EFFECT OF PHOSPHORUS AND GIBBERELLIC ACID ON GROWTH AND YIELD OF TUBEROSE

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CERTIFICATE

This is to certify that the thesis entitled **“**EFFECT OF PHOSPHORUS AND GIBBERELLIC ACID ON GROWTH AND YIELD OF TUBEROSE**”** submitted to the Department of Horticulture, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (M.S.)** in **HORTICULTURE**, embodies the result of a piece of bonafide research work carried out by **LATHUENU MARMA**, Registration No. **17-08283** 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.

December, 2019
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Dedicated to
My
Beloved Parents

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The Author

EFFECT OF PHOSPHORUS AND GIBBERELLIC ACID ON GROWTH AND YIELD OF TUBEROSE

ABSTRACT

The present study was carried out in the Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during August 2017 to October 2018 to study the effect of phosphorus and gibberellic acid on growth and yield of tuberose (*Polianthes tuberosa*). Four phosphorus levels *viz* P_0 = 0 kg $P_2O_5 ha^{-1}$, P_1 = 65 kg P_2O_5 ha^{-1}, P_2 = 85 kg P_2O_5 ha^{-1} and P_3 = 110 kg P_2O_5 ha^{-1} and three GA_3 levels *viz*. G_0 = 0 ppm GA_3, G_1 = 115 ppm GA_3 and G_2 =145 ppm GA_3 were treated. The experiment was laid out in the two factors Randomized Complete Block Design (RCBD) with three replications. Regarding P application, P_3 (110 kg P_2O_5 ha^{-1}) gave the highest plant height (61.02 cm) and number of leaves $plant^{-1}$ (7. 29.35) compared to control treatment but the highest yield parameters number of spike ha^{-1} (368.60 thousand), bulb yield (25.88 t ha^{-1}) and bulblet yield (14.21 t ha^{-1}) were found from the treatment P_2 (85 kg P_2O_5 ha^{-1}) whereas control treatment P_0 (0 kg P_2O_5 ha^{-1}) showed lowest results. In case of GA_3 application, G_2 (145 ppm GA_3) showed highest growth and yield parameter and the highest number of spike ha^{-1} (362.30 thousand), bulb yield (25.38 t ha^{-1}) and bulblet yield (14.00 t ha^{-1}) were obtained from G_2 (145 ppm GA_3) whereas the lowest results were found from the control treatment G_0 (0 ppm GA_3). Treatment combination of P and GA_3, the highest number of spike ha^{-1} (405.60 thousand), bulb yield (31.45 t ha^{-1}), and bulblet yield (16.01 t ha^{-1}) were found from P_2G_2 combination whereas the lowest number of spike ha^{-1} (189.60 thousand), bulb yield (14.57 t ha^{-1}) and bulblet yield (9.05 t ha^{-1}) was found from the control treatment combination of P_0G_0. In terms of economic analysis, the highest gross return (Tk. 471550), net return (Tk. 289337) and BCR (2.59) were also obtained from P_2G_2 (85 kg P_2O_5 ha^{-1} with 145 ppm GA_3) whereas the lowest gross return (Tk. 227470), net return (Tk. 57703) and BCR (1.34) was obtained from P_0G_0 (no P and GA_3). From the above results, it can be stated that that the P application @ 85 kg P_2O_5 ha^{-1} and GA_3 application @ 145 ppm can be considered for higher yield and economic return in commercial cultivation of tuberose.

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ABBREVIATIONS AND ACRONYMS

AEZ	=	Agro-Ecological Zone
BBS	=	Bangladesh Bureau of Statistics
cm	=	Centimeter
CV %	=	Coefficient of Variation
DAS	=	Days After Sowing
DMRT	=	Duncan’s Multiple Range Test
et al.,	=	And others
e.g.	=	exempli gratia (L), for example
etc.	=	Etcetera
FAO	=	Food and Agriculture Organization of the United Nations
i.e.	=	id est (L), that is
Kg	=	Kilogram (s)
LSD	=	Least Significant Difference
SAU	=	Sher-e-Bangla Agricultural University
var.	=	Variety
NaOH	=	Sodium hydroxide
GM	=	Geometric mean
mg	=	Miligram
UNDP	=	United Nations Development Programme
USA	=	United States of America
WHO	=	World Health Organization

CHAPTER I

INTRODUCTION

Tuberose *(Polianthes tuberosa* L.), the common name derives from the Latin *tuberosa*, meaning swollen or tuberous in reference to its root system, *Polianthes* means “many flowers” in Greek. It is an erect perennial plant with a 75-120 cm stem. It is a member of family Amaryllidacea, originated in Mexico and is grown on large scale in Asia (Khan *et al*., 2016). It blooms in summer when planted in spring and its clustered spikes are rich in fragrance. It contain the opalescent white, waxy, star shaped flowers with stamens of a beautiful golden yellow, are tabulated shape with a flared corolla. It is an important cut flower crop from aesthetic as well as commercial point of view. There are up to 30 flowers in one spike and the length of rachis varies between 14 and 28cm depending upon size of rhizome planted (Khan *et al*., 2016).

Florets open from the base upwards and spikes are harvested when the lowest florets have just opened. The tuberose flowers are durable although brittle and remain fresh for pretty long time and stand long distance transportation due to their waxy nature and occupy are considered excellent as cut flowers for floral decoration in bowls and vases (Bose and Yadav, 2002). There are three types of tuberose; single with one row of corolla segments, double having more than three rows of corolla segments and semi-double bearing flowers with two or three rows of corolla segments (Amin *et al*., 2012). For successfully tuberose production, the soil should be rich in organic matter and retain sufficient moisture for proper growth, flowering and bulbs yield (Jowkar and Hayati, 2005).

Tuberose is a gross feeder plant receives a large quantity of NPK as organic and inorganic form which have great influence on growth, flower and bulb production (Kumar *et al*. 2004, Sultana *et al*.2006 and Rajwal and Singh 2006). Effect of NPK on tuberose production has been reported by several authors for different geographical region (Yadav *et al.*, 1985). Phosphorus has a significant effect on spike production and floret quality (Banker and Mukhopadhyay, 1985).

In determining the yields of flower crops, phosphorus (P) is also one of the major and crucial limiting factors. Thus, it has been called as “the key to life” because it is directly involved in most life processes. It is an essential part of many sugar phosphates involved in photosynthesis, respiration and other metabolic processes. Deficiency of phosphorus may adversely affect the plant in maintaining the full supply of N and K and excess application of P may result in various nutritional problems including Ca and Zn deficiency (Nain *et al.*, 2016). Phosphorus has also a significant effect on spike production and floret quality (Singh *et al.*, 2005).

Also, the potential use of plant growth regulator like GA_3 in flower production has created considerable scientific interest in recent years (Padaganur *et al.*, 2005; Singh *et al.*, 2003). In Bangladesh, it is necessary to know the real impact of plant growth regulator like GA_3 on tuberose.

Normal plant growth and development are regulated by naturally produced chemicals or phytohormones. Their role can often be substituted by application of synthetic growth regulating chemicals or hormones like GA_3. Plant growth regulators are known to coordinate and control various phases of growth and development, including flowering at optimum concentrations (Amin *et al.*, 2017). It is generally accepted that exogenously applied growth substances act through the alteration in the levels of naturally occurring growth regulators, thus modifying the growth and development of the plant (Kumar and Gautam, (2011). Many studies have indicated that the application of GA_3 can stimulate the growth and development of flowers. Mukhopadhyay and Banker (1983) sprayed the plants of cv. single with GA_3 and observed that GA3 increased spike length and number of floret per spike. Duration of flower in the field was improved with GA_3. According to Dhua *et* *al*., (1987) treatment with GA_3 caused earliest flowering and gave the highest yield of spikes and flowers.

Keeping in view, the importance of tuberose and unavailability of limited local information regarding its optimum phosphorus requirements and application of GA_3, the present research was undertaken to explore the optimum doses of phosphorus and growth regulator (GA_3) which can produce healthy plants with good quality flowers and give maximum number of spike and spikelets, bulb and bulblets with the following objectives.

i. To find out the optimum level of phosphorus and GA_3 on growth, flowering and bulb production of tuberose and

ii. To find out the suitable combination of phosphorus and GA_3 on growth, flowering and bulb production of tuberose

CHAPTER II

REVIEW OF LITERATURE

Tuberose is one of the most important cut flower in Bangladesh and also in the world. Many research works have been done on various aspects of this important cut flower in different countries of the world. A few reports are available regarding the requirement of plant nutrients and growth regulators for growth, flowering and bulb production of tuberose. Different phosphorus (P) levels and GA_3 on tuberose have been studied in various part of the world. But very limited studies have been done on this crop under the agro-ecological condition of Bangladesh in respect of phosphorus and GA_3 requirement. A brief review of these pertinent to the present study has been given below:

2.1 Effect of phosphorus (P)

Nain *et al*. (2016) carried out an experiment entitled "effect of nitrogen and phosphorus on flowering and spike yield of tuberose (*Polianthes tuberose* L.)" cv. Prajwal to found out the optimum dose of nitrogen and phosphorus for flowering and spike yield of tuberose. The nitrogen (0, 10, 15 and 20 g/m^2) and phosphorus levels (0, 5 and 10 g/m^2) were used. Results found that the maximum days taken to spike initiation, days taken to flowering and duration of flowering, number of spike per clump and spike weight during both the years were observed in treatments where nitrogen at 20 g/m^2 and phosphorus at 10 g/m^2 was applied. Therefore, based on the study for better flowering and spike yield of tuberose plants nitrogen at 20 g/m^2 and phosphorus at 10 g/m^2 should be applied.

Khan *et al*. (2016) was carried out a field experiment to observe the effect of various bulb sizes i.e. >3, 2-3 and <2 cm diameter and phosphorus levels i.e. 0, 150, 300 and 450 kg ha^{-1} on growth, flowering and bulblets production of tuberose. The results showed that phosphorus and bulb size significantly affected all the parameters including plant height, days to bolting, days to 50% flowering, number of leaves per plant, number of florets per spike, plant canopy, bulb volume and number of bulblets per plant, except number of bulbs per plant. The maximum plant height, number of leaves, number of flowers per stalk, plant canopy, bulb volume, number of bulbs plant^{-1}, number of bulblets plant^{-1}, while the least days to bolting and days to 50% flowering were observed in plants grown from the largest bulbs (>3cm). The highest plant height, number of leaves, number of flowers per stalk, plant canopy, bulb volume, number of bulblets plant^{-1}, while, the least days to bolting and days to 50% flowering were observed in plants fertilized with 450 kg/ha of phosphorus.

Singh *et al*. (2000) studied the nutrient status of tuberose plants treated with different N, P and K levels (0, 10, 20, 30 and 40 kg N/ha, 0, 10 and 20 kg P/ha and 0, 10 and 20 kg K/ha) and observed that the foliar NPK increased with increase in N, P and K doses of fertilizers respectively. Leaf P and K concentrations decreased with increasing N fertilizers rate. N, P and K contents in leaves were higher than those in bulbs. Bulb N increased with increasing rates of all fertilizers. Bulb P content was affected by N and P fertilizers but not by K fertilizers and K content also increased with increasing rates of all fertilizers. Further they applied fertilizers that result in a non significant effect on the vegetative as well as floral characters except for length of spike and number of spike per clump. The length of spike at opening of last floret and number of spikes per clump were highest in the NPK @ 20:20:20 g/m2 treatment over the control (Singh *et al*., 2004).

In a pot culture experiment with sandy loam soil to evaluate the effect of N (0, 60, 120, 180, and 240 ppm as urea) and P (0, 20, 40, 60, and 80 ppm as KH_2PO_4) on the growth and dry matter yield of tuberose cv. Double, the application of N and P greatly improved the growth (plant height and number of leaves) and dry matter yield (dry weight of leaves and spike) and total dry weight (leaves+spike). Growth and dry matter yield increased up to 180 ppm N and 60 10 ppm P levels; however, further increments in N above 180 ppm and P above 60 ppm adversely affected growth and dry matter yield (Dahiya *et al*., 2001).

Mishra *et al*. (2002) conducted an experiment in Bhubaneswar, Orissa with tuberose (*Polianthes tuberosa*) cv. Single involving 4 levels of N and 2 spacing. Plant height and number of plants per clump observed after 3 months of planting were higher (4.45 cm) with 30 g N/m^2 followed by 20 g N/m^2 as compared to other treatments. Application of N delayed spike emergence; the maximum delay of 10 days was noticed in plant receiving 30 g N/m^2 compared to untreated ones. P application showed no appreciable effect on different growth parameters studied, but flowering attributes such as spike length, rachis length, and weight of florets per spike and weight of 100 florets improved due to P application at 20 g or 30 g/m^2. Yield of flowers/ha (weight basis) also improved due to P treatments at 20 or 30 g/m^2, but yield of florets per spike (weight basis) was significantly increased at 30 g/m^2.

Studies on N and P requirements of tuberose cv. 'Single' in hilly soil was conducted by Kumar *et al*. (2002). They found that application of 40 g N/m2 enhanced the plant height and number of leaves but delayed the flowering. None of the levels of P2O5 could influence the flowering but increased the flower production at 24 g P_2O_5/m^2. They were of the opinion that application of 30 g N and 24 g P_2O_5/m^2 were optimum for growth and flowering of tuberose cv. Single under hill conditions.

Sharma *et al*. (2008) conducted nutritional studies in tuberose in sandy loam soil to ascertain the effect of graded doses of N, P and K on growth, flowering and bulb production of tuberose (*Polianthes tuberosa* Linn) Double. Nitrogen was applied @ 100, 150, 200 and 250 kg per hectare with phosphorus @ 50, 60 and 70 kg P_2O_5 per hectare and potassium @ 40, 50 and 60 kg K_2O per hectare. Increasing levels of nitrogen up to 200 kg per hectare significantly increased the plant height, number of leaves per plant, flower yield and quality over control. Maximum plant height (39.3 cm), spike length (78.1 cm), number of florets per spike (38.6) was recorded with 200 kg N per hectare treatment. This level of nitrogen also produced maximum number of bulbs (10.6) and bulb weight (14.3 g). The plant receiving 70 Kg P_2O_5 per hectare produced maximum plant height (37.9 cm) and number of leaves per plant (35.3). Floral characters like spike length (76.6 cm), spike weight (73.1 g) and number of florets per spike (39.3) were also observed maximum with 70 kg P_2O_5 per hectare treatment. This treatment also improved the bulb production. The plants applied with 40 kg K_2O per hectare significantly improved the vegetative growth, floral characters and bulb production over control, however, this treatment was statistically at par with higher levels of potassium 200 kg N, 70 kg P_2O_5 and 40 kg K_2O per hectare was found optimum for tuberose cultivation under Haryana conditions.

The effects of N (0, 60, 120, 180 or 240 ppm) as urea and P (0, 20, 40, 60 or 80 ppm) as potassium dihydrogen phosphate on the nutrient content of P. tuberosa were studied under greenhouse conditions. The leaf N content at harvest increased with increasing N rate. The highest leaf N content (2.64%) was obtained with 240 ppm N + 40 ppm P. The leaf P content decreased when N was applied at 120 to 240 ppm. The leaf P content increased with increasing P level. The highest leaf P content was obtained with 0 ppm N (0.26%) and 80 ppm P (0.25%). The leaf K content was reduced from 3.64% (control) to 3.42% with 240 ppm N and from 3.62% (control) to 3.39% with 80 ppm P. The highest spike N content (2.59%) was recorded for 240 ppm N + 40 ppm P. The highest spike P content (0.53%) was obtained with 60 ppm N + 80 ppm P. The K content of spikes was reduced from 2.53% (control) to 2.35% at 240 ppm N (Mohanasundaram *et al*., 2003).

