doses of fertilizers are nitrogen (0, 90, 15 and 140 kg ha^{-1}), phosphorus (0, 20, 40 and 60 kg ha^{-1}), potassium (0, 85, 110 and 135 kg ha^{-1}) and sulfur (0, 15, 25 and 35 kg ha^{-1}) are used at different treatments.

Table 3.3 The treatment combinations

Treatments	Levels of Nitrogen (kg ha^{-1})	Levels of Phosphorus (kg ha^{-1})	Levels of Potassium (kg ha^{-1})	Levels of Sulphur (kg ha^{-1})
T_1	0	40	110	25
T_2	90	40	110	25
T_3	115	40	110	25
T_4	140	40	110	25
T_5	115	0	110	25
T_6	115	20	110	25
T_7	115	60	110	25
T_8	115	40	0	25
T_9	115	40	85	25
T_{10}	115	40	135	25
T_{11}	115	40	110	0
T_{12}	115	40	110	15
T_{13}	115	40	110	35
T_{14}	0	0	0	0

Plot size = 2 m × 1 m

Plot to plot distance = 50 cm

R_1	R_2	R_3
T_3	T_4	T_{14}
T_5	T_2	T_4
T_{14}	T_3	T_3
T_6	T_{10}	T_5
T_7	T_5	T_6
T_{13}	T_1	T_7
T_4	T_{14}	T_{11}
T_{10}	T_9	T_1
T_{11}	T_6	T_2
T_1	T_7	T_{13}
T_9	T_8	T_{12}
T_2	T_{12}	T_8
T_{12}	T_{11}	T_{10}
T_8	T_{13}	T_9

Fig 3.1 Layout of the experiment

3.1.8 Fertilizer application

The whole amount of TSP, gypsum, boric acid, zinc oxide, cow dung and ½ MOP were applied and mixed up with the soil during final land preparation. Nitrogen and the rest of potassium were applied around the plants after 15 days of transplanting and these were applied in 4 equal installments.

Table 3.4 Fertilizers and their doses used in the experiment

Fertilizers	Fertilizer doses
Urea [CO $(NH_2)_2$]	Treatment dose
TSP [Ca $(H_2PO_4)_2$ H_2O]	Treatment dose
MOP [KCl]	Treatment dose
Gypsum [$CaSO_4.H_2O$]	Treatment dose
Borax [$Na_2B_4O_7.10\ H_2O$]	2 kg ha^{-1}
Zinc sulphate [$ZnSO_4.7H_2O$]	4 kg ha^{-1}
Cow Dung	10 t ha^{-1}

3.1.9 Transplanting of seedling

Thirty days old seedlings were transplanted on the 17th November, 2011 with a spacing of 40 cm from plant to plant and 60 cm from row to row. Number of rows are 2 and number of plants per rows were 5 which were equal in all plots.

3.1.10 Intercultural operations

Intercultural operations were done in order to ensure and maintain the normal growth of the plants as and when needed. Following intercultural operations were done.

3.1.10.1 Irrigation

There was not sufficient rainfall during the growing period due to the robi season. After transplanting four flood irrigations were needed to wetting soil but not standing water between the rows of each plot throughout the growing period.

3.1.10.2 Weeding

The experimental plots were infested with some common weeds, which were removed by uprooting them from the field during the period of the experiment. Indeed three times weeding were needed.

3.1.10.3 Insect pest control

Diseases can be a major factor limiting strawberry production. Experimental crop was infested by grey mold during the flowering stage. Disease was controlled by spraying Mancozb 80WP. Fungicide was sprayed two times at 15 days interval crop was also attached by leaf feeder during the growing stage & flowering stage. The larvae were controlled by Phrithrum @ 1.5 mL L^{-1}. The insecticides were sprayed 7 days after transplanting of runners.

3.1.11 Harvesting

Ripen strawberry fruits were harvested from 1st March to 13th April, 2012. The necessary field data were recorded from eight selected plants at each treatment. The following data were collected and recorded.

1. Plant height
2. Leaves no. $plant^{-1}$
3. Flowers no. $plant^{-1}$
4. Fruits no. $plant^{-1}$
5. Fruit length

6. Fruit diameter
7. Damaged fruit no. plant^{-1}
8. Fruit weight plant^{-1}
9. Individual fruit weight
10. Yield

3.2 Collection of plant sample

Eight plants were randomly selected at each treatment for collecting the following data:

3.2.1 Plant height

Plant height from ground level to the tip of the plant was recorded from eight randomly selected plants at each treatment in cm.

3.2.2 Number of leaves

Number of leaves of the selected eight plants of each plot was recorded then calculated the average.

3.2.3 Number of flowers

The number of total flowers plant^{-1} was recorded from the randomly selected 8 plants plot^{-1}, and then calculated the average number of flowers.

3.2.4 Number of fruits

The number of total fruits plant^{-1} was recorded from the randomly selected 8 plants plot^{-1} and then calculated the average number of fruits.

3.2.5 Fruit length

Data was recorded from randomly selected fruits plant^{-1}. Then length of fruits of eight selected plants from each plot was recorded in cm and then calculated the average number of fruits length.

3.2.6 Fruit diameter

Data was recorded from randomly selected fruits plant^{-1}. Then diameter of fruits of eight selected plants plot^{-1} was recorded in cm and then calculated the average number of fruits diameter.

3.2.7 Number of damaged fruits

Damaged fruits number plant^{-1} was calculated.

3.2.8 Fruit weight

The number of total fruits weight plant^{-1} was recorded from the randomly selected 8 plants plot^{-1} and then calculated the average weight of fruits and expressed in gram.

3.2.9 Individual fruit weight

To get individual fruit weight total weight of fruits plant^{-1} was divided by the number of fruits plant^{-1} and expressed in gram.

3.2.10 Fruit yield

The total fruits weight was recorded from each plot in kg. This weight of fruit was recorded which was the yield of m^{-2} and it was converted to yield in t ha^{-1}.

3.3 Chemical analysis of shoot and fruits

3.3.1 Preparation of sample

Both shoot and fruit samples were cleaned, oven dried at 65°C for about 72 hours. The oven dried shoot and fruit were ground in a grinding machine and fruits are cut into small pieces and then both are preserved in paper bags for chemical analyses.

3.3.2 Digestion of plant samples with nitric acid and perchloric acid

Exactly 1g of finely ground fruits and shoot were taken into a 250 mL conical flask and 15 mL of di-acid mixture (HNO_3: $HClO_4$ = 2:1) was added to it. Then it was placed on an electric hot plate for heating at 180-200°C until the solid particles disappeared and white fumes were evolved from the flask. Then it was cooled at room temperature, washed with distilled water and filtered into 100 mL volumetric flasks through Whatman No. 42 filter paper making the volume up to the mark with distilled water following wet oxidation method as described by Jackson (1973). This digestion was used for determination of P, K and S.

3.3.3 Digestion of plant samples with sulphuric acid

An amount of 1 gm oven dry, ground fruit and shoot sample was taken in a 250 ml conical flask and 0.1 g catalyst mixture (K_2SO_4: $CuSO_4.5H_2O$: Se = 100:10:1), 2 mL 30% H_2O_2 and 15 mL conc. H_2SO_4 were added. The flask was swirled and allowed to stand for about 10 minutes followed by heating at 200°C. Heating was continued until the digest was clear and colorless. After cooling the contents were taken into a 100 ml volumetric flask and the volume was made with distilled water. This digestion was used for N determination exclusively.

3.3.3.1 Determination of total nitrogen

The total nitrogen content of the samples was determined by macro Kjeldhal method as described by Page *et al.* (1989).

3.3.3.2 Determination of phosphorus

Phosphorus in the digest was determined by ascorbic acid blue color method with the help of a spectrophotometer (LKB Novaspec, 4049).

3.3.3.3 Determination of potassium

Potassium content in the digested plant sample was determined by flame photometer.

3.3.3.4 Determination of sulphur

The concentration of sulphur in the extract of shoot and fruit samples were determined turbidimetrically with the help of a spectrophotometer at the wavelength of 420 nm as described by Black (1965)

3.4 Statistical analysis

Data were statistically analyzed by analysis of variance (ANOVA) technique using the MSTAT-C Statistical Computer Package Programmee in accordance with the principles of Randomized Complete Block Design (RCBD). Ducan's Multiple Range Test (DMRT) was used to compare variations among the treatments.

3.5 Regression analysis

To determine optimum rate, a quadratic equation of the following form should first be fitted to the means.

$$Y=a+bx+cx^2$$

The optimum rate of nitrogen can be computed from the equation as Gomez and Gomez (1984):

$$N_y = -b/2c$$

The N-rate that maximizes profit:

$$N_p = 1/2c\ (P_f/O_y - b)$$

Where, P_f= Price of Nitrogen and

O_y= Price of output (eg. Strawberry fruit)

N_y= Optimum rate of nitrogen

N_p= N-rate that maximizes profit

The optimum rate of phosphorus can be computed from the equation as Gomez and Gomez (1984):

$$P_y = -b/2c$$

The P-rate that maximizes profit:

$$P_p = 1/2c\ (P_f/O_y - b)$$

Where, P_f= Price of phosphorus and

O_y= Price of output (eg. Strawberry fruit)

P_y= Optimum rate of phosphorus

P_p= P-rate that maximizes profit

The optimum rate of potassium can be computed from the equation as Gomez and Gomez (1984):

$$K_y = -b/2c$$

The K-rate that maximizes profit:

$$K_p = 1/2c\ (P_f/O_y - b)$$

Where, P_f= Price of potassium and

O_y= Price of output (eg. Strawberry fruit)

K_y= Optimum rate of potassium

K_p= K-rate that maximizes profit

The optimum rate of sulphur can be computed from the equation as Gomez and Gomez (1984):

$$S_y = -b/2c$$

The S-rate that maximizes profit:

$$S_p = 1/2c\ (P_f/O_y - b)$$

Where, P_f= Price of sulphur and

O_y= Price of output (eg. Strawberry fruit)

S_y= Optimum rate of sulphur

S_p= S-rate that maximizes profit

CHAPTER IV

RESULTS AND DISCUSSION

This chapter contains results of the experiment and the follow-up discussion. For convenience, the whole chapter has been divided into two sections:

1. Agronomic characteristics
2. Chemical constituents.

4.1 Effects of different levels of nitrogen, phosphorus, potassium and sulphur on growth and yield of strawberry

4.1.1 Plant height

The plant height was not significantly affected due to the combined effects of nitrogen, phosphorus, potassium and sulphur fertilizers application (Table 4.1). However, the tallest plant (25.60 cm) was achieved at T_3 treatment where nitrogen, phosphorus, potassium and sulphur were applied at the rate of 115, 40, 110, 25 kg ha^{-1}, respectively and the shortest plant (22.53 cm) grew from T_{14} treatment (control) (Table 4.1). Hong *et al.* (2008) reported that optimizing plant nitrogen (N) and phosphorus (P) nutrition is required in healthy propagation of strawberry nursery plants for fruit production of strawberry (*Fragaria ananassa* Duch.)

The result indicates that the height of strawberry plants was not significantly affected due to the single effects of nitrogen, phosphorus, potassium and sulphur fertilizer (Table 4.2a). But the height of plants also increased progressively with added N fertilizer up to 115 kg ha^{-1}. Further increase in fertilizer tended to depress plant height (Table 4.2a). The highest plant height (25.60 cm) was obtained from 115 kg N ha^{-1} and the lowest (23.13 cm) from 0 kg ha^{-1} N dose. The maximum plant height (24.51 cm) was reported by Rana and Chandel (2003) were recorded with 100 kg N ha^{-1}.

Plant height increased with increasing rate of phosphorus up to 40 kg ha^{-1}, after that plant height decreased (Table 4.2b). The highest plant height (25.60 cm) was obtained from 40 kg P ha^{-1} and the lowest (22.93 cm) from 0 kg ha^{-1} P dose.

This result also indicates that the height of strawberry plants increased progressively with the increasing rates of K up to 110 kg ha^{-1} and therefore decreased plant height (Table 4.2c). The highest plant height (25.60 cm) was obtained from 110 kg K ha^{-1} and lowest (22.80 cm) from 0 kg ha^{-1} K dose. Dar *et al.* (2010) reported that the treatment potassium 80 kg ha^{-1} recorded maximum plant height (11.5 cm).

The single effect of sulphur showed that plant height of strawberry progressively increased up to 25 kg ha^{-1} of S application Addition of S increased decreased plant height (Table 4.2d). The highest plant height (25.60 cm) was obtained from 110 kg K ha^{-1} and lowest (22.80 cm) from 0 kg ha^{-1} S dose.

4.1.2 Number of leaves

Due to the combined effects of different levels of fertilizers significant difference was found on leaves number $plant^{-1}$ (Table 4.1). The data shows that T_3 treatment produced the highest leaves number and this is statistically similar with the treatment T_4. The treatment T_{14} produced the lowest leaves $plant^{-1}$. The second highest number of leaves $plant^{-1}$ was found from T_4 treatment where nitrogen, phosphorus, potassium and sulphur doses are 140-40-110-25 kg ha^{-1}, respectively. It was revealed from the results that nitrogen, phosphorus, potassium and sulphur enhanced the number of leaves $plant^{-1}$.

The result (Table 4.2a) indicates that the leaf number of strawberry plants was significantly affected by different levels of N fertilizer. Leaf number $plant^{-1}$ increased with increasing rate of nitrogen up to 115 kg ha^{-1} and then decreased with increasing rate. Data shows that the application of 115 kg N ha^{-1} produced the highest (21.66) and application of no N dose produced the lowest (19.13) leaves number $plant^{-1}$. Dar *et al.* (2010) reported that the treatment nitrogen 100 kg ha^{-1} recorded maximum number of leaves (8.34).

The phosphorus had significant effect on leaf number $plant^{-1}$. Number of leaves $plant^{-1}$ increased with increasing rate of phosphorus up to 40 kg ha^{-1}, after that decreased leaf number $plant^{-1}$ (Table 4.2b). The highest (21.66) leaves number $plant^{-1}$ was obtained from 40 kg P ha^{-1} and lowest (18.80) from 0 kg ha^{-1} P dose.

This result also indicates that the leaf number $plant^{-1}$ was statistically significant with potassium doses (Table 4.2c). Number of leaves $plant^{-1}$ increased with increasing rate of potassium up to 110 kg ha^{-1} and then decreased with increasing rate (Table 4.2c). The highest (21.66) leaves number $plant^{-1}$ was obtained from 110 kg K ha^{-1} and lowest (18.40) from 0 kg ha^{-1} K dose. Dar *et al.* (2010) reported that the treatment potassium 80 kg ha^{-1} recorded maximum number of leaves (8.34).

The single effect of sulphur showed significant differences among leaf number $plant^{-1}$ with different levels of sulphur doses (Table 4.2d). Leaf number of strawberry also increased progressively with added S fertilizer up to 25 kg ha^{-1}. Further increase in S fertilizer tended to depress the leaf number $plant^{-1}$. Data shows that the application of 25 kg S ha^{-1} produced the highest (21.66) and application of 0 kg ha^{-1} S dose produced the lowest (19.26) leaves number.

4.1.3 Number of flowers

Different combinations of nitrogen, phosphorus, potassium and sulphur brought about significant ($p<0.05$) variation in regard to number of flowers $plant^{-1}$ (Table 4.1). The highest (125.33) number of flowers $plant^{-1}$ found from T_3 which is statistically similar with the treatment T_4. The lowest number of flowers plant^{-1} (109.33) found from control treatments and was statistically similar to T_8 and T_5 treatments (Table 4.1).

Number of flowers plant^{-1} had significant difference with different levels of nitrogen fertilizer application (Table 4.2a). Number of flowers plant^{-1} increased with increasing level of nitrogen up to the level of 115 kg ha^{-1} and after that increasing level of nitrogen application number of flowers plant^{-1} decreased (Table 4.2a). Data shows that the application of 115 kg N ha^{-1} produced the highest (125.33) number of flowers plant^{-1} and the application of no N dose produced the lowest (114.33) number of flowers plant^{-1}. Yoshida (1992) reported that 100 kg N ha^{-1} increased the number of flowers on first inflorescens.

The single effect of different levels phosphorus showed significant differences among the number of flowers plant^{-1}. Flowers number of strawberry increased progressively with added P fertilizer up to 40 kg ha^{-1}. Further increase in P fertilizer tended to depress the number of flowers plant^{-1} (Table 4.2b). The highest (125.33) number of flowers plant^{-1} found when P was applied at 40 kg ha^{-1} and the lowest number of flowers plant^{-1} (113.66) found when P was applied at 0 kg ha^{-1} dose. Ali Y. *et al.* (2003) reported that combined application of 150 kg N ha^{-1}, 100 kg P ha^{-1} and 20 t FYM ha^{-1} resulted in the maximum number of flowers plant^{-1} (14.63).

This result also indicates that the significant variation on number of flowers of strawberry plant^{-1} under different levels of potassium (Table 4.2c). Number of flowers increased with increasing rate of potassium up to 110 kg ha^{-1} and then increasing rate decreased number of flowers plant^{-1} (Table 4.2c). The highest (125.33) number of flowers plant^{-1} found when K was applied at 110 kg ha^{-1} and the lowest number of flowers plant^{-1} (113.00) found when no K was applied. Rauf *et al.* (1998) showed that 4 g of NPK plant^{-1} gave maximum number of flowers (29) plant^{-1}.

