GROWTH AND YIELD PERFORMANCE OF STRAWBERRY AS INFLUENCED BY PHOSPHORUS AND MULCH MATERIALS

MD. ABUBAKAR SIDDIQUE

DEPARTMENT OF HORTICULTURE
SHER-E-BANGLA AGRICULURAL UNIVERSITY
DHAKA-1207

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BY

MD. ABUBAKAR SIDDIQUE

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APPROVED BY:

Prof. Dr. Md. Ismail Hossain Department of Horticulture SAU, Dhaka **Supervisor**	**Prof. Dr. Mohammad Humayun Kabir** Department of Horticulture SAU, Dhaka **Co-Supervisor**

Prof. Dr. Md. Jahedur Rahman
Chairman
Examination Committee

It is a fact that the remembrance of Allah brings peace in the heart. It is better to ponder over the verses to bring us even closer to Allah (swt).

DEDICATED TO-

MY BELOVED PARENTS

Department of Horticulture
Sher-e-Bangla Agricultural University
Sher-e -Bangla Nagar, Dhaka-1207

Memo No.: SAU/HORT/…..

Dated:……

CERTIFICATE

This is to certify that the thesis entitled ***"GROWTH AND YIELD PERFORMANCE OF STRAWBERRY AS INFLUENCED BY PHOSPHORUS AND MULCH MATERIALS"*** *submitted to the Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of* ***MASTER OF SCIENCE in HORTICULTURE****, embodies the result of a piece of authentic research work carried out by* ***MD. ABUBAKAR SIDDIQUE,*** *Registration No.* ***13-05327*** *under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Dated: June, 2020
Dhaka, Bangladesh

Prof. Dr. Md. Ismail Hossain
Department of Horticulture
Sher-e-Bangla Agricultural University
Sher-e-Bangla Nagar, Dhaka- 1207
Supervisor

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- Author

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ABSTRACT

A field experiment was accomplished in the Horticulture farm of Sher-e-Bangla Agricultural University, Dhaka during the period from October 2018 to March 2019 to study the effect of phosphorus fertilizers and mulches on strawberry. Phosphorus levels viz. P_0 (0 kg/ha.), P_1 (120 kg/ha.), P_2 (170 kg/ha.), P_3 (220 kg/ha.) and Mulches: M_0 (No mulch application), M_1 (Paddy straw), M_2 (Black polythene) were used in this experiment arranged in Randomized Complete Block Design (RCBD) with three replications. Data on different growth and yield attributes parameters were taken in which all the treatment showed significant variations. Among phosphorus levels, maximum fruits number (27.78/plant), fruit yield (14.54 g), total fruit yield (401.0 g/plant), brix percentage (6.64%) were found from P_3 whereas minimum in P_0 and among mulches, maximum fruits number (24.17/plant), fruit yield (13.78 g), total fruit yield (328.6 g/plant), brix percentage (5.84%) were found from M_2 whereas minimum in M_0. Maximum fruit yield (474.5 g/plant) were found in P_3M_2 and minimum (180.4 g/plant) in P_0M_0. In view of overall performances, this study suggests that 220 kg/ha of phosphorus fertilizers with black polythene mulch (P_3M_2) have the potentiality for higher yield of strawberry.

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ABBREVIATIONS AND ACCORONYMS

AEZ	=	Agro-ecological Zone
Agric.	=	Agricultural
ANOVA	=	Analysis of Variance
BARI	=	Bangladesh Agricultural Research Institute
Biol.	=	Biology
CV	=	Coefficient of variance
DAP	=	Days after planting
et al.	=	And others
Ex.	=	Experiment
FAO	=	Food and Agriculture Organization of the United Nations
g	=	Gram
Hort.	=	Horticulture
i.e.	=	That is
J.	=	Journal
Kg	=	Kilogram
LSD	=	Least Significance difference
mm	=	Millimeter
RCBD	=	Randomized Complete Blocked Design
Res.	=	Research
SAU	=	Sher-e-Bangla Agricultural University
Sci.	=	Science
spp.	=	Species
Technol.	=	Technology
UNDP	=	United Nations Development Programme
Viz.	=	Namely

CHAPTER I
INTRODUCTION

Strawberry (*Fragaria annanassa*) belongs to Rosaceae family, is cultivated worldwide for its fruit. Strawberry fruit is widely appreciated for its aroma and vitamin contents (Hancock, 1999), bright red color, juicy texture, sweetness also higher percentage of phenolics and flavonoids (Hakkinen and Torronen, 2000). In modern times, it is amazingly popular in the world right through 21st century while improved taste and appearance besides as healthy fruit. It is consumed in large quantities either in fresh or prepared foods. Strawberry is new fruit crop and its commercial production is possible in wide climatic range (Barney, 1999) including subtropical areas like Bangladesh. Country's weather is favorable for the production of high-quality strawberries though it is normally produced in countries having cold weather particularly in West. Strawberry cultivation technique is fairly new in Bangladesh whereas cultivation area is increasing day by day. Strawberry can be grown during month of October to April in Bangladesh.

Among the production factors affecting crop yield, nutrient is the single most important factor that plays a dominant role in yield increase if other production factors are not limiting. It is reported that chemical fertilizers today hold the key to success of production systems of Bangladesh agriculture being responsible for about 50% of the total crop production (BARC, 1997). Nutrient imbalance can be minimized by judicious application of different fertilizers. Strawberry responds greatly to major essential elements like N, P and K for its growth, yield and quality. Nitrogen, phosphorus and potassium progressively increase the marketable yield (Obreza and Vavrina, 1993) but an adequate supply is essential for vegetative growth, and desirable yield (Yoshizawa *et al*., 1981). Excessive application is not only uneconomical but also induces physiological disorder.

Phosphorus is an essential macro-nutrient that is required to meet global food requirements and make crop and livestock production profitable (Sharpley and Tunney, 2000). Plant cells need to have adequate phosphorus before they divide. Additionally, phosphorus increase root growth, grain, fiber and forage yield, enhances early plant maturity and stalk strength, and promotes resistance to root rot disease and winter kill (Norfleet, 1998). Phosphorus is important for the plants in order to store energy, and plays a role in fruit development. It is often required in adequate amounts for good strawberry production.

In Bangladesh, strawberry is grown during winter season where rainfall is scanty but it needs plenty of moisture of soil for its normal growth and development. Mulching play an important role to reduce the evaporation loss of soil and in this way, it maintains sufficient moisture in the soil. In most of the time, irrigation expenses increase the cost of production resulting in unprofitable production of strawberry and make growers frustrated.

Any practices that act as a barrier to the evaporation of water or heat from soil surface can be defined as mulching. Mulching offers tremendous potential for increased crop production through its noticeable effect on the soil environment which ensures proper growth and yield of crop (Lai, 1989). Mulching may be practical in crop cultivation which can minimize cost of production. The efficiency of phosphorus fertilizer use was normally 30% under Bangladesh context, which was increased upto 53% with special arrangement through mulching (Sweeney *et al*., 1987).

Most of the soils and climatic conditions of Bangladesh are suitable for strawberry production but the crop did not show its potentiality due to imbalance fertilizer and poor cultural practices. There is a scope for increasing yield of this crop by using phosphorus with other fertilizers and different mulches under the agro-ecological condition in Bangladesh. However, research works on the phosphorus management and suitable mulch for strawberry is

scanty in Bangladesh. Hence the present study was, therefore, undertaken to evaluate the response of strawberry to phosphorus fertilizer and mulches to find out the optimum dose of phosphorus and suitable mulch for higher yield of strawberry. Considering the above mentioned facts the present study has been planned and design with the following objectives:

Objectives

1. To study the effect of phosphorus level on growth and yield of strawberry;
2. To find out the suitable mulch for higher yield of strawberry and
3. To determine proper combination of phosphorus level and mulch for better growth and yield of strawberry.

CHAPTER II
REVIEW OF LITERATURE

Mulching and phosphorus fertilizer management practices both are important factor influencing the growth and yield of strawberry. The average yield of strawberry in Bangladesh is much lower than that of the other countries of the world. Many research works have been conducted on the effect of different mulches and phosphorus fertilizer management practices on the growth and yield of strawberry in various parts of the world. Some of the important research reports regarding strawberry and some other related crops have been reviewed here in this chapter.

2.1 Literature on phosphorus

Phosphorus is recognized as an important mineral element limiting crop growth and production. It is generally considered as the second most limiting nutrient after N for plant growth (Bieleski, 1973 and Vance, 2001). The acid-weathered soils of the tropics and subtropics are particularly prone to phosphorus deficiency and Al toxicity (Von Uexkull and Mutert, 1995).

The available P in Bangladesh soils could be considered to be between low and medium. About 20.70% areas were reported to be predominantly low in available P and 21.20% were medium in available P which is limiting crop production. Therefore, one of the adverse effects in agriculture practice in Bangladesh is phosphorus deficiency. Plants cannot live at phosphate concentration below two parts per ten million in soil solution. Plants suffering from P-deficiency showed retarded growth and low shoot/root dry matter ratio (Alsaeedi and Elprince, 2000). P-deficiency affected the development of reproductive organs and decreased number of flowers (Bould and Parfitt, 1973). The formation of fruits and seeds is especially depressed in plants subjected to P- deficiency.

Phosphorus, an important nutrient for propagation, vigor and general health of all plants, is often referred to as the ‘energizer’ because it helps store and transfer energy within plants during photosynthesis process (Busman *et al.*, 1998 and Schachtman, 1998). Knowledge of crop N and P requirements is essential in developing profitable nutrient management planning to meet plant needs for producing high quality crops (Gastal and Lemaire, 2002; Selecting cultivars efficient in nutrient use could be an option for producing high quality crops (Li *et al*., 2009).

Mohamed *et al.* (2011) observed that influence of phosphorus (0, 60, 80, 100 Kg P_2O_5/fed) and zinc (0, 5, 15, 25 Kg Zn/fed) on vegetative growth, yield and fruit quality of strawberry plants. The result indicated that, vegetative growth characters (no. of leaves, no. of runners, leaf area, foliage fresh mass and dry mass/plant) and flowering traits (no. of flower clusters/ plant and earliness) were significantly increased with the high rates of P and Zn. Early yield, marketable yield, total yield and yield/plant, generally seemed to be increased with the high rates of P and Zn. The highest mean values of average fruit weight, fruit length, fruit diameter, fruit juice content, TSS and vitamin C were figured out for plants supplied with P and Zn at the highest levels. The interaction between P and Zn reflected positive effects on all studied quantitative and qualitative characters of strawberry plants.

Yusuf *et al.* (2003) stated that combined application of 150 kg N/ha, 100 kg P/ha and 20 t FYM/ha resulted in the highest number of flowers per plant (14.63), fruit set per plant (9.13), number of fruits retained per plant (6.40), fruit weight (5.8410g), yield (7.00 t/ha), and fruit total soluble solid (10.30%) and vitamin C content (42.15%).

Odongo *et al*. (2011) stated that quality of strawberries in the tropics is partly limited by poor soil fertility, while profitability of different nutrient management strategies has not been established. The present study determined

the effect of 0, 18, 36, and 54 t/ha farmyard manure (FYM) and triple super phosphate (TSP), equivalent to 0, 17, 34 and 68 kg/ha phosphorus (P) on quality and profitability of strawberries. Profitability was calculated using berry yield-income and input-costs at the end of the study. Results varied depending on response variable. High FYM and TSP significantly ($P < 0.05$) increased fruit size, but lowered storage life. High FYM significantly lowered brix index. Low FYM plus moderate TSP significantly lowered fruit size. Thus, 54 t/ha FYM plus 34 kg/ha TSP and 36 t/ha FYM plus 17 kg/ha TSP are recommended for large-sized and sweetest, long-storing berries, respectively. Manure alone increased profitability more than TSP alone. The highest FYM and TSP did not always result in highest profitability.

Sharma and Alok (2004) observed that strawberries grown in alfisols of semiarid areas in India produces suboptimal yields. Low organic carbon and low phosphorus (P) availability, in addition to high P fixation, affects P availability drastically, even when it is applied externally. The benefit to the yield of micro propagated strawberry *Fragaria ananassa* 'Pajaro' 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) 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), 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, and the yield was comparable with uninoculated plants grown at 200 kg P/ha. The external P requirements were 71 kg/ha for mycorrhizal and 106 kg/ha for nonmycorrhizal strawberry plants to obtain 90% of the maximum fruit yield. In terms of P application, this corresponds to a savings of 35 kg /ha. The percent mycorrhizal root length

colonization, both in inoculated and uninoculated plants, was not found to differ significantly with P application.

Koszanski *et al.* (2002) stated that a field experiment was conducted in Poland during 1998-99 to determine the effects of irrigation and mineral fertilization on the yield of strawberry cultivars 'Senga Sengana', and 'Elsanta'. The treatments comprised non-irrigation and trickle irrigation when the soil water content fell beneath 70% of field water capacity, as well as application of 110, 220 or 330 kg NPK/ha. 'Senga Sengana' recorded higher crop potential than 'Elsanta'. Trickle irrigation increased the yield of both cultivars but reduced the nitrogen, nitrate, acid and vitamin C content in the fruits. Application of 110 kg NPK/ha resulted in the highest yields of both cultivars. 'Elsanta' recorded lower dry matter content than 'Senga Sengana'. Supplemental irrigation as well as higher fertilizer rates reduced the dry matter of both cultivars. High rates of mineral fertilizers increased to some extent the contents of nitrogen and organic acids but reduced the vitamin C content and sugar in the fruits. 'Senga Sengana' recorded higher transpiration, stomatal conductivity and carbon dioxide concentration in the substomatal cells. Supplemental irrigation increased leaf photosynthesis by 24%, transpiration by 17% and stomatal conductivity by 23%, but decreased leaf temperature by 0.6 degrees C and carbon dioxide concentration by 10%. The stomatal conductivity was lower in leaves which were irrigated and properly fertilized.