Gupta *et al*. (2006) conducted field studies to determine the role of nitrogen (N) at 0, 40 and 80 g/m2 and phosphorus fertilizers (P) at 0, 150 and 300 g/m2 in 4 tuberose cultivars, i.e. Single, Double, Semidouble and Variegated for reproductive growth parameters such as spike emergence, growth period of bud, total number of flowers per spike and number of flowers appeared at a time per spike. The variegated cultivar showed positive response with 80 g N/m2 and 150 and 300 g P/m2 applications.

Chaudhary (2007) ascertained the response of nitrogen, phosphorus and bio fertilizers on plant growth and bulb production in tuberose. Treatments comprised of N (0, 50, 100 and 200 kg/ha) and P (0, 25, 50 and 100 kg/ha) in combination with bio fertilizers (no bio fertilizer, Azotobacter, PSB and VAM). Application of bio fertilizers in combination with N at the rate of 100 kg per hectare and P at the rate of 50 kg per hectare proved to be equally effective to N at the rate of 200 kg/ha and P at the rate of 100 kg/ha in increasing the plant 16 height, number of leaves per plant, number of bulbs/plant and advancing the sprouting of bulbs. The higher dose of N and P independently did not affect the growth, sprouting of bulbs and bulb production in tuberose.

Yadav (2007) conducted an experiment to study the effect of N (0, 10 and 20 g/m^2) and P (0, 6 and 12 g/m^2) fertilizers on the growth and flowering of tuberose cv. Shringar. Plant height, number of leaves per plant, number of flowers per spike, length of spike, length of rachis, number of spike per plot and weight of flower per spike was remarkably increased with N and P application, alone and in combination. However, N and P fertilizers did not have any significant effect on the flower length. Plant height (35.50 cm), number of leaves per plant (34.40), number of flowers (37.50) per spike, length of spike (49.40 cm), length of rachis (20.80 cm), number of spike per plot (33.90) and weight of flower (109.50 g) per spike were higher with combination of 20 g N and 12 g P per plot.

Patel *et al*. (2006) investigated an experiment with tuberose to know the effect of N (100, 200, 300 and 400 kg N/ha) and P (100, 150 and 200 kg P_2O_5/ha) on growth and yield of tuberose and reported that phosphorus was not significant on vegetative characters while floral characters such as rachis length and number of florets/spike were found significant. Bulb yield in terms of clump weight was also found significant and 200 kg P_2O_5/ha was recorded the highest values.

Gupta *et al*. (2006) conducted field studies in Uttar Pradesh, India, during the 1998/99 and 1999/2000 cropping seasons, to determine the role of nitrogen (N) at 0, 40 and 80 g/m^2 and phosphorus fertilizers (P) at 0, 150 and 300 g/m^2 in 4 tuberose cultivars, i.e. Single, Double, Semi-double and Variegated, for reproductive growth parameters such as spike emergence, growth period of bud, total number of flowers per spike and number of flowers appeared at a time per spike and reported that the Variegated cultivar showed positive response with 80 g N/m^2 and 150 and 300 g P/m^2 applications.

Sultana *et al*. (2006) carried a field trial on tuberose to observe the response of tuberose (cv. single) to different nutrient elements. Nutrients were 4 levels of nitrogen (0, 100, 200 and 300 kg/ha), 3 levels of phosphorus (0, 45 and 90 kg P/ha) and 3 levels of potassium (0, 80 and 160 kg K/ha) along with a blanket dose of 10 t/ha cowdung. The application of NPK significantly influenced the growth, flowering and flower quality of tuberose. All the parameters except plant height were the highest with 200 kg N, 45 kg P and 80 kg K/ha along with 10 t/ha cowdung.

Mohanasundaram *et al.* (2003) conducted a study to observe the effects of N (0, 60, 120, 180 or 240 ppm) as urea and P (0, 20, 40, 60 or 80 ppm) as potassium dihydrogen phosphate on the nutrient content of *Polianthes tuberosa* under greenhouse conditions. P increased the leaf N content, although no significant variation between rates was observed. The leaf P content increased with increasing P level. The highest leaf P content was obtained at 80 ppm P (0.25%).

Tuberose *(P. tuberosa)* cv. Single bulbs were supplied with 0, 10, 20, 30 or 40 g N/m^2 and 0, 12, 24 or 32 g P/m^2 in a field experiment conducted in Meghalaya, India during 1998-99 by Kumar *et al*. (2002). The authors reported that plant height, number of leaves per clump, number of days before flowering, number of bulbs per clump, rachis length, increased with increasing rates of P up to 24 g/m^2. P application had no significant effects on the rachis and spike length, number of florets per spike, durability of spike and bulb size of the crop.

The effects of N (150, 200 and 250 kg/ha) and P (250, 300 and 350 kg/ha) on the growth and yield of tuberose *(P. tuberosa)* cv. Single were determined in a field experiment conducted in Maharashtra, India during 1998-2001 by Kawarkhe and Jane (2002). The authors reported that plant height, number of leaves per plant, length of spike per plant, length of rachis, number of florets per spike and per plant, and number of spikes per pot and per hectare increased with increasing rates of P up to 300 kg/ha except for plant height and number of leaves per plant which increased with increasing rates of P up to 350 kg/ha.

Mishra *et al.* (2002) conducted an experiment in Bhubaneswar, Orissa, India, from March to December 1997 with tuberose cv. Single involving 4 levels of N, i.e. 0, 10, 20 and 30 g / m^2; 3 levels of P, i.e. 0, 20 and 30 g/m^2; and 2 levels of spacing maintained at 15 cm ×15 cm and 30 cm × 20 cm. The authors reported that P application showed no appreciable effect on different growth parameters studied, but flowering attributes such as spike length, rachis length, and weight of florets per spike and weight of 100 florets improved due to P application at 20 g or 30 g /m. Yield of flowers/ha (weight basis) also improved due to P treatments at 20 or 30 g/m, but yield of florets per spike (weight basis) was significantly increased at 30 g/m.

Dahiya *et al.* (2001) undertaken a pot culture experiment with sandy loam soil to evaluate the effect of N (0, 60, 120, 180, and 240 ppm as urea) and P (0, 20, 40, 60, and 80 ppm as KH) on the growth and dry matter yield of tuberose cv. Double. The authors observed that application of N and P greatly improved the growth (plant height and number of leaves) and dry matter yield (dry weight of leaves and spike), and total dry weight (leaves + spike). Growth and dry matter yield increased up to 180 ppm N and 60 ppm P levels. However, further increments in N above 180 ppm and P above 60 ppm adversely affected growth and dry matter yield.

An experiment was investigated to know the effect of 4 rates of fertilizers *viz*. 150:50:50, 150:100:100, 200:150:150 and 250:200:200 kg NPK/ha in Karnataka, India. Among the fertilizer rates, 250:200:200 kg NPK/ha resulted in the highest number of shoots, leaves and spikes, maximum plant height and flower yield (Patil *et al.* 1999).

Gowda *et al.* (1991) reported the effect of N, P and K on growth and flowering of tuberose cv. Double. Three rates of N application (100, 150 and 200 kg/ha), three of P_2O_5 (50, 75 and 100 kg/ha) and three of K_2O (100,125 and 150 kg/ha) were compared for a cutflower crop of tuberose. The authors observed that increasing P and K_2O rates resulted in a greater number of flower spikes and number of florets/spike. The highest yield of florets (40.20/spike), the longest spike (81.28 cm) and the longest duration of flowering (29.75 days) were obtained with 200 kg N+75 kg P_2O_5+125 g K_2O/ha.

Parthiban and Khader (1991) observed the effect of N, P and K on yield component and yield in tuberose cv. Single. N was applied at 50, 75, 100 or 125 kg; P at 258, 50 or 75 kg and K at 37.5, 62.5 or 87.5 kg/ha. Application of 100 g N+75 kg P+62.5 kg K/ha resulted the highest number of spikes/plant (1.72), number of florets/spike (39.67) and the highest flower yield (3578.6 kg/ha).

Bankar *et al.* (1990) evaluated the effect of NPK on growth and flowering of tuberose cv. double. N was applied at 0, 5, 10, 15, g/m^2, P_2O_5 at 0, 20 or 40 g/m^2 and K_2O at 0, 20 or 40 g/m^2. Fertilization of tuberose with N: P_2O_5 : K_2O at 20:20:20 g/m is recommended.

2.2 Effect of GA_3

Amin *et al*. (2017) conducted a field experiment to study the effect of plant growth regulators on growth and yield of tuberose. Treatments of the experiment were as control (No plant growth regulators), NAA 100 ppm, NAA 200 ppm, NAA 300 ppm, NAA 400 ppm, GA_3 100 ppm, GA_3 200 ppm, GA_3 300 ppm, GA_3 400 ppm, 4-CPA 100 ppm, 4-CPA 200 ppm, 4-CPA 300 ppm and 4-CPA 400 ppm. Different concentration of growth regulators showed significant variation on most of the parameters. Tallest tuberose plant (68.9 cm), longest length of rachis (21.9 cm), highest number of floret/spike (41.2), highest diameter of spike (1.1 cm), maximum weight of single spike (40.1 g) and highest number of spikes per hectare (3.9 lac) were obtained from GA_3 at 300 ppm.

Sultana *et al*. (2006) conducted an experiment to study the morphological characteristics of tuberose as influenced by gibberellic acid incorporated with organic manures. The experiment consisted with three levels of organic manure; control, cow dung 30 tha^{-1} and poultry litter 20 t ha^{-1} behind with 0 ppm, 100 ppm, 200 ppm and 300 ppm gibberellic acid were tested with three replications. Application of organic manures with GA_3 showed significant variations among the parameters. Yield of spike (3,50,000 ha^{-1}) and bulb (21.72 t ha^{-1}) was recorded in poultry litter @ 20 t ha^{-1} with 200 ppm GA_3 compared to other treatments which was more potential for production of tuberose.

Singh and Desai (2013) conducted an investigation to study the influence of GA_3 and CCC on growth and flowering of tuberose cv. ‘Single’. The treatments comprised three different concentration of GA3 (100, 200 and 300 mg/l) and CCC (0.5, 1.0 and 1.5 ml/l) with three methods of application (bulbs dipping, spraying and dipping + spraying). Application of GA_3 200 mg/l (dipping + spraying) was found to be most effective in improving the growth, flowering, quality and yield characteristics of tuberose.

Asil *et al*. (2011) shown that the effect of different chemical treatments on quantitative characteristics of *Polianthes tuberosa* L. (cv. Goldorosht Mahallat) was investigated. This research was conducted in a factorial experiment based on Randomized Block design with 3 replications. The flowers were sprayed with various concentration of Gibberellic acid (GA) and Benzyladenine (BA) (0, 50 and 100 ppm) at 40 and 50 days after planting,. The results showed that flowering, stem length and leaves length were greatest with GA_3 at 100 ppm while BA no increase these traits compared to the control. BA and GA_3 decreased number of floret. Greatest of floret and vase life of cut flower was BA at 50 and 100 ppm, respectively.

A study was conducted by Nejad and Etemadi (2010) to evaluate the effects of Gibberellic acid (GA_3) on flower quality and flowering date of tuberose (*Polianthes tuberosa*) . Double cultivar tuberose bulbs, ranging from 6 to 7 cm in diameter were used. GA_3 solutions were used 100, 200 and 300 ppm. The bulbs were soaked before cultivation and bud sprouts were sprayed with GA_3 solutions at two stages of plant development. GA_3 application methods did not show significant differences on the evaluated characters, while significant variations were observed among various GA_3 concentrations. Comparing the date of flowering harvest indicated that the highest number of flowers were picked 3 to 4 weeks after flowering for both GA_3 application method. The application of GA_3 (300 ppm) by soaking the bulbs before cultivation significantly increased the number of flowering shoots and flowering time.

Bharti and Ranjon (2009) conducted a field experiment to find out the effect of foliar spray of growth regulators in three doses each in GA_3 (50, 00 and 150 ppm), Kinetin (50, 100 and 150 ppm), NAA (50, 100 and 150 ppm), Ethrel (100, 200 and 300 ppm) and SADH (100, 200 and 300 ppm) on the flowering of two cultivars of tuberose *viz*., Shringer and Kalyani Double. Cultivar Shringar was superior in inducing early spike emergence, first floret opening and also produced maximum number of spikes/m^2 . However, cv. Kalyani

Double showed maximum number of florets and spike length and flowering duration. Among various treatment, GA_3 (150 ppm) was observed best in inducing early spike emergence, opening of first floret, 50 percent floret opening and maximum spike yield per sq. meter. The spike characteristics, such as length of rachis and spike, number of florets per spike, increased significantly with the application GA_3 (100 ppm). Maximum days to withering of first opened floret and flowering duration were observed with Kinetin (150 ppm). However, Ethrel (300 ppm) exhibited delayed flowering, maximum flowering duration and reduced length of spike characters.

Jitendra *et al*. (2009) conducted an experiment to study the effect of GA_3 and nitrogenous fertilizer (urea) on growth and floral parameters in tuberose cv. Pearl Double, consisting of two levels of GA_3 (100 ppm and 200 ppm) and two levels of urea (55 and 110 g/m). There are 4 treatment combinations, replicated three times and laid out in factorial randomized block design. The results revealed that combined application of gibberellic acid and nitrogenous fertilizer (urea) at different doses showed the beneficial effect in different growth and flowering attributes viz., days taken for bulb sprouting, plant height, number of leaves/plant, number of floret/spike, rachis length, spike length and floret length but delay in appearance of initial spike and opening of first florets was recorded by the individual application of gibberellic acid at higher concentration (GA_3 @ 200 ppm).

Padaganur *et al*. (2005) studied the effects of gibberellic acid (GA_3 at 50, 100 or 150 ppm), paclobutrazol (500, 1000 or 1500 ppm) and maleic hydrazide (500, 1000 or 1500 ppm) on the growth and yield of tuberose (Polianthes tuberosa cv. Single) in Dharwad, Karnataka, India, during 2001-02. GA_3 increased plant height, number of leaves, number of shoots, and leaf area. Paclobutrazol and maleic hydrazide reduced plant height, number of leaves, leaf area and spike length. Early flowering was obtained by 150 ppm GA_3, 1500 ppm maleic hydrazide and 1500 ppm paclobutrazol. Plants treated with

150 ppm GA_3 exhibited the earliest flowering (137.67 days), and recorded the greatest spike length (86.01 cm), spike weight (28.09 g), spike girth (0.630 cm), floret diameter (0.817 cm), floret length (5.69 cm), and loose flower yields per plot (3.66 kg) and hectare (6.35 t). The increase in the concentrations of the growth regulators increased the spike yield per hectare.

Satya and shukla (2005) shown that the effect of bulb size (<2, 2-3, and 3 cm, corresponding to small, medium and large bulbs) and pretreatment of bulbs with GA_3 [gibberellic acid] and CCC [chlormequat] on the yield of *Polianthes tuberosa* were studied in Bakewar, Etawah, Uttar Pradesh, India. The highest number of flowers per spike (38.30) and number of bulbs and bulblets per clump (28.71) were obtained with large bulbs treated with 400 ppm GA_3. Large bulbs treated with 400 ppm CCC gave the highest weight of flowers per spike (91.40 g).

Sanap *et al.* (2014) conducted a field experiment during 1996/97 at Pune, Maharashtra, Indiamto evaluate the effects of GA_3 (100, 150 and 200 ppm) and CCC [chlormequat] (100, 200 and 300 ppm) on tuberose cv. Single. Foliar spraying of the growth regulators was performed at 40, 55 and 70 days after planting. Data were recorded for various growth (number of leaves, leaf length and leaf breath) and flowering characters (days to flower spike emergence, days to flowering and days from spike emergence to flower harvest). All growth regulator treatments were significantly superior to the control (water spray), with at 150 ppm and CCC at 200 ppm sprays giving optimum growth and earliest flowering.