Table 4.1 Effects of different fertilizer treatments on plant height, leaves plant^{-1} and flowers plant^{-1} of strawberry

Treatments N-P-K-S kg ha^{-1}	Plant height (cm)	Leaves plant^{-1} (no.)	Flowers plant^{-1} (no.)
T_1 (0-40-110-25)	23.13	19.13gh	114.33e-g
T_2 (90-40-110-25)	24.93	20.86c	122.60b
T_3 (115-40-110-25)	25.60	21.66a	125.33a
T_4 (140-40-110-25)	25.06	21.46ab	124.00ab
T_5 (115-0-110-25)	22.93	18.80gh	113.66gh
T_6 (115-20-110-25)	24.06	19.40d-f	115.66c-e
T_7 (115-60-110-25)	24.13	20.33c-e	119.00bc
T_8 (115-40- 0- 25)	22.80	18.40gh	113.00gh
T_9 (115-40-85-25)	23.86	19.33d-e	115.06c-e
T_{10} (115-40-135-25)	24.53	20.80cd	122.00b
T_{11} (115-40-110-0)	23.33	19.26e-g	114.66e-g
T_{12} (115-40-110-15)	24.46	20.66cd	120.00bc
T_{13} (115-40-110-35)	24.10	20.00c-e	117.00bd
T_{14} (0 – 0 – 0 – 0)	22.53	15.53h	109.33h
Significant level	NS	*	*
LSD $_{0.05}$	-	0.80	2.35
CV (%)	4.16	7.53	7.67

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

NS → Non significant

* → 5% level of significance

Table 4.2 Single effect of N, P, K and S on plant height, leaves number plant^{-1} and flowers number plant^{-1} of strawberry plant

a) Effect of nitrogen on plant height, leaves number plant^{-1} and flowers number plant^{-1}

Nutrient levels (N kg ha^{-1})	Plant height (cm)	Leaves plant^{-1} (no.)	Flowers plant^{-1} (no.)
0	23.13	19.13d	114.33d
90	24.93	20.86c	122.60c
115	25.60	21.66a	125.33a
140	25.06	21.46ab	124.0ab
Significant level	NS	*	*
LSD $_{0.05}$	-	0.80	2.35
CV (%)	4.16	7.53	7.67

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

NS → Non significant

* → 5% level of significance

b) Effect of phosphorus on plant height, leaves number plant^{-1} and flowers number plant^{-1}

Nutrient levels (P kg ha^{-1})	Plant height (cm)	Leaves plant^{-1} (no.)	Flowers plant^{-1} (no.)
0	22.93	18.80d	113.66d
20	24.06	19.40c	115.66c
40	25.60	21.66a	125.33a
60	24.13	20.33b	119.00b
Significant level	NS	*	*
LSD $_{0.05}$	-	0.80	2.35
CV (%)	4.16	7.53	7.67

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

NS→ Non significant

* → 5% level of significance

c) Effect of potassium on plant height, leaves number $plant^{-1}$ and flowers number $plant^{-1}$

Nutrient levels ($K\ kg\ ha^{-1}$)	Plant height (cm)	Leaves $plant^{-1}$ (no.)	Flowers $plant^{-1}$ (no.)
0	22.80	18.40d	113.00d
85	23.86	19.33c	115.06c
110	25.60	21.66a	125.33a
135	24.53	20.80b	122.00b
Significant level	NS	*	*
$LSD_{0.05}$	-	0.80	2.35
CV (%)	4.16	7.53	7.67

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

NS → Non significant

* → 5% level of significance

d) Effect of sulphur on plant height, leaves number $plant^{-1}$ and flowers number $plant^{-1}$

Nutrient levels ($S\ kg\ ha^{-1}$)	Plant height (cm)	Leaves $plant^{-1}$ (no.)	Flowers $plant^{-1}$ (no.)
0	23.33	19.26c	114.66d
15	24.46	20.66b	120.00b
25	25.60	21.66a	125.33a
35	24.10	20.00bc	117.00c
Significant level	NS	*	*
$LSD_{0.05}$	-	0.80	2.35
CV (%)	4.16	7.53	7.67

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

NS → Non significant

* → 5% level of significance

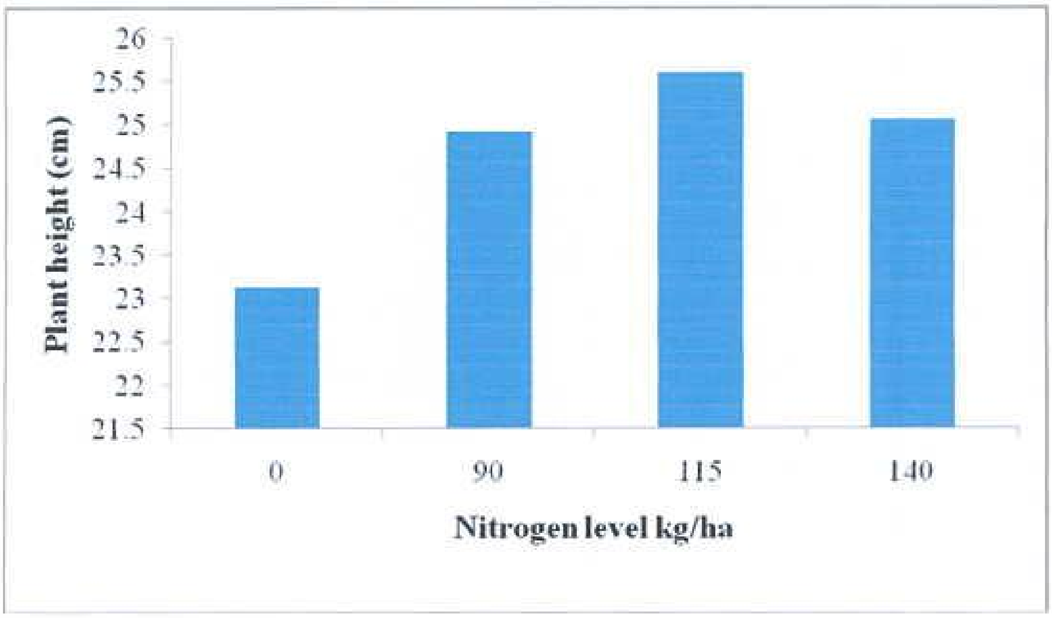


Figure 4.1 Effect of different nitrogen levels on plant height of strawberry plant

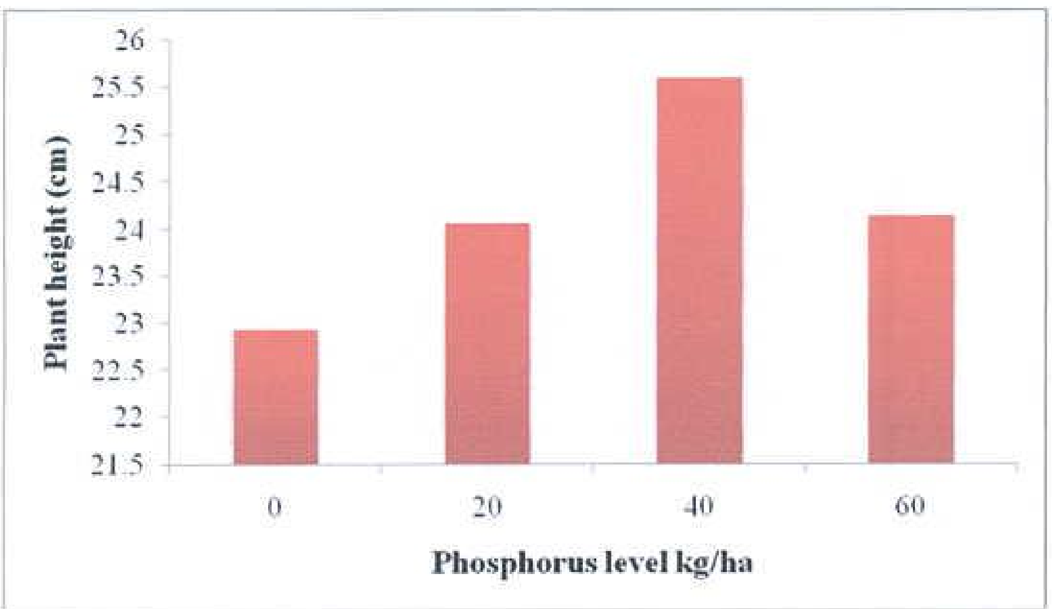


Figure 4.2 Effect of different Phosphorus levels on plant height of strawberry plant

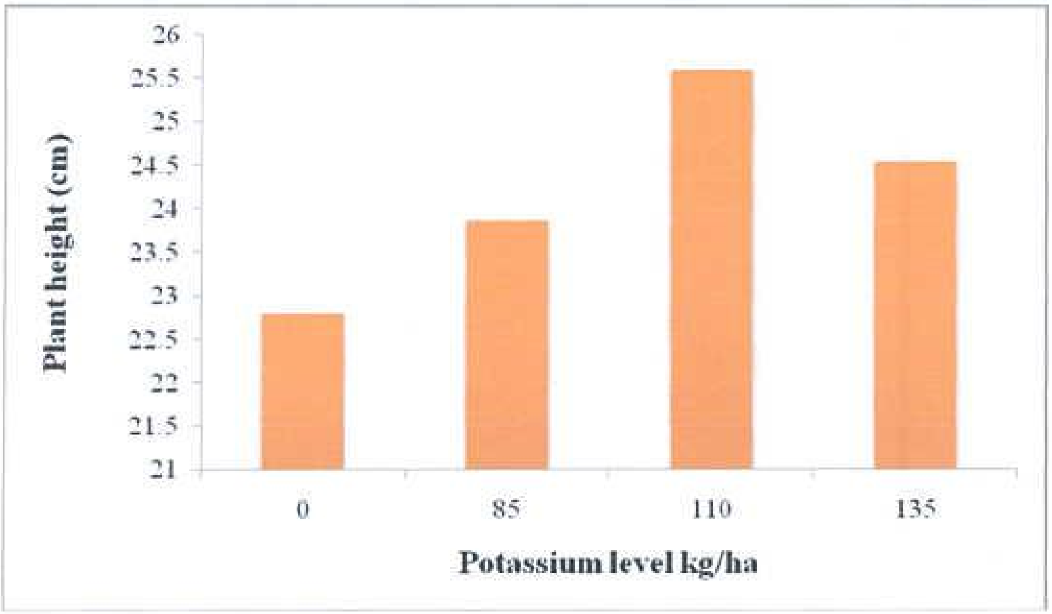


Figure 4.3 Effect of different potassium levels on plant height of strawberry plant

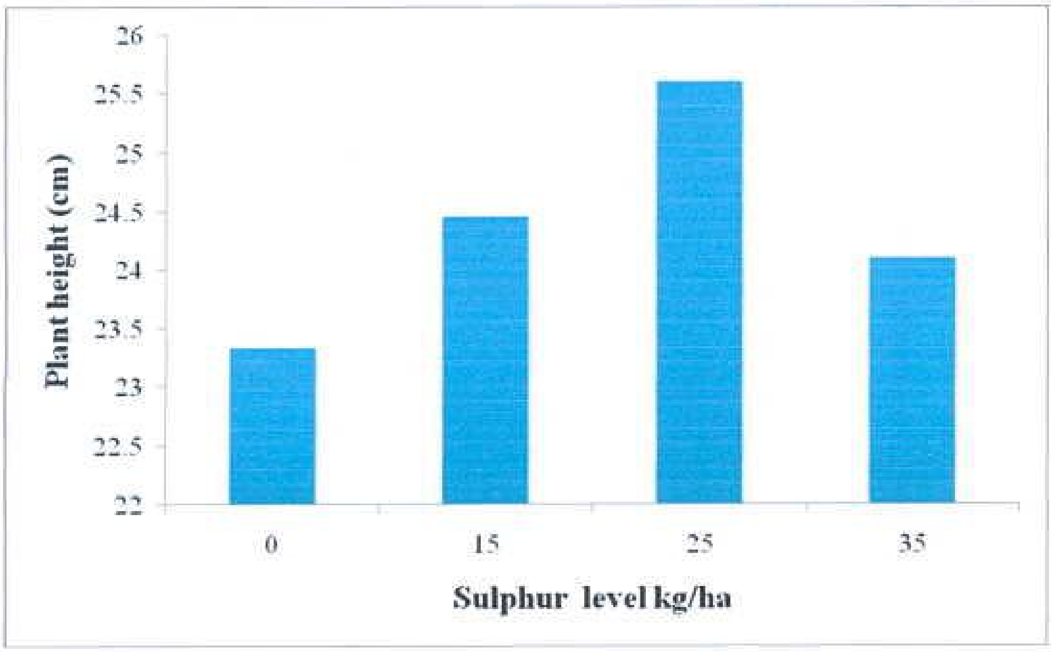


Figure 4.4 Effect of different sulphur levels on plant height of strawberry plant

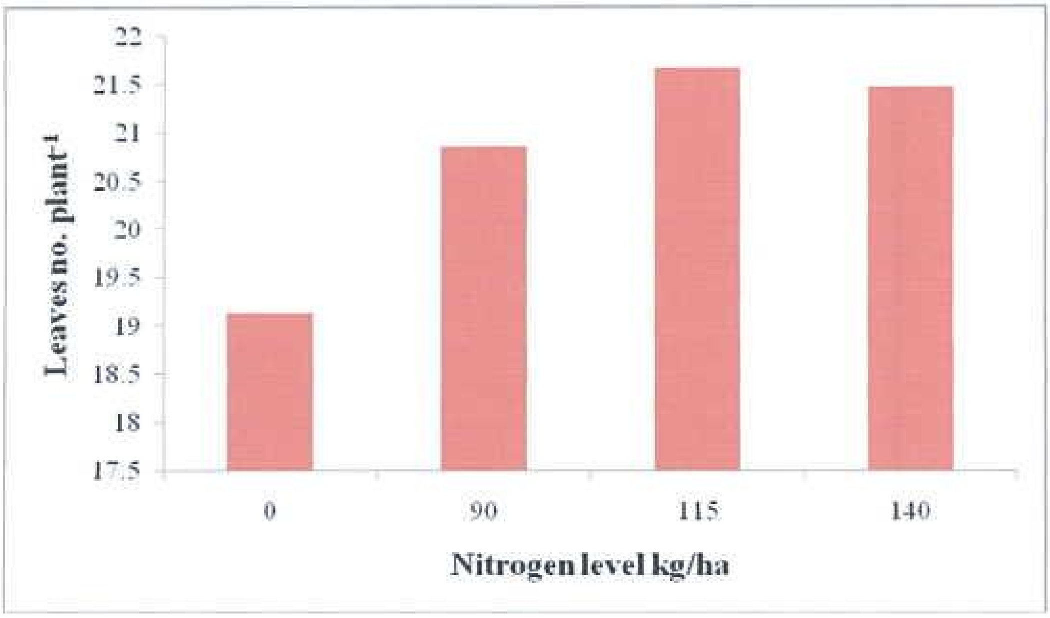


Figure 4.5 Effect of different nitrogen levels on leaves no. plant^{-1} of strawberry

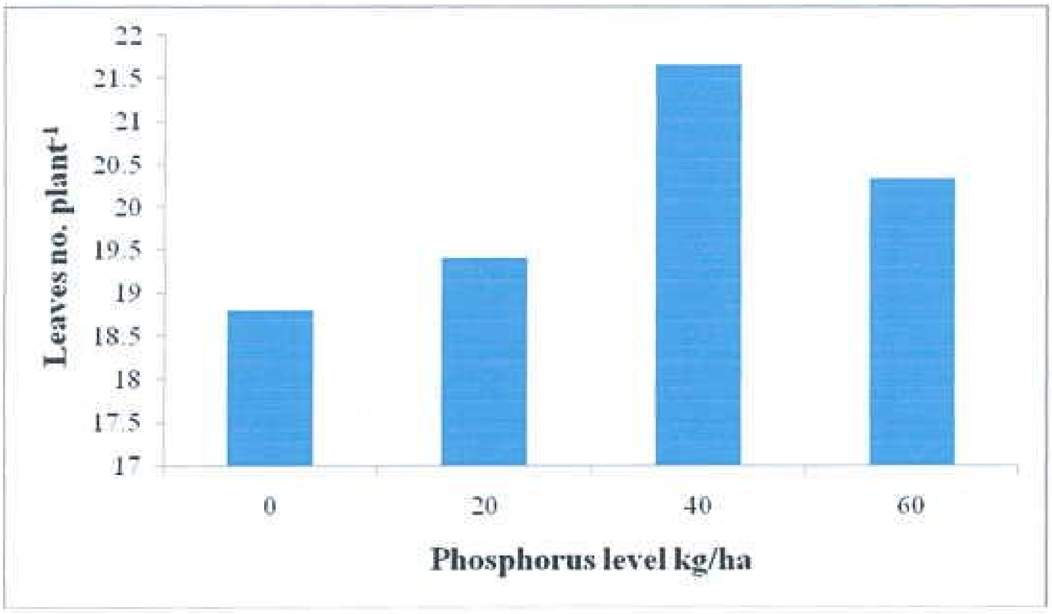


Figure 4.6 Effect of different phosphorus levels on leaves no. plant^{-1} of strawberry

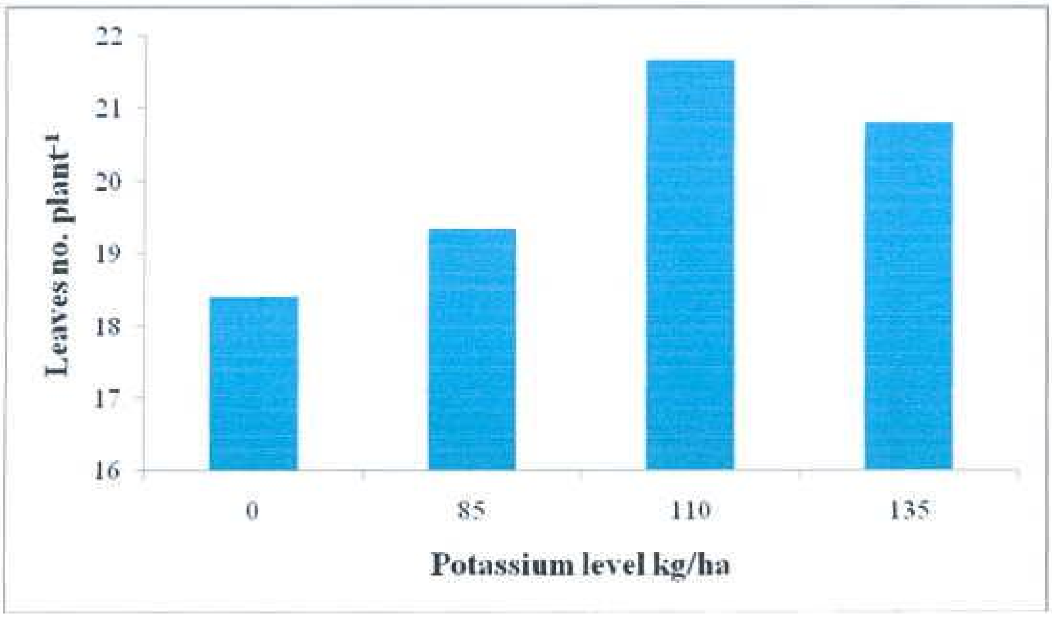


Figure 4.7 Effect of different potassium levels on leaves no. plant^{-1} of strawberry

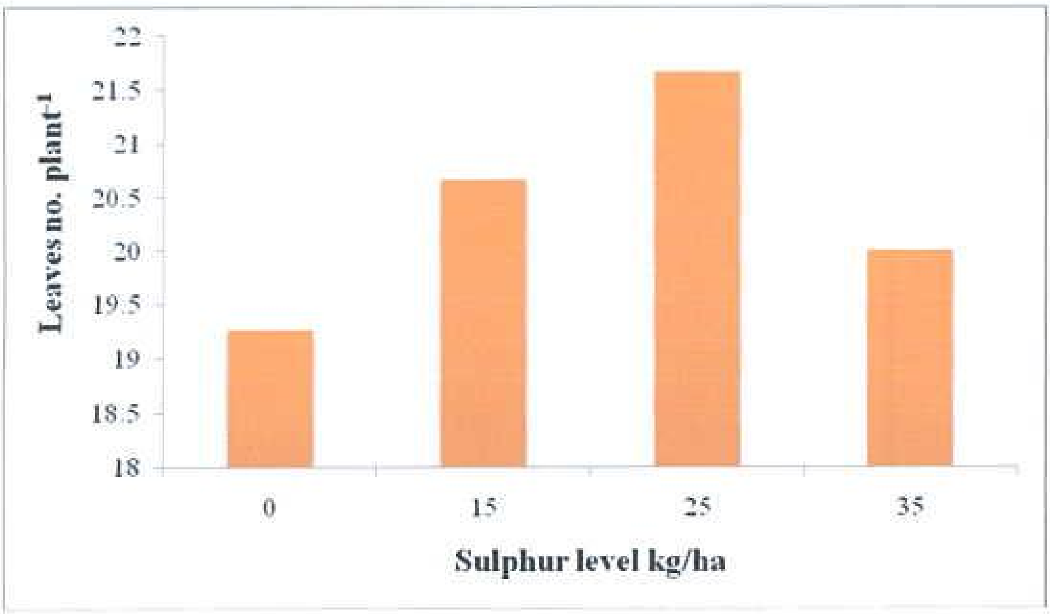


Figure 4.8 Effect of different sulphur levels on leaves no. plant^{-1} of strawberry