Zargar *et al.* (2008) stated that a pot experiment was carried out at Shalimar, Srinagar (J&K) to evaluate the interaction effect of inoculation of three levels of each bio-fertilizers (Azotobacter, PSB, VAM), nitrogen, (50, 100, 225 kg/ha) and phosphorus (50, 75, 150 kg/ha) 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 (225kg/ha), phosphorus (150 kg/ha) and bio-fertilizer (Azotobacter) showed the highest values of average fruit weight (19.00 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), calcium (3985 kg/ha), magnesium (184.37 kg/ha) and sulphur (13.60 kg/ha). Similarly, the treatment combination of nitrogen (225 kg/ha), phosphorus (150 kg/ha) and bio-fertilizers (PSB) significantly affected number of primary flowers (8.00), number of secondary flowers (10.00), total number of flowers per plant (18.00), number of primary fruits per plant (7.00), number of secondary fruits (10.00), total number of fruits (17.00), available phosphorus (11 kg/ha), leaf phosphorus (0.30%). The treatments containing *Azotobacter* and PSB have decreased the organic matter content, the pH was slightly decreased while as no specific effect was observed on the electrical conductivity of soil.

Mahaveer *et al.* (2004) reported that strawberries grown in alfisols of semiarid areas in India results in suboptimal yields. Low organic carbon and low phosphorus (P) availability, in addition to high P fixation, affects P availability drastically, even when it is applied externally. The benefit to the yield of micro propagated strawberry 'Pajaro' through inoculation with arbuscular mycorrhizal (AM) fungi and P application was examined in a field experiment. Inoculated plants had a significantly greater fruit yield when grown at 150 kg P/ha, and the yield was comparable with uninoculated plants grown at 200 kg P/ha.

Talebnejad *et al.* (2007) reported that the effects of NPK on strawberry have been widely studied, but comparatively there was limited information about the effects of these application at flower induction period on production components. Therefore the effect of N and P (0, 25, 50, 100 μg/g soil) and K (0, 20, 40, 60 μg/g soil) treatments was investigated on the number of truss per plant, number of flower in the truss, number of achene per fruit, size and quality of fruit, total soluble solid and vitamin C. Nitrogen (25 mg/g) increased the number of flower in the truss however N (100 μg/g) decreased it. The effect of NPK and interaction of them on the number of the truss per plant was not significant. Different levels of N accompanied with application of P (100 μg/g)

increased vitamin C significantly. All levels of N and the interaction of all 3 nutrients caused an increase in achene number. The ratio of N:P is a key factor that influences fruit weight. When this ratio is near to one, fruit weight is the highest.

An experiment was conducted by Rosen *et al*. (1988) to determine the influence of supplemental N-P-K foliar fertilizers (9-8-7 or 16-2-3) applied during flowering, fruit enlargement and/or flower initiation on yield, quality, and nutrition of 'Earliglow' strawberries (*Fragaria ananassa D*). All plots received soil applied fertilizer at planting and at renovation according to soil test recommendations. Foliar fertilizers did not significantly increase total yield at any of the rates or times of application employed. Average yields the first year were 1.50 times greater than those the second year, regardless of whether foliar fertilizers were applied. Treatments did not significantly affect mean berry weight or percent soluble solids. Concentrations of N and P in recently matured leaves sampled during harvest were not significantly affected by foliar treatments, but K level was increased in the second year of the study by some foliar treatments.

Rauf *et al.* (1998) used different level of N.P.K. for strawberry Cv. 'Gorella' grown in containers. Four levels of N.P.K. i.e. 0, 2, 4 and 6 g/plant were studied. The data showed that 4 g of N.P.K./plant gave maximum number of flowers (29.00) per plant, maximum number of fruits/plant (19.00) and maximum number of runners/plant (1.50) by 2 g N.P.K/Plant and 6 g N.P.K/plant.

Hong *et al.* (2008) stated that optimizing plant nitrogen (N) and phosphorus (P) nutrition is required in healthy propagation of strawberry plants for fruit production. Strawberry (*Fragaria ananassa*) nutrient NPK supply was respectively at the rates of 105, 145 and 165 kg/ha, based on soil testing and regional recommendation. Results showed that strawberry 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 and total P uptake was 0.29±0.06 g/plant among the seven cultivars. Whole plant P accumulation increased with increasing of N accumulation (up to 4.70 g/plant, $R_2 = 0.76$, $P < 0.01$). It was suggested that strawberry plant propagation could be enhanced with nutrition accumulation ranges of 2.47-3.26 g N/plant and 0.25-0.34 g P/plant. Runner thinning would be an option for regulating strawberry plant N and P nutrition and plant productivity.

Nam *et al.* (2006) reported that elevated nitrogen and potassium concentrations in the fertilizer solution increased disease severity in contrast to phosphorus and calcium. The dry weight of the strawberry plants increased significantly with elevated concentrations of nitrogen (R_2=0.90) and phosphorus (R_2=0.88), but was not influenced by the elevated amounts of potassium (R_2=0.85) and calcium (R_2=0.65) concentrations.

Rahman *et al.* (1995) conducted an experiment on mineral fertilizers and green to estimate the effect on nutrient uptake, yield and internal tip-urn. Large applications of mineral fertilizers in increased growth, total nitrogen and nitrate concentrations at harvest, and increased the occurrence of internal tip-burn. Green mulch, as the only fertilizer or in combination with small amounts of mineral fertilizers, resulted in slower growth and lower total nitrogen and nitrate concentrations at harvest, and also prevented the occurrence of internal tip-burn. No visible symptoms of nutrient deficiencies were detected, but plant analyses showed that the concentrations of magnesium, zinc, manganese and copper were below the estimated sufficiency limits in all fertilizer regimes. High soil pH, 6.4-6.8, and large amounts of calcium in the soil decreased the availability of these elements. The results demonstrate the importance of simultaneous analyses of several elements in revealing suboptimal

concentrations and/or imbalances that depress yield and quality but do not result in visible symptoms.

Arancon *et al.* (2004) reported that vermicompost was incorporated into the top 10 cm of soil and supplemented, based on chemical analyses, with amounts of inorganic NPK fertilizers calculated to equalize the initial fertilizer rates of 85-155-125 kg/ha NPK applied to the inorganic fertilizer plots. All treatments were replicated four times, in a completely randomized design; at two field sites on Doles silt loam or Hoytville silty clay loam at Piketon and Fremont, Ohio, respectively. Vermicompost applications increased strawberry growth and yields significantly; including increases of up to 37% in leaf areas, 37% in plant shoot biomass, 40% in numbers of flowers, 36% in numbers of plant runners and 35% in marketable fruit weights.

Talebnejad *et al.* (2007) reported that the effects of NPK on strawberry have been widely studied, but comparatively there was limited information about the effects of this application at flower induction period on production components. Therefore the effect of N and P (0, 25, 50, 100 μg/g soil) and K (0, 20, 40, 60 μg/g soil) treatments was investigated on the number of truss per plant, number of flower in the truss, number of achene per fruit, size and quality of fruit, total soluble solid and vitamin C. Nitrogen (25 mg/g) increased the number of flower in the truss however N (100 μg/g) decreased it. The effect of NPK and interaction of them on the number of the truss per plant was not significant. Different levels of N accompanied with application of P (100 μg/g) increased vitamin C significantly. All levels of N and the interaction of all 3 nutrients caused an increase in achene number. The ratio of N:P is a key factor that influences fruit weight. When this ratio is near to one, fruit weight is the highest.

2.2 Literature on mulch

Collins (1997) reported that black polythene and polythene coated black paper mulches increased soil temperature and advanced emergence of potato. He also reported that transparent black polythene and polythene coated black paper mulches non significantly reduced the yield of potato from bare soil of 46.9 and 48.3 t/ha and clear polythene mulch.

Lai *et al.* (1989) studied the effect of different ratios of NPK combination on yield and nitrate accumulation of Chinese cabbage (*Brassica pekinensis*). The levels of N were 0, 180, 360, and 540 kg/ha; the levels of P_2O_5 were 0, 90, 180, 270 kg/ha; the levels of K_2O were 0, 90, 180, 270 kg/ha. The plant density of Chinese cabbage was 31thin500/ha. The results showed that the best results were obtained with N360 + P90 + K180. The nitrate accumulation was increased with the increase of the amount of N applied. Phosphate fertilizer had no significant effect on nitrate accumulation in plant; however, potassium fertilizer had a significant effect on nitrate content in plant. Thirty and 50 days after planting were two key periods for fertilizer application on Chinese cabbage.

The allelopathic potential of isothiocyanates released by turnip with mulch was evaluated by Petersen *et al.* (2001) in Germany. Six different mulches were identified for turnip cultivation. In their recorded results it was found that yield and yield contributing characters was reportable than the control condition. Again, in the soil where mulch was incorporated, only low amounts of weeds were recorded.

Saifullah *et al*. (1996) while working with mulches and irrigation on cabbage in the Horticulture Farm, Bangladesh Agricultural University, Mymensingh and reported that yield and most of the yield contributing characters like plant height, number of loose leaves per plant, diameter and thickness of head, weight of loose leaves, stem, roots, head, whole plant and total dry matter per

head were significantly increased by the application of irrigation and mulches. Mulching was found to be more effective during the early stage of plant growth. The highest marketable yield was obtained by irrigation treatment (37.09 t/ha) followed by black polythene (33.16 t/ha), water hyacinth (26.91 t/ha), sawdust (20.66 t/ha) and straw (24.64 t/ha) and the lowest (12.68 t/ha) by the control condition. They concluded that as an alternative to irrigation, water hyacinth and straw can be adopted as feasible mulches to increase the yield by conserving the residual soil moisture.

Shamim and Kamruzzaman (2004) studied the effect of four levels of nitrogen and mulching on growth and yield of Chinese cabbage and found that levels of nitrogen and mulching had significant influence on the growth and yield. The maximum plant height, spread of plant, root length, stem length, fresh weight roots, dry matter of root, days to maturity, marketable yield (77.13't/ha) and gross yield (103.90 t/ha) were recorded when nitrogen was applied at the rate of 240 kg/ha. The highest gross yield (104.04 t/ha) was obtained from the black polythene mulch followed by water hyacinth mulch (99.60 t/ha). Black polythene mulch produced the highest marketable yield (78.14 t/ha). The maximum gross yield (118.4 t/ha) and marketable yield (94.03 t/ha) were found in the treatment combination of 240 kg N/ha with polythene mulch.

Mahdieh *et al.* (2012) conducted an experiment using three kinds of mulches (Transparent and black PE and rice straw) and found that plastic mulch increased minimum temperature of soil, accelerated plant height, early growth, early yield, and bring satisfactory weed control without any application of herbicides. Results also showed that garlic total yield, bulb ash percent, TSS, vitamin C and flavonoids content were affected by mulching. Although mulching could improve some quality indices in garlic but no effect on forcing was observed. Due to two years experiment and interaction between year and mulches the usage of rice straw in rainy and cool season and plastic mulch in low rain fall and warm season recommended increasing crop quality.

Mulching helps in significant increase in N, P and K uptake over unmulched (Hossain *et al*., 2007). Therefore, a better understanding of the uses of mulching in garlic production is very important in order to develop management strategies, which optimize moisture and increasing returns to the producers by increasing Garlic yield and quality.

Taja *et al.* (1991) reported that mulching by rice straw with optimum inorganic fertilizer application of 50 kg N/ha were good for canopy coverage of potato.

In an experiment conducted by Yoon *et al.* (1984) to study the effect of mulches on Chinese cabbage growth and yield in Vegetable Research Institute, Seoul, Korea Republic and found that black polythene, straw and clear polythene gave higher rate of growth and development.

Leaf area, leaf number of sweet potato cv. Jewel were significantly higher for mulched than for unmulched plants as concluded by Hochmuth and Howell (1983) adding that the highest marketable yield (18. 6 t/ha) was obtained from mulched raised beds where flat unmulched beds gave the lowest yield treatments.

CHAPTER III
MATERIALS AND METHODS

An experiment was conducted in the Horticulture Farm of Sher-e Bangla Agricultural University, Dhaka, Bangladesh during the period from October 2018 to March 2019 to study the effect of different levels of phosphorus and mulching on growth and yield of strawberry. This chapter includes materials and methods that were used conducting in the experiment. It consists of a short description of locations of the experimental site, characteristics of soil, climate, materials used for the seedlings, treatment of the investigation, layout and design of the experiment, land preparation, manuring and fertilizing, transplanting of seedlings, intercultural operations, harvesting, data collection procedure and statistical analysis etc. The details regarding materials and methods of this experiment are presented below under the following headings –

3.1 Experimental sites

The experiment was conducted at the Horticulture Farm, Sher-e-Bangla Agricultural University, Dhaka, during the period from October, 2018 to March, 2019. The location of the site is $23^0$74' N latitude and $90^0$35' E longitudes with an elevation of 8.2 meter from sea level (Anon., 1989) in Agro-Ecological Zone of Madhupur Tract (AEZ No. 28).

3.2 Climatic conditions

The experiment site was located in the subtropical monsoon climatic zone, set a parted by heavy rainfall during the months from April to September (Kharif season) and scanty of rainfall during the rest of the year (Rabi season). In addition, under the sub-tropical climatic condition, this is individualized by high temperature, high humidity and heavy precipitation with seasonal unexpected winds and relatively long in Kharif season (April- September) and sufficient sunlight with moderately low temperature, intensity of humidity and short day period of during Rabi season (October-March). The information of

weather regarding the atmospheric temperature, relative humidity, rainfall, sunshine hours and soil temperature persuaded at the experimental site during the whole period of observation (Appendix I).