Singh *et al.* (2003) conducted an experiment in Meerut, Uttar Pradesh, India during 1997-98 on tuberose cv. Double. The treatments comprised of water dipping (control); dipping in GA_3 , IAA and NAA at 50 and 100 ppm each; spraying GA_3 and 100 ppm each; spraying GA_3, IAA and NAA; and dipping + spraying GA_3, IAA and NAA. The number of flowers, flower length and longevity of the whole spike were highest for bulbs dipped in 100 ppm Ga_3 for

24 hours before planting + spraying with 100 ppm GA_3 at 30 days after planting. Spike length and rachis length were also highest in bulbs dipped and sprayed with 100 ppm GA_3 at 100 ppm (dipping + spraying) increased the number (28.4), weight (90.52gm), diameter (4.20cm) and yield (305.25 g/ha) of tuberose.

Manisha *et al.* (2002) studied tuberose cv. Single in Varanasi, Uttar Pradesh, India, during 1999-2000. Treatments comprised of a control of foliar spray of gibberellic acid at 100, 150 and 200 ppm at 40, 60 and 80 days after planting. Treatment with GA_3 at all concentrations promoted the height of the plants and increased the number of leaves/plant, being highest (55.50cm and 15.99, respectively) with 150 ppm application. Approximately 5 days early appearance of floral bud (96.82 days) over control (102.00 days) was also observed with this treatment. GA_3 at all concentration significantly increased the number of spike/plant, number of flowers/spike and yield/ha. All these characters were the highest in plants applied with GA_3 at 150 ppm.

Nagar and Saraf (2002) conducted an experiment of identify the effects of gibberellic acid (GA_3 : 0, 100, 200 and 300 mg/litre) and nitrogen fertilizer (0, 15, 30, and 50 kg/feddan as ammonium nitrate), singly or in combination, on tuberose (*P. tuberose* cv. Double) in Alexandria, Egypt during the summer seasons of 2000 and 2001. The roots are soaked in GA_3 for 24 months after planting and twice within the following 42 days. The application of 200 mg GA_3/litre + 30 kg N/faddan resulted in the earliest flowering (109.30 days),and the greatest average plant height (99.34 cm), number of leaves/plant (51.85), leaf dry weight (14.88 g), number of spike/plant (4.94), number of florets/spike (29.91), flower duration (18.28 days), number of corms and cormels/clump (28.74), fresh and dry weights of corms and cormels/clump (121.72 and 8.67 gm respectively), and total cholorophyll content (229.87 mg/100gm leaf fresh weight). The highest average floret dry weight (4.47gm) was obtained with 300 mg GA_3 /litre + 550 kg N/Feddan. The contribution ratio of soil N decreased with increasing N fertilizer rate but increased with increasing GA_3 rate.

Tiwari and Singh (2002), observed an experiment to identify the effects of bulb size, i.e. large (>1.5 cm diameter), medium (1.0-1.5 cm), and small (<1.00cm), and preplanting soaking in gibberellic acid (GA_3) at 50, 100 150, 200 and 250 ppm on the growth flowering, and yield of tuberose in India during 1992-93. Plants raised from large bulbs had the greatest plant height, number of leaves/clump, leaf length, leaf width, foliage weight, clump weight, bulb and bulblets/clump, inflorescence length, spike length, flower length, spike diameter, flowers/spike, spikes/plant and showed the earliest flowering. Similar results were recorded for plants from bulbs treated with 200 ppm GA_3 . Large bulbs soaked in 200 ppm GA_3 showed significant increase in growth flowering and bulb production.

Wankhede *et al.* (2002) conducted an experiment during 200-2001 to study the effect of gibberellic acid with bulb soaking treatment and foliar spray on growth, flowering and yield of tuberose. Data indicated that higher concentration of GA_3 (150 ppm) for bulb soaking treatment and 200 ppm of GA_3 as a foliar spray showed significant increase in plant height, number of leaves, number of florets/spike and number of spikes/plant under study. Early sprouting, early emergence to flower stalk and early opening of the first pair of florets were recorded by bulb soaking in water and foliar spray of water and of these with control treatment combination.

In a greenhouse experiment Yang *et al*. (2002) on P. tuberose soaked bulbs with GA_3 (40 and 80 ml/litre) at 4^0 C for 30 days or at 30^0 C for 15 days before planting. Bulbs were planted in October, November and December. The tubers treated with low temperature and planted in October had high spouting rates. The low temperature combined with gibberellic acid increased the flowering rate. The highest flowering rate was over 95% with an average of 62%.

In a trail by Sanap *et al.* (2000) at Pune, tuberose plants were sprayed with 100, 200 or 300 ppm CCC chlormequat 40, 55 and 70 days after planting. Flower yield was highest (27.5 t/ha) when 150 ppm GA_3 was used.

Dalal *et al.* (1999) conducted a field experiment to study the influence of N application rate (0, 50, 60 or 70 kg/ha) and gibberellic acid (GA**3**) concentration (0, 10, 20 or 40 ppm) on flower quality of *P. tuberose***.** The optimum N application rate was70 kg/ha; rachis length, flower stalk length, flower weight and vase life were 30.68 cm, 88.78 cm, 89.14 g/plant and 12.74 days, respectively. The optimum concentration of GA_3 was 40 ppm; rachis length, flower stalk length, flower weight and vase life were 30.93cm, 91.06cm, (106.14) gm/plant and 12.94 days, respectively. The interaction between N and GA_3 was significant only in respect of weight of flowers per plant.

An experiment was conducted by Devendra *et al*. (1999) to study the effect of foliar applied plant growth regulators on the flowering and vase life of tuberose. The treatment comprised: 50, 100 and 150 ppm GA3; 100, 150 and 200 ppm NAA; 1000, 1500 and 2000 mg thiourea /litre. Foliar application was conducted at 30, 60 and 90 days after planting. GA3at 150 ppm gave the earliest number of days required for spike emergence (43.48) and longest vase life (11.35 days). Further, GA3gave maximum spike length (6.65 cm) and floret diameter (3.88 cm).

Singh (1999) noted the effects of gibberellic acid (GA_3 at 100 and 200 ppm), ethephon (200 and 400 ppm) and kinetin (50 and 100 ppm) on the growth, flowering and yield of tuberose cv. Double were investigated in Medziphema, Nagaland, India during 1998. The plant growth regulators were applied as foliar sprays 40 days after planting. The second application was conducted 3 weeks after the initial spraying. All growth regulators improved the performance of tuberose compared with the control. GA_3 at 200 ppm produced the tallest plants (35.87 cm) with the highest number of leaves per plant

(27.41), spike length (63.17 cm), number of florets per spike (35.99) and floret weight per plant (52.16 g). This treatment likewise resulted in the longest flowering duration (17.33 days). The number of bulbs per plant (9.74) and bulb weight per plant (76.95 g) were highest in plants treated with 100 ppm kinetin. Plants treated with ethephon (400 ppm) exhibited the earliest flowering (117 days).

Singh and Manoj (1999) conducted an experiment in Meerut, Uttar Pradesh, India during 1997-98 on tuberose cv. Double. The treatments comprised of water dipping (control); dipping in GA_3, IAA and NAA at 50 and 100 ppm each; spraying GA_3 and 100 ppm each; spraying GA_3, IAA and NAA; and dipping + spraying GA_3, IAA and NAA. The number of flowers, flower length and longevity of the whole spike were highest for bulbs dipped in 100 ppm GA_3 for 24 hour before planting + spraying with 100 ppm GA_3 at 30 days after planting. Spike length and rachis length were also highest in bulbs dipped and sprayed with 100 ppm GA_3 at 100 ppm (dipping + spraying) increased the number (28.4), weight (90.52 g), diameter (4.20 cm) and yield (305.25 g/ha) of tuberose.

Nagaraj *et al.* (1999) conducted an experiment to investigate the effect of growth regulators on the growth and flowering of tuberose. The tuberose bulbs were soaked for 24 hour in solutions of GA_3, Ethrel (ethephon) or BA each at 100, 500, 1000 and 1500 ppm and then planted in a randomized block design. All treatments influenced growth and flowering characteristics. All treatments resulted in earlier plant emergence, a higher percentage of sprouting and earlier flowering compared to the control with GA_3 at 500 and 1500 ppm being particularly effective. Plant height was greatest with GA_3 at 100 ppm while ethrel at all concentrations reduced plant height compared to the control. The number of spikes/plant and floret/spike were enhanced by GA_3 at 500 and 1500 ppm. All GA_3 treatments increased flower, spike length and rachis length. Length of flowering was greatest with ethrel at 1000 ppm. All GA_3

treatments and ethrel at 100 ppm increased bulb number where as all other ethrel and all BA treatments reduced bulb number.

Preeti *et al*. (1997) observed a field experiment during 1993-94 at Biswanath college of Agriculture, Sonitpur, Assam, India, to study the effects of pre-planting treatment of bulbs of (cv. Single) with GA_3 (50, 100 or 200 ppm), Ethrel [ethephon] (100, 200 or 400 ppm) or thiourea (1 and 2%) on growth. Compared with the control, treatment of bulbs with GA_3 , Ethrel or thiourea prompted the early appearance of flower spikes and promoted the number of flower spikes, but reduced the number of bulbs production/plant. Ethrel-treated plants gave a mixed response; flower production tended to decrease with increasing concentration of Ethrel. Treatment with GA_3 at 200 ppm produced the highest number of floret/spike.

Deotale *et al*. (1995) observed that Chrysanthemum (cv. Raja) was planted on 24 June and spraying with 105 ppm GA_3 produced the heaviest (2.15g) and largest (6.42 cm diameter) flowers.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted during August 2017 to October 2018 to study the effect of phosphorus (P) and gibberellic acid **(**GA_3) on growth, flowering and bulb of tuberose (*Polianthes tuberosa*). The details of the materials and methods have been presented below:

3.1 Experimental location

The present piece of research work was conducted in the Horticulture Farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka. The location of the site is90°33´ E longitude and 23°77´ N latitude with an elevation of 8.2 m from sea level. Location of the experimental site presented in Appendix I.

3.2 Soil

The soil of the experimental area belongs to the Modhupur Tract (UNDP, 1988) under AEZ No. 28 and was dark grey terrace soil. The selected plot was medium high land and the soil series was Tejgaon (FAO, 1988). The characteristics of the soil under the experimental plot were analyzed in the Soil Testing Laboratory, SRDI, Khamarbari, Dhaka. The details of morphological and chemical properties of initial soil of the experiment plot were presented in Appendix II.

3.3 Climate

The climate of experimental site was subtropical, characterized by three distinct seasons, the winter from November to February and the pre-monsoon period or hot season from March to April and the monsoon period from May to October (Edris *et al.,* 1979). Details on the meteorological data of air temperature, relative humidity, rainfall and sunshine hour during the period of the experiment was collected from the Weather Station of Bangladesh, Sher-e-Bangla Nagar, presented in Appendix III.

3.4 Plant materials

The tuberose variety ‘Double’ was used for the present study. Bulb of tuberose was collected from Barishal Narsery, Savar, Dhaka.

3.5 Experimental details

3.5.1 Treatments

The experiment comprised of two factors.

Factor A: Phosphorus

1. P_0 = Control
2. P_1 = 140 kg TSP ha^{-1} = 65 kg P_2O_5 ha^{-1}
3. P_2 = 190 kg TSP ha^{-1} =85 kg P_2O_5 ha^{-1}
4. P_3 = 240 kg TSP ha^{-1} = 110 kg P_2O_5 ha^{-1}

Factor B: GA_3

1. G_0 = Control
2. G_1 = 115 ppm GA_3
3. G_2 = 145 ppm GA_3

Treatment combinations - 12 treatment combinations

P_0G_0, P_0G_1, P_0G_2, P_1G_0, P_1G_1, P_1G_2, P_2G_0, P_2G_1, P_2G_2, P_3G_0, P_3G_1 and P_3G_2.

3.5.2 Experimental design and layout

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The layout of the experiment was prepared for distributing the different combination of phosphorus and GA_3 levels. The 12 treatment combinations of the experiment were assigned at random into 36 plots. The size of each unit plot 1.5 m × 1 m. The distance between blocks and plots were 1.0 m and 0.5 m respectively. The layout of the experiment field is presented here.

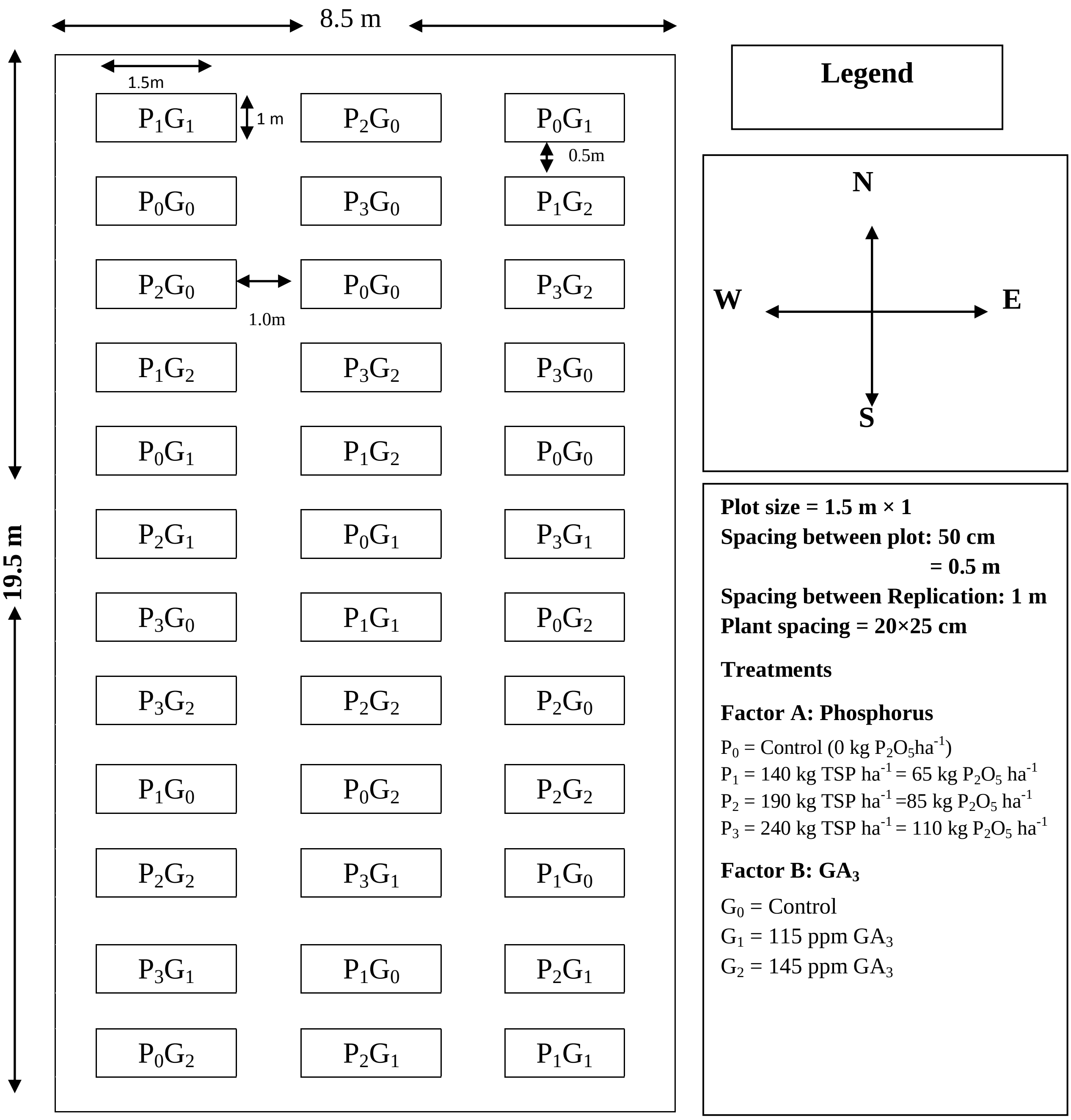

Fig. 1. Lay out of experimental plot.