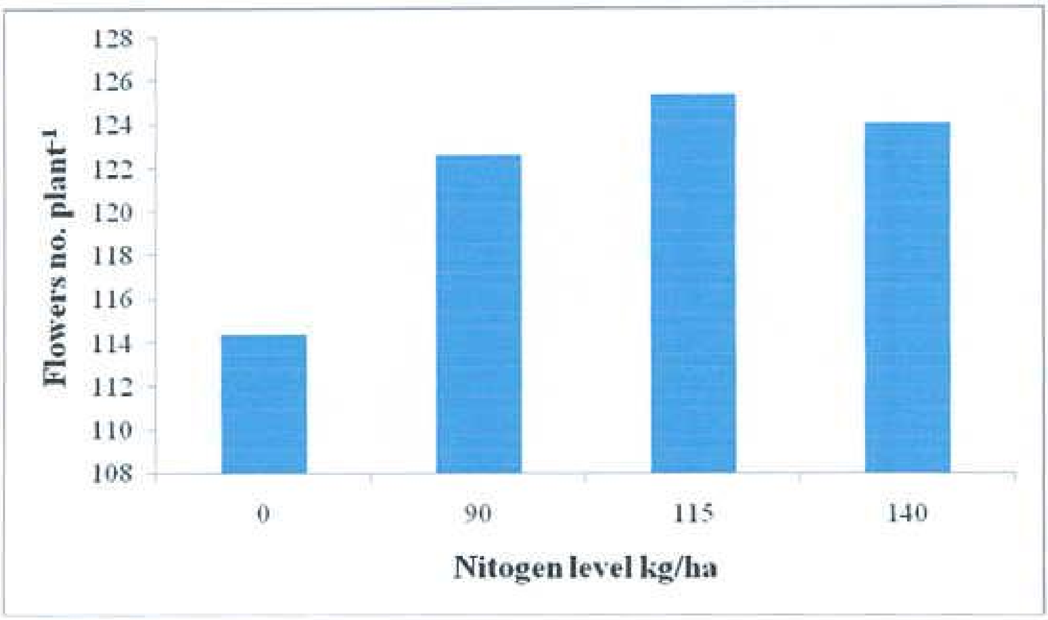


Figure 4.9 Effect of different nitrogen levels flowers no. plant^{-1} of strawberry

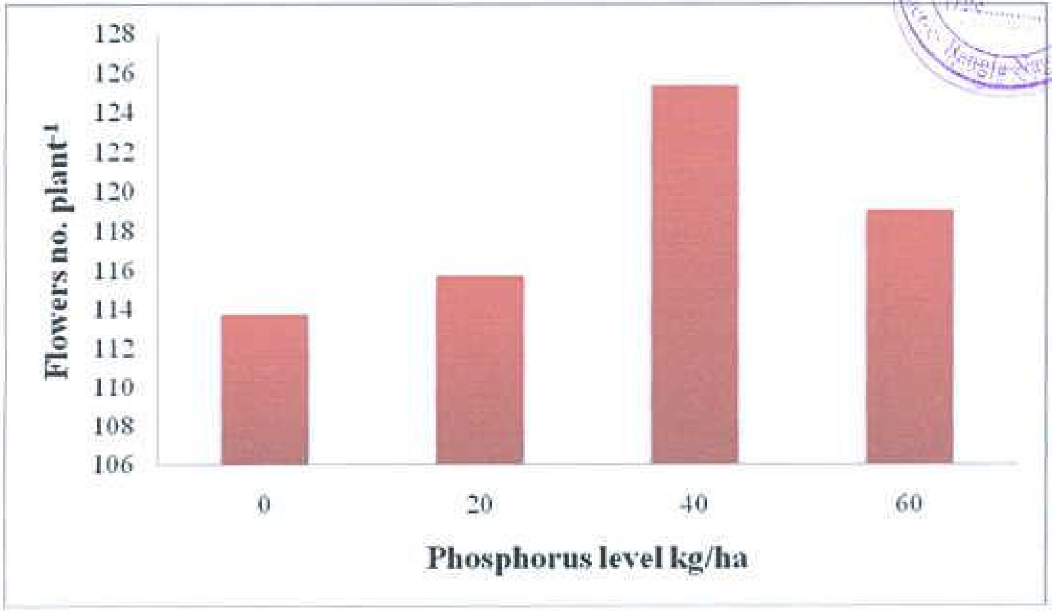


Figure 4.10 Effect of different phosphorus levels on flowers no. plant^{-1} of strawberry

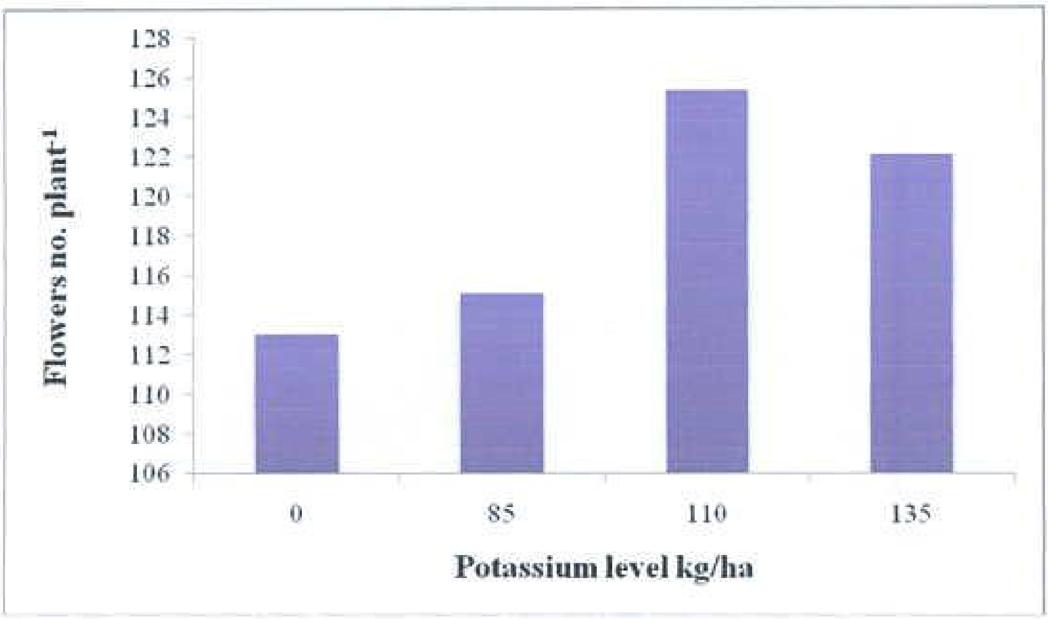


Figure 4.11 Effect of different potassium levels on flowers no. plant^{-1} of strawberry

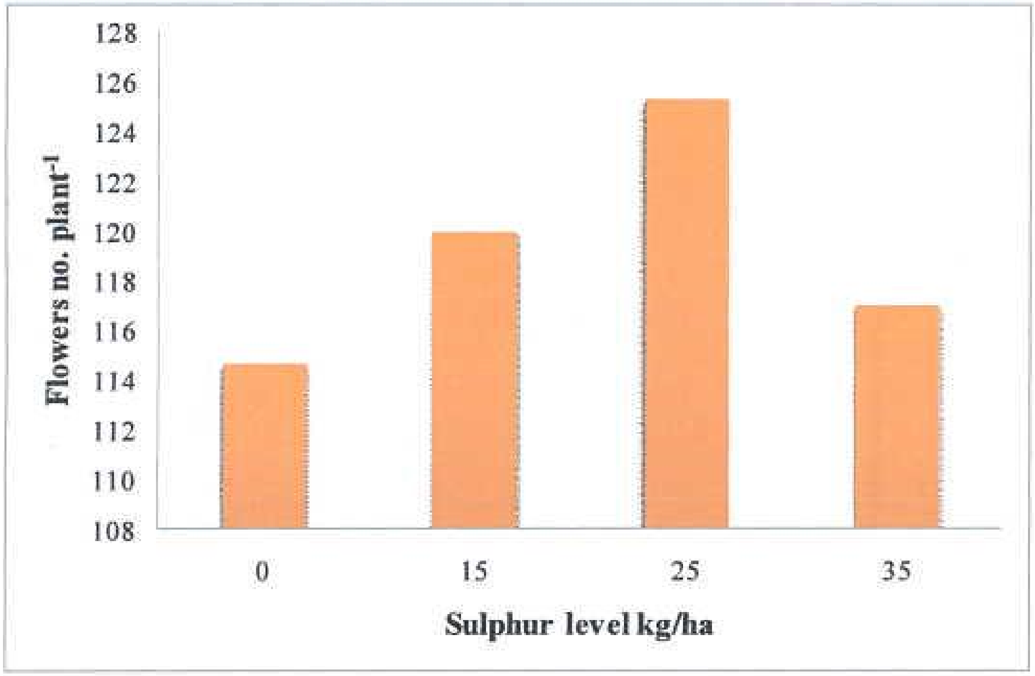


Figure 4.12 Effect of different sulphur levels on flowers no. plant^{-1} of strawberry

The single effect of different levels of sulphur showed significant differences among the number of flowers $plant^{-1}$ (Table 4.2d). Number of flowers $plant^{-1}$ of strawberry at first increased with increasing rate of sulphur up to 25 kg ha^{-1}, after that number of flowers $plant^{-1}$ decreased with increasing rate of sulphur (Table 4.2d). The highest (125.33) number of flowers $plant^{-1}$ found when S was applied at 25 kg ha^{-1} and the lowest number of flowers $plant^{-1}$ (114.66) found when no S was applied.

4.1.4 Number of fruits

Table 4.3 shows that the number of fruits $plant^{-1}$ significantly ($p<0.05$) varied due to the combined effects of nitrogen, phosphorus, potassium and sulphur. The highest number of fruits $plant^{-1}$ (12.35) found when the crop was fertilized with 115, 40, 110, 25 kg NPKS ha^{-1} respectively (T_3 treatment) which was statistically similar with the treatment T_4, T_{10} and T_{12} and the lowest (7.15) found in T_{14} (control). It is revealed from the results that nitrogen, phosphorus, potassium and sulphur enhanced the number of fruits $plant^{-1}$.

This result indicates that the significant variation on number of fruits strawberry $plant^{-1}$ under different levels of nitrogen (Table 4.4 a). Fruit number of strawberry $plant^{-1}$ increased with increasing level of nitrogen application up to115 kg N ha^{-1} and then decreased number of fruits $plant^{-1}$. Data shows that the application of 115 kg N ha^{-1} produced the highest (12.35) number of fruits $plant^{-1}$ and application of 0 kg ha^{-1} N dose produced the lowest (8.15) number of fruits $plant^{-1}$. Gariglio *et al.* (2000) reported the same result. They showed that increasing level of nitrogen application increased in fruit number but not in fruit weight.

The single effect of phosphorus showed that the number of fruits $plant^{-1}$ significantly ($p<0.05$) varied due to application of phosphorus. Fruit number $plant^{-1}$ of strawberry also increased progressively with added P fertilizer up to 40 kg ha^{-1}. Further increase in P fertilizer tended to depress the number of fruits plant^{-1} (Table 4.4 b). Ali *et al.* (2003) reported that combined application of 150 kg N ha^{-1}, 100 kg P ha^{-1} and 20 t FYM ha^{-1} resulted in the maximum number of fruits retained plant^{-1} (6.40).

This result also indicates that the fruit number plant^{-1} significantly ($p<0.05$) varied due to application of different levels of potassium. Fruit number plant^{-1} increased with increasing rate of potassium up to 110 kg ha^{-1}, after that the leaf number plant^{-1} decreased with increasing rate of potassium (Table 4.4c). Rauf *et al.* (1998) showed that 4 g of NPK plant^{-1} gave maximum number of fruits plant^{-1} (13.25).

The single effect of sulphur showed that the significant variation on number of fruits plant^{-1} under different levels of sulphur. Fruit number plant^{-1} increased with increasing rate of sulphur up to 25 kg ha^{-1}, after that decreased fruit number plant^{-1} (Table 4.4d). Data shows that the application of 25 kg S ha^{-1} produced the highest (12.35) number of fruits plant^{-1} and application of no S fertilizer produced the lowest (9.05) number of fruits plant^{-1} (Table 4.4d).

4.1.5 Fruit length

There was a significant ($p<0.05$) variation on fruit length (cm) due to the combined effects of nitrogen, phosphorus, potassium and sulphur fertilizers application (Table 4.3). The highest fruit length (4.16 cm) was found with T_3 which was statistically similar with the treatment T_2, T_4, T_6, T_7, T_9, T_{10}, T_{11}, T_{12} and T_{13} and the lowest (3.15 cm) from T_{14} treatment.

There was a significant ($p<0.05$) effect of nitrogen on fruit length (Table 4.4 a). The effect of nitrogen showed that fruit length of strawberry increased with increasing rate of nitrogen up to 115 kg ha^{-1}, after that increasing rate decreased fruit length (Table 4.4a). The highest (4.16 cm) fruit length found when N was applied at 115 kg ha^{-1} and the lowest fruit length (3.24 cm) found when no N fertilizer was applied. Dar *et al.* (2010) showed the same result. They showed that the treatment nitrogen 100 kg ha^{-1} recorded maximum fruit length (1.40 cm).

The single effect of phosphorus showed significant ($p<0.05$) effect on fruit length of strawberry (Table 4.4b). Length of fruits increased with increasing rate of phosphorus up to 40 kg ha^{-1} and then decreased fruit length with increasing rate of phosphorus (Table 4.4b). The highest (4.16 cm) fruit length found when P was applied at 40 kg ha^{-1} and the lowest fruit length (3.26 cm) found when no P fertilizer was applied.

This result also indicates that the fruit length of strawberry significantly ($p<0.05$) varied due to application of different levels of potassium (Table 4.4c). Fruit length increased with increasing rate of potassium up to 110 kg ha^{-1}, after that decreased fruit length (Table 4.4c). The highest (4.16 cm) fruit length found when K was applied at 110 kg ha^{-1} and the lowest fruit length (3.35 cm) found when no K fertilizer was applied. Dar *et al.* (2010) showed that the treatment potassium 80 kg ha^{-1} recorded maximum fruit length (1.40 cm).

The single effect of sulphur showed significant variation on the fruit length of strawberry (Table 4.4d). Fruit length of strawberry Fruit yield increased progressively with the increasing rates of S up to 25 kg ha^{-1} and therefore decreased (Table 4.4d). The highest (4.16 cm) fruit length found when S was applied at 110 kg ha^{-1} and the lowest fruit length (3.35 cm) found when no S fertilizer was applied.

4.1.6 Fruit diameter

Fruit diameter varied significantly due to combined effects of nitrogen, phosphorus, potassium and sulphur fertilizers application (Table 4.3). T_3 treatment produced the highest fruit diameter (3.41 cm) and the lowest (2.16 cm) was obtained from T_{14} treatment (control). T_2, T_4, T_7, T_{10}, T_{12} and T_{13} treatments were statistically similar with T_3 treatment where got higher fruit diameter. It is revealed from the results that nitrogen, phosphorus, potassium and sulphur enhanced the fruit diameter.

The present study indicates significant variation due to application of different levels of nitrogen on fruit diameter (Table 4.4a). Fruit diameter increased with increasing rate of nitrogen up to 115 kg ha^{-1}, after that increasing rate decreased fruit diameter (Table 4.4a). Data shows that the application of 115 kg N ha^{-1} produced the highest (3.41 cm) fruit diameter and application of no N fertilizer produced the lowest (2.35 cm) fruit diameter. Gaur and Gangwar (2003) reported that N at 150 kg ha^{-1} gave the highest fruit width.

The single effect of different levels of phosphorus showed significant variation on the fruit diameter $plant^{-1}$ (Table 4.4b). Fruit diameter increased with increasing rate of phosphorus up to 40 kg ha^{-1} and then decreased fruit diameter with increasing rate (Table 4.4 b). Data shows that the application of 40 kg P ha^{-1} produced the highest (3.4 cm) fruit diameter and application of no P fertilizer produced the lowest (2.48 cm) fruit diameter.

The result also indicates that the fruit diameter of strawberry significantly ($p<0.05$) varied due to application of different levels of potassium (Table 4.4c). Fruit diameter increased with increasing level of potassium doses up to 110 kg ha^{-1}, after that increasing rate decreased fruit diameter (Table 4.4c). Data shows that the application of 110 kg K ha^{-1} produced the highest (3.41 cm) fruit diameter and application of no K fertilizer produced the lowest (2.55 cm) fruit diameter.

Table 4.3 Effects of different fertilizer treatments on fruits no. plant^{-1}, fruit length and fruit diameter of strawberry

Treatments N-P-K-S Kg ha^{-1}	Fruits plant^{-1} (no.)	Fruit length (cm)	Fruit diameter (cm)
T_1 (0-40-110-25)	8.15g	3.24cd	2.35gh
T_2 (90-40-110-25)	11.55b	3.97a-c	3.25ab
T_3 (115-40-110-25)	12.35a	4.16a	3.41a
T_4 (140-40-110-25)	11.85ab	4.08ab	3.29ab
T_5 (115-0-110-25)	8.45f-h	3.26cd	2.48f-h
T_6 (115-20-110-25)	9.95c-e	3.48a-d	2.88b-f
T_7 (115-60-110-25)	10.65b-d	3.65a-d	3.08a-d
T_8 (115-40- 0- 25)	9.05e-g	3.35b-d	2.55e-h
T_9 (115-40-85-25)	9.65d-f	3.45a-d	2.75c-g
T_{10} (115-40-135-25)	11.25a-c	3.90a-d	3.18a-c
T_{11} (115-40-110-0)	9.35d-g	3.41a-d	2.68d-g
T_{12} (115-40-110-15)	11.05a-c	3.78a-d	3.12a-d
T_{13} (115-40-110-35)	10.35c-e	3.56a-d	2.95a-e
T_{14} (0 – 0 – 0 – 0)	7.15h	3.15d	2.16h
Significant level	*	*	*
$LSD_{0.05}$	1.017	0.17	0.22
CV (%)	6.42	8.85	7.25

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

* → 5% level of significance

Table 4.4 Single effect of N, P, K and S fertilizers on fruits no. plant^{-1}, fruit length and fruit diameter of strawberry

a) Effects of nitrogen fruits no. plant^{-1}, fruit length and fruit diameter

Nutrient levels (N kg ha^{-1})	Fruits plant^{-1} (no.)	Fruit length (cm)	Fruit diameter (cm)
0	8.15c	3.24c	2.35c
90	11.55b	3.97bc	3.25b
115	12.35a	4.16a	3.41a
140	11.85ab	4.08ab	3.29ab
Significant level	*	*	*
LSD $_{0.05}$	1.017	0.17	0.22
CV (%)	6.42	8.85	7.25

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

* → 5% level of significance

b) Effects of phosphorus fruits no. plant^{-1}, fruit length and fruit diameter

Nutrient levels (P kg ha^{-1})	Fruits plant^{-1} (no.)	Fruit length (cm)	Fruit diameter (cm)
0	8.45d	3.26c	2.48d
20	9.95c	3.48bc	2.88c
40	12.35a	4.16a	3.41a
60	10.65b	3.65b	3.08b
Significant level	*	*	*
LSD $_{0.05}$	1.017	0.17	0.22
CV (%)	6.42	8.85	7.25

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

* → 5% level of significance

c)Effects of potassium fruits no. plant^{-1}, fruit length and fruit diameter

Nutrient levels (K kg ha^{-1})	Fruits plant^{-1} (no.)	Fruit length (cm)	Fruit diameter (cm)
0	9.05d	3.35cd	2.55d
85	9.65c	3.45c	2.75c
110	12.35a	4.16a	3.41a
135	11.25b	3.90b	3.18b
Significant level	*	*	*
$LSD_{0.05}$	1.017	0.17	0.22
CV (%)	6.42	8.85	7.25

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

* → 5% level of significance

d) Effects of sulphur fruits no. plant^{-1}, fruit length and fruit diameter

Nutrient levels (S kg ha^{-1})	Fruits plant^{-1} (no.)	Fruit length (cm)	Fruit diameter (cm)
0	9.35d	3.41d	2.68d
15	11.05b	3.78b	3.12b
25	12.35a	4.16a	3.41a
35	10.35c	3.56c	2.95c
Significant level	*	*	*
$LSD_{0.05}$	1.017	0.17	0.22
CV (%)	6.42	8.85	7.25