3.3 Characteristics of soil

The experimental soil belongs to the Modhupur Tract under AEZ No. 28 (UNDP-FAO, 1988). The land which selected was medium high and the soil series was Tejgaon. The soil characteristics of experimental plot were analyzed in the SRDI, Soil Testing Laboratory, Khamarbari, Dhaka and the experiment field primarily had a pH of 6.5.

3.4 Experimental materials

3.4.1 Planting materials

The seedlings of RABI-3 variety were collected from Green Garden Landscape Nursery, Agargaon, Dhaka which were used as planting materials in this experiment.

3.4.2 Phosphorus and mulch materials

Phosphorus fertilizers and different mulch materials like paddy straw and black polythene were collected from local market.

3.5 Treatment of the experiment

The experiment was designed to study the effects of different levels of P and mulch materials on growth and yield of strawberry. The experiment considered of two factors. Details are presented below:

Factor A: Levels of P fertilizer

In this experiment four levels of phosphorus fertilizers used-

P_0 - 0 kg/ha
P_1- 120 kg/ha
P_2 - 170 kg/ha
P_3 - 220 kg/ha

Factor B: Mulch materials

Three different types of mulch used in this experiment:

M_0: (No mulch application)

M_1: Paddy straw

M_2: Black polythene

The treatment combinations were:

P_0M_0, P_0M_1, P_0M_2, P_1M_0, P_1M_1, P_1M_2, P_2M_0, P_2M_1, P_2M_2, P_3M_0, P_3M_1, P_3M_2

3.6 Design and layout of the experiment

The two factorial experiment was provoked Randomized Complete Block Design (RCBD) with three replications thus comprised 36 plots in the experiment (Figure 1).

3.6.1 Spacing and plot size

The size of each plot was 1.2 m × 0.8 m. The distance between blocks and plots were 1 m and 0.5 m, respectively. There were 6 plants in a unit plot with spacing 40 cm × 40 cm.

3.7 Production methodology

3.7.1 Land preparation

The land was first open by ploughing with the help of power tiller and then it kept open to sun for seven days prior to further ploughing. Afterwards it was prepared by ploughing and cross ploughing followed by laddering. The weeds and stubbles were removed after each laddering. Simultaneously, the clods were broken and the soil was made into good tilth.

3.7.2 Application of manure and fertilizers

The manures and fertilizers and their methods of application for the present experiment were as follows:

Table 1. Manures and fertilizer with BARI recommended dose along with plot wise application dose

SL No.	Manures/ fertilizers	Recommended dose/ha.	Recommended dose/research area
1	Cowdung	10 t	21.6 kg
2	Urea	200 kg	864 g
3	MoP	100 kg	432 g
4	Gypsum	10kg	43.2 g

Half of the quantity of cowdung and entire quantity of gypsum applied during land preparation. The remaining half cowdung, the entire amount of TSP and one third of each Urea and MoP applied during bed preparation (prior a week of transplanting). The rest of Urea and MoP applied as top dressing in two equal installments at 15 and 30 days after sowing.

3.7.3 Transplanting of seedling

Healthy and disease free seedlings were planted according to treatment. Seedlings were transplanted in such a way that the crown did not go much under the soil or did not remain in shallow. On an average, seedlings were planted at 7 cm depth in pot on 15th October, 2018. There were 36 plots and each plot had 6 plants.

3.8 Intercultural operations

Following operations were done.

3.8.1 Weeding

Weeding was necessary to keep the plant free from weeds. The newly emerged weeds were uprooted carefully from the field after complete emergence of sprouts and afterwards when necessary.

3.8.2 Top dressing

After basal doses, the remaining doses of urea top dressed in 15 days after planting. The fertilizers were applied on both sides of plant rows and mixed with the soil by hand.

3.8.3 Roguing

Roguing refers to the act of identifying and removing plants with undesirable characteristics from agricultural fields. Rogues are removed from the fields to preserve the quality of the crop being grown. Diseased plants were removed from the strawberry field.

3.8.4 Protection

The crop was protected from the attack of insect-pest by spraying Malathion. The insecticide application was made fortnightly as a matter of routine work from transplanting to the end of fruit setting. Anthracnose is responsible for major losses of strawberry production worldwide. Fruit rot and flower blight are the common symptoms in fruiting fields. Bavistin DF, Dithane M- 45, Sulcox 50 WP, Corzim 50 WP and Rovral 50 WP were tested against the fungus and among these Bavistin DF & Rovral 50 WP found effective.

3.8.5 Harvesting

The crop was harvested depending upon the maturity. Days to harvest were calculated also from the date of showing up to the attainment of edible fruit maturity stage.

3.9 Parameters of the experiment

Data were collected in respect of following parameters:

1. **Growth related parameters**
    a) Plant height
    b) Number of leaves
    c) Leaf area

d) Number of runners per plant
e) Runner length
f) Days to bud initiation
g) Days to flowering
h) Days to fruiting
i) Days to fruit maturity

2. Yield attributing parameters

j. Flower number per plant
k. Fruit number per plant
l. Fruit length
m. Fruit diameter
n. Individual Fruit weight
o. Yield per plant
p. Yield per hectare

3. Quality attributing parameters

q. Brix percentages

3.10 Data collection

Five plants were selected from each unit plot for the collection of data. However, the yield of all plants was considered per plot yield. Data have been collected on the basis of three attributes like- growth related parameters, yield attributing parameters and quality attributes parameters.

3.10.1 Plant height

Plant height of each sample plant was measured in centimeter from the ground level to the tip of the longest leaf and mean value was calculated and expressed in cm.

3.10.2 Number of leaves per plant

The number of leaves per plant was counted from the selected plants and their average mean was taken as the number of leaves per plant. It was recorded during different days at 20 DAT, 40 DAT and 60 DAT.

3.10.3 Leaf area measurement

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

3.10.4 Number of runners

Number of runners per plant was recorded by counting all runners from each plant and mean was calculated. After 60 days of transplanting number of runners was not counted and all of runners including newly emerged were removed for better yield and quality fruits.

3.10.5 Length of runner

The length of runner was measured using a meter scale and was expressed in centimeter.

3.10.6 Days to flower bud initiation, flowering, fruit setting and harvesting

Days to flower bud initiation (visual observation), flowering, fruiting and harvesting were counted the days from the date of strawberry plantlets transplanting.

3.10.7 Number of flowers per plant

Number of flowers per plant was counted and the data were recorded from selected 5 plants and mean value was calculated.

3.10.8 Number of fruits per plant

Number of fruits per plant was counted and the data were recorded from randomly selected 5 plants and mean value was recorded.

3.10.9 Fruit length and diameter measurement

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

3.10.10 Individual fruit weights

Fruit weight was measured by Electronic Precision Balance in gram. Total fruit weight of each plot was obtained by addition of weight of the total fruit number and average fruit weight was obtained from division of the total fruit weight by total number of fruits.

3.10.11 Measurement of brix percentage

Brix percentages were measured by Portable Refractometer. Every single fruit was blend and juice was collected to measure brix percentage. Mean was calculated for each treatment. Brix percentage of fruits was measured at room temperature.

3.10.12 Yield per plant

The total fruit weight of per plant was obtained by addition of the weight of total fruit measured by using a weighing balance and was expressed in gram.

3.10.13 Yield per hectare

The weight of fruits from each plot was measured by using a weighing balance and converted into hectare and was expressed in t/ha.

3.11 Statistical Analysis

The data recorded for different parameters were statistically analyzed using MSTAT-C computer package program to find out the significance of variation among the treatments and treatment means were compared by Duncan's Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

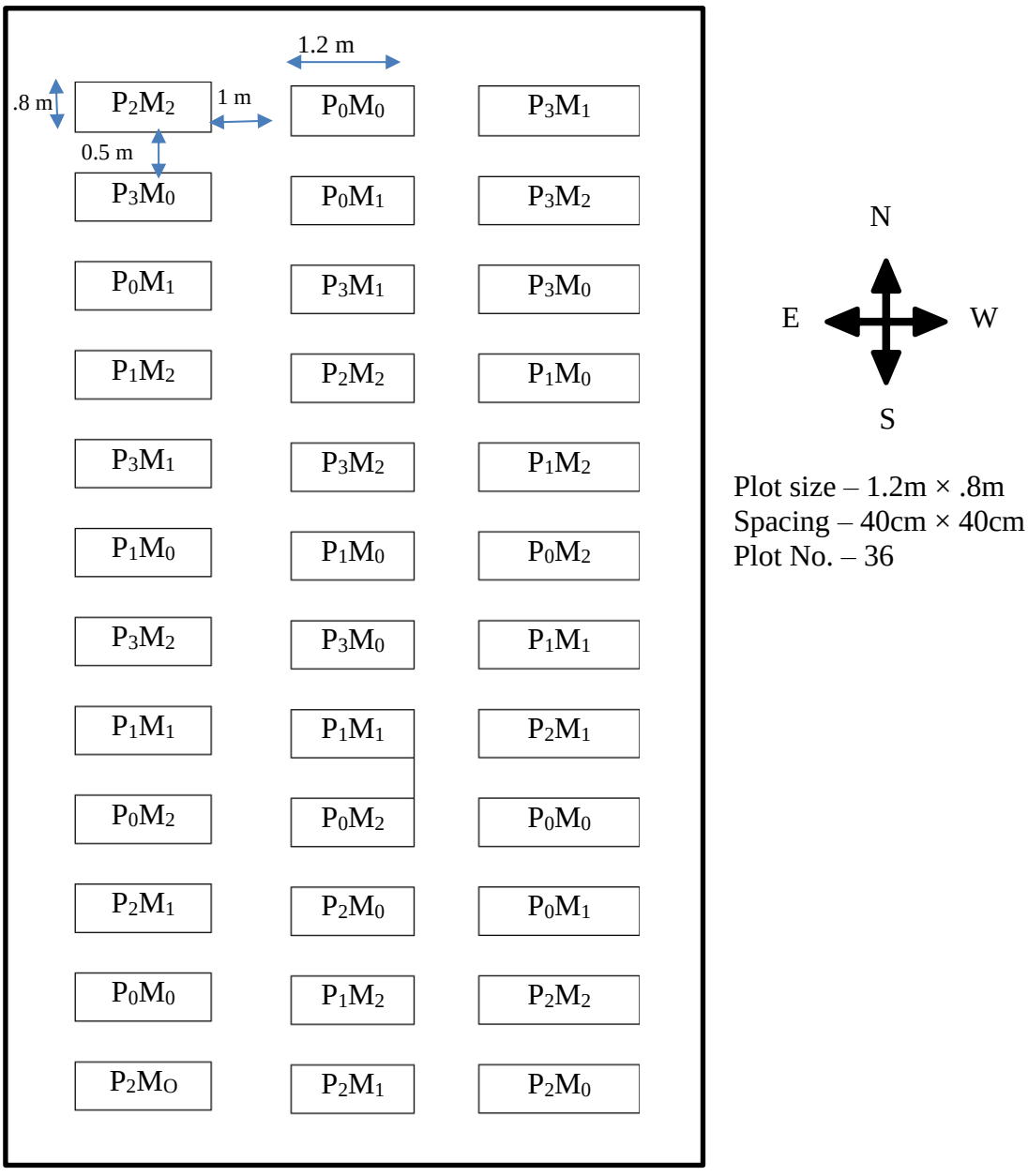

Figure 1. Lay out of the experiment

CHAPTER IV
RESULT AND DISCUSSION

The present experiment was conducted to find out the effect of phosphorus fertilizers and mulches on growth and yield of strawberry. Data on different yield contributing characters and yield was recorded. The analysis of variance (ANOVA) of the data on different growth parameters and yield of strawberry are given in Appendix II-VII. The results have been presented and discussed, and possible interpretations have been given under the following headings-

4.1 Plant height

Plant height is obviously important growth parameters in strawberry. Significant variation was found in the effect of different phosphorus levels in terms of plant height (Appendix II). The mean plant height ranged from 8.20 to 22.30 cm at 20, 40 and 60 DAT. At 20 DAT, the tallest plant was found from P3 (15.97 cm) where was the shortest from P_0 (8.18 cm) (Figure 2). At 40 DAT, the tallest plant was found from P_3 (19.24 cm) where was the shortest from P_0 (10.84 cm) (Figure 2). At 60 DAT, the tallest plant was found from P_3 (22.30 cm) where was the shortest from P_0 (14.30 cm) (Figure 2). The present finding also agreed to the results of Yusuf *et al.* (2003). Plant height as well as growth of plant significantly increased with the application of phosphorus fertilizers reported (Zargar *et al.*, 2008). They observed that plant height was significantly increased with the high rates of fertilizer application specially phosphorus. Hong *et al*. (2008) reported that optimizing phosphorus (P) nutrition is required in healthy propagation of strawberry plants as well as for fruit production.