3.6 Preparation of the main field

The plot selected for the experiment was opened in the first week of August, 2017 with a power tiller, and was exposed to the sun for a few days, after, which the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain a good tilth. Weeds and stubble were removed and finally obtained a desirable tilth of soil for transplanting. The land operation was completed on 16 August 2017. The individual plots were made by making ridges around each plot to restrict lateral runoff of irrigation water.

3.7 Fertilizers and manure application

The manure and fertilizer were applied according to BARI recommendation, 2018. N, P and K were applied through urea, TSP and MoP, respectively. Cowdung also used as organic manure. P was applied through TSP as per treatment. Nutrient doses used under the present study are presented as follows:

Nutrients	Manures/fertilizers	Doses ha^{-1}
-	Cowdung	10 ton
N	Urea	260 kg
P	TSP	As per treatmnt
K	MoP	250 kg

One third (1/3) of whole amount of Urea and full amount of TSP, MoP and cowdung were applied at the time of final land preparation. The remaining Urea was top dressed in two equal installments- at 30 and 55 days after transplanting (DAP).

3.8 Application and preparation of GA_3

The stock solution of 1000 ppm of GA_3 was made by mixing of 1 g of GA_3 with small amount of ethanol to dilute and then mixed in 1 litre of water. Then as per requirement of 115 ppm and 145 ppm solution of GA_3, 115 ml and 145 ml of stock solution were mixed with 1 litre of water respectively. Application of GA_3 was done at 40 days and 60 days after planting of bulb.

3.9 Collection and planting of bulbs

The bulbs of tuberose were used as planting materials in this experiment. The bulbs were collected from Barisal Nursery, Savar, Dhaka. The collected bulbs were planted in the experimental field on 16 August 2017. The bulbs were transplanted following raised bed system with 5 cm depth maintaining 20 cm × 25 cm plant spacing. After transplanting, the bulbs were covered with loose soil.

3.10 Intercultural operations

After establishment of seedlings, various intercultural operations were accomplished for better growth and development of the tuberose.

3.10.1 Weeding

The plots were kept free from weeds by three weeding. First weeding was done at 30 days after planting (DAP), second at 55 DAP and third weeding at 80 DAP. The weeds were eradicated with roots carefully so that the transplanted tuberose bulb did not affect during weeding.

3.10.2 Irrigation

Irrigation was applied for three times, where the first irrigation at 25 DAP, second at 45 DAP and the last irrigation at 65 DAP.

3.10.3 Pest management

Mole cricket, field cricket and cutworm are the major insects in particularly during seedling stage for tuberose cultivation. As a preventive measure against the insect pest, Dursban 20 EC was applied at the rate of 0.2% at 15 days interval for three times starting from 20 days after emergence of bulb.

3.10.4 Disease management

The crop was healthy and disease free and therefore no fungicide was used in this experiment.

3.11 Harvesting

The spikes were harvested when the basal floret opened and data were recorded for number spike/ha and yield/ha.

3.12 Data collection

Data on the following parameters were recorded from the sample plants during the course of experiment.

1. Plant height (cm)
2. Number of leaves plant^{-1}
3. Number of side shoots plant^{-1}
4. Spike length (cm)
5. Spike diameter
6. Rachis length (cm)
7. Number of florets spike^{-1}
8. Single spike weight (g)
9. Number of spike ha^{-1}
10. Bulb length (cm)
11. Bulb diameter (cm)
12. Number of bulb plant^{-1}
13. Fresh weight of bulb plant^{-1}
14. Bulb yield (t ha^{-1})
15. Number of bulblets plant^{-1}
16. Fresh weight of bulblet plant^{-1}
17. Bulblet yield (t ha^{-1})

3.13 Procedure of recording data

The following procedure was followed to record data on different parameters

3.13.1 Plant height (cm)

The height of plant was recorded in centimeter (cm) at 30, 55, 80 and 105 days after planting (DAP) in the experimental plots. The height was measured from the attachment of the ground level up to the tip of the growing point.

3.13.2 Number of leaves plant^{-1}

The number of leaves produced by mother plant was referred to the number of leaves per mother bulb. All the leaves of ten randomly selected plants were counted and their mean was calculated. The data recorded four times at an interval of 25 days starting from 30 DAP to 105 DAP.

3.13.3 Number of side shoots plant^{-1}

All the green shoots above the soil surface which developed from mother bulb and adjoined to it were counted as side shoot. It was measured at an interval of 25 days starting from 30 days after planting (DAP) till 80 days.

3.13.4 Spike length (cm)

The average length of spike (from mother bulb) was measured in centimeter from ten randomly selected plants with a meter scale from the basal (cutting) end of the spike to the last point of the tip floret of the spike in each treatment.

3.13.5 Spike diameter

Diameter of spike from ten selected plants was measured with the help of a slide calipers just after harvest of tuberose spike. Mean diameter was taken from top, middle and bottom portions of the harvested spikes.

3.13.6 Rachis length (cm)

Immediately after harvest of spike, the length of rachis which raised from mother bulbs was measured with the help of a meter scale from ten random selected plants and mean was expressed in centimeter. Length of rachis refers to the length from the basal floret to the tip of the last floret.

3.13.7 Number of florets spike^{-1}

After harvest, the number of florets/spike was counted and average was recorded which only produced from mother bulbs.

3.13.8 Single spike weight (g)

Ten spikes were cut from randomly selected plants from each unit plot and the weights of spikes were recorded to calculate their mean.

3.13.9 Number of spike ha^{-1}

Number of spikes per hectare was computed from numbers of spikes per plot and converted to hectare.

3.13.10 Bulb length (cm)

A slide calipers was used to measure the length of the bulb and expressed in centimeter and mean of 10 bulbs was calculated.

3.13.11Bulb diameter (cm)

A slide calipers was used to measure the diameter of the bulb and expressed in centimeter and mean of 10 bulbs was calculated.

3.13.12 Number of bulb plant^{-1}

It was calculated from the number of bulb obtained from ten randomly selected plants and mean was recorded.

3.13.13 Fresh weight of bulb plant^{-1}

It was determined by weighting the bulbs ten randomly selected plants just after harvest and mean weight was calculated.

3.13.14 Bulb yield (t ha^{-1})

Total bulb yield per plot was recorded by adding the total harvested bulb in a plot and expressed in kilogram and converting the yield of tuberose bulb per plot to per hectare and expressed in ton per hectare.

3.13.15 Number of bulblets plant^{-1}

It was calculated from the number of bulblet obtained from ten randomly selected plants and mean was recorded.

13.13.16 Fresh weight of bulblet plant^{-1}

Individual weight of bulblet was recorded from the mean weight of ten randomly selected sample bulblets and expressed in gram.

13.13.17 Bulblet yield (t ha^{-1})

Total bulblet yield per plot was recorded by adding the total harvested bulb in a plot and expressed in kilogram and converting the yield of tuberose bulblet per plot to per hectare and expressed in ton per hectare.

3.14 Statistical analysis

The data collected from the experimental plots were analyzed statistically with the help of computer software programme MSTAT-C. The mean differences were adjusted with LSD Test (Gomez and Gomez, 1984).

3.15 Economic analysis

Economic analysis was done to find out the cost effectiveness of different treatments like different levels of phosphorus and GA_3 in cost and return were done in details according to the procedure of Alam *et al*. (1989).

3.15.1 Analysis of total cost of production

All the material and non-material input cost, interest on fixed capital of land and miscellaneous cost were considered for calculating the total cost of production. Total cost of production (input cost, overhead cost), gross return, net return and BCR are presented in Appendix X.

3.15.2 Gross income

Gross income was calculated on the basis of mature spike, bulb and bulblet of tuberose sale. The price was assumed on the basis of local market value.

3.15.3 Net return

Net return was calculated by deducting the total production cost from gross income for each treatment combination.

3.15.4 Benefit cost ratio (BCR)

The economic indicator BCR was calculated by the following formula for each treatment combination.

$$\text{Benefit cost ratio (BCR)} = \frac{\text{Gross income per hectare}}{\text{Total cost of production per hectare}}$$

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was carried out to find out the effect of phosphorus (P) and gibberellic acid **(**GA_3) on growth, flowering and bulb production of tuberose. The analysis of variance (ANOVA) of the data on different growth parameter and yield of flower, bulb and bulblet are presented in Appendix V-XII. The results have been presented and discussed, and possible interpretations given under the following sub headings:

4.1 Growth parameters

4.1.1 Plant height

Significant influence was observed in plant height of tuberose at different growth stages (Fig. 2 and Appendix IV). Results indicated that the highest plant heights (22.54, 45.37, 52.30 and 61.02 cm at 30, 55, 80 and 105 DAP, respectively) were found from the treatment P_3 (110 kg P_2O_5 ha^{-1}) which was significantly different from all other treatments whereas the shortest plant was recorded in control P_0 (0 kg $P_2O_5ha^{-1}$) at all growth stages (17.53, 37.35, 44.87 and 52.41 cm at 30, 55, 80 and 105 DAP, respectively). This result indicates that phosphorous has tremendous effect on growth and development in tuberose and was found that plant height was increased with increasing P levels. This result is supported by Sultana *et al.* (2006) in tuberose whom reported that phosphorus had much more influence on plant growth and development in tuberose.

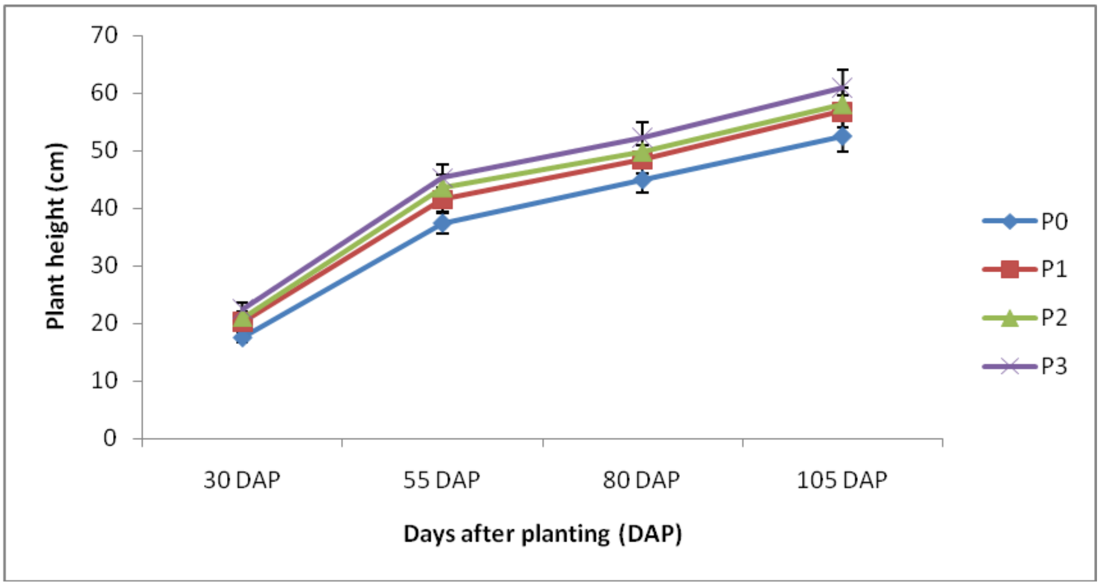

Fig. 2: Plant height of tuberose at different days after planting as influenced by phosphorus

P_0 = Control (0 kg $P_2O_5 ha^{-1}$), P_1 = 140 kg TSP ha^{-1} = 65 kg P_2O_5 ha^{-1}, P_2 = 190 kg TSP ha^{-1} =85 kg P_2O_5 ha^{-1}, P_3 = 240 kg TSP ha^{-1} = 110 kg P_2O_5 ha^{-1}

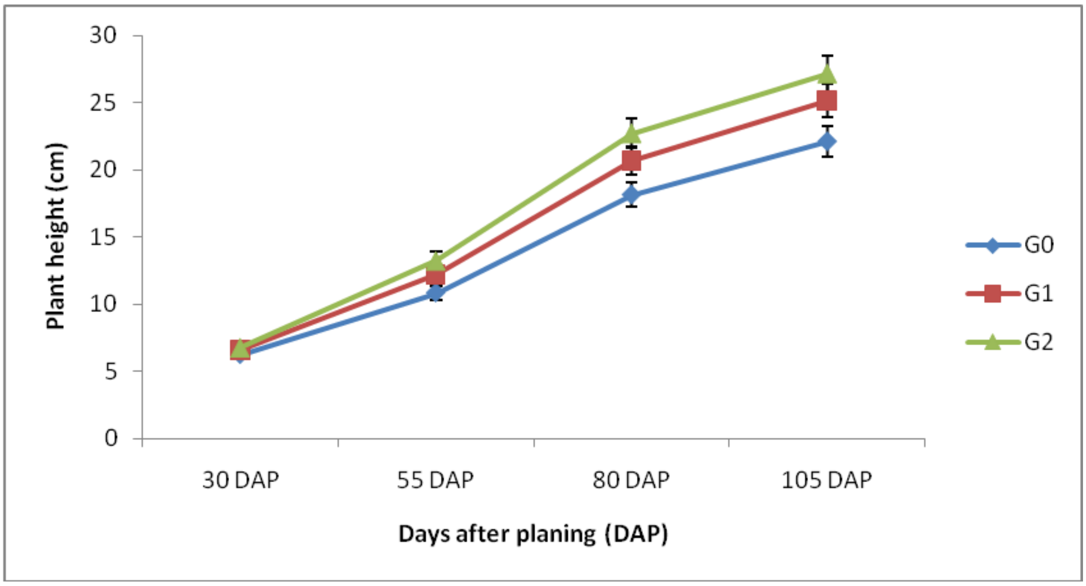

Fig. 3: Plant height of tuberose at different days after planting as influenced by GA_3

G_0 = Control, G_1 = 115 ppm GA_3, G_2 = 145 ppm GA_3

Variation on plant height among the treatments was significant at different growth stages of tuberose (Fig. 3 and Appendix IV). Results showed that the highest plant height (21.67, 4.91, 51.05 and 59.46 cm at 30, 55, 80 and 105 DAP, respectively) was found from the treatment G_2 (145 ppm GA_3) whereas the lowest plant height (18.90, 40.03, 46.51 and 54.33 cm at 30, 55, 80 and 105 DAP, respectively) was found from the control treatment G_0 (0 ppm GA_3). This result indicated that the plant height increased linearly with the increasing level of GA_3. The observed results were in agreement with the findings of Nagaraja *et al*. (1999) and Wankhade *et al*. (2002a) and they found that plant height was increased with the increasing level of GA_3 to a certain level.