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

* → 5% level of significance

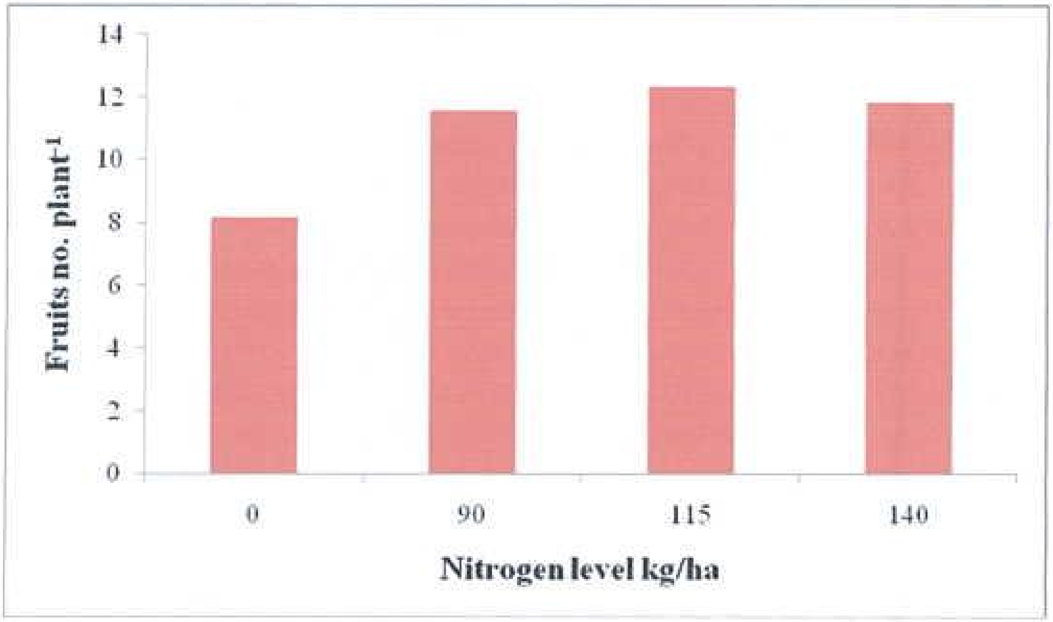


Figure 4.13 Effect of different nitrogen levels on fruits no. plant^{-1} of strawberry

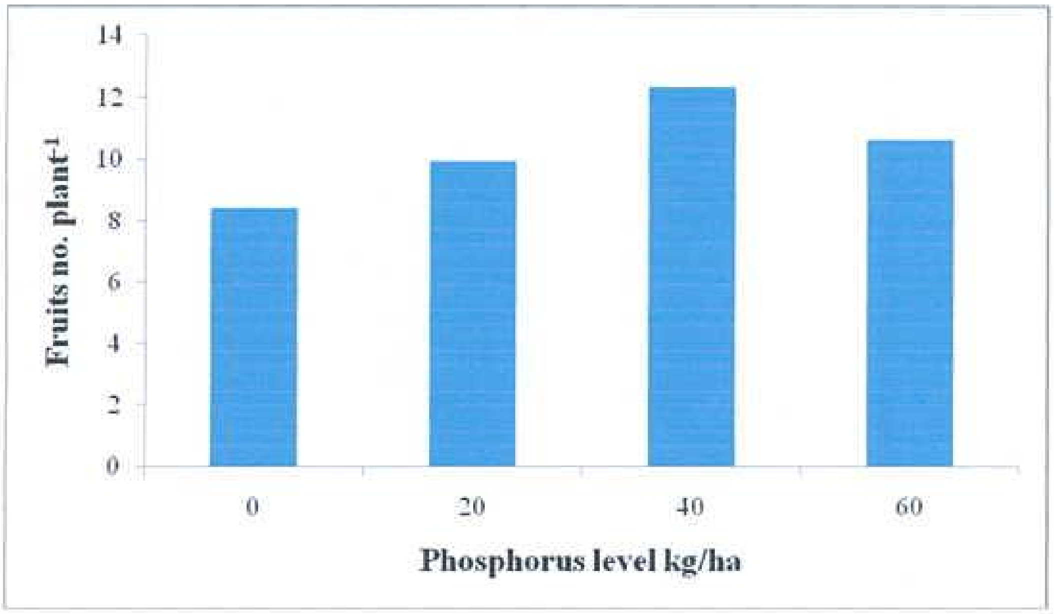


Figure 4.14 Effect of different phosphorus levels on fruits no. plant^{-1} of strawberry

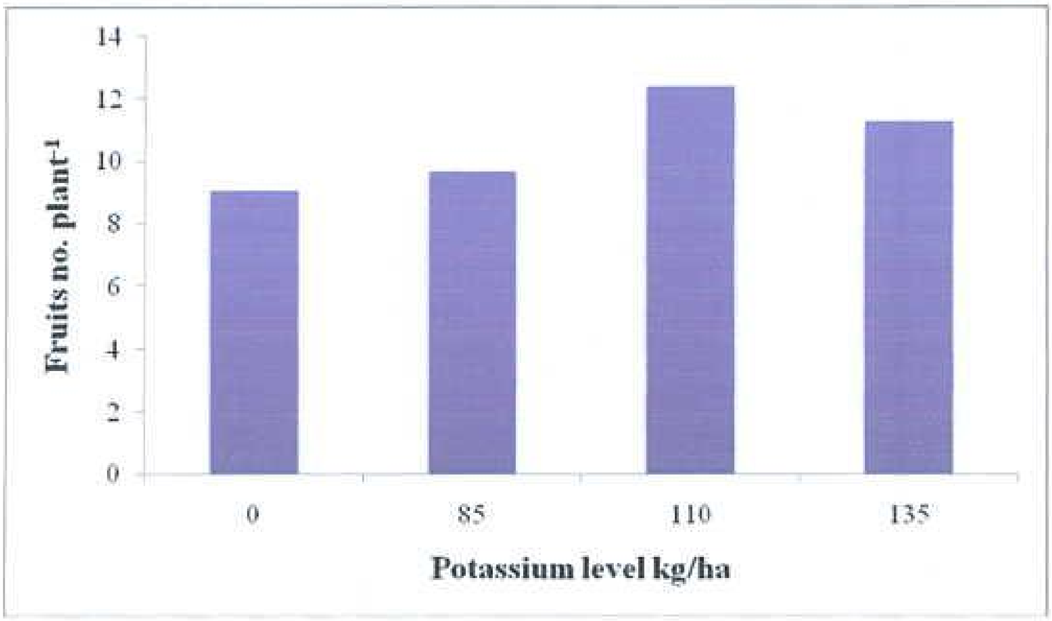


Figure 4.15 Effect of different potassium levels on fruits no. plant^{-1} of strawberry

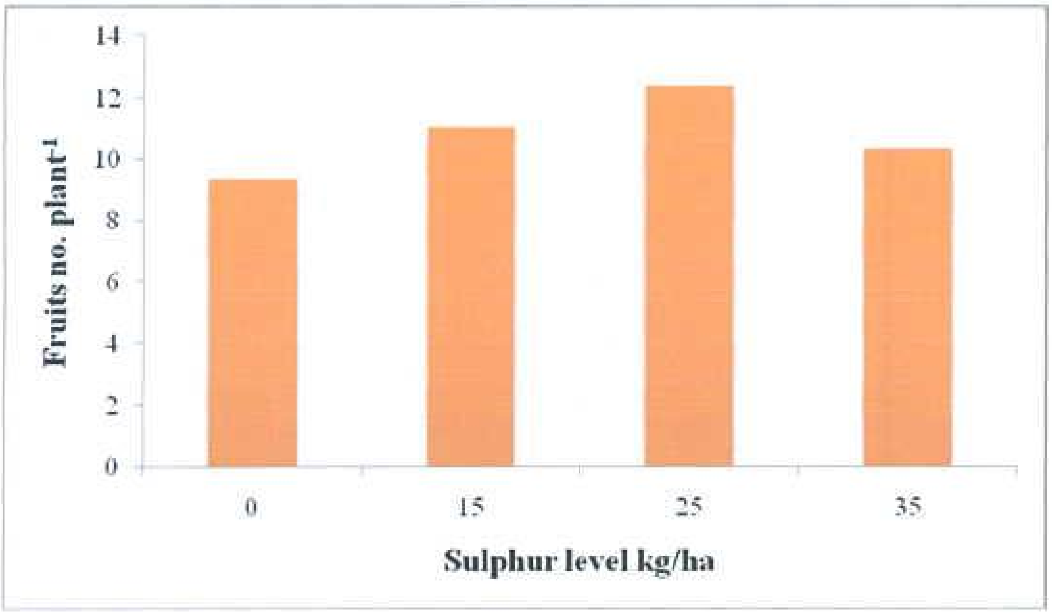


Figure 4.16 Effect of different sulphur levels on fruits no. plant^{-1} of strawberry

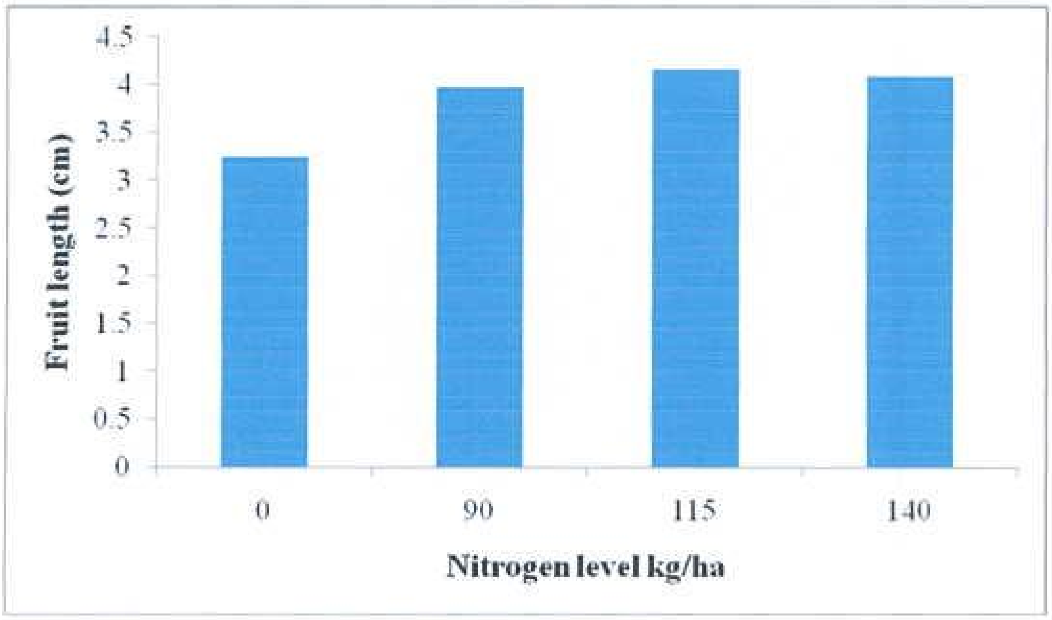


Figure 4.17 Effect of different nitrogen levels on fruit length of strawberry

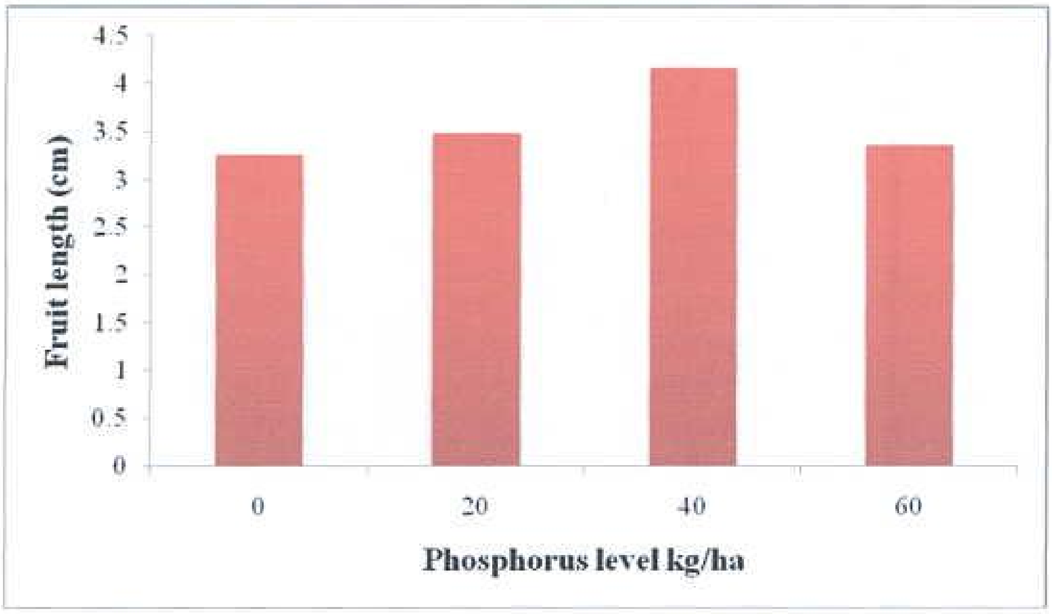


Figure 4.18 Effect of different phosphorus levels on fruit length of strawberry

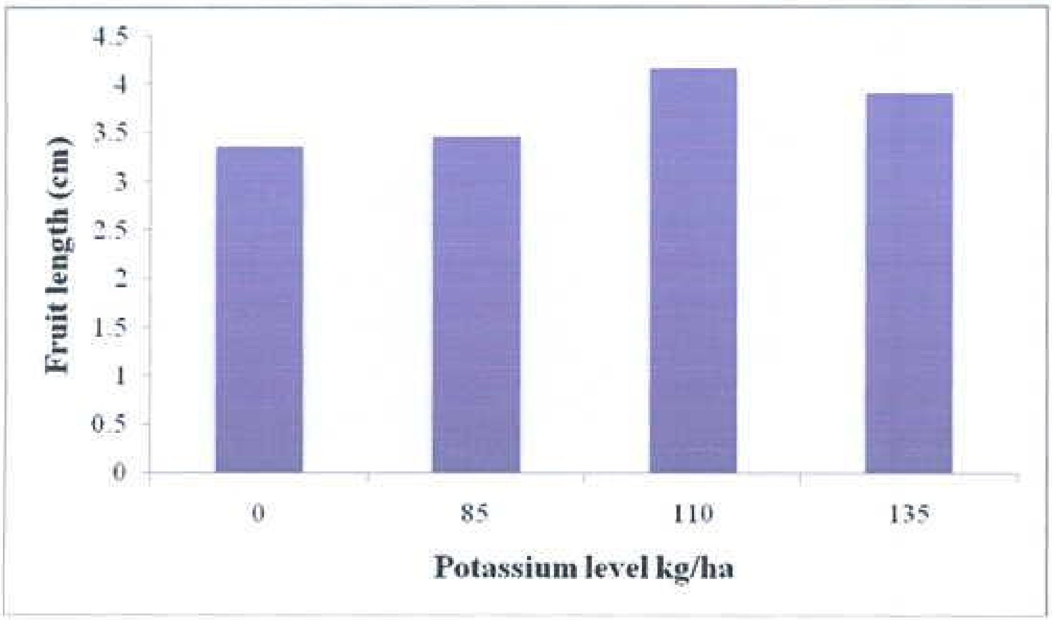


Figure 4.19 Effect of different potassium levels on fruit length of strawberry

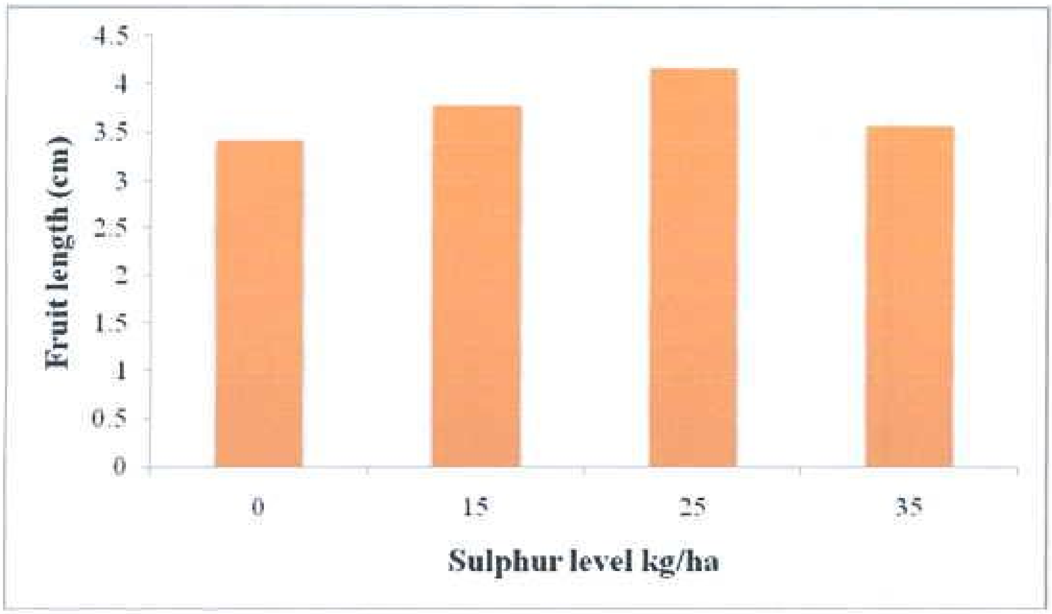


Figure 4.20 Effect of different sulphur levels on fruit length of strawberry

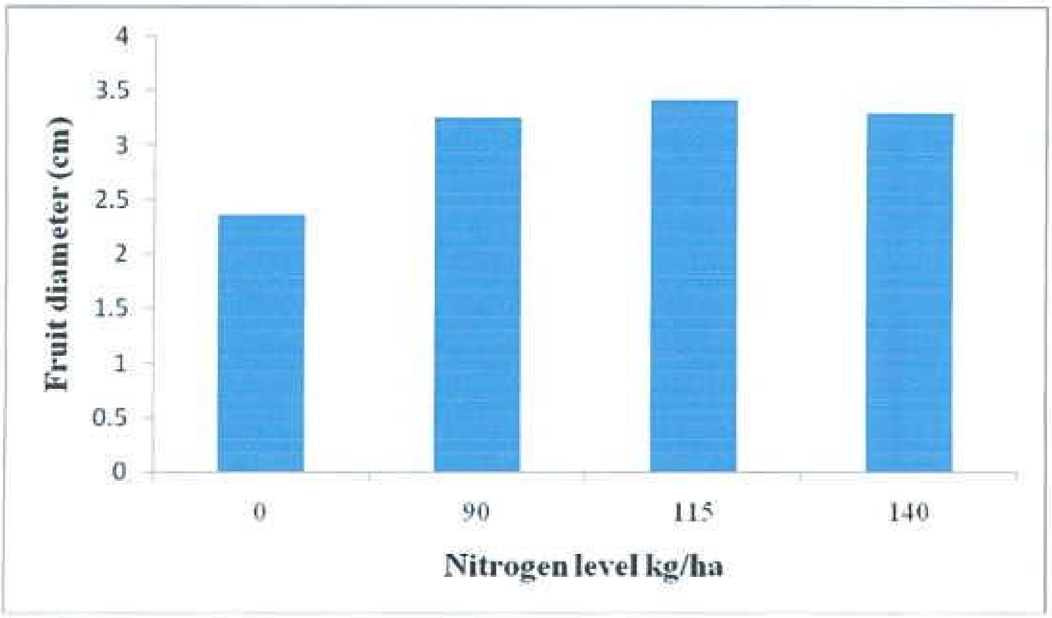


Figure 4.21 Effect of different nitrogen levels on fruit diameter of strawberry

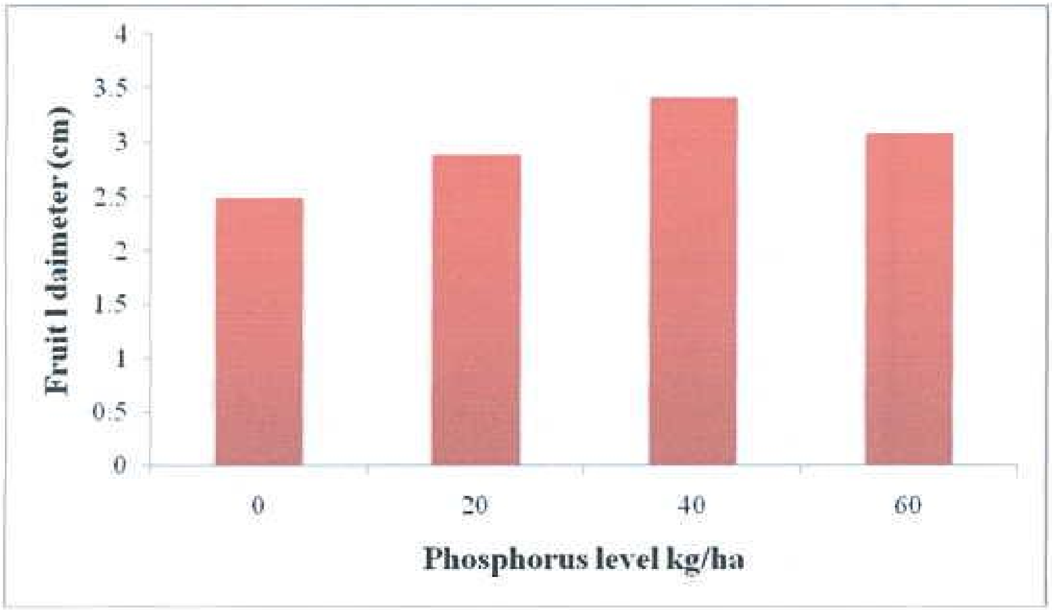


Figure 4.22 Effect of different phosphorus levels on fruit diameter of strawberry