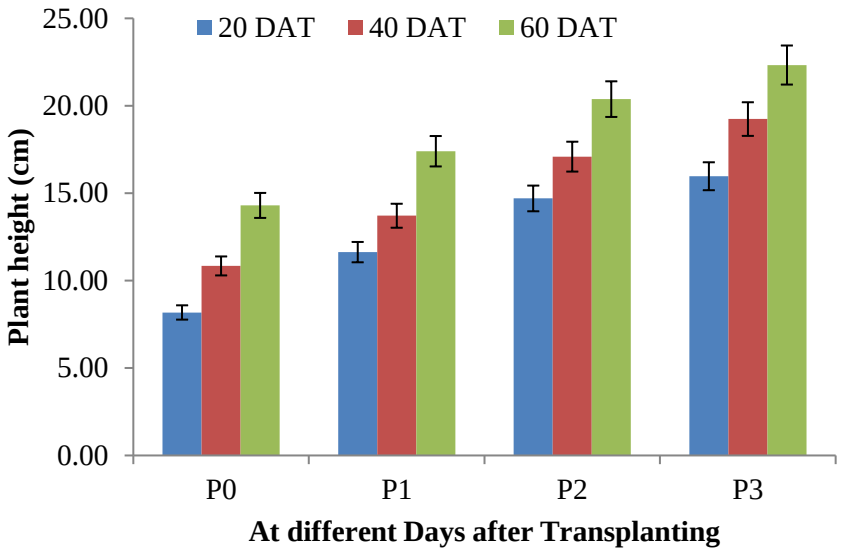

Figure 2. Effect of phosphorus levels on plant height of strawberry at different days after transplanting

(Here, P_0: 0 kg/ha, P_1: 120 kg/ha, P_2: 170 kg/ha, P_3: 220 kg/ha)

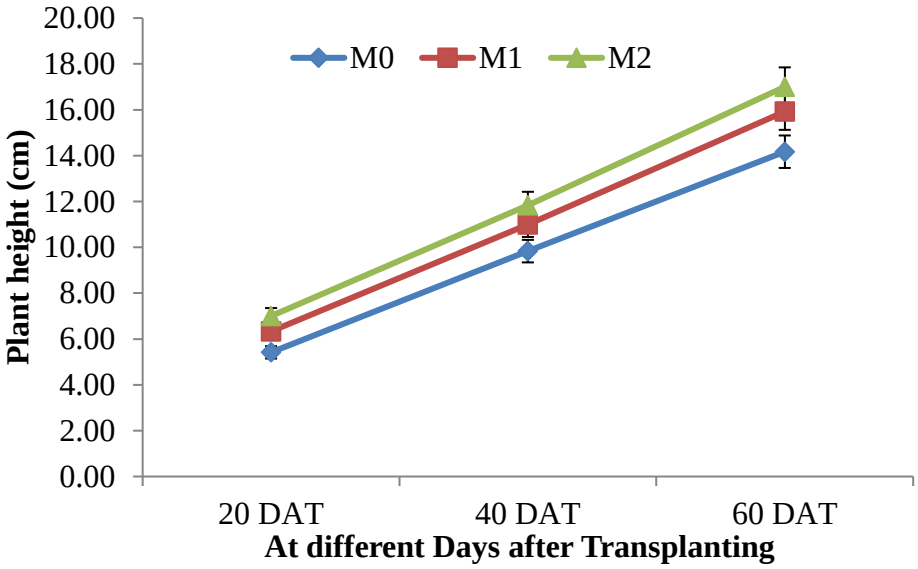

Figure 3. Effect of different mulch on plant height of strawberry at different days after transplanting

(Here, M_0: No mulch, M_1: Paddy straw, M_2: Black polythene mulch)

Different mulches showed significant variation in plant height at different days after planting (Appendix II). The mean plant height ranged from 11.05 cm to 20.00 cm at 20, 40 and 60 DAT. At 20 DAT, the highest plant height (14.17 cm) was measured with the plants grown over black polythene mulch (M_2) while the lowest (5.42 cm) in no mulch treatment (M_0) (Figure 3). At 40 DAT, the highest plant height (15.92 cm) was measured with the plants grown over black polythene mulch (M_2) while the lowest (6.33 cm) in no mulch treatment (M_0) (Figure 3). At 60 DAT, the highest plant height (20.00 cm) was measured with the plants grown over black polythene mulch (M_2) while the lowest (16.80 cm) in no mulch treatment (M_0) (Figure 3). The effect of black polythene mulch may be accounted for conserving sufficient soil moisture resulting in maximum plant height. On the contrary, plants grown without mulch may suffer from water stress and cannot accomplish full vegetative growth. Shamim and Kamruzzaman (2004) reported that growth of mulched Chinese cabbage plant was taller than the control.

Significant differences were observed due to the combined effect of phosphorus levels and mulches on plant height at 20, 40 and 60 DAT (Appendix II). The mean plant height ranged from 7.73 cm to 24.60 cm at 20, 40 and 60 DAT. It was found that tallest (17.930 cm) plant was produced by P_3M_2 and the shortest plant (7.73 cm) was obtained from P_0M_0 treatment at 20 DAT (Table 2). It was found that tallest (21.37 cm) plant was produced by P_3M_2 and the shortest plant (10.70 cm) was obtained from P_0M_0 treatment at 40 DAT (Table 2). It was observed that tallest (24.60 cm) plant was produced by P_3M_2 and the shortest plant (13.77 cm) was obtained from P_0M_0 treatment at 60 DAT (Table 2).

Table 2. Interaction effect of phosphorus levels and mulches on plant height of strawberry at different days after transplanting

Plant height at (cm)			
Treatment	20 DAT	40 DAT	60 DAT
P_0M_0	7.73 h	10.70 g	13.77 f
P_0M_1	8.00 h	10.83 g	14.53 ef
P_0M_2	8.80 g	11.00 g	14.60 ef
P_1M_0	10.00 f	12.37 f	15.70 e
P_1M_1	12.33 e	14.20 e	17.90 d
P_1M_2	12.57 e	14.57 e	18.60 d
P_2M_0	12.70 e	14.40 e	17.70 d
P_2M_1	15.60 c	18.23 c	21.33 b
P_2M_2	15.80 c	18.63 bc	22.10 b
P_3M_0	13.77 d	16.87 d	19.90 c
P_3M_1	16.20 b	19.50 b	22.50 b
P_3M_2	17.93 a	21.37 a	24.60 a
LSD $_{(0.05)}$	0.39	1.14	1.27
CV%	1.82	4.41	4.03

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

Here, P_0: 0 kg/ha, P_1: 120 kg/ha, P_2: 170 kg/ha, P_3: 220 kg/ha and M_0: No mulch, M_1: Paddy straw, M_2: Black polythene mulch

4.2 Number of leaves

Significant difference was found in respect of number of leaf due to application of different levels of phosphorus at different days of transplanting of strawberry (Appendix III). The mean of leaf number ranged from 3.90 to 20.00 at 20, 40 and 60 DAT. At 20 DAT, the maximum (8.22) number of leaves per plant was recorded from P_3 and the minimum leaf number (3.89) was obtained from control (Figure 4). At 40 DAT, the maximum (13.56) number of leaves per plant was recorded from P_3 and the minimum leaf number (8.00) was obtained from control (Figure 4). At 60 DAT, the maximum (20.00) number of

leaves per plant was recorded from P_3 and the minimum leaf number (12.10) was obtained from control (Figure 4). The result also supported to the finding of Mohamed *et al.* (2011).

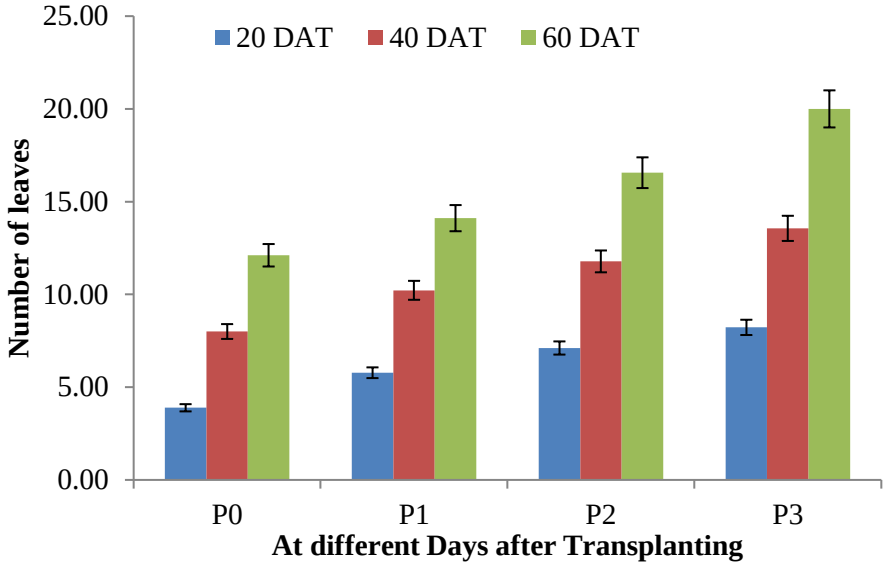

Figure 4. Effect of phosphorus levels on plant height of strawberry at different days after transplanting

(Here, P_0: 0 kg/ha, P_1: 120 kg/ha, P_2: 170 kg/ha, P_3: 220 kg/ha)

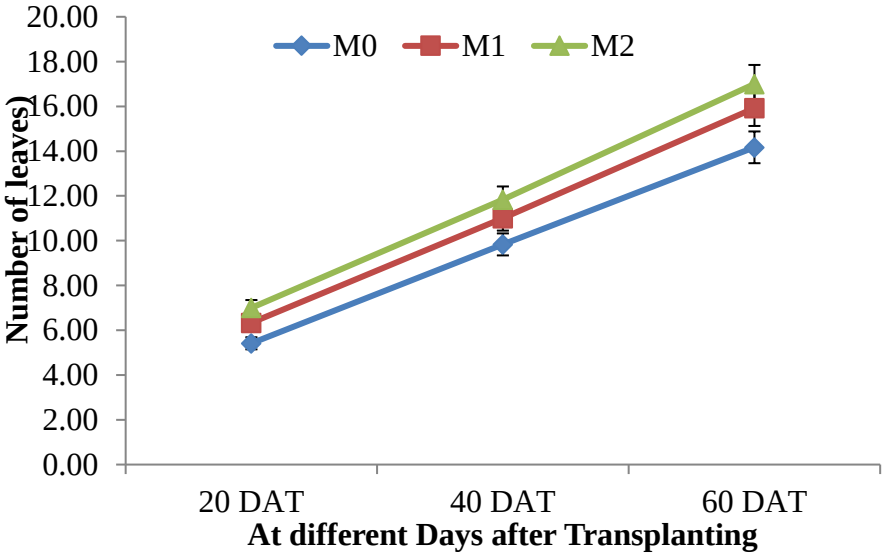

Figure 5. Effect of different mulch on leaf number of strawberry at different days after transplanting

(Here, M_0: No mulch, M_1: Paddy straw, M_2: Black polythene mulch)

Statistically significant variation was recorded in terms of number of leaves per plant varied statistically due to the mulching of strawberry at 20, 40 and 60 days after transplanting (Appendix III). The mean of leaf number ranged from 5.40 to 17.00 at 20, 40 and 60 DAT. At 20 DAT, the maximum (14.17) number of leaves per plant was recorded from M_2 and the minimum (5.42) was from M_0 (Figure 4). At 40 DAT, the maximum (15.92) number of leaves per plant was recorded from M_2 and the minimum (6.33) was from M_0 (Figure 4). At 60 DAT, the maximum (17.00) number of leaves per plant was recorded from M_2 and the minimum (7.00) was from M_0 (Figure 4). Mulch increases the growth and development of plant and the maximum number of leaves per plant was found in mulch condition. Mikkelsen (2000) recorded maximum number of leaves with mulching condition using black polythene mulch and water hyacinth.

In case of combined effect of phosphorus levels and mulches, significant differences were observed due to the number of leaves at 20, 40 and 60 DAT (Appendix III). The mean of leaf number ranged from 3.33 to 22.33 at 20, 40 and 60 DAT. The maximum number of leaf (9.33) was found in P_3M_2 and the minimum (3.33) was obtained from P_0M_0 treatment at 20 DAT (Table 3). The maximum number of leaf (15.33) was found in P_3M_2 and the minimum (7.67) was obtained from P_0M_0 treatment at 40 DAT (Table 3). The maximum number of leaf (22.33) was found in P_3M_2 and the minimum (11.33) was obtained from P_0M_0 treatment at 60 DAT (Table 3).

Table 3. Interaction effect of phosphorus levels and mulches on leaf number of strawberries at different days after transplanting

Number of leaves at			
Treatment	20 DAT	40 DAT	60 DAT
P_0M_0	3.33 h	7.67 h	11.33 h
P_0M_1	4.00 g	8.00 h	12.33 gh
P_0M_2	4.33 g	8.33 h	12.67 fg
P_1M_0	5.33 f	9.33 g	13.67 ef
P_1M_1	5.67 ef	10.33 f	14.00 e
P_1M_2	6.33 d	11.00 ef	14.67 e
P_2M_0	6.00 de	10.67 f	14.33 e
P_2M_1	7.33 c	12.00 cd	17.00 d
P_2M_2	8.00 b	12.67 c	18.33 c
P_3M_0	7.00 c	11.67 de	17.33 cd
P_3M_1	8.33 b	13.67 b	20.33 b
P_3M_2	9.33a	15.33 a	22.33 a
$LSD_{(0.05)}$	0.66	0.75	1.19
CV%	6.23	4.05	4.49

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

Here, P_0: 0 kg/ha, P_1: 120 kg/ha, P_2: 170 kg/ha, P_3: 220 kg/ha and M_0: No mulch, M_1: Paddy straw, M_2: Black polythene mulch

4.3 Leaf area

Significant variation was found for leaf area in case of phosphorus levels and control condition (Appendix IV). Maximum leaf area (64.50 cm^2) was observed (P_3) condition and minimum leaf area (36.00 cm^2) was observed in (P_0) treatment (Figure 6). Arancon *et al.* (2004) found the similar results.