Table 1: Plant height of tuberose at different days after planting as influenced by phosphorus and GA_3

Treatments	Plant height (cm)			
	30 DAP	55 DAP	80 DAP	105 DAP
P_0G_0	16.85 i	36.35 i	44.24 i	50.82 h
P_0G_1	17.55 h	37.50 hi	44.83 hi	52.74 g
P_0G_2	18.19 g	38.20 gh	45.53 gh	53.68 fg
P_1G_0	18.78 fg	39.38 g	46.51 fg	54.33 f
P_1G_1	19.84 e	41.04 f	47.43 ef	56.47 de
P_1G_2	22.03 c	44.12 cd	51.30 c	59.69 c
P_2G_0	19.28 ef	42.49 ef	47.25 ef	55.00 ef
P_2G_1	21.27 d	42.77 de	49.91 d	58.81 c
P_2G_2	22.54 bc	45.49 bc	52.17 c	60.31 bc
P_3G_0	20.68 d	41.92 ef	48.07 e	57.16 d
P_3G_1	23.00 b	46.37 ab	53.63 b	61.75 b
P_3G_2	23.92 a	47.83 a	55.20 a	64.15 a
$LSD_{0.05}$	0.6245	1.557	1.078	1.559
CV(%)	6.56	8.36	10.30	9.61

In a column, figure (s) bearing same letter do not differ significantly at $P \leq 0.05$ by LSD

P_0 = Control (0 kg $P_2O_5 ha^{-1}$), P_1 = 140 kg TSP ha^{-1} = 65 kg P_2O_5 ha^{-1}, P_2 = 190 kg TSP ha^{-1} =85 kg P_2O_5 ha^{-1}, P_3 = 240 kg TSP ha^{-1} = 110 kg P_2O_5 ha^{-1}

G_0 = Control, G_1 = 115 ppm GA_3, G_2 = 145 ppm GA_3

Significant variation was recorded due to combined effect of P and GA_3 in terms of plant height of tuberose at 30, 55, 60, 80 and 105 days after planting (DAP) (Table 1 and Appendix IV). The highest plant height (23.92, 47.83, 55.20 and 64.15 cm at 30, 55, 80 and 105 DAP, respectively) was found from the treatment combination of P_3G_2 whereas the lowest plant height (16.85, 36.35, 44.24 and 50.82 cm at 30, 55, 80 and 105 DAP, respectively) was found from the control treatment combination of (P_0G_0). It was revealed that P_3G_2 ensure maximum vegetative growth of plants and the ultimate results was the highest plant height of tuberose.

4.1.2 Number of leaves plant^{-1}

Significant differences were recorded on number of leaves plant^{-1} at different growth stages except at 30 DAP by applying different levels of P plant^{-1} (Fig. 4 and Appendix V). The highest number of leaves plant^{-1} (7.02, 13.92, 24.14 and 29.35 at 30, 55, 80 and 105 DAP, respectively) was found from the treatment P_3 (110 kg P_2O_5 ha^{-1}) whereas the lowest number of leaves plant^{-1} (6.00, 9.53, 15.89 and 19.34 at 30, 55, 80 and 105 DAP, respectively) was found from the control treatment P_0 (0 kg P_2O_5ha^{-1}). Results revealed that leaf production was greater in phosphorus applied plots than control plots indicating application of phosphorus had effect on leaf production. Result further revealed that leaf production increased with increasing phosphorus level.

Significant variation was found in case of number of leaves plant^{-1} due to application of different levels of GA_3 at different days after planting except 30 DAP. (Fig. 5 and Appendix V). The highest number of leaves plant^{-1} (6.80, 13.24, 22.73 and 27.17 at 30, 55, 80 and 105 DAP, respectively) was found from the treatment G_2 (145 ppm GA_3) whereas the lowest number of leaves plant^{-1} (6.24, 10.83, 18.13 and 22.10 at 30, 55, 80 and 105 DAP, respectively) was found from the control treatment G_0 (0 ppm GA_3). The number of leaves increased with the advancement of time with increasing of GA_3. The higher number of leaves per plant achieved on account of higher level of plant growth regulator. The present findings also support to the results of Wankhede *et al.* (2002).

Significant variation was recorded on number of leaves plant^{-1} of tuberose due to combined effect of P and GA_3 in terms of except 30 DAP (Table 2 and Appendix V). It was observed that the highest number of leaves plant^{-1} (7.33, 15.11, 26.13 and 31.95 at 30, 55, 80 and 105 DAP, respectively) was found from the treatment combination of P_3G_2. At 105 DAP, the highest number of leaves plant^{-1} (29.35) was statistically similar with the treatment combination of P_3G_1. The lowest number of leaves plant^{-1} (5.91, 8.16, 14.97 and 18.39 at 30, 55, 80 and 105 DAP, respectively) was found from the control treatment combination of P_0G_0. At 105 DAP, the lowest number of leaves plant^{-1} (18.39) was statistically similar with the treatment combination of P_0G_1 and P_0G_2.

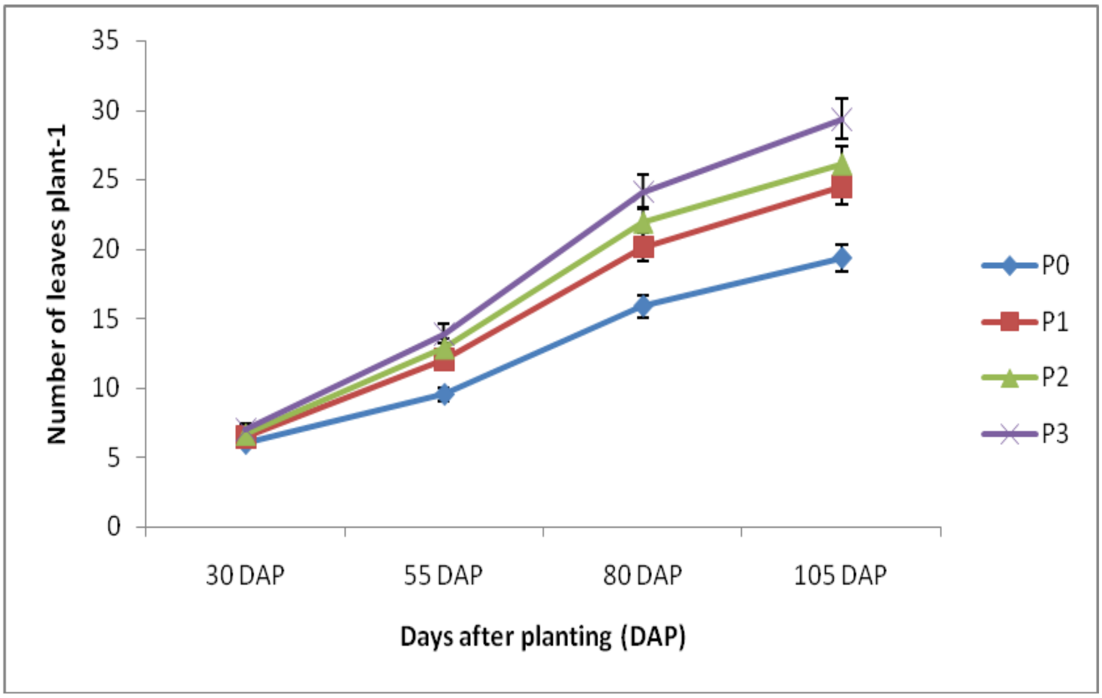

Fig. 4: Number of leaves plant of tuberose at different days after planting as influenced by phosphorus

P_0 = Control (0 kg P_2O_5ha^{-1}), P_1 = 140 kg TSP ha^{-1} = 65 kg P_2O_5 ha^{-1}, P_2 = 190 kg TSP ha^{-1} =85 kg P_2O_5 ha^{-1}, P_3 = 240 kg TSP ha^{-1} = 110 kg P_2O_5 ha^{-1}

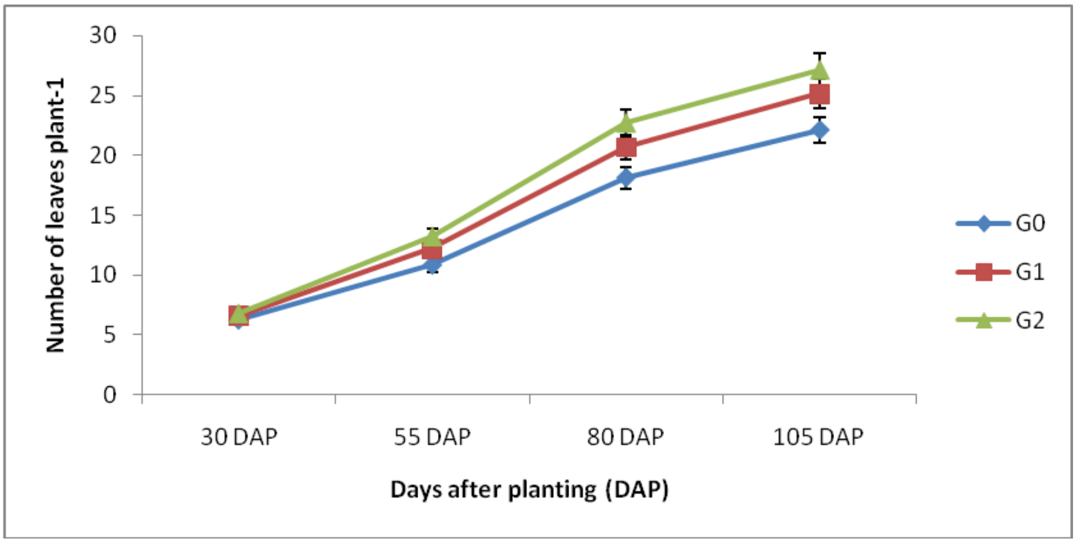

Fig. 5: Number of leaves plant of tuberose at different days after planting as influenced by GA_3

G_0 = Control, G_1 = 115 ppm GA_3, G_2 = 145 ppm GA_3

Table 2: Number of leaves plant of tuberose at different days after planting as influenced by phosphorus and GA_3

Treatments	Number of leaves plant^{-1}			
	30 DAP	55 DAP	80 DAP	105 DAP
P_0G_0	5.91	8.16 i	14.97 g	18.39 h
P_0G_1	6.01	9.75 h	16.03 fg	19.07 h
P_0G_2	6.08	10.69 g	16.67 fg	20.57 gh
P_1G_0	6.10	11.19 fg	17.72 ef	21.57 g
P_1G_1	6.44	11.77 ef	19.20 e	24.14 ef
P_1G_2	6.85	13.17 cd	23.42 bc	27.71 cd
P_2G_0	6.28	11.67 ef	18.60 e	22.64 fg
P_2G_1	6.75	12.90 d	22.40 cd	27.16 cd
P_2G_2	6.95	14.01 bc	24.72 ab	28.46 bc
P_3G_0	6.67	12.29 de	21.23 d	25.78 de
P_3G_1	7.05	14.35 ab	25.07 ab	30.30 ab
P_3G_2	7.33	15.11 a	26.13 a	31.95 a
$LSD_{0.05}$	NS	0.8992	1.777	2.233
CV(%)	5.96	6.39	6.03	8.31

In a column, figure (s) bearing same letter do not differ significantly at $P \leq 0.05$ by LSD

P_0 = Control (0 kg $P_2O_5ha^{-1}$), P_1 = 140 kg TSP ha^{-1} = 65 kg P_2O_5 ha^{-1}, P_2 = 190 kg TSP ha^{-1} =85 kg P_2O_5 ha^{-1}, P_3 = 240 kg TSP ha^{-1} = 110 kg P_2O_5 ha^{-1}

G_0 = Control, G_1 = 115 ppm GA_3, G_2 = 145 ppm GA_3

4.1.3 Number of side shoots plant^{-1}

Significant variation was observed in terms of number of side shoot plant^{-1} affected by different levels of P at different growth stages (Table 3 and Appendix VI). The maximum number of side shoot plant^{-1} (2.04, 4.47 and 6.69 at 30, 55 and 80 DAP, respectively) was found from the treatment P_2 (85 kg P_2O_5 ha^{-1}) which was statistically identical with P_3 (110 kg P_2O_5 ha^{-1}) at all growth stages whereas the minimum number of side shoot plant^{-1} (0.92, 2.17 and 4.07 at 30, 55 and 80 DAP, respectively) was found from the control treatment P_0 (0 kg P_2O_5 ha^{-1}). Different levels of P showed a gradual increasing trend in terms of number of side shoot per plant of tuberose with the increasing of P application to a certain level. The lesser amount of phosphorus application may not available for uptake by the plants in control plots and probably was not sufficient for normal plant growth and development and resulted in reduction of number of side shoots plant^{-1}. This result is in full agreement with that of Dahiya *et al*. (2001) who stated that the number of side shoots plant^{-1} increased with increasing phosphorous levels from 30 to 150 kg P_2O_5 ha^{-1} in tube rose.

Different concentrations of GA_3 showed significant difference on number of side shoot plant^{-1} at different growth stages (Table 3 and Appendix VI). The highest number of side shoot plant^{-1} (2.00, 4.43 and 6.64 at 30, 55 and 80 DAP, respectively) was found from the treatment G_2 (145 ppm GA_3) whereas the lowest number of side shoot plant^{-1} (1.13, 2.59 and 4.57 at 30, 55 and 80 DAP, respectively) was found from the control treatment G_0 (0 ppm GA_3). Pathak *et al*. (1980) found similar trend of results in their trail which is support to the present finding by using GA_3 they found that side shoot was increased with increasing GA3 rate and it was highest with 200 ppm.

Table 3: Number of side shoot plant^{-1} of tuberose at different days after planting as influenced by phosphorus and GA_3

Treatments	Number of side shoot plant^{-1}		
	30 DAP	55 DAP	80 DAP
Effect of phosphorus (P)			
P_0	0.92 c	2.17 c	4.07 c
P_1	1.52 b	3.36 b	5.57 b
P_2	2.04 a	4.47 a	6.69 a
P_3	1.94 a	4.35 a	6.55 a
$LSD_{0.05}$	0.201	0.205	0.221
CV(%)	4.22	7.64	9.74
Effect of GA_3			
G_0	1.13 c	2.59 c	4.57 c
G_1	1.69 b	3.75 b	5.96 b
G_2	2.00 a	4.43 a	6.64 a
$LSD_{0.05}$	0.142	0.17	0.187
CV(%)	4.22	7.64	9.74
Combined effect of P and GA_3			
P_0G_0	0.73 i	1.70 h	3.17 i
P_0G_1	0.87 hi	1.95 gh	4.10 h
P_0G_2	1.17 gh	2.85 f	4.95 g
P_1G_0	1.02 ghi	2.16 g	4.44 h
P_1G_1	1.66 de	3.77 d	5.86 e
P_1G_2	1.87 cd	4.16 c	6.42 d
P_2G_0	1.29 fg	3.09 ef	5.20 fg
P_2G_1	2.18 b	4.85 b	7.07 bc
P_2G_2	2.66 a	5.49 a	7.79 a
P_3G_0	1.48 ef	3.42 e	5.47 f
P_3G_1	2.03 bc	4.43 c	6.78 cd
P_3G_2	2.32 b	5.21 a	7.40 b
$LSD_{0.05}$	0.301	0.343	0.386
CV(%)	4.22	7.64	9.74

In a column, figure (s) bearing same letter do not differ significantly at $P \leq 0.05$ by LSD

P_0 = Control (0 kg P_2O_5ha^{-1}), P_1 = 140 kg TSP ha^{-1} = 65 kg P_2O_5 ha^{-1}, P_2 = 190 kg TSP ha^{-1} =85 kg P_2O_5 ha^{-1}, P_3 = 240 kg TSP ha^{-1} = 110 kg P_2O_5 ha^{-1}

G_0 = Control, G_1 = 115 ppm GA_3, G_2 = 145 ppm GA_3

Combined effect of P and GA_3 showed the significant variation in terms of number of side shoot per plant of tuberose at different growth stages (Table 3 and Appendix VI). The highest number of side shoot plant^{-1} (2.66, 5.49 and

7.79 at 30, 55 and 80 DAP, respectively) was recorded from the treatment combination of P_2G_2 whereas the lowest number of side shoot plant^{-1} (0.3, 1.70 and 3.17 at 30, 55 and 80 DAP, respectively) was found from the control treatment combination of P_0G_0.

4.2 Yield contributing parameters and yield

4.2.1 Spike length (cm)

Different levels of phosphorus significantly influenced the spike length (Table 4 and Appendix VII). Results showed that spike length increased with increasing phosphorus rate. The highest spike length (79.13 cm) was found from the treatment P_2 (85 kg P_2O_5 ha^{-1}) which was statistically identical with P_3 (110 kg P_2O_5 ha^{-1}) whereas the lowest spike length (64.06 cm) was found from the control treatment P_0 (0 kg P_2O_5 ha^{-1}). The lesser amount of phosphorus application may not available for uptake by the plants in control treatment and might be insufficient for normal plant growth and development and resulted in reduction of number of side shoots plant^{-1}. This result is in agreement with the findings of Dahiya *et al*. (2001) who reported that the number of side shoots plant^{-1} increased with increasing phosphorous levels from 30 to 150 kg P_2O_5 ha^{-1} in tuberose.