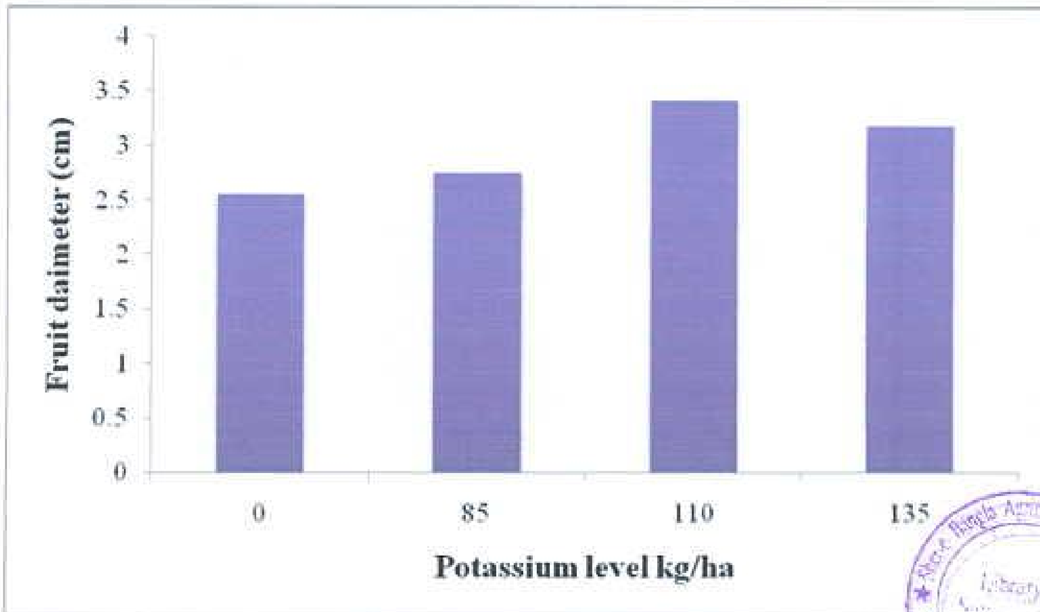


Figure 4.23 Effect of different potassium levels on fruit diameter of strawberry

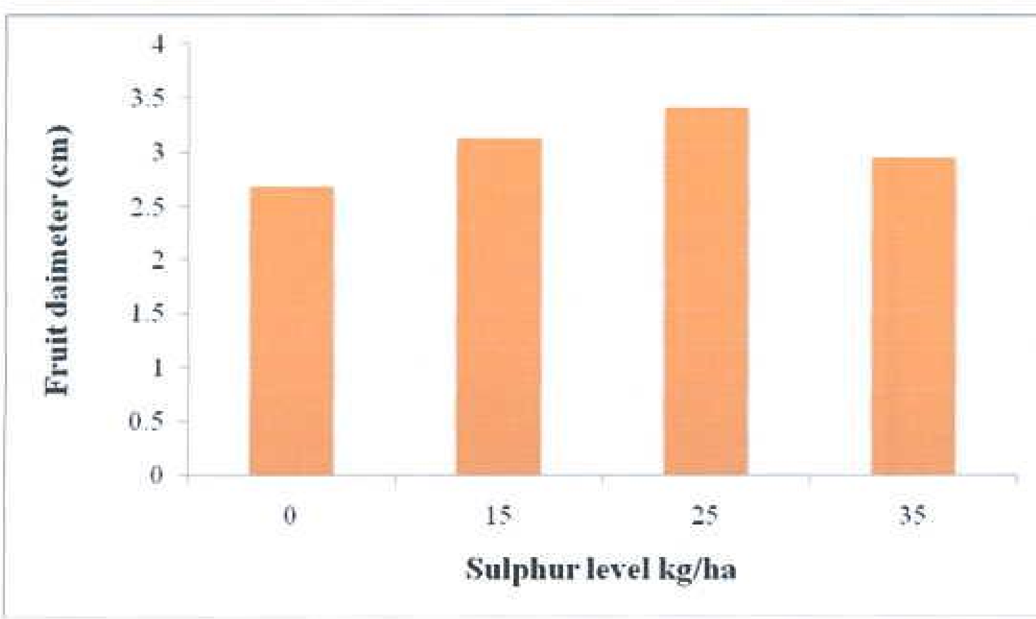


Figure 4.24 Effect of different sulphur levels on fruit diameter of strawberry

Study shows significant variation due to the application of different levels of sulphur on fruit diameter (Table 4.4d). Fruit diameter increased with increasing level of sulphur doses up to 25 kg S ha^{-1} and therefore decreased (Table 4.4d). The highest (3.41 cm) fruit diameter found when S was applied at 25 kg ha^{-1} and the lowest fruit diameter (2.68 cm) was found at no S reftilizer application.

4.1.7 Number of damaged fruits

Number of damaged fruits $plant^{-1}$ of BARI Strawberry 1 varied significantly ($p<0.05$) due to the combined effects of nitrogen, phosphorus, potassium and sulphur (Table 4.5). The highest number of damaged fruits $plant^{-1}$ (11) achieved when nitrogen, phosphorus, potassium and sulphur was applied at the rate of 115, 40, 110, 25 kg ha^{-1} respectively (T_3 treatment) and statistically similar to those given by T_2 (10.33), T_4 (10.66), and T_{10} (10.30) treatments. The lowest (6) was achieved at T_{14} (control) treatment.

Number of damaged fruits $plant^{-1}$ of BARI Strawberry 1 varied significantly ($p<0.05$) by the application of different levels of nitrogen (Table 4.6a).The present study indicates that destroyed fruit number $plant^{-1}$ increased with increasing level of nitrogen but up to 115 kg ha^{-1}, after that decreased number of destroyed fruits $plant^{-1}$ (Table 4.6a). The highest (11.00) number of destroyed fruit $plant^{-1}$ found when N was applied at 115 kg ha^{-1} and the lowest number of destroyed fruit $plant^{-1}$ (9.32) found when no N fertilizer was applied.

Data indicates that damaged fruit number $plant^{-1}$ varied significantly ($p<0.05$) by the application of different levels of phosphorus (Table 4.6b). Only 40 kg P ha^{-1} gave the highest (11) number of damaged fruits $plant^{-1}$. Less than or more than that linearly gave lower damaged fruits (Table 4.6b). The lowest number of damaged fruits $plant^{-1}$ (9.00) found when no P fertilizer was applied and the highest (11.00) number of damaged fruits $plant^{-1}$ found when P was applied at 40 kg ha^{-1}.

The effect of different levels of potassium showed significant variation on the number of damaged fruits plant^{-1} (Table 4.6c). There was an increasing trend in the number of damaged fruits plant^{-1} with the increased dose of potassium up to 110 kg ha^{-1} after that decreased number of damaged fruit plant^{-1}. The highest (11.00) number of damaged fruit plant^{-1} found when K was applied at 110 kg ha^{-1} and the lowest number of damaged fruit plant^{-1} (8.00) found when no K fertilizer was applied.

Data shows that the application of sulphur had a significant variation at 5% level of probability regarding the number of damaged fruits plant^{-1} (Table 4.6d). Number of damaged fruits also increased with S doses (25 kg S ha^{-1}). Less than or more than that linearly gave lower destroyed fruits. The highest (11.00) number of damaged fruits plant^{-1} found when S was applied at 25 kg ha^{-1} and the lowest number of damaged fruits plant^{-1} (9.33) found when no S fertilizer was applied.

4.1.8 Individual fruit weight

Table 4.5 showed a significant ($p<0.05$) variation in individual fruit weight (g) by the combined application of nitrogen, phosphorus, potassium and Sulphur fertilizers. The highest fruit weight (17.85 g) was found in T_3 treatment and was statistically similar to those given by T_2, T_4, T_7, T_{10}, T_{12} and T_{13} treatments. The lowest (11.10 g) individual fruit weigh was recorded from T_{14} (control) treatment.

The single effect of different levels of nitrogen showed significant variation on the individual fruit weight (Table 4.6a). Individual fruit weight linearly increased with increasing level of nitrogen doses up to 115 kg ha^{-1} and after that the increasing dose of nitrogen gave lower individual fruit weight (Table 4.6a). No nitrogen application gave lower individual fruit weigh (12.80 g) and the highest (17.85 g) individual fruit weight found when N was applied at 115 kg ha^{-1}. Gaur and Gangwar (2003) reported that N at 150 kg ha^{-1} gave the highest average fruit weight.

Individual fruit weight was significantly ($p<0.05$) affected by application of different levels of phosphorus (Table 4.6b). There was an increasing trend in the individual fruit weight with the increasing dose of phosphorus. Individual fruit weight linearly increased with increasing level of phosphorus doses up to 40 kg ha^{-1} and after that the increasing dose of nitrogen gave lower individual fruit weight (Table 4.6b). The highest (17.85 g) individual fruit weight found when P was applied at 40 kg ha^{-1} and the lowest (13.20 g) was found when no P fertilizer was applied. Suckkee *et al.* (2002) reported that the maximum fresh weight production seems to be possible when phosphorus concentration in soil solution was around 90 mg L^{-1} in hydroponic strawberry culture.

Table 4.6c showed a significant ($p<0.05$) variation in individual fruit weight (g) by the application of different levels of potassium. There was an increasing trend in the individual fruit weight with the increasing dose of potassium. Individual fruit weight linearly increased with increasing level of K doses up to 110 kg ha^{-1} and after that gave lower individual fruit weight (Table 4.6c). The highest (17.85 g) individual fruit weight found when K was applied at 40 kg ha^{-1} and the lowest (13.75 g) was found when no K fertilizer was applied.

The single effect of different levels of sulphur showed significant variation on the individual fruit weight (Table 4.6d).There was an increasing trend in the individual fruit weight with the increasing dose of sulphur. Individual fruit weight linearly increased with increasing level of S doses up to 25 kg ha^{-1}.and after that the increasing dose of nitrogen gave lower individual fruit weight (Table 4.6d). The highest (17.85 g) individual fruit weight found when S was applied at 25 kg ha^{-1} and the lowest (14.35 g) was found when no S fertilizer was applied.

4.1.9 Fruit weight plant^{-1}

Fruit weight plant^{-1} (g) was significantly ($p<0.05$) affected due to the combined application of nitrogen, phosphorus, potassium and sulphur fertilizers (Table 4.5). The highest (215.10 g) fruit weight was found when the crop received 115, 40, 110 and 25 kg NPKS ha^{-1} respectively (T_3 treatment) and is statistically similar to those given by T_2 (199.65 g), T_4 (205.95 g), T_7 (180.95 g), T_{10} (195.80 g) and T_{12} (1585.75 g) treatments. The lowest (125.35 g) fruit weight was found when no additional nitrogen, phosphorus, potassium and sulphur (T_{14} treatment) was applied.

The single effect of different levels of nitrogen showed significant variation on the of fruit weight plant^{-1} (Table 4.6a). Fruit weight plant^{-1} linearly increased with increasing level of nitrogen doses up to 115 kg ha$^{-1,}$ then more than that rate decreased fruit weight plant^{-1} (Table 4.6a). The highest (215.10 g) fruit weight plant^{-1} found when N was applied at 115 kg ha^{-1} and the lowest (142.65 g) fruit weight plant^{-1} found when no N fertilizer was applied. Yoshida (1992) reported fruit malformation occurred more severely than in plants without nitrogen application and the increase in ratio of small fruits (<20 g) resulted in reduced yield.

Fruit weight plant^{-1} (g) was significantly ($p<0.05$) affected due to the single effect of phosphorus application (Table 4.6b). There was an increasing trend in the fruit weight plant^{-1} with the increasing dose of phosphorus up to 40 kg ha^{-1} after that increasing rate decreased fruit weight plant^{-1} (Table 4.6b). The highest (215.10 g) fruit weight plant^{-1} found when P was applied at 40 kg ha^{-1} and the lowest (145.45 g) fruit weight plant^{-1} found when no P fertilizer was applied. Ali *et al.* (2003) reported that combined application of 150 kg N ha^{-1}, 100 kg P ha^{-1} and 20 t FYM ha^{-1} resulted in the highest number fruit weight plant^{-1}.

The single effect of different levels of potassium showed significant variation on the of fruit weight plant^{-1} (Table 4.6c). The data indicates that only 110 kg

K ha^{-1} gave the highest (215.10 g) weight of fruit $plant^{-1}$ and less than or more than that gave lower fruit weight which were significantly ($p<0.05$) affected due to the application of different levels of potassium (Table 4.6c). The lowest (152.45 g) fruit weight $plant^{-1}$ found when no K fertilizer was applied.

The single effect of different levels of sulphur showed significant variation on the of fruit weight $plant^{-1}$ (Table 4.6d). Study shows that fruit weight $plant^{-1}$ increased with the increasing dose of sulphur up to 25 kg ha^{-1}.and after that the increasing dose of sulphur gave lower fruit weight $plant^{-1}$. 25 kg S ha^{-1} gave the highest (215.10 g) weight of fruit $plant^{-1}$. Less than or more than that gave lower fruit weight $plant^{-1}$. The lowest (155.65 g) fruit weight $plant^{-1}$ found when no S fertilizer was applied.

4.1.10 Fruit yield

Fruit yield per hectare was significantly ($p<0.05$) influenced due to the combined effects of nitrogen, phosphorus, potassium and sulphur fertilizers application (Table 4.5). The highest (11.50 t ha^{-1}) fruit yield was found when the crop received 115, 40, 110 and 25 kg NPKS ha^{-1} respectively (T_3 treatment) which was statistically similar with T_2 (11.10 t ha^{-1}), T_4 (11.50 t ha^{-1}), T_7 (10.15 t ha^{-1}), T_{10} (10.95 t ha^{-1}), T_{12} (10.68 t ha^{-1}) and T_{13} (10.70 t ha^{-1}) treatments. The lowest (8.20 t ha^{-1}) fruit yield was found when no nitrogen, phosphorus, potassium and sulphur (T_{14}) fertilizers were applied.

Fruit yield was significantly ($p<0.05$) affected by the application of different levels of nitrogen fertilizer (Table 4.7 a). Fruit yield increased progressively with the increasing rates of N up to 115 kg ha^{-1} and therefore decreased. (Table 4.7a). The highest (11.50 t ha^{-1}) fruit yield found when N was applied at 115 kg ha^{-1} and the lowest (8.95 t ha^{-1}) fruit yield found when no N fertilizer was applied. Gariglio *et al.* (2000) were conducted an experiment where they showed that yield increased to increasing N rates from 0 to 53 kg ha^{-1}. However, the yield difference between the highest and the lowest yielding treatment was 28% (Table 4.7a). Gutal *et al.* (2005) reported that yield increase (15.6%) can be achieved by using 75 kg ha^{-1} nitrogen.

The single effect of different levels of phosphorus showed significant variation on the fruit yield (Table 4.7b). Fruit yield of strawberry also increased progressively with added P fertilizer up to 40 kg ha^{-1}. Further increase in P fertilizer tended to decrease. The yield difference between the highest and the lowest treatment was 26% (Table 4.7b). The highest (11.50 t ha^{-1}) fruit yield found when P was applied at 40 kg ha^{-1} and the lowest (9.15 t ha^{-1}) fruit yield found when no P fertilizer was applied. Ali *et al.* (2003) reported that combined application of 150 kg N ha^{-1}, 100 kg P ha^{-1} and 20 t FYM ha^{-1} resulted in the highest yield (7 t ha^{-1}).

Fruit yield was significantly ($p<0.05$) affected by application of different levels of potassium fertilizer (Table 4.7c). Progressively increase in fruit yield up to 110 kg ha^{-1} of K application. Addition of potassium increased fruit yield 5, 23 and 17% by 85, 110 and 135 kg K ha^{-1} respectively, over the K-control. The highest (11.50 t ha^{-1}) fruit yield found when K was applied at 110 kg ha^{-1} and the lowest (9.38 t ha^{-1}) fruit yield found when no K fertilizer was applied. Dar *et al.* (2010) showed the same result. They showed that the treatment potassium 80 kg ha^{-1} recorded highest yield $plant^{-1}$ (367.60 g).

Fruit yield was significantly ($p<0.05$) affected by application of different levels of sulphur fertilizer (Table 4.7d). Study shows that fruit yield increased with the increasing dose of sulphur up to 25 kg ha^{-1} and more or less than that the fruit yield decreased. The highest (11.50 t ha^{-1}) fruit yield found when S was applied at 25 kg ha^{-1} and the lowest (9.62 t ha^{-1}) fruit yield found when no S fertilizer was applied. Sulphur increased fruit yield significantly up to 25 kg ha^{-1}. The highest increase in fruit yield over S-control due to S application was 20% over without sulphur fertilizer (Table 4.7 d).