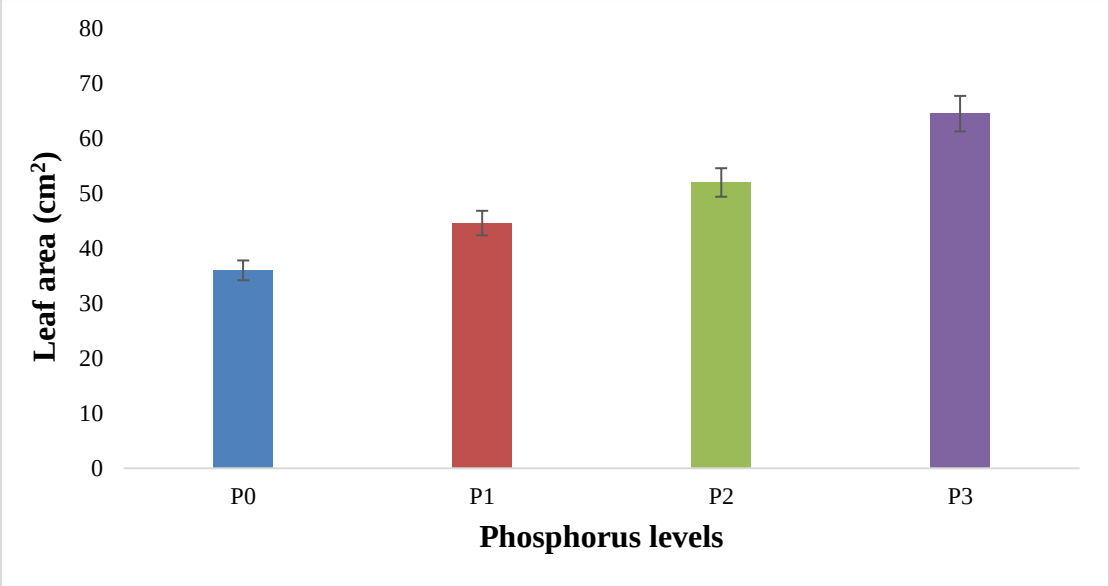

Figure 6. Effect of phosphorus levels on leaf area of strawberry

(Here, P_0: 0 kg/ha, P_1: 120 kg/ha, P_2: 170 kg/ha, P_3: 220 kg/ha)

In case of mulches, significant variation was found in leaf area (Appendix IV). Maximum leaf area (55.20 cm^2) was found in black polythene mulch (M_2) while minimum (43.60 cm^2) found in M_0 where no mulch was used (Figure 7). Taja *et al*. (1991) reported that leaf length and leaf canopy increased with application of mulch.

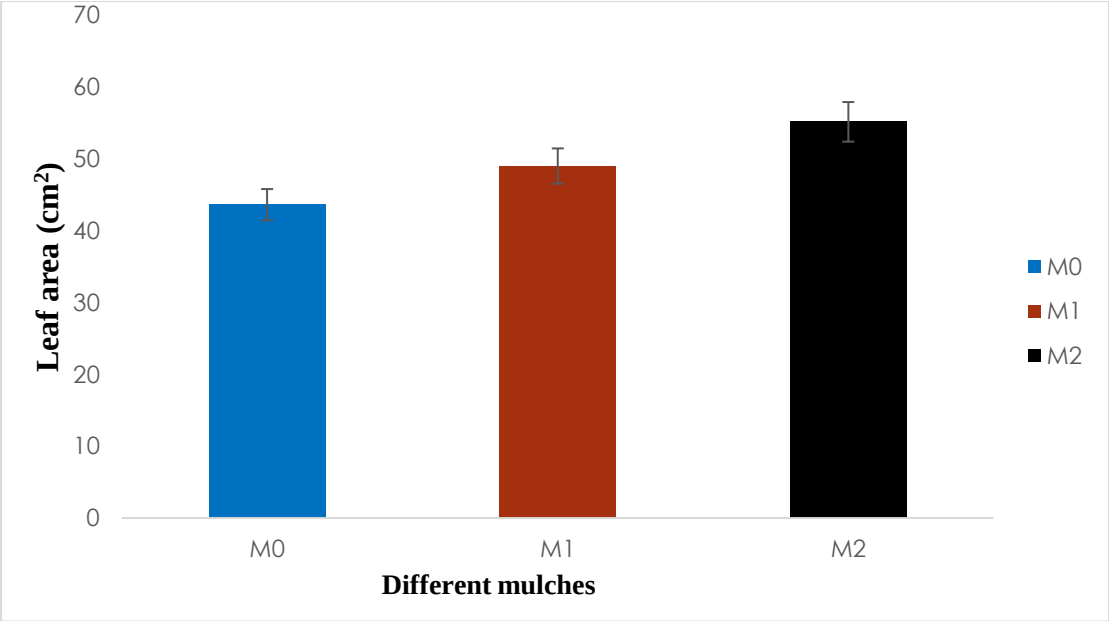

Figure 7. Effect of different mulch on leaf area of strawberry

(Here, M_0: No mulch, M_1: Paddy straw, M_2: Black polythene mulch)

In case of combined effect of phosphorus fertilizers levels and different mulches, leaf area of strawberry showed significant variation (Appendix IV). Maximum leaf area (73.27 cm^2) was found in 220kg/ha of phosphorus used with black polythene (P_3M_2) and minimum leaf area (33.27 cm^2) was found in control treatment (P_0M_0) (Table 4).

4.4 Number of runners

Phosphorus fertilizers significantly affected on runner number production of strawberry (Appendix IV). Maximum number of runner (15.30) was observed in P_3 whereas minimum (8.00) in P_0 (Figure 8). Sharma and Alok (2004) described similar opinion that increasing rate of phosphorus increased number of runners per plant of strawberry.

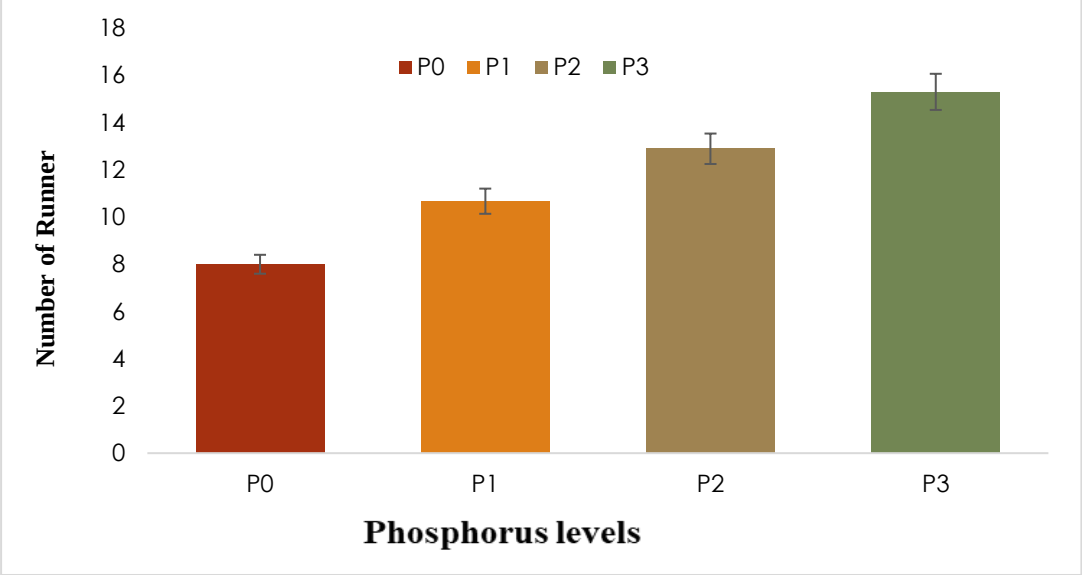

Figure 8. Effect of phosphorus levels on runner number of strawberry
(Here, P_0: 0 kg/ha, P_1: 120 kg/ha, P_2: 170 kg/ha, P_3: 220 kg/ha)

In case of mulches, significant variation was found in runner number per plant (Appendix IV). Maximum number of runner (12.90) was found in black polythene mulch (M_2) while minimum (10.50) found in M_0 where no mulch was used (Figure 9). A similar result was found in Mohamed *et al.* (2011).

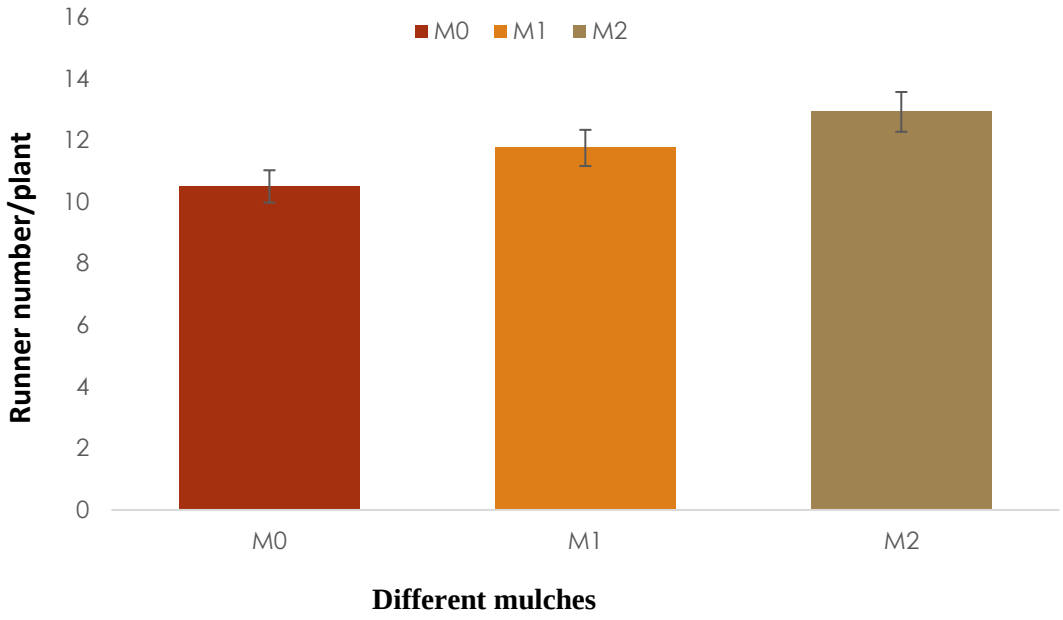

Figure 9. Effect of different mulch on runner number of strawberry
(Here, M_0: No mulch, M_1: Paddy straw, M_2: Black polythene mulch)

In case of combined effect of phosphorus fertilizer levels and different mulches, runner number of strawberry showed significant variation (Appendix IV). Maximum number of runner (17.00) was found in 220kg/ha. of phosphorus used with black polythene (P_3M_2) and minimum number of runner (7.33) was found in control treatment (P_0M_0) (Table 4).

Table 4. Interaction effect of phosphorus levels and mulches on leaf area, runner number, runner length and flower number of strawberry

Treatment	leaf area (cm^2)	Runner number	Runner length (cm)	Flower/plant
P_0M_0	33.27 i	7.33 i	17.73 i	20.33 h
P_0M_1	36.23 h	8.00 hi	18.00 i	21.00 h
P_0M_2	38.37 h	8.67 h	18.20 i	21.33 h
P_1M_0	42.80 g	9.67 g	19.03 h	23.67 g
P_1M_1	44.53 fg	10.67 f	20.77 g	24.67 fg
P_1M_2	46.47 f	11.67 e	21.50 f	25.67 f
P_2M_0	43.70 g	11.33 ef	21.10 fg	24.67 fg
P_2M_1	49.67 e	13.00 d	24.47 e	27.33 e
P_2M_2	62.57 c	14.33 c	26.23 c	28.67 d
P_3M_0	54.73 d	13.67 cd	25.23 d	30.00 c
P_3M_1	65.63 b	15.33 b	27.17 b	33.33 b
P_3M_2	73.27 a	17.00 a	30.50 a	37.33 a
LSD $_{(0.05)}$	2.47	0.78	0.70	1.11
CV%	2.96	3.91	1.83	2.48

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

Here, P_0: 0 kg/ha, P_1: 120 kg/ha, P_2: 170 kg/ha, P_3: 220 kg/ha and M_0: No mulch, M_1: Paddy straw, M_2: Black polythene mulch

4.5 Length of runner

Significant variation was found for runner length in case of phosphorus levels (Appendix IV). The highest runner length (27.60 cm) was observed (P_3) condition and the lowest runner length (18.00 cm) were observed in control (P_0) treatment (Figure 10).

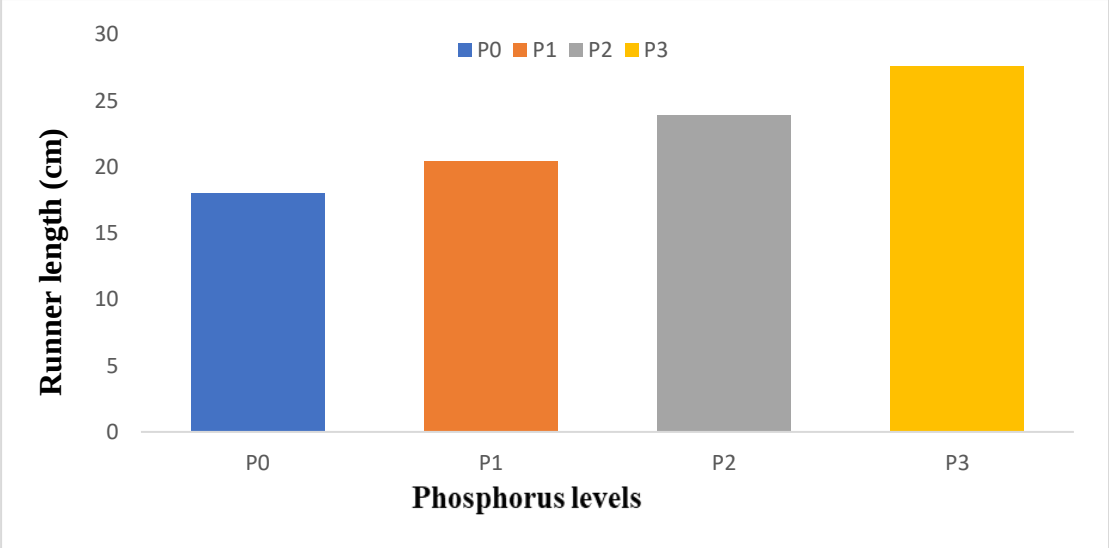

Figure 10. Effect of phosphorus levels on runner length of strawberry

(Here, P_0: 0 kg/ha, P_1: 120 kg/ha, P_2: 170 kg/ha, P_3: 220 kg/ha)

In case of mulches, significant variation was found in length of runner (Appendix IV). The highest length of runner (24.10 cm) was found in black polythene mulch (M_2) while minimum (20.80 cm) found in M_0 where no mulch was used (Figure 11).