Application of different concentration of GA_3 showed significant variation on length of spike (Table 4 and Appendix VII). The highest spike length (78.66 cm) was found from G_2 (145 ppm GA_3) and the lowest spike length (67.24 cm) was found from the control treatment G_0 (0 ppm GA_3). Results also showed that spike length was increased with increasing rate of GA_3. The results also agreed with the findings of Singh (1999) in tuberose plant who reported that the higher spike length was due to 150 ppm compared to 50 and 100 ppm GA_3.

Application of different combination of P and GA_3 showed significant variation on spike length (Table 4 and Appendix VII). The highest spike length (85.96 cm) was found from the treatment combination of P_2G_2 which was significantly different from all other treatment combinations. The lowest spike length (60.64 cm) was found from the control treatment combination of P_0G_0.

4.2.2 Spike diameter (cm)

Different levels of phosphorus did not show significant influence on spike diameter (Table 4 and Appendix VII). However, the highest spike diameter (1.93 cm) was found from the treatment P_2 (85 kg P_2O_5 ha^{-1}) and the lowest spike diameter (1.65 cm) was found from the control treatment P_0 (0 kg P_2O_5 ha^{-1}).

Application of different concentration of GA_3 showed non-significant variation among the treatment on spike diameter (Table 4 and Appendix VII). However, the highest spike diameter (1.95 cm) was found from the treatment G_2 (145 ppm GA_3) whereas the lowest spike diameter (1.78 cm) was found from the control treatment G_0 (0 ppm GA_3).

Significant variation was not found in terms of spike diameter influenced by different levels of P and GA3 combination (Table 4 and Appendix VII). However, the highest spike diameter (2.22 cm) was found from the treatment combination of P_2G_2 whereas the lowest spike diameter (1.62 cm) was found from the control treatment combination of P_0G_0.

4.2.3 Rachis length (cm)

Different levels of phosphorus significantly influenced the rachis length (Table 4 and Appendix VII). The highest rachis length (31.21 cm) was found from the treatment P_2 (85 kg P_2O_5 ha^{-1}) which was statistically identical with P_3 (110 kg P_2O_5 ha^{-1}) whereas the lowest rachis length (24.91 cm) was found from the control treatment P_0 (0 kg P_2O_5 ha^{-1})

Application of different concentration of GA_3 showed significant variation on rachis length (Table 4 and Appendix VII). The highest rachis length (31.01 cm) was found from the treatment G_2 (145 ppm GA_3) which was significantly different from all other treatments. The lowest rachis length (26.33 cm) was found from the control treatment G_0 (0 ppm GA_3)

Combined effect of P and GA_3 showed significant variation in terms of rachis length of tuberose (Table 4 and Appendix VII). The highest rachis length (34.20 cm) was found from the treatment combination of P_2G_2 which was significantly different from all other treatment combinations followed by P_3G_2. The lowest rachis length (23.07 cm) was found from the control treatment combination of P_0G_0.

4.2.4 Number of florets spike^{-1}

Different levels of phosphorus showed significant influenced on number of florates spike^{-1} (Table 4 and Appendix VII). Results indicated that the highest no. of florates spike^{-1} (21.95) was found from the treatment P_2 (85 kg P_2O_5 ha^{-1}) which was statistically identical with P_3 (110 kg P_2O_5 ha^{-1}). The lowest no. of florates spike^{-1} (14.96) was found from the control treatment P_0 (0 kg P_2O_5 ha^{-1}).

Different concentrations of GA_3 showed significant difference on no. of florates spike^{-1} (Table 4 and Appendix VII). It was observed that the highest no. of florates spike^{-1} (21.75) was found from the treatment G_2 (145 ppm GA_3) whereas the lowest no. of florates spike^{-1} (16.72) was found from the control treatment G_0 (0 ppm GA_3).

Combined effect of P and GA_3 demonstrated the significant variation regarding no. of florates spike^{-1} of tuberose (Table 4 and Appendix VII). It was noted that the highest no. of florates spike^{-1} (24.57) was found from the treatment combination of P_2G_2 which was statistically similar with P_3 (110 kg P_2O_5 ha^{-1}) whereas the lowest no. of florates spike^{-1} (12.37) was found from the control treatment combination of P_0G_0.

4.2.5 Single spike weight (g)

Different levels of phosphorus significantly influenced the single spike weight (Table 4 and Appendix VII). The highest single spike weight (69.22 g) was found from the treatment P_2 (85 kg P_2O_5 ha^{-1}) which was statistically identical with P_3 (110 kg P_2O_5 ha^{-1}) whereas the lowest single spike weight (58.67 g) was found from the control treatment P_0 (0 kg P_2O_5 ha^{-1}).

Application of different concentration of GA_3 showed significant variation on single spike weight (Table 4 and Appendix VII). The highest single spike weight (68.71 g) was found from the treatment G_2 (145 ppm GA_3) which was significantly different from all other treatments. The lowest single spike weight (60.85 g) was found from the control treatment G_0 (0 ppm GA_3).

Different concentrations of P and GA_3 combinations showed statistically significant variation on single spike weight (Table 4 and Appendix VII). The highest single spike weight (74.50 g) was found from the treatment combination of P_2G_2 which was significantly different from all other treatment combinations followed by P_3G_2. The lowest single spike weight (56.13 g) was found from the control treatment combination of P_0G_0 which was also significantly different from all other treatment combinations.

4.2.6 Number of spike ha^{-1} ('000')

Different levels of phosphorus significantly influence the no. of spike ha^{-1} (Table 4 and Appendix VII). The highest no. of spike ha^{-1} (368.60 thousand) was found from the treatment P_2 (85 kg P_2O_5 ha^{-1}) which was statistically identical with P_3 (110 kg P_2O_5 ha^{-1}). The lowest number of spike ha^{-1} (241.30 thousand) was found from the control treatment P_0 (0 kg P_2O_5 ha^{-1}).

Application of different concentration of GA_3 showed significant variation on no. of spike ha^{-1} (Table 4 and Appendix VII). The highest no. of spike ha^{-1} (362.30 thousand) was found from the treatment G_2 (145 ppm GA_3) which was significantly different from G_1 (115 ppm GA_3) and control treatment. The lowest no. of spike ha^{-1} (277.80 thousand) was found from the control treatment G_0 (0 ppm GA_3). The result obtained from the present study was similar with the findings of Bharti and Ranjon (2009) who concluded that GA_3 (150 ppm) was observed best in inducing early spike emergence and maximum spike yield per sq. meter.

Different concentrations of P and GA_3 combinations showed significant variation on number of spike ha^{-1} (Table 4 and Appendix VII). The highest no. of spike ha^{-1} (405.60 thousand) was found from the treatment combination of P_2G_2 which was statistically identical with the treatment combination of P_3G_2 followed by P_2G_1. The lowest no. of spike ha^{-1} (189.60 thousand) was found from the control treatment combination of P_0G_0.

4.2.7 Bulb length (cm)

Different levels of phosphorus significantly influenced the bulb length (Table 5 and Appendix VIII). However, the highest bulb length (7.69 cm) was found from the treatment P_2 (85 kg P_2O_5 ha^{-1}) whereas the lowest bulb length (6.71 cm) was found from the control treatment P_0 (0 kg P_2O_5 ha^{-1}).

Application of different concentration of GA_3 showed significant variation on bulb length (Table 5 and Appendix VIII). However, the highest bulb length (7.68 cm) was found from the treatment G_2 (145 ppm GA_3) whereas the lowest bulb length (6.89 cm) was found from the control treatment G_0 (0 ppm GA_3).

Table 4: Yield contributing parameters and yield of tuberose spike as influenced by phosphorus and GA_3

Treatments	Yield contributing parameters and yield of tuberose spike					
	Spike length (cm)	Spike diameter (cm)	Rachis length (cm)	No. of florates $Spike^{-1}$	Single spike weight (g)	Spike yield (No. of spike ha^{-1}) ('000')
Effect of phosphorus (P)						
P_0	64.06 c	1.65	24.91 c	14.96 c	58.67 c	241.30 c
P_1	72.93 b	1.70	28.47 b	19.14 b	64.45 b	323.60 b
P_2	79.13 a	1.93	31.21 a	21.95 a	69.22 a	368.60 a
P_3	78.23 a	1.80	31.04 a	21.79 a	68.07 a	365.30 a
$LSD_{0.05}$	2.142	0.412^{NS}	0.9956	0.9708	1.294	9.082
CV(%)	8.98	8.55	6.76	5.10	7.33	8.12
Effect of GA_3						
G_0	67.24 c	1.78	26.33 c	16.72 c	60.85 c	277.80 c
G_1	74.85 b	1.86	29.39 b	19.92 b	65.75 b	334.00 b
G_2	78.66 a	1.95	31.01 a	21.75 a	68.71 a	362.30 a
$LSD_{0.05}$	1.796	0.491^{NS}	1.375	1.193	1.404	8.001
CV(%)	8.98	8.55	6.76	5.10	7.33	8.12
Combined effect of P and GA_3						
P_0G_0	60.64 i	1.62	23.07 i	12.37 h	56.13 i	189.60 j
P_0G_1	63.53 h	1.63	24.98 h	14.69 g	58.43 h	241.80 i
P_0G_2	68.01 fg	1.71	26.69 fg	17.83 f	61.45 g	292.40 g
P_1G_0	65.99 g	1.69	25.80 gh	16.10 g	60.19 g	267.50 h
P_1G_1	75.58 d	1.92	29.46 de	20.20 de	65.54 e	345.80 de
P_1G_2	77.23 cd	1.97	30.15 d	21.11 cd	67.61 d	357.70 cd
P_2G_0	70.07 ef	1.84	27.64 f	18.60 ef	63.03 f	321.50 f
P_2G_1	81.36 b	2.03	31.78 c	22.67 bc	70.14 bc	378.70 b
P_2G_2	85.96 a	2.22	34.20 a	24.57 a	74.50 a	405.60 a
P_3G_0	72.29 e	1.89	28.79 e	19.79 de	64.06 f	332.50 ef
P_3G_1	78.95 c	2.00	31.32 c	22.11 bc	68.87 cd	369.80 bc
P_3G_2	83.46 b	2.09	33.01 b	23.49 ab	71.28 b	393.60 a
$LSD_{0.05}$	NS	0.675	1.119	1.681	1.467	14.10
CV(%)	8.98	8.55	6.76	5.10	7.33	8.12

In a column, figure (s) bearing same letter do not differ significantly at $P \leq 0.05$ by LSD

P_0 = Control (0 kg $P_2O_5ha^{-1}$), P_1 = 140 kg TSP ha^{-1} = 65 kg P_2O_5 ha^{-1}, P_2 = 190 kg TSP ha^{-1} =85 kg P_2O_5 ha^{-1}, P_3 = 240 kg TSP ha^{-1} = 110 kg P_2O_5 ha^{-1}

G_0 = Control, G_1 = 115 ppm GA_3, G_2 = 145 ppm GA_3

Different concentrations of P and GA3 combinations showed statistically significant variation on bulb length (Table 5 and Appendix VIII). The highest bulb length (8.19 cm) was found from the treatment combination of P2G2 which was statistically similar with P3 (110 kg P2O5 ha-1) whereas the lowest bulb length (6.51 cm) was found from the control treatment combination of P0G0.

4.2.8 Bulb diameter (cm)

Different levels of phosphorus significantly influenced the bulb diameter (Table 5 and Appendix VIII). The highest bulb diameter (4.11 cm) was found from the treatment P_2 (85 kg P_2O_5 ha^{-1}) which was statistically identical with P_3 (110 kg P_2O_5 ha^{-1}) whereas the lowest bulb diameter (3.17 cm) was found from the control treatment P_0 (0 kg P_2O_5 ha^{-1}).

Due to application of different concentrations of GA_3 showed significant variation on bulb diameter (Table 5 and Appendix VIII). The highest bulb diameter (4.09 cm) was found from the treatment G_2 (145 ppm GA_3) which was significantly different from all other treatments. The lowest bulb diameter (3.42 cm) was found from the control treatment G_0 (0 ppm GA_3).

Different concentrations of P and GA_3 combinations showed significant variation on bulb diameter (Table 5 and Appendix VIII). The highest bulb diameter (4.52 cm) was found from the treatment combination of P_2G_2 which was statistically similar with P_3G_2 followed by P_2G_1. The lowest bulb diameter (2.90 cm) was found from the control treatment combination of P_0G_0.

4.2.9 Number of bulb plant^{-1}

Different levels of phosphorus significantly influenced the number of bulb $plant^{-1}$ (Table 5 and Appendix VIII). The highest no. of bulb $plant^{-1}$ (5.02) was found from the treatment P_2 (85 kg P_2O_5 ha^{-1}) which was statistically identical with P_3 (110 kg P_2O_5 ha^{-1}) whereas the lowest no. of bulb $plant^{-1}$ (3.32) was found from the control treatment P_0 (0 kg P_2O_5 ha^{-1}).

Application of different concentration of GA_3 showed significant variation on no. of bulb plant^{-1} (Table 5 and Appendix VIII). The highest no. of bulb plant^{-1} (4.95) was found from the treatment G_2 (145 ppm GA_3) whereas the lowest no. of bulb plant-1 (3.67) was found from the control treatment G_0 (0 ppm GA_3).

Different concentrations of P and GA3 combinations showed significant variation on no. of bulb plant-1 (Table 5 and Appendix VIII). The highest no. of bulb plant-1 (5.77) was found from the treatment combination of P_2G_2 which was statistically identical with P3G2 followed by P2G1. The lowest no. of bulb plant-1 (2.81) was found from the control treatment combination of P_0G_0.

4.2.10 Fresh weight of bulb plant^{-1} (g)

Different levels of phosphorus significantly influenced the fresh weight of bulb plant^{-1} (Table 5 and Appendix VIII). The highest fresh weight of bulb plant^{-1} (129.4 g) was found from the treatment P_2 (85 kg P_2O_5 ha^{-1}) which was significantly different from all other treatments. The lowest fresh weight of bulb plant^{-1} (82.87 g) was found from the control treatment P_0 (0 kg P_2O_5 ha^{-1})

Application of different concentration of GA_3 showed significant variation on fresh weight of bulb plant^{-1} (Table 5 and Appendix VIII). The highest fresh weight of bulb plant^{-1} (126.9 g) was found from the treatment G_2 (145 ppm GA_3) whereas the lowest fresh weight of bulb plant^{-1} (90.99 g) was found from the control treatment G_0 (0 ppm GA_3).

Different concentrations of P and GA_3 combinations showed significant variation on fresh weight of bulb plant^{-1} (Table 5 and Appendix VIII). The highest fresh weight of bulb plant^{-1} (157.3 g) was found from the treatment combination of P_2G_2 which was significantly different from all other treatment combinations followed by P_3G_2. The lowest fresh weight of bulb plant^{-1} (72.85 g) was found from the control treatment combination of P_0G_0.

4.2.11 Bulb yield (t ha^{-1})

Different levels of phosphorus significantly influenced the bulb yield (Table 5 and Appendix VIII). The highest bulb yield (25.88 t ha^{-1}) was found from the treatment P_2 (85 kg P_2O_5 ha^{-1}) which was significantly different from all others. The lowest bulb yield (16.57 t ha^{-1}) was found from the control treatment P_0 (0 kg P_2O_5 ha^{-1}). Similar result was also observed by Sharma *et al*. (2008) and they fond that 70 kg P_2O_5 per hectare treatment improved the bulb production.