Table 4.5 Effects of different fertilizer treatments on damaged fruits plant^{-1}, individual fruit weight, fruit weight plant^{-1} and yield of strawberry

Treatments N-P-K-S Kg ha^{-1}	Damaged fruits plant^{-1} (no.)	Individual fruit wt. (g)	Fruit wt. plant^{-1}(g)	Yield (t ha^{-1})
T_1 (0-40-110-25)	9.32d-e	12.80gh	142.65gh	8.95ef
T_2 (90-40-110-25)	10.33a-c	16.80a-c	199.65a-c	11.10ab
T_3 (115-40-110-25)	11.00a	17.85a	215.10a	11.50a
T_4 (140-40-110-25)	10.66ab	17.40ab	205.95ab	11.32ab
T_5 (115-0-110-25)	9.00e-g	13.20f-h	145.45f-h	9.15d-f
T_6 (115-20-110-25)	9.63b-d	15.20b-f	165.35c-g	10.15a-e
T_7 (115-60-110-25)	9.66b-d	15.90a-e	180.95a-f	10.48a-e
T_8 (115-40- 0- 25)	8.00h	13.75e-g	152.45f-h	9.38d-f
T_9 (115-40-85-25)	9.60b-d	14.85c-g	160.35d-h	9.90b-e
T_{10} (115-40-135-25)	10.30a-c	16.40a-d	195.80a-d	10.95a-c
T_{11} (115-40-110-0)	9.33d-f	14.35d-g	155.65e-h	9.62c-f
T_{12} (115-40-110-15)	10.00b-d	16.10a-d	185.75a-e	10.68a-d
T_{13} (115-40-110-35)	9.61b-d	15.55a-e	175.30b-g	10.70a-e
T_{14} (0 – 0 – 0 – 0)	6.00i	11.10h	125.35h	8.20f
Significant level	*	*	*	*
$LSD_{0.05}$	1.01	1.69	25.24	1.012
CV (%)	8.44	7.9	8.45	9.95

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

* → 5% level of significance

Table 4.6 Single effect of N, P, K and S on damaged fruits plant^{-1}, individual fruit weight, fruit weight plant^{-1} of strawberry

a) Effects of nitrogen on damaged fruits plant^{-1}, individual fruit weight and fruit weight plant^{-1}

Nutrient levels (N kg ha^{-1})	Damaged fruits plant^{-1} (no.)	Fruit wt. plant^{-1} (g)	Individual fruit wt. (g)
0	9.32c	142.65c	12.80c
90	10.33bc	199.65b	16.80b
115	11.00a	215.10a	17.85a
140	10.66b	205.95ab	17.40ab
Significant level	*	*	*
LSD $_{0.05}$	1.01	25.24	1.69
CV (%)	8.44	8.45	7.9

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

* → 5% level of significance

b) Effects of phosphorus on damaged fruits plant^{-1}, individual fruit weight and fruit weight plant^{-1}

Nutrient levels (P kg ha^{-1})	Damaged fruits plant^{-1} (no.)	Fruit wt. plant^{-1} (g)	Individual fruit wt. (g)
0	9.00c	145.45d	13.20d
20	9.63bc	165.35c	15.20c
40	11.00a	215.10a	17.85a
60	9.66b	180.95b	15.90b
Significant level	*	*	*
LSD $_{0.05}$	1.01	25.24	1.69
CV (%)	8.44	8.45	7.9

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

* → 5% level of significance

c) Effect of potassium on damaged fruits plant^{-1}, individual fruit weight and fruit weight plant^{-1}

Nutrient levels (K kg ha^{-1})	Damaged fruits plant^{-1} (no.)	Fruit wt. plant^{-1} (g)	Individual fruit wt. (g)
0	8.00d	152.45d	13.75d
85	9.60c	160.35c	14.85c
110	11.00a	215.10a	17.85a
135	10.30b	195.80b	16.40b
Significant level	*	*	*
$LSD_{0.05}$	1.01	25.24	1.69
CV (%)	8.44	8.45	7.9

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

* → 5% level of significance

d) Effect of sulphur on damaged fruits plant^{-1}, individual fruit weight and fruit weight plant^{-1}

Nutrient levels (S kg ha^{-1})	Damaged fruits plant^{-1} (no.)	Fruit wt. plant^{-1} (g)	Individual fruit wt. (g)
0	9.33c	155.65d	14.35d
15	10.00ab	185.75b	16.10b
25	11.00a	215.10a	17.85a
35	9.61b	175.30c	15.55c
Significant level	*	*	*
$LSD_{0.05}$	1.01	25.24	1.69
CV (%)	8.44	8.45	7.9

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

* → 5% level of significance

Table 4.7 Single effect of N, P, K and S on yield of strawberry

a) Effect of nitrogen on yield of strawberry

Nutrient levels ($N\ kg\ ha^{-1}$)	Fruit yield ($t\ ha^{-1}$)	% Yield increase over control
0	8.95c	-
90	11.10b	24
115	11.50a	28
140	11.32ab	26
Significant level	*	-
$LSD_{0.05}$	1.012	-
CV%	9.95	-

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

* → 5% level of significance

b) Effect of phosphorus on yield of strawberry

Nutrient levels ($P\ kg\ ha^{-1}$)	Fruit yield ($t\ ha^{-1}$)	% Yield increase over control
0	9.15d	-
20	10.15c	11
40	11.50a	26
60	10.48b	15
Significant level	*	-
$LSD_{0.05}$	1.012	-
CV%	9.95	-

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

* → 5% level of significance

c) Effect of potassium on yield of strawberry

Nutrient levels (K kg ha^{-1})	Fruit yield (t ha^{-1})	% Yield increase over control
0	9.38d	-
85	9.90c	5
110	11.50a	23
135	10.95b	17
Significant level	*	-
$LSD_{0.05}$	1.012	-
CV%	9.95	-

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

* → 5% level of significance

d) Effect of sulphur on yield of strawberry

Nutrient levels (S kg ha^{-1})	Fruit yield (t ha^{-1})	% Yield increase over control
0	9.62c	-
15	10.70b	10
25	11.50a	20
35	10.68c	11
Significant level	*	-
$LSD_{0.05}$	1.012	-
CV%	9.95	-

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

* → 5% level of significance

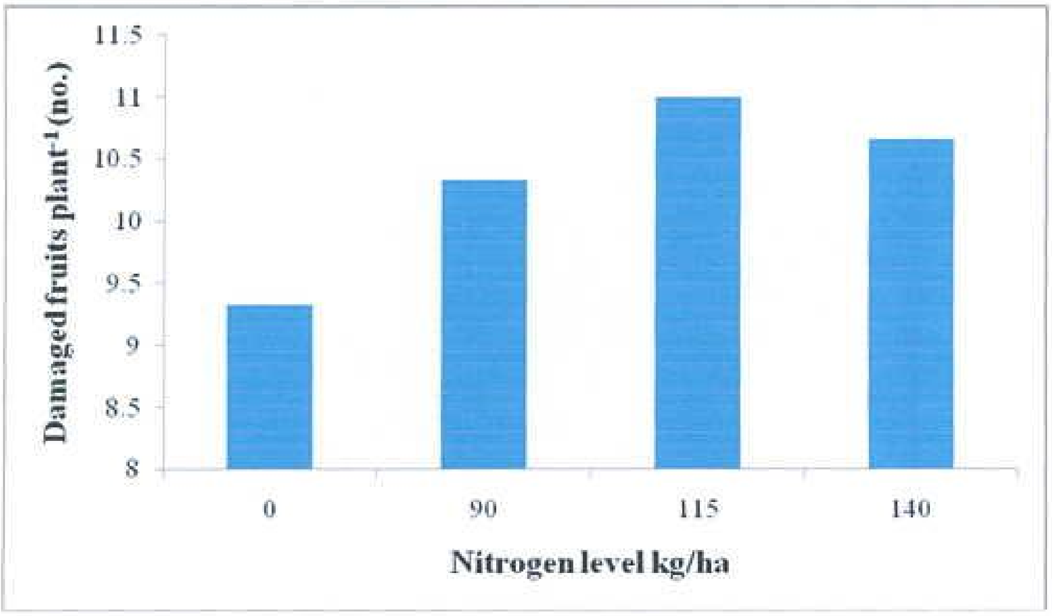


Figure 4.25 Effect of different nitrogen levels on damaged fruit plant^{-1} of strawberry plant

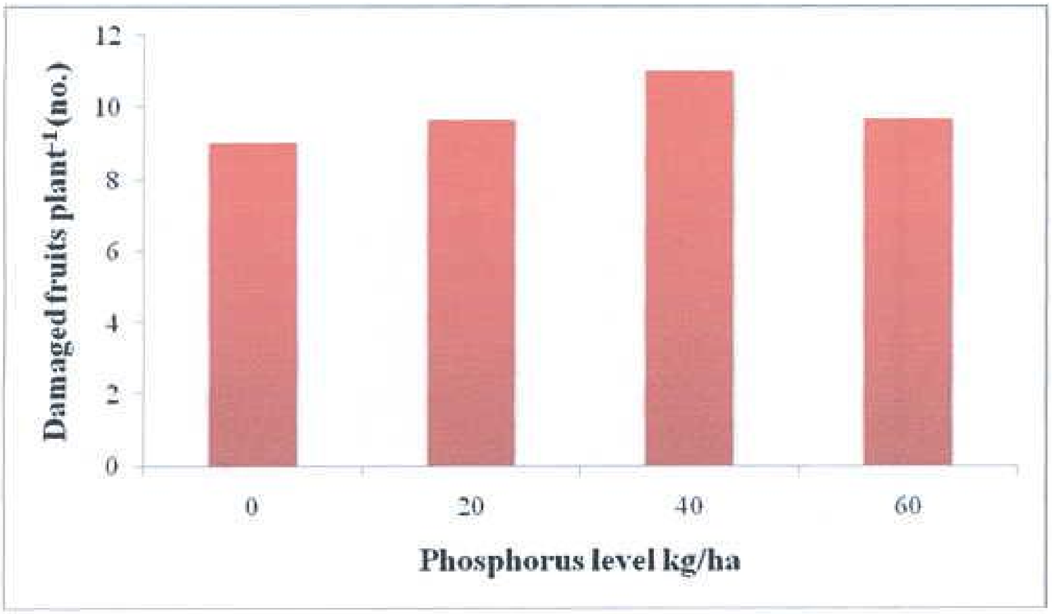


Figure 4.26 Effect of different phosphorus levels on damaged fruit plant^{-1} of strawberry plant

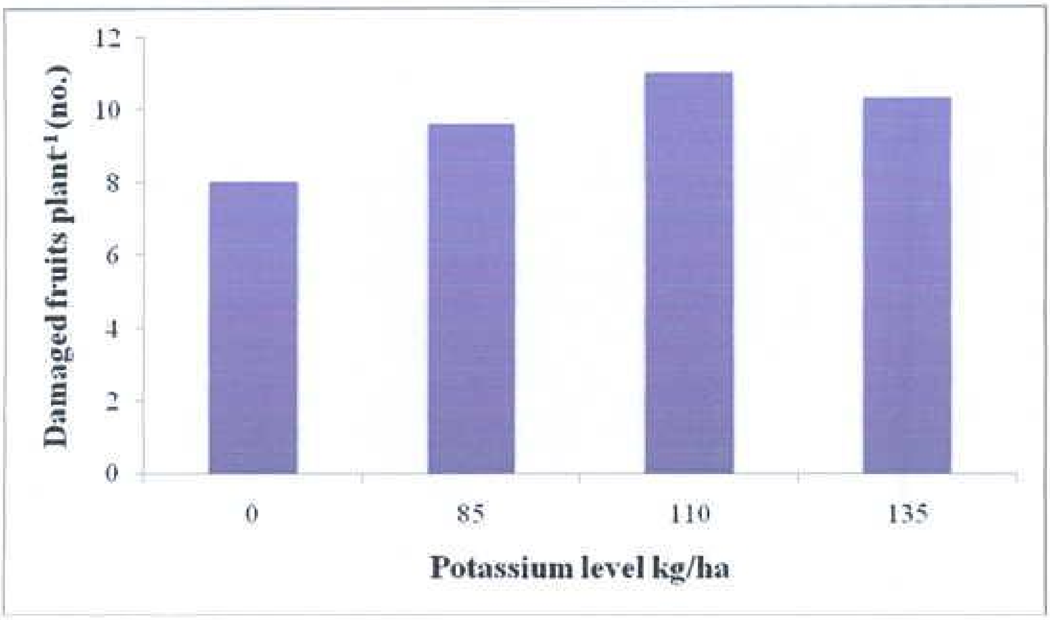


Figure 4.27 Effect of different potassium levels on damaged fruit plant^{-1} of strawberry plant

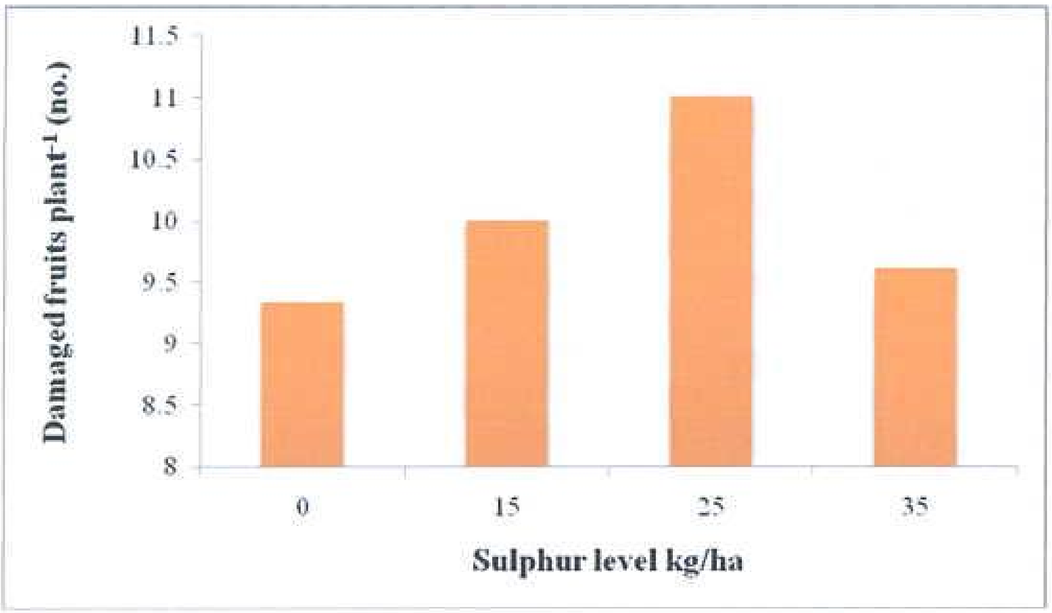


Figure 4.28 Effect of different sulphur levels on damaged fruits plant^{-1} of strawberry plant

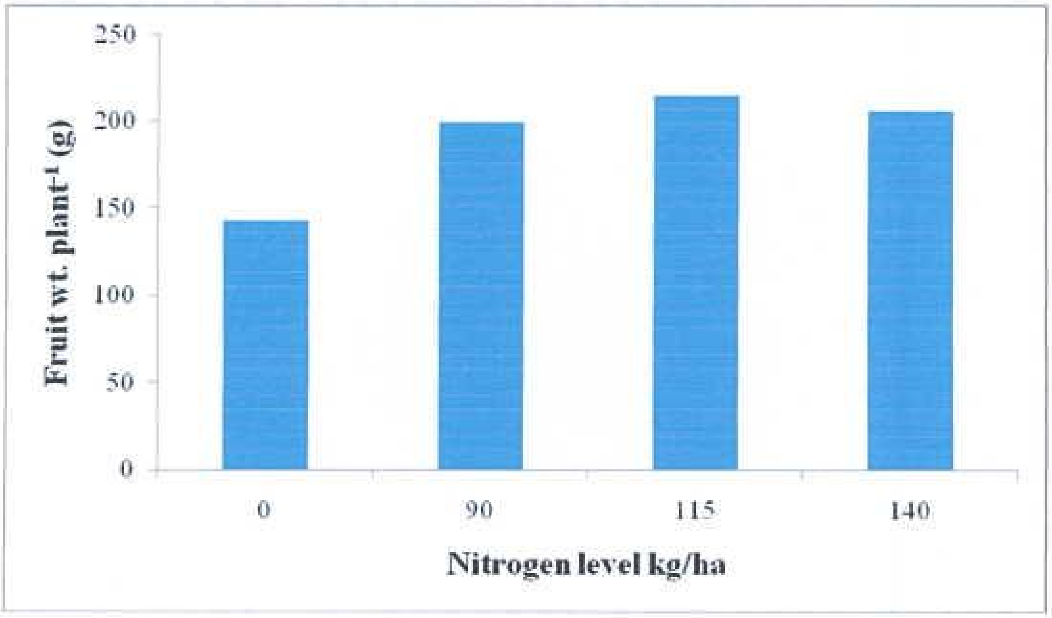


Figure 4.29 Effect of different nitrogen levels on fruit wt. plant^{-1} of strawberry plant

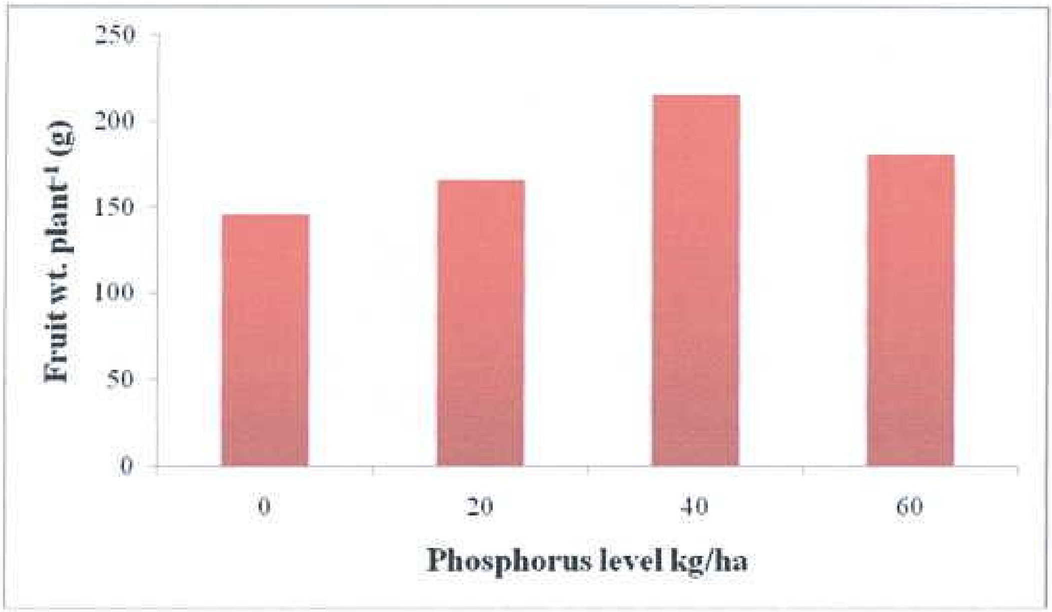


Figure 4.30 Effect of different phosphorus levels on fruit wt. plant^{-1} of strawberry plant

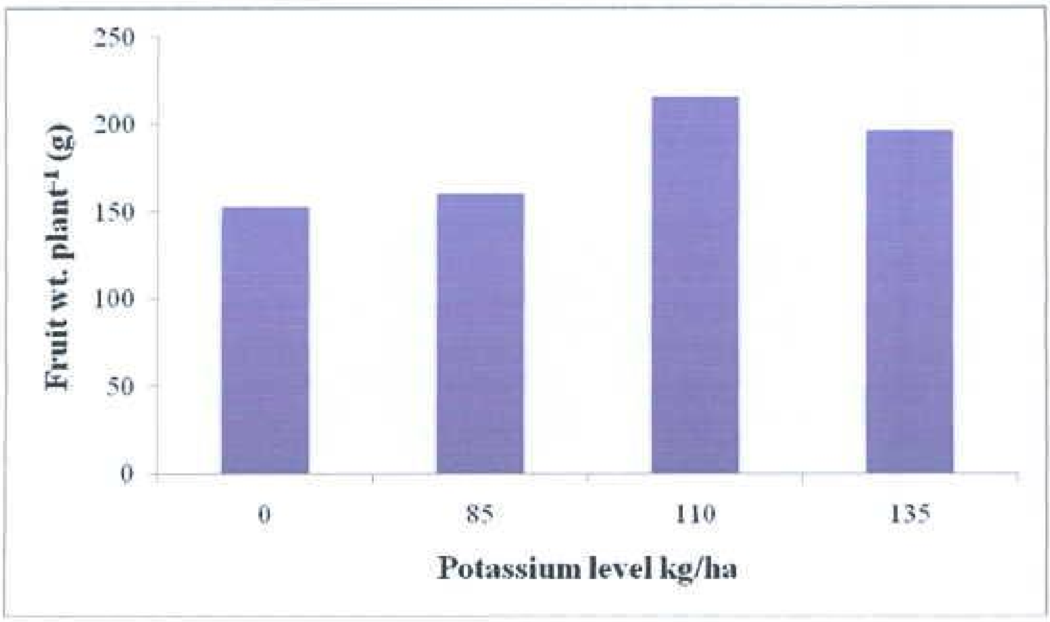


Figure 4.31 Effect of different potassium levels on fruit wt. plant^{-1} of strawberry plant