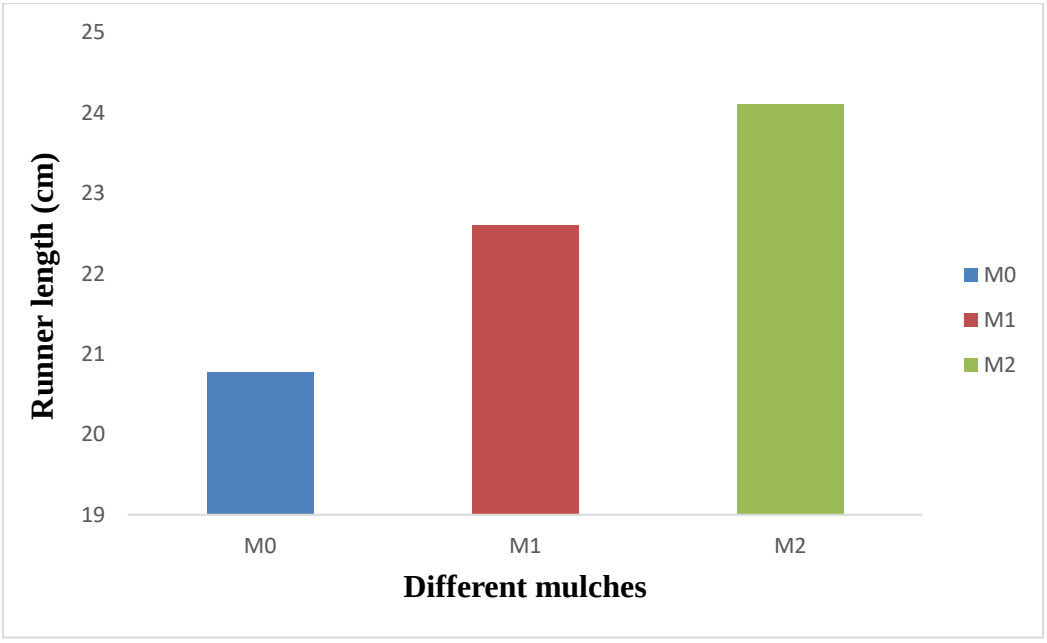

Figure 11. Effect of different mulch on runner number of strawberry

(Here, M_0: No mulch, M_1: Paddy straw, M_2: Black polythene mulch)

In case of combined effect of phosphorus fertilizers levels and different mulches, runner length of strawberry showed significant variation (Appendix IV). The highest length of runner (30.50 cm) was found in 220kg/ha. of phosphorus used with black polythene (P_3M_2) and the lowest length of runner (17.73 cm) was found in control treatment (P_0M_0) (Table 4).

4.6 Days to bud initiation

Days to flower bud initiation was significantly affected by phosphorus fertilizers (Appendix V). Flower bud initiation was earliest in (P_3) where required days (61.86) and delayed in control (P_0: 79.84 days) (Table 5). Early flower bud initiation is vital to minimize cropping period that will increase cropping intensity.

In case of mulches, significant variation was found in days to flower bud initiation (Appendix V). Flower bud initiation was earliest in black polythene mulch (M_2) where required days (66.90) and delayed in control (M_0: 74.39 days) (Table 6).

In case of combined effect of phosphorus fertilizers levels and different mulches, days to bud initiation of strawberry showed significant variation (Appendix V). Flower bud initiation was earliest in 220kg/ha of phosphorus used with black polythene (P_3M_2) where required days (56.90) which was statistically similar with (P_3M_1) and delayed in control treatment (P_0M_0: 81.87) which was statistically similar with P_0M_1 (Table 7).

Table 5. Effect of phosphorus levels on days to bud initiation, days to flowering, days to fruiting and days to harvesting of strawberry

Treatment	Days to Bud initiation	Days to flowering	Days to fruiting	Days to harvesting
P_0	79.84 a	84.89 a	91.44 a	106.40 a
P_1	70.88 b	75.44 b	82.11 b	98.67 b
P_2	68.86 c	72.89 c	78.78 c	90.11 c
P_3	61.86 d	66.56 d	73.33 d	84.11 d
LSD $_{(0.05)}$	1.15	1.12	0.91	0.86
CV%	1.67	1.52	1.15	0.93

Here, P_0: 0 kg/ha, P_1: 120 kg/ha, P_2: 170 kg/ha, P_3: 220 kg/ha

4.7 Days to flowering

Days to flowering was significantly affected by phosphorus fertilizers (Appendix V). Flowering was earliest in (P_3) where required days (66.56) and delayed in control (P_0: 84.89 days) (Table 5). Early flower bud initiation is vital to minimize cropping period that will increase cropping intensity.

In case of mulches, significant variation was found in days to flower bud initiation (Appendix V). Flowering was earliest in black polythene mulch (M_2) where required days (71.67) and delayed in control (M_0: 78.83 days) (Table 6).

In case of combined effect of phosphorus fertilizers levels and different mulches, days to flowering of strawberry showed significant variation (Appendix V). Flower bud initiation was earliest in 220kg/ha of phosphorus used with black polythene (P_3M_2) where required days (61.67) and delayed in control treatment (P_0M_0: 86.67) which was statistically similar with P_0M_1 (Table 7).

4.8 Days to fruiting

Days to fruiting was significantly affected by phosphorus fertilizers (Appendix V). Fruiting was earliest in (P_3) where required days (73.33) and delayed in control (P_0: 91.44 days) (Table 5).

In case of mulches, significant variation was found in days to flower bud initiation (Appendix V). Fruiting was earliest in black polythene mulch (M_2) where required days (77.83) and delayed in control (M_0: 85.58 days) (Table 6).

In case of combined effect of phosphorus fertilizers levels and different mulches, days to fruiting of strawberry showed significant variation (Appendix V). Flower bud initiation was earliest in 220kg/ha of phosphorus used with black polythene (P_3M_2) where required days (67.33) and delayed in control treatment (P_0M_0: 93.00) which was statistically similar with P_0M_1 (Table 7).

4.9 Days to harvesting

Days to harvesting was significantly affected by phosphorus fertilizers (Appendix V). Harvesting was earliest in (P_3) where required days (84.11) and delayed in control (P_0: 106.40 days) (Table 5).

In case of mulches, significant variation was found in days to flower bud initiation (Appendix V). Flower bud initiation was earliest in black polythene mulch (M_2) where required days (90.58) and delayed in control (M_0: 100.30 days) (Table 6).

In case of combined effect of phosphorus fertilizers levels and different mulches, days to harvesting of strawberry showed significant variation (Appendix V). Flower bud initiation was earliest in 220kg/ha of phosphorus used with black polythene (P_3M_2) where required days (77.67) and delayed in control treatment (P_0M_0: 109.30) which was statistically similar with P_0M_1 (Table 7).

Table 6. Effect of different mulches on days to bud initiation, days to flowering, days to fruiting and days to harvesting of strawberry

Treatment	Days to Bud initiation	Days to flowering	Days to fruiting	Days to harvesting
M_0	74.39 a	78.83 a	85.58 a	100.30 a
M_1	69.78 b	74.33 b	80.83 b	93.67 b
M_2	66.90 c	71.67 c	77.83 c	90.58 c
LSD $_{(0.05)}$	1.00	0.97	0.79	0.75
CV%	1.67	1.52	1.15	0.93

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

Here, M_0: No mulch, M_1: Paddy straw, M_2: Black polythene mulch

Table 7. Combined effect of phosphorus levels and mulches on days to bud initiation, days to flowering, days to fruiting and days to harvesting of strawberry

Treatment	Days to Bud initiation	Days to flowering	Days to fruiting	Days to harvesting
P_0M_0	81.87 a	86.67 a	93.00 a	109.30 a
P_0M_1	80.07 a	85.67 a	91.67 a	106.30 b
P_0M_2	77.60 b	82.33 b	89.67 b	103.70 c
P_1M_0	73.27 c	77.67 c	84.33 c	101.30 d
P_1M_1	70.57 d	75.00 de	81.67 d	98.33 e
P_1M_2	68.80 d	73.67 ef	80.33 de	96.33 f
P_2M_0	72.63 c	76.67 cd	83.33 c	99.00 e
P_2M_1	69.63 d	73.00 f	79.00 e	86.67 h
P_2M_2	64.30 e	69.00 g	74.00 f	84.67 i
P_3M_0	69.80 d	74.33 ef	81.67 d	91.33 g
P_3M_1	58.87 f	63.67 h	71.00 g	83.33 i
P_3M_2	56.90 f	61.67 i	67.33 h	77.67 j
LSD $_{(0.05)}$	1.99	1.93	1.58	1.50
CV%	1.67	1.52	1.15	0.93

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

Here, P_0: 0 kg/ha, P_1: 120 kg/ha, P_2: 170 kg/ha, P_3: 220 kg/ha and M_0: No mulch, M_1: Paddy straw, M_2: Black polythene mulch

4.10 Flower number per plant

Number of flowers per plant was significantly varied with levels of phosphorus fertilizers (Appendix VI). Maximum number of flower (33.60) was observed in P_3 whereas minimum number of flower (20.90) in P_0 (Figure 12). Zargar *et al.* (2008) who found that the number of flowers per plant was gradually increased with the increasing level of P_2O_5.

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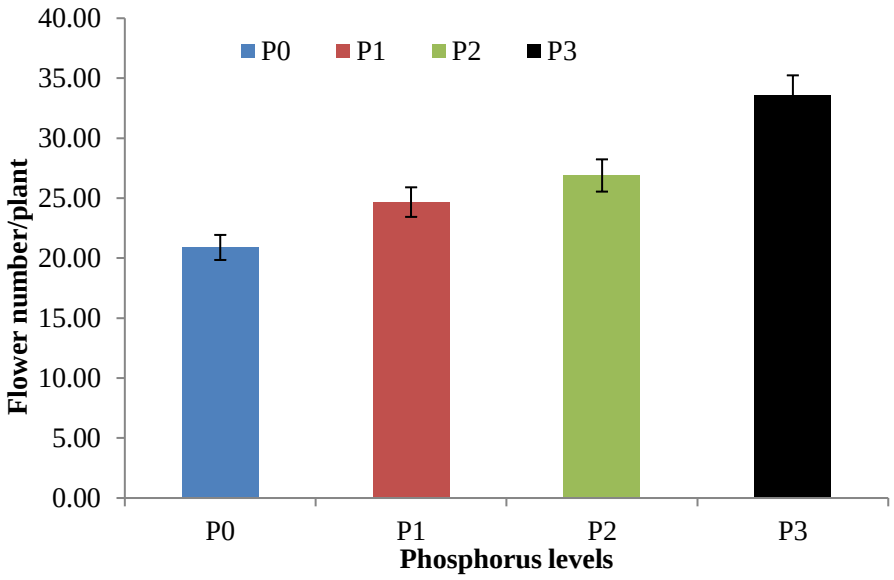

Figure 12. Effect of phosphorus levels on flower number of strawberry

(Here, P_0: 0 kg/ha, P_1: 120 kg/ha, P_2: 170 kg/ha, P_3: 220 kg/ha)

In case of mulches, significant variation was found in flower number per plant of strawberry (Appendix VI). The maximum number of flower (28.30) was found in black polythene mulch (M_2) while minimum number of flower (24.70) found in M_0 where no mulch was used (Figure 13). Collins (1977) reported that mulch increases yield with increasing flower number.

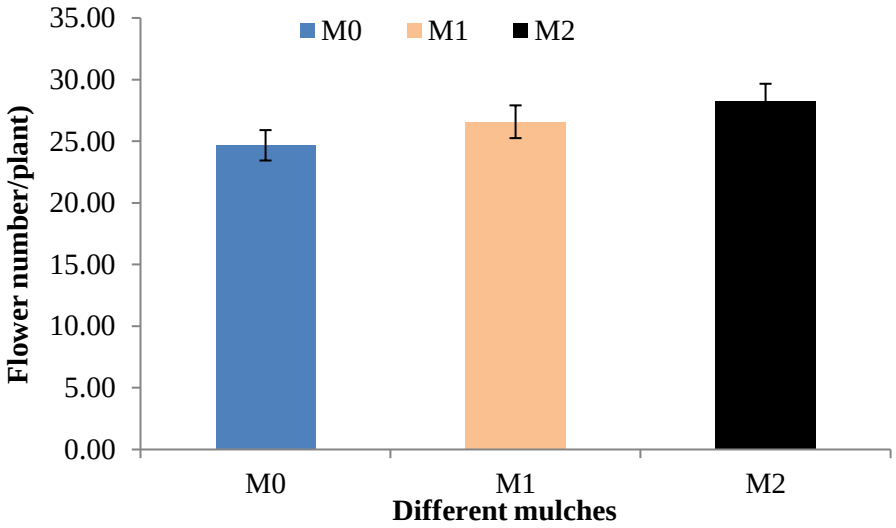

Figure 13. Effect of different mulch on flower number of strawberry

(Here, M_0: No mulch, M_1: Paddy straw, M_2: Black polythene mulch)

In case of combined effect of phosphorus fertilizers levels and different mulches, flower number of strawberry showed significant variation (Appendix VI). The maximum number of flower (37.30) was found in 220kg/ha. of phosphorus used with black polythene (P_3M_2) and the minimum number of flower (20.30) was found in control treatment (P_0M_0) (Table 4).

4.11 Fruit number per plant

Number of fruits per plant was significantly varied with levels of phosphorus fertilizers (Appendix VI). Maximum number of fruit (27.78) was observed in P_3 whereas minimum number of fruits was found (17.00) in P_0 (Table 8). Mahaveer *et al.* (2004) found the similar results in strawberry production.