Application of different concentration of GA_3 showed significant variation on bulb yield (Table 5 and Appendix VIII). The highest bulb yield (25.38 t ha^{-1}) was found from the treatment G_2 (145 ppm GA_3) but the lowest bulb yield (18.20 t ha^{-1}) was found from the control treatment G_0 (0 ppm GA_3). Tiwari and Singh (2002) also found similar result on bulb production and concluded that 200 ppm GA_3 showed significant increase in bulb production.

Different concentrations of P and GA_3 combinations showed significant variation on bulb yield (Table 5 and Appendix VIII). The highest bulb yield (31.45 t ha^{-1}) was found from the treatment combination of P_2G_2 which was significantly different from all other treatment combinations followed by P_3G_2. The lowest bulb yield (14.57 t ha^{-1}) was found from the control treatment combination of $P_0G_{0.}$

Table 5: Yield and yield contributing parameters as influenced by phosphorus and GA_3

Treatments	Yield contributing parameters and yield of tuberose bulb				
	Bulb length (cm)	Bulb diameter (cm)	No. of bulb $plant^{-1}$	Fresh weight of bulb $plant^{-1}$ (g)	Bulb yield ($t\ ha^{-1}$)
Effect of phosphorus (P)					
P_0	6.71	3.17 c	3.32 c	82.87 d	16.57 d
P_1	7.28	3.74 b	4.23 b	102.8 c	20.56 c
P_2	7.69	4.11 a	5.02 a	129.4 a	25.88 a
P_3	7.67	4.08 a	4.91 a	123.1 b	24.63 b
$LSD_{0.05}$	0.996^{NS}	0.320	0.1749	4.198	1.027
CV(%)	5.68	5.96	5.72	10.37	7.37
Effect of GA_3					
G_0	6.89	3.42 c	3.67 c	90.99 c	18.20 c
G_1	7.45	3.82 b	4.48 b	110.8 b	22.15 b
G_2	7.68	4.09 a	4.95 a	126.9 a	25.38 a
$LSD_{0.05}$	0.863^{NS}	1.340	0.126	3.809	0.8968
CV(%)	5.68	5.96	5.72	10.37	7.37
Combined effect of P and GA_3					
P_0G_0	6.51 i	2.90 j	2.81 i	72.85 j	14.57 j
P_0G_1	6.71 hi	3.15 i	3.30 h	82.23 i	16.44 i
P_0G_2	6.91 gh	3.59 gh	3.85 g	93.53 gh	18.70 gh
P_1G_0	6.82 gh	3.40 h	3.53 h	87.68 hi	17.54 hi
P_1G_1	7.44 e	3.92 def	4.48 de	109.5 e	21.89 e
P_1G_2	7.57 de	4.01 cde	4.67 cd	111.3 e	22.25 e
P_2G_0	7.01 fg	3.70 fg	4.05 fg	99.13 fg	19.82 fg
P_2G_1	7.87 c	4.22 bc	5.23 b	131.9 c	26.38 c
P_2G_2	8.19 a	4.52 a	5.77 a	157.3 a	31.45 a
P_3G_0	7.20 f	3.83 ef	4.30 ef	104.3 ef	20.86 ef
P_3G_1	7.77 cd	4.14 cd	4.92 c	119.5 d	23.90 d
P_3G_2	8.05 ab	4.39ab	5.51 a	145.6 b	29.11 b
$LSD_{0.05}$	0.233	0.226	0.273	8.110	1.622
CV(%)	5.68	5.96	5.72	10.37	7.37

In a column, figure (s) bearing same letter do not differ significantly at $P \leq 0.05$ by LSD

P_0 = Control (0 kg $P_2O_5 ha^{-1}$), P_1 = 140 kg TSP ha^{-1} = 65 kg P_2O_5 ha^{-1}, P_2 = 190 kg TSP ha^{-1} =85 kg P_2O_5 ha^{-1}, P_3 = 240 kg TSP ha^{-1} = 110 kg P_2O_5 ha^{-1}

G_0 = Control, G_1 = 115 ppm GA_3, G_2 = 145 ppm GA_3

4.2.12 Number of bulblets plant^{-1}

Different levels of phosphorus significantly influenced the single spike weight (Table 6 and Appendix IX). The highest no. of bulblets plant^{-1} (12.75) was found from the treatment P_2 (85 kg P_2O_5 ha^{-1}) which was statistically identical with P_3 (110 kg P_2O_5 ha^{-1}) whereas the lowest no. of bulblets plant^{-1} (8.86) was found from the control treatment P_0 (0 kg P_2O_5 ha^{-1})

Application of different concentration of GA_3 showed significant variation on number of bulblets plant^{-1} (Table 6 and Appendix IX). The highest no. of bulblets plant^{-1} (12.66) was found from the treatment G_2 (145 ppm GA_3) which was significantly different from others whereas the lowest number of bulblets plant^{-1} (9.60) was found from the control treatment G_0 (0 ppm GA_3)

Different concentrations of P and GA_3 combinations showed significant variation on number of bulblets plant^{-1} (Table 6 and Appendix IX). The highest number of bulblets plant^{-1} (14.41) was found from the treatment combination of P_2G_2 which was statistically identical with the treatment combination of P_3G_2. The lowest no. of bulblets plant^{-1} (7.66) was found from the control treatment combination of P_0G_0.

4.2.13 Fresh weight of bulblet plant^{-1} (g)

Due to application of different levels of phosphorus significantly influenced on the fresh weight of bulblet plant^{-1}(Table 6 and Appendix IX). The highest fresh weight of bulblet plant^{-1} of tuberose (71.03 g) was found from the treatment P_2 (85 kg P_2O_5 ha^{-1}) which was statistically identical with P_3 (110 kg P_2O_5 ha^{-1}) whereas the lowest fresh weight of bulblet plant^{-1} (50.10 g) was found from the control treatment P_0 (0 kg P_2O_5 ha^{-1})

Application of different concentration of GA_3 showed significant variation on fresh weight of bulblet plant^{-1} (Table 6 and Appendix IX). The highest fresh weight of bulblet plant^{-1} (70.01 g) was found from the treatment G_2 (145 ppm GA_3) which was significantly different from others whereas the lowest fresh weight of bulblet plant^{-1} (54.07g) was found from the control treatment G_0 (0 ppm GA_3)

Different concentrations of P and GA_3 combinations showed significant variation on fresh weight of bulblet plant^{-1} (Table 6 and Appendix IX). The highest fresh weight of bulblet plant^{-1} (80.04 g) was found from the treatment combination of P_2G_2 which was statistically identical with the treatment combination of P_3G_2. The lowest fresh weight of bulblet plant^{-1} (45.25 g) was found from the control treatment combination of P_0G_0.

4.2.14 Bulblet yield (t ha^{-1})

Different levels of phosphorus significantly influenced the bulblet yield (Table 6 and Appendix IX). The highest bulblet yield (14.21 t ha^{-1}) was found from the treatment P_2 (85 kg P_2O_5 ha^{-1}) which was statistically identical with P_3 (110 kg P_2O_5 ha^{-1}) whereas the lowest bulblet yield (10.02 t ha^{-1}) was found from the control treatment P_0 (0 kg P_2O_5 ha^{-1}).

Application of different concentration of GA_3 showed significant variation on bulblet yield (Table 6 and Appendix IX). The highest bulblet yield (14.00 t ha^{-1}) was found from the treatment G_2 (145 ppm GA_3) which was significantly different from others whereas the lowest bulblet yield (10.81 t ha^{-1}) was found from the control treatment G_0 (0 ppm GA_3).

Table 6: Yield contributing parameters and yield of tuberose bulblets as influenced by phosphorus and GA_3

Treatments	Yield contributing parameters of tuberose		
	No. of bulblets plant^{-1}	Fresh weight of bulblet plant^{-1} (g)	Bulblet yield (t ha^{-1})
Effect of phosphorus (P)			
P_0	8.86 c	50.10 c	10.02 c
P_1	11.12 b	61.55 b	12.31 b
P_2	12.75 a	71.03 a	14.21 a
P_3	12.47 a	69.55 a	13.91 a
$LSD_{0.05}$	1.147	2.333	0.466
CV(%)	6.93	8.78	7.48
Effect of GA_3			
G_0	9.60 c	54.07 c	10.81 c
G_1	11.64 b	65.10 b	13.02 b
G_2	12.66 a	70.01 a	14.00 a
$LSD_{0.05}$	0.662	1.911	0.492
CV(%)	6.93	8.78	7.48
Combined effect of P and GA_3			
P_0G_0	7.66 i	45.25 i	9.05 i
P_0G_1	8.77 h	50.33 h	10.07 h
P_0G_2	10.14 g	54.71 g	10.94 g
P_1G_0	9.18 h	52.72 gh	10.54 gh
P_1G_1	11.88 e	64.09 e	12.82 e
P_1G_2	12.29 de	67.85 d	13.57 d
P_2G_0	10.60 fg	58.24 f	11.65 f
P_2G_1	13.25 bc	74.82 b	14.97 b
P_2G_2	14.41 a	80.04 a	16.01 a
P_3G_0	10.97 f	60.07 f	12.01 f
P_3G_1	12.66 cd	71.16 c	14.23 c
P_3G_2	13.78 ab	77.42 ab	15.48 ab
$LSD_{0.05}$	0.783	2.780	0.603
CV(%)	6.93	8.78	7.48

In a column, figure (s) bearing same letter do not differ significantly at $P \leq 0.05$ by LSD

P_0 = Control (0 kg P_2O_5ha^{-1}), P_1 = 140 kg TSP ha^{-1} = 65 kg P_2O_5 ha^{-1}, P_2 = 190 kg TSP ha^{-1} =85 kg P_2O_5 ha^{-1}, P_3 = 240 kg TSP ha^{-1} = 110 kg P_2O_5 ha^{-1}

G_0 = Control, G_1 = 115 ppm GA_3, G_2 = 145 ppm GA_3

Different concentrations of P and GA_3 combinations showed statistically significant variation on bulblet yield (Table 6 and Appendix IX). The highest bulblet yield (16.01 t ha-1) was found from the treatment combination of P_2G_2 which was statistically identical with the treatment combination of P_3G_2. The lowest bulblet yield (9.05 t ha^{-1}) was found from the control treatment combination of P_0G_0.

4.3 Economic analysis

All the material and non-material input cost like land preparation, tuberose bulb, organic manure, irrigation and manpower required for all the operations, interest on fixed capital of land (Leased land by ban loan basis) and miscellaneous cost were considered for calculating the total cost of production were recorded for unit plot and converted into cost per hectare (Table 7 and Appendix XI). Price of tuberose in terms of spike, bulb and bulblet were considered at market rate. The economic analysis is presented under the following headlines:

4.3.1 Gross income

The combination of different phosphorus (P) and GA_3 levels showed different gross return (Table 7). Gross income was calculated on the basis of sale of spike, bulb and bulblet. The highest gross return (Tk. 471550) obtained from P_2G_2 (85 kg P_2O_5 ha^{-1} with 145 ppm GA_3) treatment combination and lowest gross return (Tk. 227470) obtained from the treatment combination of P_0G_0 (no P and GA_3).

Table 7: Cost and return analysis of tuberose cultivation as influenced by phosphorus and GA_3

Treatments	Cost of production (Tk. ha^{-1})	Spike yield ha^{-1} (no.) ('000')	Bulb yield (t ha^{-1})	Bulblet yield (t ha^{-1})	Gross return from spike (Tk. ha^{-1})	Gross return from bulb yield (Tk. ha^{-1})	Gross return from bulblet yield (Tk. ha^{-1})	Total gross return (Tk. ha^{-1})	Net return (Tk. ha^{-1})	BCR
P_0G_0	169767	189.60	14.57	9.05	94800	87420	45250	227470	57703	1.34
P_0G_1	175425	241.80	16.44	10.07	120900	98640	50350	269890	94465	1.54
P_0G_2	176901	292.40	18.70	10.94	146200	112200	54700	313100	136199	1.77
P_1G_0	173681	267.50	17.54	10.54	133750	105240	52700	291690	118009	1.68
P_1G_1	179339	345.80	21.89	12.82	172900	131340	64100	368340	189001	2.05
P_1G_2	180815	357.70	22.25	13.57	178850	133500	67850	380200	199385	2.10
P_2G_0	175079	321.50	19.82	11.65	160750	118920	58250	337920	162841	1.93
P_2G_1	180737	378.70	26.38	14.97	189350	158280	74850	422480	241743	2.34
P_2G_2	182213	405.60	31.45	16.01	202800	188700	80050	471550	289337	2.59
P_3G_0	176476	332.50	20.86	12.01	166250	125160	60050	351460	174984	1.99
P_3G_1	182135	369.80	23.90	14.23	184900	143400	71150	399450	217315	2.19
P_3G_2	183611	393.60	29.11	15.48	196800	174660	77400	448860	265249	2.44

- Selling cost of spike = Tk. 500/- per 1000 spike
- Selling cost of bulb = Tk. 6000/- per ton
- Selling cost of bulblet = Tk. 5000/- per ton

4.3.2 Net return

Treatment combinations of different P and GA_3 rate showed net returns variation (Table 7 and Appendix X). The highest net return (Tk. 289337/ha) obtained from the treatment combination of P_2G_2 (85 kg P_2O_5 ha^{-1} with 145 ppm GA_3) and lowest net return (Tk. 57703/ha) obtained from the treatment combination of P_0G_0 (no P and GA_3).

4.3.3 Benefit cost ratio (BCR)

Among different treatment combinations of P and GA_3, variation on benefit cost ration (BCR) was observed among the treatment combinations (Table 7 and Appendix X). The highest BCR (2.59) was obtained from the treatment combination of P_2G_2 (85 kg P_2O_5 ha^{-1} with 145 ppm GA_3) and lowest BCR (1.34) was obtained from P0G0 (no P and GA_3) treatment combination. From economic point of view, it was noticeable from the above results, the treatment combination of P_2G_2 (85 kg P_2O_5 ha^{-1} with 145 ppm GA_3) was more profitable than rest of the treatment combinations.

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted in the Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during August 217 to October 2018 to study the Effect of phosphorus (P) and gibberellic acid (GA_3) on growth yield of tuberose (*Polianthes tuberosa*). The experiment considered of two factors *viz*. Factor A (4 phosphorus levels): P_0 (0 kg P_2O_5ha^{-1}), P_1 (65 kg P_2O_5 ha^{-1}), P_2 (85 kg P_2O_5 ha^{-1}) and P_3 (110 kg P_2O_5 ha^{-1}) and Factor B (3 GA_3 levels): G_0 (0 ppm GA_3), G_1 (115 ppm GA_3) and G_2 (145 ppm GA_3). The experiment was laid out in the two factors Randomized Complete Block Design (RCBD) with three replications. Data on different growth, yield components and yield of tuberose were recorded.