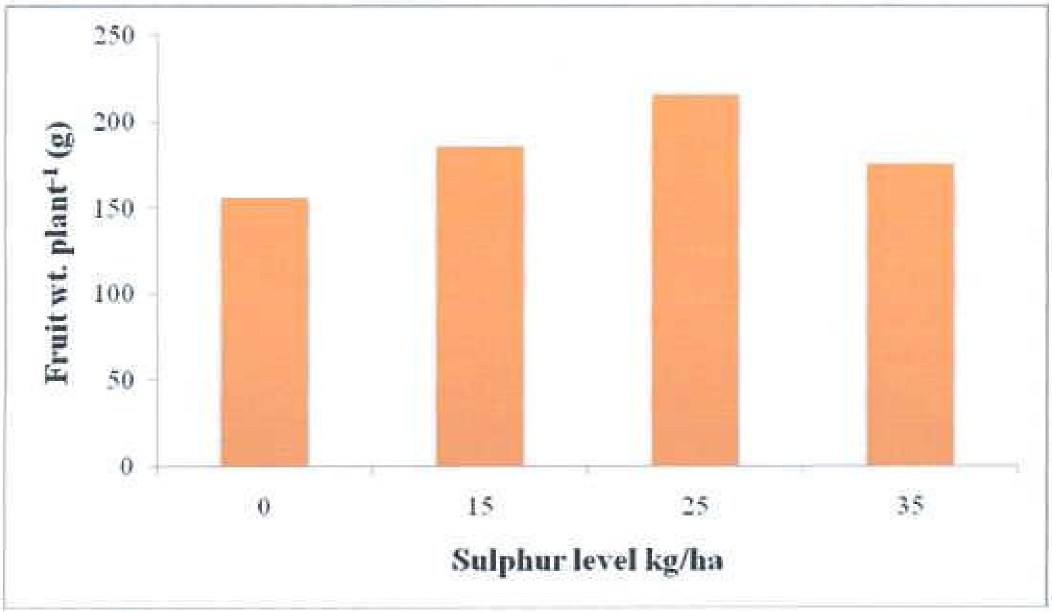


Figure 4.32 Effect of different sulphur levels on fruit wt. plant^{-1} of strawberry plant

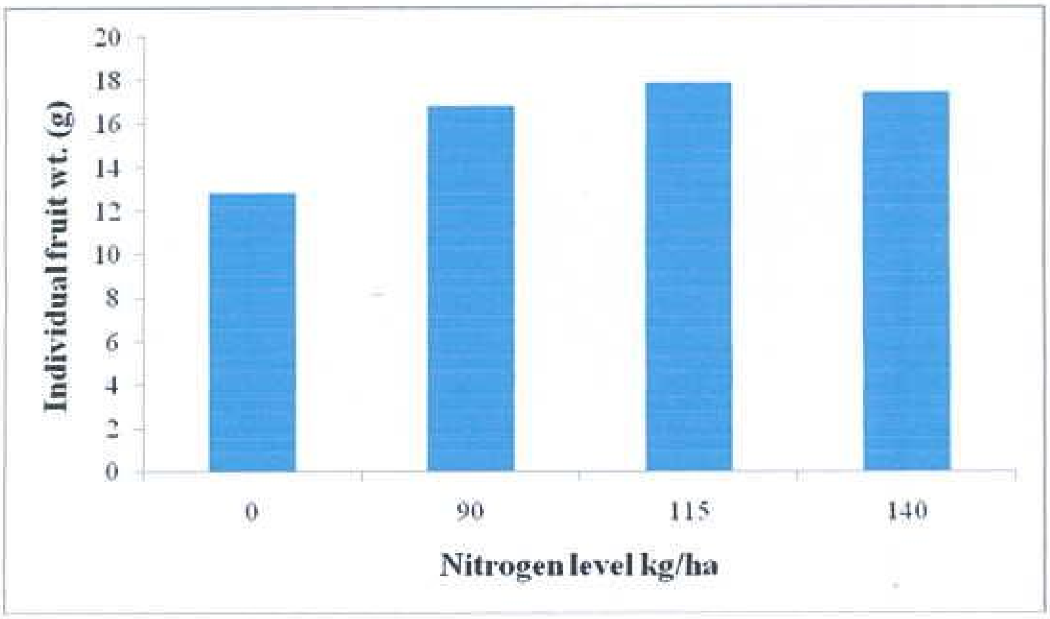


Figure 4.33 Effect of different nitrogen levels on individual fruit wt. of strawberry plant

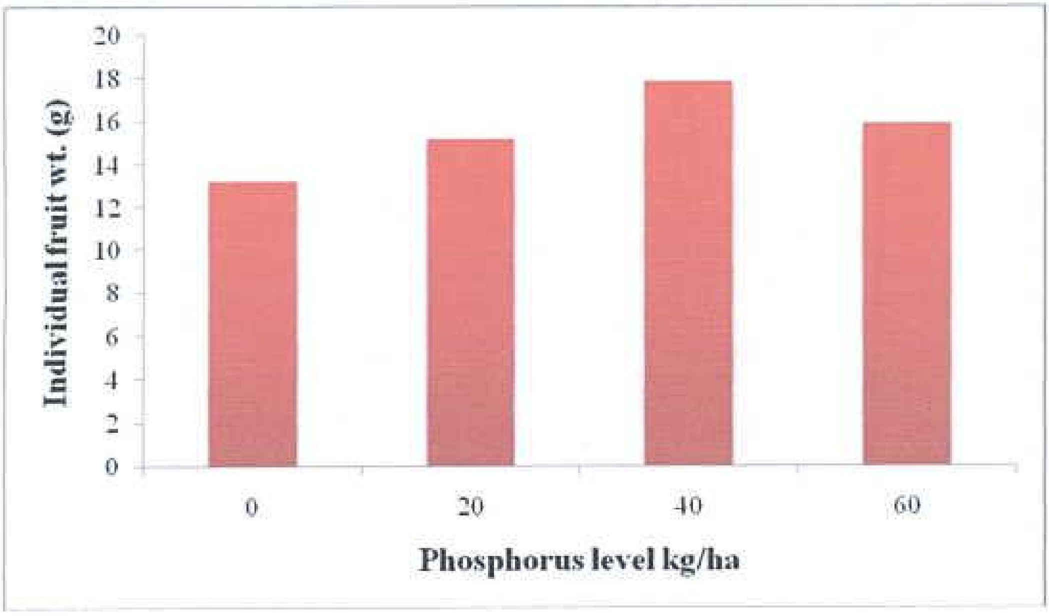


Figure 4.34 Effect of different sulphurs levels on individual fruit wt. of strawberry plant

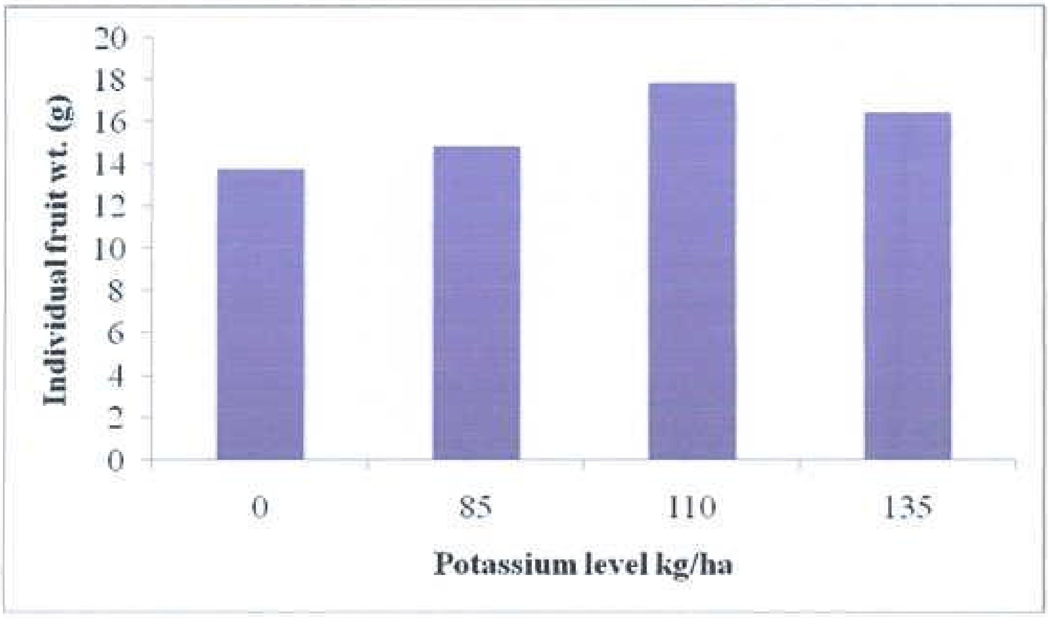


Figure 4.35 Effect of different potassium levels on individual fruit wt. of strawberry plant

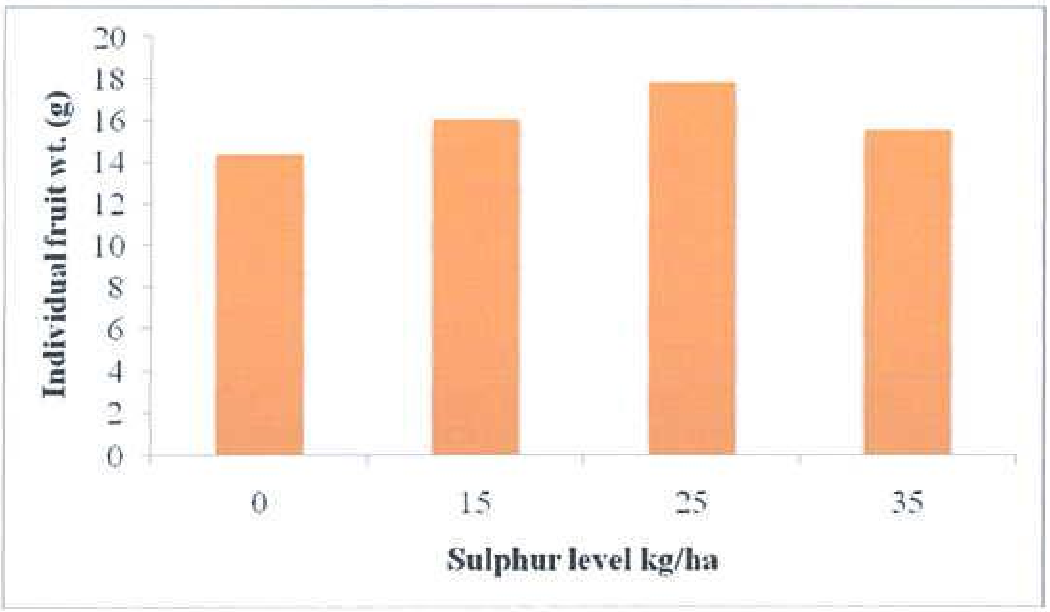


Figure 4.36 Effect of different sulphur levels on individual fruit wt. of strawberry plant

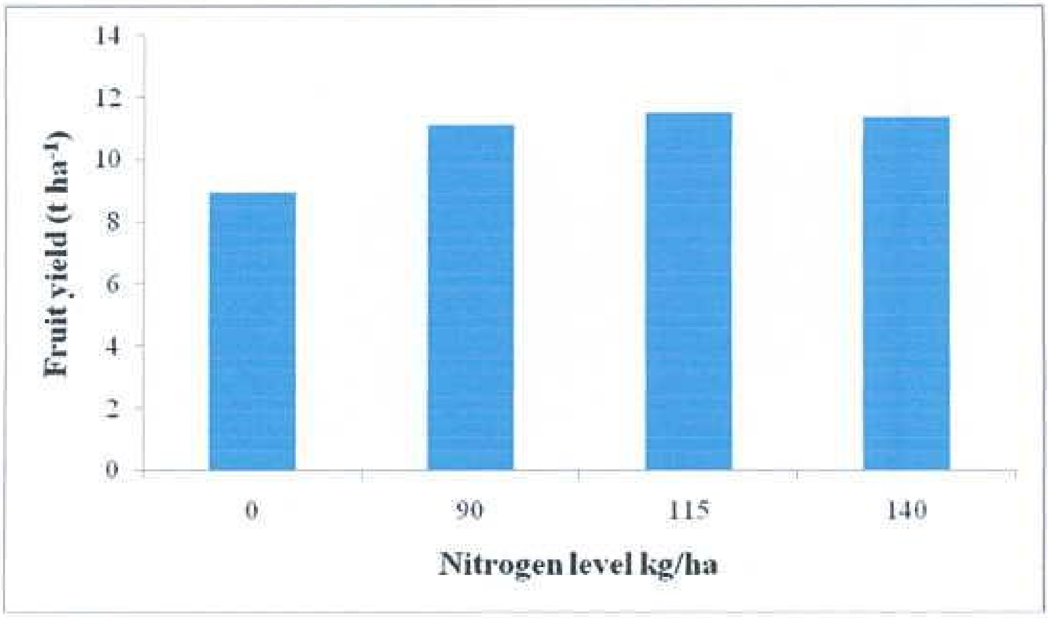


Figure 4.37 Effect of different nitrogen levels on fruit yield of strawberry plant

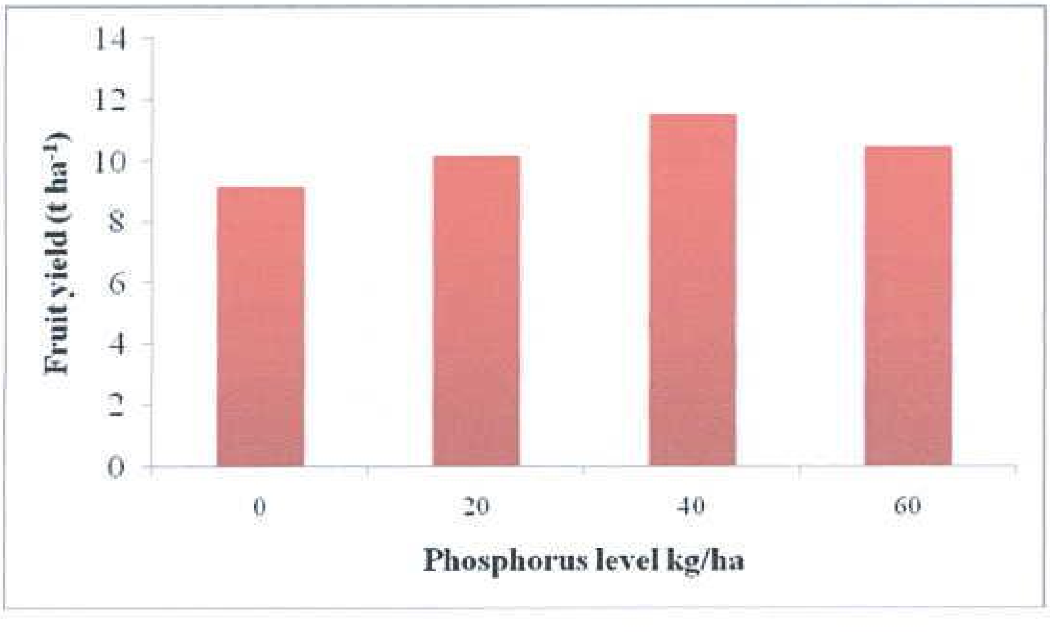


Figure 4.38 Effect of different phosphorus levels on fruit yield of strawberry plant

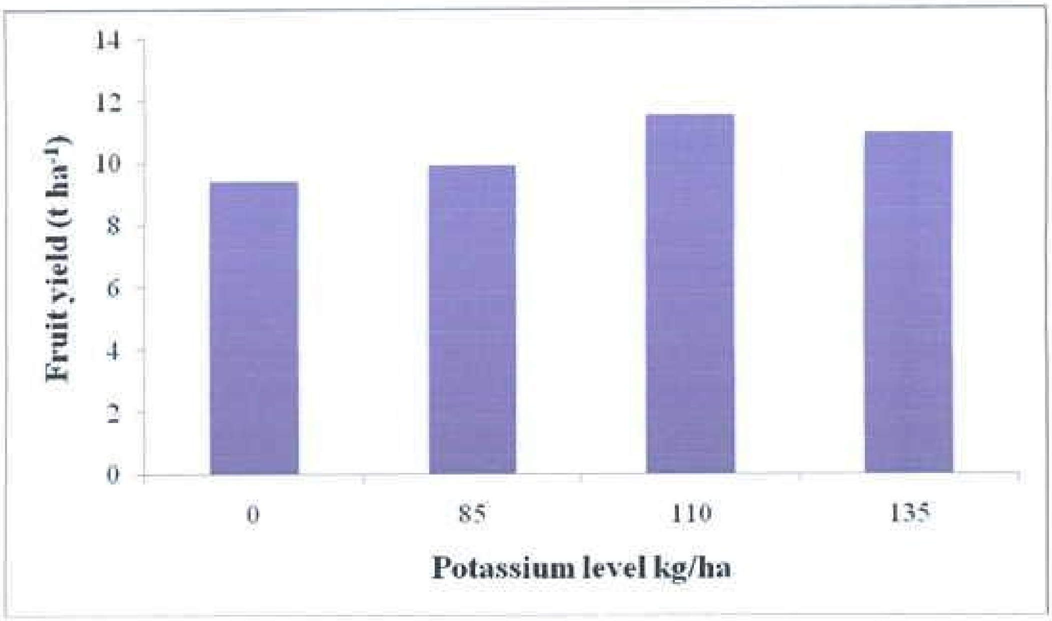


Figure 4.39 Effect of different potassium levels on fruit yield of strawberry plant

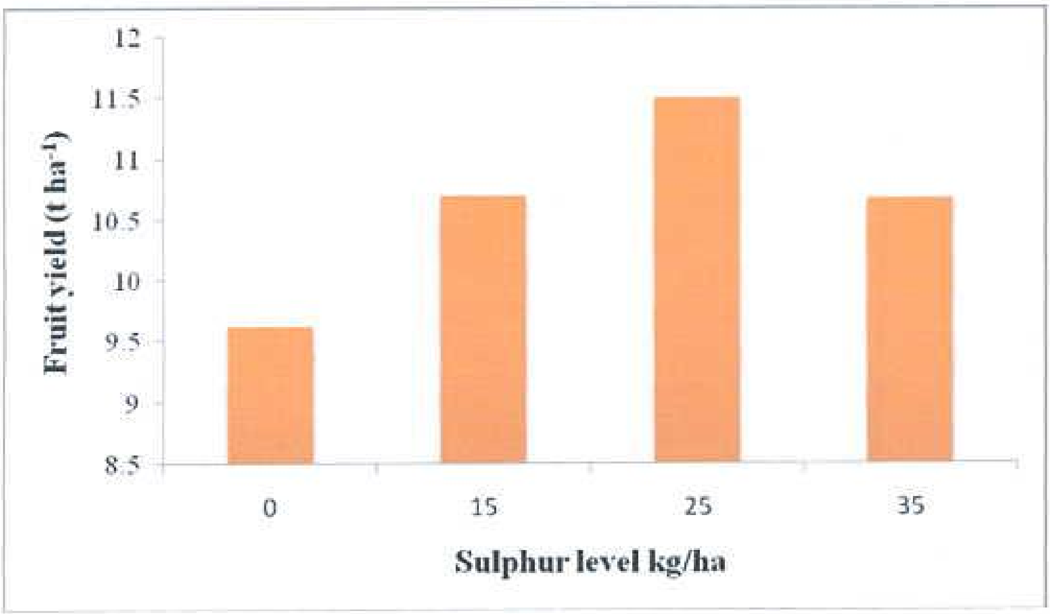


Figure 4.40 Effect of different sulphur levels on fruit yield of strawberry plant

4.2 Effects of different levels of nitrogen, phosphorus, potassium and sulphur on nutrient content of strawberry shoot and fruit

4.2.1 Nitrogen content in shoot and fruit

The effect of nitrogen on nitrogen content in shoot of strawberry was statistically significant due to the different combined doses of N, P, K and S fertilizers (Table 4.8 and Table 4.9). It was found that nitrogen application increased the nitrogen content in shoot. The highest N content (1.68%) was obtained in T_4 treatment which was statistically identical to treatment T_3. The lowest (0.48%) N content was found in control (Table 4.8). Data shows that nitrogen content in shoot increased with increasing level of nitrogen application. Faedi *et al.* (2006) reported that increasing N supply (0-55-110 kg N ha^{-1}) in spring increased N- availability in the soil and leaf N.