In case of mulches, significant variation was found in fruit number per plant of strawberry (Appendix VI). The maximum number of fruit (24.17) was found in black polythene mulch (M_2) while minimum number of fruit (19.42) found in M_0 where no mulch was used (Table 9). Similar result was found in Saifullah *et al.* (1996). The results were reported by Yoon *et al.* (1984).

In case of combined effect of phosphorus fertilizers levels and different mulches, fruit number of strawberry showed significant variation (Appendix VI). The maximum number of fruit (31.67) was found in 220kg/ha. of phosphorus used with black polythene (P_3M_2) and the minimum number of flower (16.33) was found in control treatment (P_0M_0) (Table 10).

4.12 Fruit length

Considering the fruit length of strawberry significant variation was found with levels of phosphorus fertilizers (Appendix VI). Maximum fruit length (3.96 cm) was observed in P_3 whereas shortest fruit was found (2.64) in P_0 (Table 8). Rosen *et al.* (1988) observed that fruit size increased with fertilizer application.

In case of mulches, significant variation was found in fruit length of strawberry (Appendix VI). The Maximum fruit length (3.54 cm) was found in black polythene mulch (M_2) while shortest fruit was (3.20 cm) found in M_0 where no mulch was used (Table 9).

In case of combined effect of phosphorus fertilizers levels and different mulches, the fruit length of strawberry showed significant variation (Appendix VI). The Maximum fruit length (4.23 cm) was found in 220kg/ha. of phosphorus used with black polythene (P_3M_2) while shortest fruit was (2.53 cm) was found in control treatment (P_0M_0) which was statistically similar with (P_0M_1) (Table 10).

4.13 Fruit breadth

Considering the fruit breadth of strawberry significant variation was found with levels of phosphorus fertilizers (Appendix VI). Maximum fruit breadth (25.74 mm) was observed in P_3 whereas shortest fruit breadth was found (16.51 mm) in P_0 (Table 8).

In case of mulches, significant variation was found in fruit breadth of strawberry (Appendix VI). The Maximum fruit breadth (23.95 mm) was found in black polythene mulch (M_2) while shortest fruit breadth was (20.52 mm) found in M_0 where no mulch was used (Table 9).

In case of combined effect of phosphorus fertilizers levels and different mulches, the fruit breadth of strawberry showed significant variation (Appendix VI). The Maximum fruit breadth (27.23 mm) was found in 220kg/ha. of phosphorus used with black polythene (P_3M_2) while shortest fruit breadth was (16.03 mm) was found in control treatment (P_0M_0) which was statistically similar with (P_0M_1) (Table 10).

4.14 Individual fruit weight

Considering the individual fruit weight of strawberry significant variation was found with levels of phosphorus fertilizers (Appendix VII). Maximum individual fruit weight (14.54 g) was observed in P_3 whereas shortest individual fruit weight was found (11.46 g) in P_0 (Table 8).

In case of mulches, significant variation was found in individual fruit weight of strawberry (Appendix VII). The Maximum individual fruit weight (13.78 g) was found in black polythene mulch (M_2) while shortest individual fruit weight was (12.58 g) found in M_0 where no mulch was used (Table 9). Rahman *et al*. (1995) found that growth and yield directly influenced with different mulches.

In case of combined effect of phosphorus fertilizers levels and different mulches, the individual fruit weight of strawberry showed significant variation (Appendix VII). The Maximum individual fruit weight (15.53 g) was found in 220kg/ha of phosphorus used with black polythene (P_3M_2) while minimum individual fruit weight (11.07 g) was found in control treatment (P_0M_0) (Table 10).

Table 8. Effect of phosphorus levels on number of fruits per plant, fruit length, fruit breadth and fruit weight of strawberry

Treatment	Number of Fruits/plant	Fruit length (cm)	Fruit breadth (mm)	Fruit weight (g)
P_0	17.00 d	2.64 d	16.51 d	11.46 d
P_1	19.89 c	3.07 c	21.52 c	12.90 c
P_2	24.00 b	3.78 b	23.48 b	13.94 b
P_3	27.78 a	3.96 a	25.74 a	14.54 a
LSD $_{(0.05)}$	0.55	0.07	0.16	0.14
CV%	2.51	2.1	0.77	1.11

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

Here, P_0: 0 kg/ha, P_1: 120 kg/ha, P_2: 170 kg/ha, P_3: 220 kg/ha

Table 9. Effect of different mulches on number of fruits per plant, fruit length, fruit breadth and fruit weight of strawberry

Treatment	Number of Fruits/plant	Fruit length (cm)	Fruit breadth (mm)	Fruit weight (g)
M_0	19.42 c	3.20 c	20.52 c	12.58 c
M_1	22.92 b	3.34 b	21.98 b	13.27 b
M_2	24.17 a	3.54 a	22.95 a	13.78 a
LSD $_{(0.05)}$	0.47	0.06	0.14	0.12
CV%	2.51	2.1	0.77	1.11

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

Here, M_0: No mulch, M_1: Paddy straw, M_2: Black polythene mulch

Table 10. Interaction effect of phosphorus levels and different mulches on number of fruits per plant, fruit length, fruit breadth and fruit weight of strawberry

Treatment	Number of Fruits/plant	Fruit length (cm)	Fruit breadth (mm)	Fruit weight (g)
P_0M_0	16.33 i	2.53 h	16.03 j	11.07 i
P_0M_1	17.00 hi	2.63 h	16.70 i	11.50 h
P_0M_2	17.67 h	2.77 g	16.80 i	11.80 g
P_1M_0	19.33 g	2.93 f	20.30 h	12.43 f
P_1M_1	19.67 g	3.03 f	21.60 g	12.83 e
P_1M_2	20.67 f	3.23 e	22.67 f	13.43 d
P_2M_0	20.00 fg	3.63 d	21.63 g	13.33 d
P_2M_1	25.33 d	3.77 d	23.70 e	14.13 c
P_2M_2	26.67 c	3.93 b	25.10 c	14.37 bc
P_3M_0	22.00 e	3.70 cd	24.10 d	13.50 d
P_3M_1	29.67 b	3.93 b	25.90 b	14.60 b
P_3M_2	31.67 a	4.23 a	27.23 a	15.53 a
LSD $_{(0.05)}$	0.94	0.12	0.28	0.25
CV%	2.51	2.1	0.77	1.11

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

Here, P_0: 0 kg/ha, P_1: 120 kg/ha, P_2: 170 kg/ha, P_3: 220 kg/ha and M_0: No mulch, M_1: Paddy straw, M_2: Black polythene mulch

4.15 Brix percentages

Considering the brix percentages of strawberry significant variation was found with levels of phosphorus fertilizers (Appendix VII). Maximum brix percentages (6.64%) was found in P_3 whereas minimum (4.77%) in P_0 (Table 11).

In case of mulches, significant variation was found in brix percentages of strawberry (Appendix VII). The Maximum brix percentages (5.84) were found

in black polythene mulch (M_2) while minimum (5.00%) found in M_0 where no mulch was used (Table 12).

In case of combined effect of phosphorus fertilizers levels and different mulches, brix percentages of strawberry showed significant variation (Appendix VII). The maximum brix percentages (7.57%) was found in 220kg/ha. of phosphorus used with black polythene (P_3M_2) while minimum yield (4.40%) was found in control treatment (P_0M_0) (Table 13).

4.16 Yield per plant

Considering the fruit weight per plant of strawberry significant variation was found with levels of phosphorus fertilizers (Appendix VII). Maximum fruit weight (401.00 g) was observed in P_3 whereas minimum fruit yield was found (194.20 g) in P_0 (Table 11). Talebnejad *et al.* (2007) found the similar results.

In case of mulches, significant variation was found in fruit weight per plant of strawberry (Appendix VII). The Maximum fruit weight (328.60 g) was found in black polythene mulch (M_2) while minimum fruit weight per plant was (245.60 g) found in M_0 where no mulch was used (Table 12). Hochmuth and Howell (1983) found that yield increased with using mulch.

In case of combined effect of phosphorus fertilizers levels and different mulches, the fruit weight per plant of strawberry showed significant variation (Appendix VII). The maximum yield per plant (474.50 g) was found in 220kg/ha. of phosphorus used with black polythene (P_3M_2) while minimum yield (180.40 g) was found in control treatment (P_0M_0) (Table 13).

4.17 yield per hectare

Considering the yield per hectare of strawberry significant variation was found with levels of phosphorus fertilizers (Appendix VII). Maximum yield (21.99 t) was observed in P_3 whereas minimum yield was found (10.86 t) in P_0 (Table

11). Rauf *et al.* (1998) reported that fertilizers application with phosphorus fertilizers increase yield in strawberry production.

In case of mulches, significant variation was found in yield per hectare of strawberry (Appendix VII). The Maximum yield (18.16 t) was found in black polythene mulch (M_2) while minimum yield per hectare was (13.73 t) found in M_0 where no mulch was used (Table 12). Petersen *et al.* (2001) studied that using mulch increased yield.

In case of combined effect of phosphorus fertilizers levels and different mulches, the fruit yield per hectare of strawberry showed significant variation (Appendix VII). The maximum yield per hectare (26.30 t) was found in 220kg/ha of phosphorus used with black polythene (P_3M_2) while minimum yield (10.23 t) was found in control treatment (P_0M_0) (Table 13).

Table 11. Effect of phosphorus levels on yield per plant, yield per hectare and brix percentages of strawberry

Treatment	Brix (%)	yield/plant (g)	yield/ha (t)
P_0	4.77 d	194.20 d	10.86 d
P_1	5.23 c	254.30 c	14.08 c
P_2	5.58 b	323.90 b	18.02 b
P_3	6.64 a	401.00 a	21.99 a
$LSD_{(0.05)}$	0.16	3.42	0.10
CV%	2.98	1.19	0.61

Here, P_0: 0 kg/ha, P_1: 120 kg/ha, P_2: 170 kg/ha, P_3: 220 kg/ha

Table 12. Effect of different mulches on yield per plant, yield per hectare and brix percentages of strawberry

Treatment	Brix (%)	yield/plant (g)	yield/ha (t)
M_0	5.00 b	245.60 c	13.73 b
M_1	5.83 a	305.80 b	16.83 a
M_2	5.84 a	328.60 a	18.16 a
LSD $(_{0.05})$	0.14	2.96	0.08
CV%	2.98	1.19	0.61

Here, M_0: No mulch, M_1: Paddy straw, M_2: Black polythene mulch

Table 13. Interaction effect of phosphorus levels and different mulches on yield per plant, yield per hectare and brix percentages of strawberry

Treatment	Brix (%)	Yield/plant (g)	Yield/ha (t)
P_0M_0	4.40 h	180.40 l	10.23 l
P_0M_1	5.20 f	194.60 k	10.83 k
P_0M_2	4.70 g	207.70 j	11.50 j
P_1M_0	4.50 g	238.90 i	13.40 i
P_1M_1	5.70 cd	249.10 h	13.83 h
P_1M_2	5.50 de	274.90 f	15.00 f
P_2M_0	5.33 ef	266.00 g	14.67 g
P_2M_1	5.80 c	348.50 d	19.57 d
P_2M_2	5.60 ce	357.30 c	19.83 c
P_3M_0	5.77 cd	297.40 e	16.60 e
P_3M_1	6.60 b	431.10 b	23.07 b
P_3M_2	7.57 a	474.50 a	26.30 a
LSD $_{(0.05)}$	0.28	5.93	0.17
CV%	2.98	1.19	0.61

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

Here, P_0: 0 kg/ha, P_1: 120 kg/ha, P_2: 170 kg/ha, P_3: 220 kg/ha and M_0: No mulch, M_1: Paddy straw, M_2: Black polythene mulch

CHAPTER V
SUMMARY AND CONCLUSION

5.1 Summary

The experiment was conducted at the experimental field, Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from October, 2018 to March, 2019. The objective of the study was to determine the effect of phosphorus levels and different mulches on growth and yield of strawberry. The experiment consisted of four levels of phosphorus fertilizer, viz. P_0: 0 kg P_2O_5 /ha, P_1: 120 kg P_2O_5/ha, P_2: 170 kg P_2O_5/ha and P_3: 220 kg P_2O_5/ha and mulches viz. M_0: No mulch, M_1: paddy straw, M_2: black polythene. The two-factor experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Collected data were statistically analyzed for the evaluation of treatments for the detection of the best phosphorus levels and the best mulches. The findings and conclusion have been described in this segment.

Significant variations were observed in case of phosphorus levels as well as mulch application of all parameters like as following –The highest plant height was found from P_3 (22.33 cm) and from M_2 (19.98 cm) whereas the shortest from P_0 (14.30 cm) and from M_0 (16.77 cm) at 60 days after transplanting. In case of treatment combination, the tallest plant (24.60 cm) was found in P_3M_2 as well as the shortest plant (13.77 cm) was found in P_0M_0 at 60 days after transplantation.

The maximum number of leaves (20.00) was found from P_3 and minimum (12.11) from P_0 at 60 DAT. The maximum number of leaves (17.00) was found from M_2 and minimum from M_0 (14.17) with 60 days after transplanting. In case of combined effect, maximum number of leaves (21.33) was found from P_3M_2 and minimum (11.33) from P_0M_0 at 60 days after transplantation.

Regarding the leaf area, maximum leaf area (64.50 cm^2) was found in P_3 and minimum (36.00 cm^2) in P_0. In case of mulch, maximum leaf area (55.20 cm^2) was found in M_2 and minimum (43.60 cm^2) in M_0. Combined effect of phosphorus levels and mulches, maximum leaf area (73.30 cm^2) was found in P_1M_2 and minimum (33.30 cm^2) in P_0M_0.

Considering phosphorus levels, maximum runner number (15.30) was found in P_3 and minimum (8.00) in P_0. In case of mulch, maximum runner number (12.90) was found in M_2 and minimum (10.50) in M_0. Combined effect of phosphorus levels and mulches, maximum runner umber (17.00) was found in P_3M_2 and minimum (7.30) in P_0M_0.

The highest runner length (27.60 cm) was found in P_3 and the lowest (18.00 cm) in P_0. In case of mulch, highest runner length (24.10 cm) was found in M_2 and minimum (20.80 cm) in M_0. Combined effect of phosphorus levels and mulches, highest runner length (30.50) was found in P_3M_2 and minimum (17.70 cm) in P_0M_0.

Significant variation found in days to bud initiation of strawberry, maximum days required to bud initiation (79.84) was found in P_0 and minimum (61.86) in P_3. In case of mulch, maximum days required to bud initiation (74.39) was found in M_0 and minimum (66.90) in M_2. Combined effect of phosphorus levels and mulches, maximum days required to bud initiation (81.87) was found in P_0M_0 and minimum (56.90) in P_3M_2.

In terms of phosphorus fertilizers, maximum days required to flowering (84.89) was found in $P_0$and minimum (66.56) in P_3. In case of mulch, maximum days required to flowering (78.83) was found in M_0 and minimum (71.67) in M_2. Combined effect of phosphorus levels and mulches, maximum days required to flowering (86.67) was found in P_0M_0 and minimum (61.67) in P_3M_2.

In case of phosphorus levels, maximum days required to fruiting (91.44) was found in P_0 and minimum (73.33) in P_3. In terms of mulch, maximum days required to fruiting (85.58) were found in M_0 and minimum (77.83) in M_2. Combined effect of phosphorus levels and mulches, maximum days required to fruiting (93.00) was found in P_0M_0 and minimum (67.33) in P_3M_2.

Considering phosphorus levels, maximum days required to harvesting (106.40) was found in P_0 and minimum (84.11) in P_3. In case of mulch, maximum days required to harvesting (100.30) were found in M_0 and minimum (90.58) in M_2. Combined effect of phosphorus levels and mulches, maximum days required to harvesting (109.30) was found in P_0M_0 and minimum (77.67) in P_3M_2.

In terms of phosphorus levels, maximum flower number (33.60) was found in P_3 and minimum (20.90) in P_0. Considering of mulch, maximum flower number (28.30) was found in M_2 and minimum (24.70) in M_0. Combined effect of phosphorus levels and mulches, maximum flower number (37.30) was found in P_3M_2 and minimum (20.30) in P_0M_0.

In case of phosphorus levels, maximum fruit number (27.78) was found in P_3 and minimum (17.00) in P_0. Considering of mulch, maximum fruit number (24.17) was found in M_2 and minimum (19.42) in M_0. Combined effect of phosphorus levels and mulches, maximum fruit number (31.67) was found in P_3M_2 and minimum (16.33) in P_0M_0.

Considering phosphorus levels, highest fruit length (3.96 cm) was found in P_3 and minimum (2.64 cm) in P_0. In case of mulch, highest fruit length (3.54 cm) was found in M_2 and minimum (3.20 cm) in M_0. Combined effect of phosphorus levels and mulches, highest fruit length (4.23) was found in P_3M_2 and minimum (2.53 cm) in P_0M_0.

The highest fruit breadth (25.74 mm) was found in P_3 and minimum (16.51 mm) in P_0. Considering mulch, highest fruit breadth (22.95 mm) was found in M_2 and minimum (20.52 mm) in M_0. Combined effect of phosphorus levels and mulches, highest fruit breadth (27.23 mm) was found in P_3M_2 and minimum (16.03 mm) in P_0M_0.

In terms of phosphorus levels, maximum fruit weight (14.54 g) was found in P_3 and minimum (11.46 g) in P_0. In case of mulch, maximum fruit weight (13.78 g) was found in M_2 and minimum (12.58 g) in M_0. Combined effect of phosphorus levels and mulches, maximum fruit weight (15.53 g) was found in P_3M_2 and minimum (11.07 g) in P_0M_0.

Yield per plant varied significantly, maximum yield per plant (401.00 g) was found in P_3 and minimum (194.20 g) in P_0. In case of mulch, maximum yield per plant (328.60 g) was found in M_2 and minimum (240.60 g) in M_0. Combined effect of phosphorus levels and mulches, maximum yield per plant (474.50 g) was found in P_3M_2 and minimum (180.40 g) in P_0M_0.

In case of phosphorus levels, maximum yield per hectare (21.99 t) was found in P_3 and minimum (10.86 t) in P_0. Considering of mulch, maximum yield per hectare (18.16 t) was found in M_2 and minimum (13.73 t) in M_0. Combined effect of phosphorus levels and mulches, maximum yield per hectare (26.30 t) was found in P_3M_2 and minimum (10.23 t) in P_0M_0.

Considering phosphorus levels, maximum brix percentages (6.64 %) were found in P_3 and minimum (4.77%) in P_0. In case of mulch, a maximum brix percentage (5.84%) was found in M_2 and minimum (5.00%) in M_0. Combined effect of phosphorus levels and mulches, maximum brix percentages (7.57%) was found in P_3M_2 and minimum (4.40 %) in P_0M_0.

5.1 Conclusion

1. Regard the results it can be concluded that P_3 (220 kg/ha.) stood for early bud initiation, flowering, fruiting and harvesting, greatest leaf area, utmost number of flowers and fruits. Weight of fruit, total fruit weight per plant, fruit length, fruit diameter and percentage of brix were premier in P_3.

2. On the other hand, black polythene mulch (M_2) performs as excellent among the different mulches used in terms of all parameters.

3. Besides the combination, phosphorus fertilizer (P_3: 220 kg/ha.) with black polythene mulch (M_2) performed as the best combination (P_3M_2). On the basis of above results it can be articulated that P_3 is the most suitable levels and black polythene mulch is the appropriate for better growth, yield and quality attributes of strawberry.

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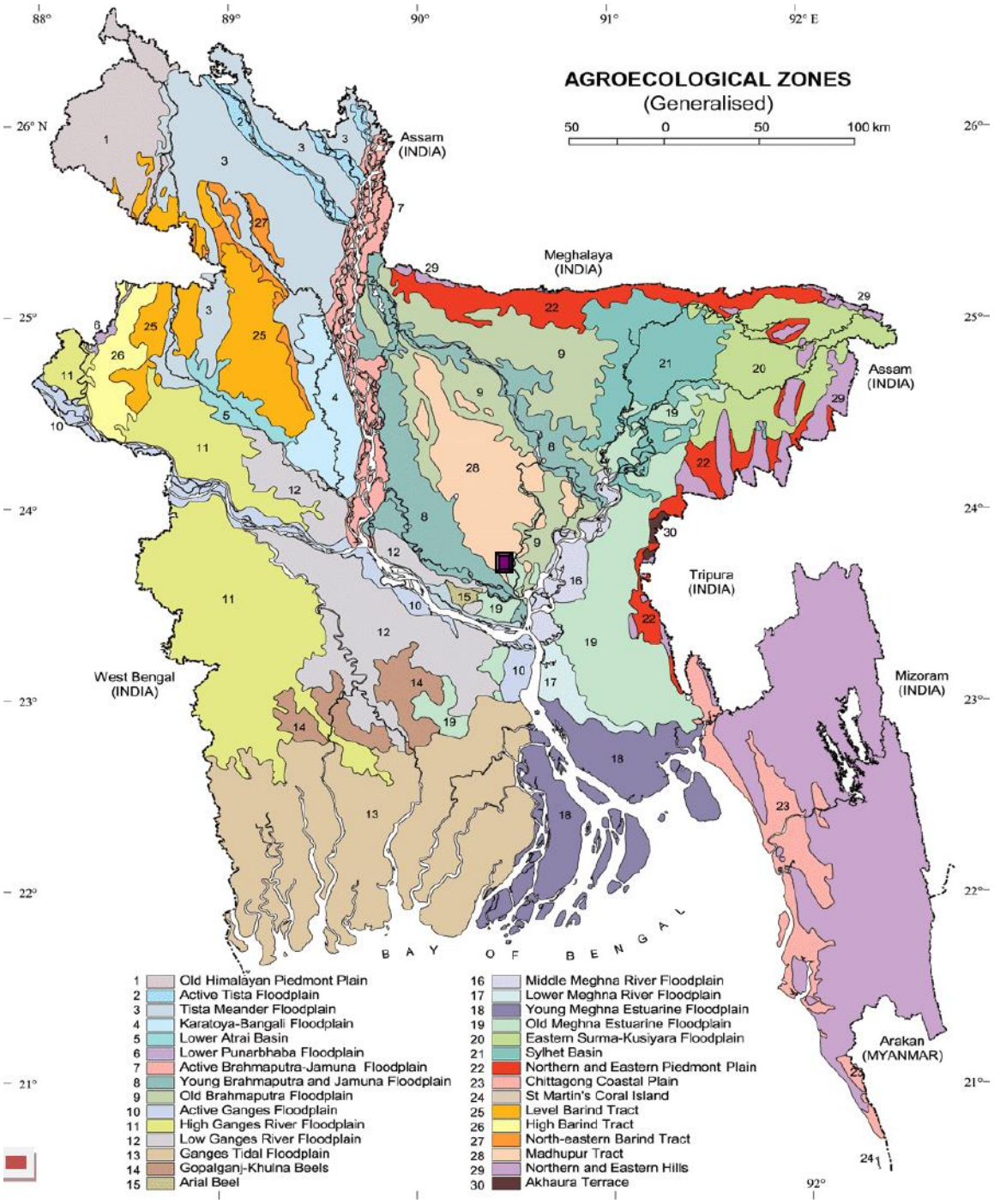
APPENDICES

Appendix I. Map showing the experimental site under the study



The experimental site under study

Appendix II. Monthly record of air temperature, relative humidity and rainfall of the experimental site during the period from November, 2018 to March, 2019

Month	*Air temperature (°C)		*Relative humidity (%)	**Rainfall (mm) (total)
	Maximum	Minimum		
October, 2018	33.3	21.6	55	37.2
November,2018	29.6	19.2	53	34.4
December, 2018	26.4	14.1	50	12.8
January, 2019	25.4	12.7	46	7.7
February, 2019	28.1	15.6	37	28.9
March, 2019	32.5	20.4	38	65.8

*Monthly average,

**Source: Bangladesh Meteorological Department (Climate & weather division) Agargaon, Dhaka-1207

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

Source of Variation	Degrees of freedom	Mean Square for plant height at (cm)		
		20 DAT	40 DAT	60 DAT
Replication	2	0.005	0.053	0.097
Factor A (Phosphorus levels)	3	108.700*	123.333*	111.085*
Factor B (Mulches)	2	23.819*	25.644*	32.817*
Interaction (A×B)	6	1.774*	3.438*	2.634*
Error	22	0.053	0.450	0.561

***Significant at 0.05 level of probability**

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

Source of Variation	Degrees of freedom	Mean Square for number of leaves at		
		20 DAT	40 DAT	60 DAT
Replication	2	0.088	0.134	0.054
Factor A (Phosphorus levels)	3	31.287*	50.074*	103.880*
Factor B (Mulches)	2	7.583*	12.111*	24.528*
Interaction (A×B)	6	0.398*	1.185*	3.046*
Error	22	0.152	0.194	0.497

***Significant at 0.05 level of probability**

Appendix V. Analysis of variance on leaf area, runner number and runner length of strawberry

Source of Variation	Degrees of freedom	Mean Square of		
		Leaf area (cm^2)	Runner number	Runner length (cm)
Replication	2	0.483	0.004	1.760
Factor A (Phosphorus levels)	3	1319.172*	88.111*	159.381*
Factor B (Mulches)	2	400.205*	17.528*	33.434*
Interaction (A×B)	6	56.277*	0.639*	4.414*
Error	22	2.125	0.210	0.169

***Significant at 0.05 level of probability**

Appendix VI. Analysis of variance on days to bud initiation, days to flowering, days to fruiting and days to harvesting of strawberry

Source of Variation	Degrees of freedom	Mean Square of			
		Days to bud initiation	Days to flowering	Days to fruiting	Days to harvesting
Replication	2	0.083	1.18	2.33	0.004
Factor A (Phosphorus levels)	3	494.435*	521.222*	520.028*	860.333*
Factor B (Mulches)	2	171.351*	157.444*	183.250*	292.583*
Interaction (A×B)	6	18.649*	157.444*	23.139*	24.250*
Error	22	1.385	1.301	0.871	0.780

***Significant at 0.05 level of probability**

Appendix VII. Analysis of variance on flower number, fruit number, fruit length and fruit breadth of strawberry

Source of Variation	Degrees of freedom	Mean Square of			
		Flower number	Fruit number	Fruit length (cm)	Fruit breadth (mm)
Replication	2	0.46	0.35	0.10	0.04
Factor A (Phosphorus levels)	3	254.333*	200.185*	3.382*	139.267*
Factor B (Mulches)	2	38.583*	72.750*	0.354*	17.997*
Interaction (A×B)	6	6.028*	15.157*	0.013*	1.094*
Error	22	0.432	0.311	0.005	0.028

***Significant at 0.05 level of probability**

Appendix VIII. Analysis of variance on fruit weight, yield/plant, yield/ha. and brix percentages of strawberry

Source of Variation	Degrees of freedom	Mean Square of			
		Individual fruit weight (g)	Brix percentages (%)	Yield per plant (g)	Yield per hectare (t)
Replication	0.05	0.57	0.19	20.52	0.005
Factor A (Phosphorus levels)	3	16.483*	5.737*	71607.38*	209.680*
Factor B (Mulches)	2	4.348*	2.779*	22049.16*	62.084*
Interaction (A×B)	6	0.270*	0.517*	4245.553*	13.247*
Error	22	0.021	0.027	12.257	0.010

***Significant at 0.05 level of probability**