In case of strawberry fruit the effect of combined doses of N, P, K and S fertilizers varied significantly on N content (Table 4.9). It was observed that the N content gradually increased with treatment T_4 the content of nitrogen was the highest (2.06%) and statistically similar to treatment T_3. The lowest N content (0.28%) was found in control. Haynes and Goh (2008) showed that with the high N rates accumulation of high levels of ammonium nitrogen.

4.2.2 Phosphorus content in shoot and fruit

The P concentration in shoot and fruit of strawberry was influenced significantly by the application of combined doses of N, P, K and S fertilizers. The P content in shoot varied from 0.05 to 0.84 % (Tables 4.8 and Table 4.9). The maximum P content (0.48 %) was recorded in the treatment T_7 which is statistically identical to treatment T_3. The lowest P content was found in control (Table 4.8). Sharma and Adholeya (2004) reported that the highest level of P content in shoot was obtained by the application of P (200 kg ha^{-1}).

In case of strawberry fruit the effect of phosphorus varied significantly on P content of fruit but difference is very little (Table 4.9). It was observed that the P content gradually increased with increasing level of phosphorus which was the highest (0.88%) at T_7 treatment which was statistically similar to treatment T_3 and then the lowest p content (0.38 %) was found in control. Chen *et al.* (1999) reported that P concentration were low in all plant parts, but were higher in leaves, roots and stems.

4.2.3 Potassium content in shoot and fruit

The effects of different levels of combined doses of N, P, K and S fertilizers on potassium content in strawberry shoot and fruit was statistically significant (Table 4.8 and Table 4.9). The results on the K concentration in the shoot of strawberry have been presented in Tables 4.8. Application of potassium increased K content in strawberry shoot. The maximum K content (3.07%) was recorded in T_{10} treatment and second highest treatment was T_3 which was statistically similar. The lowest K content (0.90%) was found in T_{14} treatment. Eckstein and Blanke (2000) reported that K-deficient strawberry showed reduced leaf growth and reduced uptake of K and N.

In case of strawberry fruit the effect of potassium varied significantly on K content (Table 4.9). It was observed that the K content gradually increased with level of K. T_{10} treatment which was the highest (1.77%) and which was statistically similar to treatment T_3. The lowest K content (1.09%) was found in T_{14} (control) treatment.

4.2.4 Sulphur content in shoot and fruit

The concentration of S in the shoot and fruit of strawberry was not significantly by the different levels of combined doses of N, P, K and S fertilizers (Table 4.8 and Table 4.9). The S content in shoot ranged from 0.11% to 0.31 %. The maximum S content (0.31%) was found in T_{13} treatment and the minimum (0.11%) was in T_{14} treatment (Table 4.8).

Table 4.8 Effects of N, P, K and S application on nutrient content of strawberry shoot

Treatments (kg ha^{-1}) N – P – K - S	Nutrient content (%) in root			
	N	P	K	S
T_1 (0-40-110-25)	0.58 e	0.44 e	1.67 g	0.20
T_2 (90-40-110-25)	1.25 cd	0.59 cd	2.58 d	0.22
T_3 (115-40-110-25)	1.62 a	0.80 a	2.99 a	0.30
T_4 (140-40-110-25)	1.68 a	0.70 b	2.72 c	0.27
T_5 (115-0-110-25)	1.32 bc	0.38 f	1.89 e	0.15
T_6 (115-20-110-25)	1.39 b	0.65 c	2.70 c	0.24
T_7 (115-60-110-25)	1.47 b	0.84 a	2.89 b	0.28
T_8 (115-40- 0- 25)	1.28 cd	0.46 e	1.28 h	0.21
T_9 (115-40-85-25)	1.35 b	0.63 c	1.88 e	0.25
T_{10} (115-40-135-25)	1.44 b	0.74 b	3.07 a	0.26
T_{11} (115-40-110-0)	1.27 cd	0.47 e	1.51 f	0.15
T_{12} (115-40-110-15)	1.37 b	0.62 c	2.52 de	0.18
T_{13} (115-40-110-35)	1.41 b	0.72 b	2.82 b	0.31
T_{14} (0 – 0 – 0 – 0)	0.48 e	0.05 g	0.90 i	0.11
Significant level	*	*	*	NS
$LSD_{0.05}$	0.14	0.06	0.08	-
CV (%)	2.21	3.16	2.82	5.11

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

NS → Non significant

* → 5% level of significant

Table 4.9 Effects of N, P, K and S application on nutrient content of strawberry fruit

Treatments ($kg\ ha^{-1}$) N – P – K - S	Nutrient content (%) in fruit			
	N	P	K	S
T_1 (0-40-110-25)	0.42 e	0.63 cd	1.29 g	0.16
T_2 (90-40-110-25)	1.12 d	0.66 c	1.38 e	0.21
T_3 (115-40-110-25)	1.98 a	0.82 a	1.70 a	0.32
T_4 (140-40-110-25)	2.06 a	0.71 bc	1.65 b	0.29
T_5 (115-0-110-25)	0.96 de	0.46 d	1.36 f	0.17
T_6 (115-20-110-25)	1.65 b	0.74 bc	1.41 de	0.23
T_7 (115-60-110-25)	1.57 bc	0.88 a	1.58 c	0.26
T_8 (115-40- 0- 25)	0.78 de	0.59 cd	1.18 h	0.16
T_9 (115-40-85-25)	1.42 cd	0.62 cd	1.45 d	0.19
T_{10} (115-40-135-25)	1.58 bc	0.76 b	1.77 a	0.24
T_{11} (115-40-110-0)	0.84 de	0.61 cd	1.34 f	0.14
T_{12} (115-40-110-15)	1.45 cd	0.68 c	1.48 d	0.24
T_{13} (115-40-110-35)	1.65 b	0.78 b	1.56 c	0.35
T_{14} (0 – 0 – 0 – 0)	0.28f	0.38 e	1.09 i	0.12
Significant level	*	*	*	NS
$LSD_{0.05}$	0.22	0.04	0.04	-
CV (%)	2.34	3.12	3.43	5.51

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

NS → Non significant

* → 5% level of significance

In the fruit of strawberry, the S content did not significantly differ by the application of different levels of N, P, K and S fertilizers (Table 4.9). The highest S content (0.35%) was found in T_{13} treatment. The lowest S content (0.12%) was found in control. The result is in agreement with the findings of Chandal *et al.* (2003) that increasing S levels significantly increased S content up to 45 kg S ha^{-1}.

4.3 Correlation and regression studies

Different correlation matrix and regression lines have been shown in Table 4.10, Figure 4.1 and Figure 4.2.

4.3.1 Regression analysis

Regression analysis of strawberry yield was done to fit the quadratic functions for estimating the optimum levels of each nutrient over the different levels of NPKS ha^{-1} (Fig 4.1 and Fig 4.2). Dobermann and Fairhurst (2000) stated that the optimum rate of fertilizer application to a crop is that rate which produces the maximum economic returns at the minimum cost and can be derived from a nutrient response curve.

The large and significant R^2 value in case of N, P, K and S of regression for strawberry indicates that the quadratic response fitted the data. Response curve showed that yield increased with the increasing rates of nutrient up to a certain level and thereafter decreased (Figure 4.1 & Figure 4.2).

From the regression equation the agronomic and economically optimum levels of NPKS were estimated as 125-46-117-23 kg ha^{-1} and 120-45-115-20 kg NPKS ha^{-1} respectively (Table 4.10).

Table 4.10 Response function of strawberry yield to N, P, K and S fertilizers

Nutrients	Regression equation	R^2	Optimum rates of nutrient (kg ha^{-1})	
			Agronomic	Economic
N	$Y = 8.0943 + 0.025x - 0.0001x^2$	0.993	125	120
P	$Y = 9.014 + 0.092x - 0.001x^2$	0.948	46	45
K	$Y = 9.363 + 0.0234x - 0.0001x^2$	0.937	117	115
S	$Y = 9.557 + 0.091x - 0.002x^2$	0.957	23	20

The present result indicates that judicious nutrient management in strawberry can ensure high persecution and profit. Application of 120-45-115-20 kg NPKS ha^{-1} would be the beneficial and economically optimum for strawberry production in Grey Terrace Soil of Joydebpur under AEZ 28.

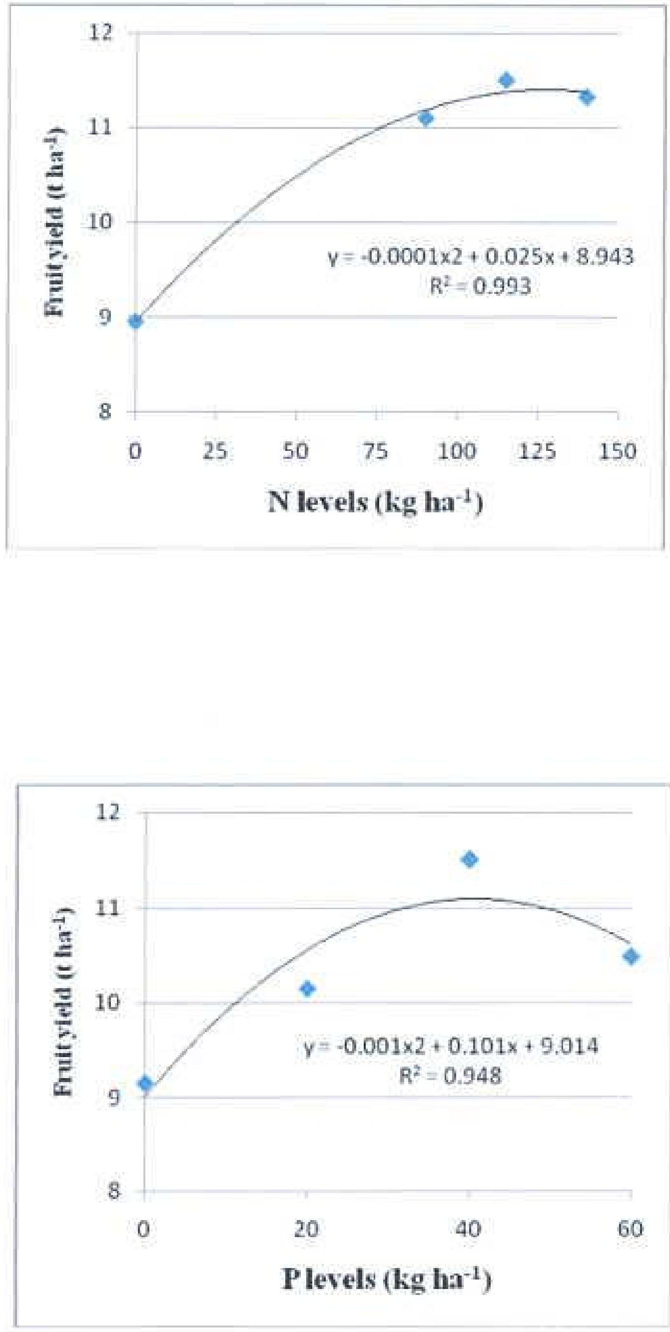
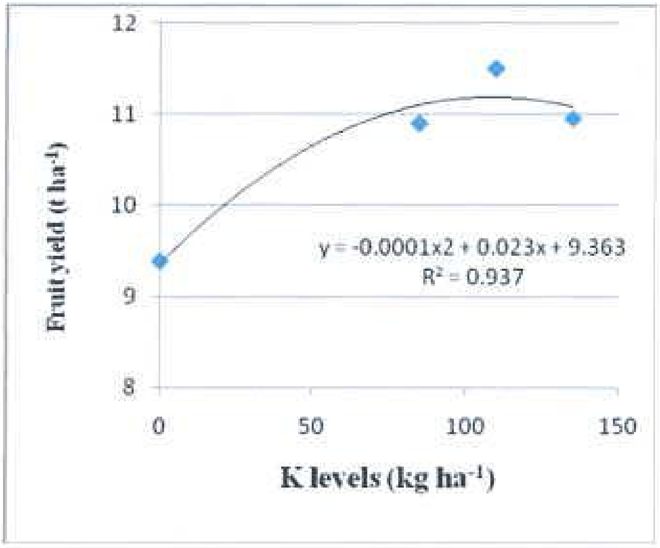


Figure 4.41 Functional relationship between strawberry fruit yield and N, P fertilizers



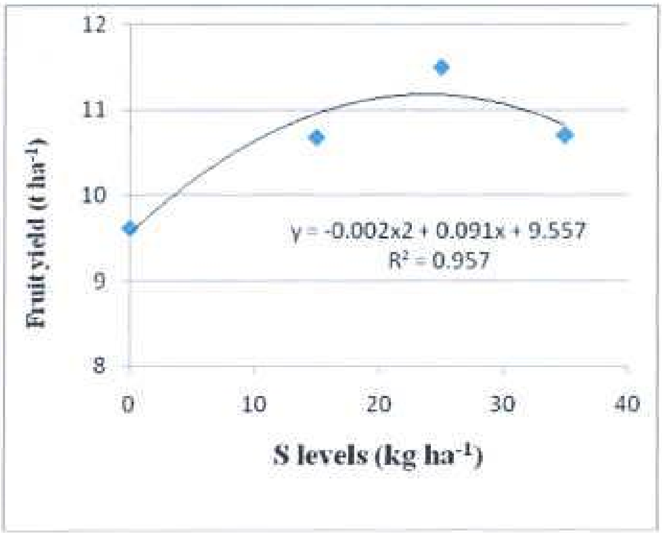


Figure 4.42 Functional relationship between strawberry fruit yield and K, S fertilizers

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted at the Horticultural Research Farm, BARI, Joydebpur Gazipur during robi season of 2011-2012 to evaluate the effect of different levels of nitrogen, phosphorus, potassium and sulphur on yield and nutrient content of 'BARI Strawberry 1'. Thirty days old seedlings were transplanted on the 17th November, 2011 with a spacing of 40 cm from plant to plant and 60 cm from row to row. The experiment comprised of 14 treatments consisting of 4 levels of nitrogen (0, 90, 115 and 140 kg N ha^{-1}), phosphorus (0, 20, 40 and 60 kg P ha^{-1}), potassium (0, 85, 110 and 135 kg K ha^{-1}) and sulphur (0, 15, 25 and 35 kg S ha^{-1}). The experiment was laid out in the Randomized Complete Block Design (RCBD) with 3 replications.

There was no significant difference on plant height of strawberry plant on the application different combinations of fertilizers. However, the tallest plant (25.60 cm) was achieved at T_3 (115-40-110-25 kg N-P-K-S ha^{-1} respectively) treatment and the shortest plant (22.53 cm) grew from T_{14} treatment (control). Due to the effect of different combinations of fertilizers significant differences were found on leaf number, flowers, fruits, destroyed fruits and fruit weight $plant^{-1}$, fruit length, fruit diameter, individual fruit weight and fruit yield.

Data showed that T_3 treatment (115-40-110-25 kg N-P-K-S ha^{-1}) produced the highest number of leaves (21.66), flowers (125.33), fruits (12.35), damaged fruits (11) and fruit weight (215.10 g) $plant^{-1}$, fruit length (4.16 cm), fruit diameter (3.41 cm), individual fruit weight (17.85 g) and fruit yield (11.50 t ha^{-1}).

The lowest number of leaves (15.53), flowers (109.33), fruits (7.15), damaged fruits (6) and fruit weight $plant^{-1}$ (125.35 g), fruit length (3.15 cm), fruit diameter (2.16 cm), , individual fruit weight (11.10 g) and fruit yield (8.20 t ha^{-1}) were found from treatment T_4 (control).

The single effect of N-P-K-S fertilizers on plant height of strawberry was not significant. Height of strawberry plant increased progressively with added N-P-K-S fertilizers up to 115-40-110-25 kg ha^{-1}. Further increase in N-P-K-S fertilizers tended to depress the plant height. The highest plant height was obtained from 115 kg N ha^{-1} (25.60 cm); 40 kg P ha^{-1} (25.60 cm); 110 kg K ha^{-1} (25.60 cm); 25 kg S ha^{-1} (25.60 cm) and the lowest 0 kg ha^{-1} N dose (23.13 cm); 0 kg ha^{-1} P dose (23.13 cm); 0 kg ha^{-1} K dose (23.13 cm); 0 kg ha^{-1} S dose (23.13 cm).

Due to the single effect of different levels of N-P-K-S fertilizers significant differences were found on number of leaves, flowers, fruits, damaged fruits and fruit weight $plant^{-1}$, fruit length, fruit diameter, individual fruit weight and fruit yield of strawberry plant. These growth and yield attributes increased with increasing rate of N-P-K-S up to 115-40-110-25 kg ha^{-1} N-P-K-S respectively, after that these growth and yield attributes were decreased.

There was significant effects due to the combined application of N-P-K-S fertilizers in content of N, P and K nutrient in strawberry shoot and fruit. Whereas the content of S was not significantly affected by the application of combined fertilizers.

It was found that nitrogen application increased nitrogen content in shoot and fruit. The highest N content in shoot (1.68%) and fruit (2.06%) were obtained at T_4 treatment whereas N fertilizer was applied at 140 kg ha^{-1} and T_4 had no significant differences. The lowest N content in shoot (0.48%) and fruit (0.28%) were found in control treatment.

The P content in shoot and fruit increased with increasing level of P fertilizer application in the combination treatment. The maximum P content in shoot (0.84%) and fruit (0.88%) were recorded with T_7 treatment which was statistically similar with T_3 treatment and the lowest P content in shoot (0.o5%) and fruit (0.38%) were found in control treatment.

Application of increasing level of potassium fertilizer in combination doses increased K content in strawberry shoot and fruit. The maximum K content in shoot (3.07%) and fruit (1.77%) were recorded at T_{10} treatment which had no significant differences with T_3 treatment. The lowest K content in shoot (0.90%) and fruit (1.09%) were recorded in control treatment.

The S content in shoot and fruit increased with increasing level of S fertilizer application in combined fertilization. The maximum S content in shoot (0.31%) and fruit (0.35%) were found at T_{13} treatment and the minimum in shoot (0.11%) and fruit (0.12%) were in control treatment.

From the result of present investigation it was revealed that -

1. The combined fertilization of 115-40-110-25 kg ha^{-1} N-P-K-S respectively showed the better performance for most of the characters as well as yield of strawberry.
2. N, P, K and S content of strawberry shoot and fruit increased with increasing rate of N-P-K-S fertilizer application in combination treatment.
3. N, P, K and S content in strawberry fruit was more than shoot at the same fertilizer combination.

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

1. Such study is needed in different agro-ecological zones (AEZ) of Bangladesh for regional adaptability and other performances.
2. Another doses of N-P-K-S fertilizers and time of application may be included in the further study.
3. Inorganic fertilizer combined with organic fertilizer can be also included in the program for future study.

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APPENDICES

Appendix I. Monthly records of Air temperature, Relative humidity and Rainfall of the experiment site during the period from November 2011 to April, 2012.

Month	* Air temperature (° C)		*Relative humidity (%)	*Rainfall (mm)
	Maximum	Minimum		
November,2011	25.82	16.04	78	0
December, 2011	22.4	13.50	74	0
January, 2012	24.5	12.4	68	0
February, 2012	27.1	16.7	67	30
March, 2012	31.4	19.6	54	38
April, 2012	33.2	21.4	51	52

*Monthly Average

Source: Bangladesh Metrological Department (climate and weather division) Agargaon, Dhaka- 1207

a) NPKS (control)

b) NPKS (115-40-110-25) kg ha^{-1}

Plate 1 Effect of nitrogen, phosphorus, potassium and sulphur on growth of strawberry