Phosphorus had great influence on different growth and yield and yield contributing parameters of tuberose. Considering growth parameters, results indicated that the highest plant height (61.02 cm) and number of leaves plant^{-1} (29.35) were found from the treatment P_3 (110 kg P_2O_5 ha^{-1}) but the highest number of side shoot plant^{-1} (6.69) was found from the treatment P_2 (85 kg P_2O_5 ha^{-1}) whereas the lowest plant height (52.41 cm) number of leaves plant^{-1} (19.34) and number of side shoot plant^{-1} (4.07) were found from the control treatment P_0 (0 kg P_2O_5 ha^{-1}). In terms of yield and yield contributing parameters of tuberose, spike length (79.13 cm), spike diameter (1.93 cm), rachis length (31.21 cm), no. of florates spike^{-1} (21.95), single spike weight (69.22 g), no. of spike ha^{-1} (368.60 thousand), bulb length (7.69 cm), bulb diameter (4.11 cm), no. of bulb plant^{-1} (5.02), fresh weight of bulb plant^{-1} (129.4 g), bulb yield (25.88 t ha^{-1}), no. of bulblets plant^{-1} (12.75), fresh weight of bulblet plant^{-1} (71.03 g) and bulblet yield (14.21 t ha^{-1}) were found from the treatment P_2 (85 kg P_2O_5 ha^{-1}) whereas the lowest spike length (64.06 cm), spike diameter (1.65 cm), rachis length (24.91 cm), no. of florates spike^{-1}

(14.96), single spike weight (58.67 g), no. of spike ha^{-1} (241.30 thousand), bulb length (6.71 cm), bulb diameter (3.17 cm), no. of bulb $plant^{-1}$ (3.32), fresh weight of bulb $plant^{-1}$ (82.87 g), bulb yield 16.57 (t ha^{-1}), no. of bulblets $plant^{-1}$ (8.86), fresh weight of bulblet $plant^{-1}$ (50.10 g) and bulblet yield (10.02 t ha^{-1}) were found from the control treatment P_0 (0 kg P_2O_5 ha^{-1})

GA_3 also showed significant variation on different growth, yield and yield contributing parameters of tuberose. Regarding growth parameters, the highest plant height (59.46 cm), number of leaves $plant^{-1}$ (27.17) and number of side shoot $plant^{-1}$ (6.64) were found from the treatment G_2 (145 ppm GA_3) whereas the lowest plant height (54.33 cm), number of leaves $plant^{-1}$ (22.10) and number of side shoot $plant^{-1}$ (4.57) were found from the control treatment G_0 (0 ppm GA_3). Likewise, in terms of yield and yield contributing parameters of tuberose, the highest spike length (78.66 cm), spike diameter (1.95 cm), rachis length (31.01 cm), no. of florates $spike^{-1}$ (21.75), single spike weight (68.71 g), no. of spike ha^{-1} (362.30 thousand), bulb length (7.68 cm), bulb diameter (4.09 cm), no. of bulb $plant^{-1}$ (4.95), fresh weight of bulb $plant^{-1}$ (126.9 g), bulb yield (25.38 t ha^{-1}), no. of bulblets $plant^{-1}$ (12.66), fresh weight of bulblet $plant^{-1}$ (70.01 g) and bulblet yield (14.00 t ha^{-1}) were also found from the treatment G_2 (145 ppm GA_3) whereas the lowest spike length (67.24 cm), spike diameter (1.78 cm), rachis length (26.33 cm), no. of florates $spike^{-1}$ (16.72), single spike weight (60.85 g), no. of spike ha^{-1} (277.80 thousand), bulb length (6.89 cm), bulb diameter (3.42 cm), no. of bulb $plant^{-1}$ (3.67), fresh weight of bulb $plant^{-1}$ (90.99 g), bulb yield (18.20 t ha^{-1}), no. of bulblets $plant^{-1}$ (9.60), fresh weight of bulblet $plant^{-1}$ (54.07g) and bulblet yield (10.81 t ha^{-1}) were found from the control treatment G_0 (0 ppm GA_3)

Combine effect of P and GA_3 showed significant difference among the treatments regarding different parameters. In terms of growth parameters, results showed that the highest plant height (64.15 cm) and number of leaves $plant^{-1}$ (31.95) were found from the treatment combination of P_3G_2 but the highest number of side shoot plant^{-1} (7.79) was found from the treatment combination of P_2G_2 whereas the lowest plant height (50.82 cm), number of leaves plant^{-1} (18.39 a) and number of side shoot plant^{-1} (3.17) were found from the control treatment combination of P_0G_0. In case of yield and yield contributing parameters of tuberose, the highest spike length (85.96 cm), spike diameter (2.22 cm), rachis length (34.20 cm), no. of florates spike^{-1} (24.57), single spike weight (74.50 g) no. of spike ha^{-1} (405.60 thousand), bulb length (8.19 cm), bulb diameter (4.52 cm), no. of bulb plant^{-1} (5.77), fresh weight of bulb plant^{-1} (157.3 g), bulb yield (31.45 t ha^{-1}), no. of bulblets plant^{-1} (14.41), fresh weight of bulblet plant^{-1} (80.04 g) and bulblet yield (16.01 t ha^{-1}) were found from the treatment combination of P_2G_2 whereas the lowest spike length (60.64 cm), spike diameter (1.62 cm), rachis length (23.07 cm), no. of florates spike^{-1} (12.37), single spike weight (56.13 g), no. of spike ha^{-1} (189.60 thousand), bulb length (6.51 cm), bulb diameter (2.90 cm), no. of bulb plant^{-1} (2.81), fresh weight of bulb plant^{-1} (72.85 g), bulb yield (14.57 t ha^{-1}), no. of bulblets plant^{-1} (7.66), fresh weight of bulblet plant^{-1} (45.25 g) and bulblet yield (9.05 t ha^{-1}) was found from the control treatment combination of P_0G_0.

In terms of economic analysis, the highest gross return (Tk. 471550/ha), net return (Tk. 289337/ha) and BCR (2.59) were obtained from the treatment combination of P_2G_2 (85 kg P_2O_5 ha^{-1} with 145 ppm GA_3) whereas the lowest gross return (Tk. 227470/ha), net return (Tk. 57703/ha) and BCR (1.34) was obtained from P_0G_0 (no P and GA_3).

From the above results, it can be concluded that the treatment combination of P_2G_2 (85 kg P_2O_5 ha^{-1} with 145 ppm GA_3) showed highest yield advantage regarding economic return. Therefore, the results suggest that the combination of P and GA_3 i.e. P_2G_2 (85 kg P_2O_5 ha^{-1} with 145 ppm GA_3) is suitable for the higher spike, bulb and bulblet yield production of tuberose. So, this treatment combination can be considered as the best treatment combination (85 kg P_2O_5 ha^{-1} with 145 ppm GA_3) considering yield and economic return.

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APPENDICES

Appendix I: Agro-Ecological Zone of Bangladesh showing the experimental location

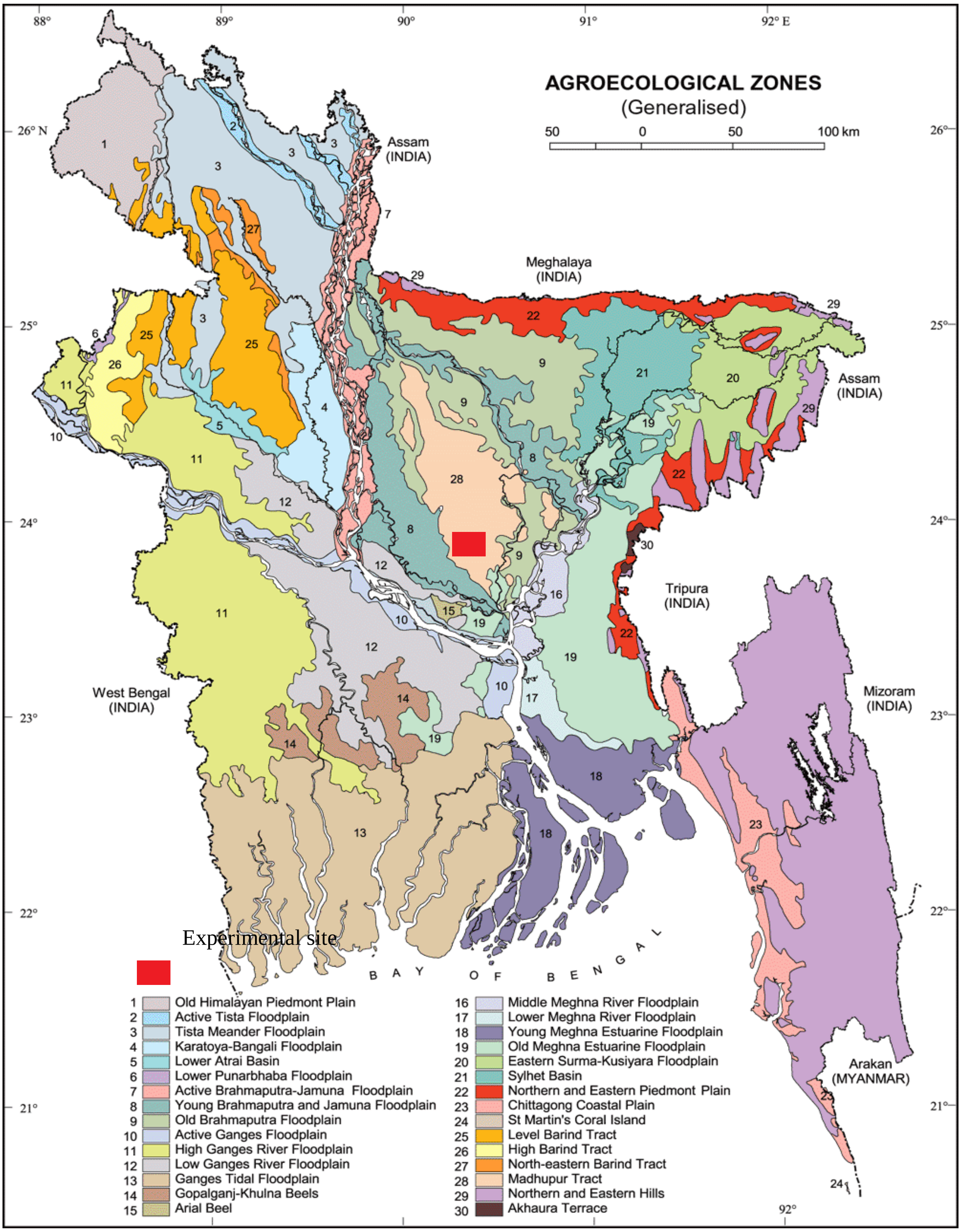

Fig. 6: Experimental site

Appendix II: Monthly records of air temperature, relative humidity and rainfall during the period from August 2017 to October 2018

Year	Month	Air temperature (°C)			Relative humidity (%)	Rainfall (mm)
		Max	*Min*	*Mean*		
2017	August	30.72	26.40	28.56	78.20	288.64
2017	September	29.84	21.72	25.78	73.40	103.52
2017	October	29.48	20.84	25.16	70.20	62.60
2017	November	28.32	16.60	22.46	54.50	0.00
2017	December	26.72	14.34	20.53	53.70	0.00
2018	January	23.80	11.70	17.75	46.20	0.00
2018	February	22.75	14.26	18.51	37.90	0.00
2018	March	35.20	21.00	28.10	52.44	20.40
2018	April	34.70	24.60	29.65	65.40	165.00
2018	May	32.64	23.85	28.25	68.30	182.20
2018	June	27.40	23.44	25.42	71.28	190.00
2018	July	30.52	24.80	27.66	78.00	536.00
2018	August	31.00	25.60	28.30	80.00	348.00
2018	September	30.8	21.80	26.30	71.50	78.52
2018	October	30.42	16.24	23.33	68.48	52.60

Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka-1212.

Appendix III: Characteristics of experimental soil analyzed at Soil Resources Development Institute (SRDI), Farmgate, Dhaka.

A. Morphological characteristics of the experimental field

Morphological features	**Characteristics**
Location	Horticulture Farm, SAU, Dhaka
AEZ	Modhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping pattern	Not Applicable

Source: Soil Resource Development Institute (SRDI)

B. Physical and chemical properties of the initial soil

Characteristics	**Value**
Partical size analysis % Sand	27
%Silt	43
% Clay	30
Textural class	Silty Clay Loam (ISSS)
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20
Exchangeable K (me/100 g soil)	0.1
Available S (ppm)	45

Source: Soil Resource Development Institute (SRDI)

Appendix IV: Plant height of tuberose at different days after planting as influenced by phosphorus and GA_3

Sources	df	Plant height (cm)			
		30 DAP	55 DAP	80 DAP	105 DAP
Replication	2	21.026	4.744	1.063	0.457
Factor A	3	39.659*	107.28*	86.410*	114.830*
Factor B	2	23.158*	45.058*	61.836*	80.177*
AB	6	0.976**	3.873**	6.393*	2.793*
Error	22	0.860	3.346	0.405	0.848

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix V: Number of leaves plant of tuberose at different days after planting as influenced by phosphorus and GA_3

Sources	df	Number of leaves $plant^{-1}$			
		30 DAP	55 DAP	80 DAP	105 DAP
Replication	2	12.100	7.100	0.095	0.157
Factor A	3	1.630^{NS}	31.438*	110.01*	156.63*
Factor B	2	0.948^{NS}	17.586*	63.763*	78.394*
AB	6	0.058^{NS}	0.293**	4.384*	4.119*
Error	22	0.004	0.282	1.531	1.739

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix VI: Number of side shoot $plant^{-1}$ of tuberose at different days after planting as influenced by phosphorus and GA_3

Sources	df	Number of side shoot $plant^{-1}$		
		30 DAP	55 DAP	80 DAP
Replication	2	0.954	3.741	4.739
Factor A	3	2.348*	10.317*	13.088*
Factor B	2	2.349**	10.342*	13.319*
AB	6	0.130**	0.397**	0.147**
Error	22	0.032	0.041	0.532

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix VII: Yield contributing parameters and yield of tuberose spike as influenced by phosphorus and GA_3

Sources	df	Yield contributing parameters and yield of tuberose spike					
		Spike length (cm)	Spike diameter (cm)	Rachis length (cm)	No. of florates $Spike^{-1}$	Single spike weight (g)	Spike yield (No. of spike ha^{-1}) ('000')
Replication	2	0.277	0.001	0.221	0.271	0.213	53.665
Factor A	3	430.514*	0.144^{NS}	77.993*	95.850*	202.713*	711.025*
Factor B	2	405.677*	0.137^{NS}	67.975*	77.912*	188.972*	499.875*
AB	6	13.899*	0.012^{NS}	1.601**	1.446**	5.829*	9.629*
Error	22	4.799	0.001	0.637	0.986	0.751	19.559

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix VIII: Yield and yield contributing parameters as influenced by phosphorus and GA_3

Sources	df	Yield contributing parameters and yield of tuberose bulb				
		Bulb length (cm)	Bulb diameter (cm)	No. of bulb $plant^{-1}$	Fresh weight of bulb $plant^{-1}$ (g)	Bulb yield (t ha^{-1})
Replication	2	0.024	0.000	0.011	8.125	0.324
Factor A	3	1.897^{NS}	1.688**	5.506*	4011.566*	160.446*
Factor B	2	2.000^{NS}	1.364**	5.028*	3885.079*	155.299*
AB	6	0.093**	0.027**	0.114**	270.200*	10.829*
Error	22	0.039	0.017	0.026	22.940	0.917

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix IX: Yield contributing parameters and yield of tuberose bulblets as influenced by phosphorus and GA_3

Sources	df	Yield contributing parameters of tuberose		
		No. of bulblets $plant^{-1}$	Fresh weight of bulblet $plant^{-1}$ (g)	Bulblet yield (t ha^{-1})
Replication	2	0.130	2.077	0.084
Factor A	3	28.446*	828.123*	33.104*
Factor B	2	29.031*	799.607*	31.977*
AB	6	0.546**	24.812*	0.989**
Error	22	0.614	5.695	0.227

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix X: Cost of production of tuberose per hectare

A. Input cost (Tk. ha-1)

Treatments	Labor cost	Ploughing cost	Bulb cost	Irrigation	Fertilizer				Cost of GA_3	Subtotal (A)
					Cowdung	Urea	TSP	MOP		
P_0G_0	16000	6000	52000	3000	5000	4160	0	3750	0	89910
P_0G_1	16000	6000	52000	3000	5000	4160	0	3750	5060	94970
P_0G_2	16000	6000	52000	3000	5000	4160	0	3750	6380	96290
P_1G_0	16000	6000	52000	3000	5000	4160	3500	3750	0	93410
P_1G_1	16000	6000	52000	3000	5000	4160	3500	3750	5060	98470
P_1G_2	16000	6000	52000	3000	5000	4160	3500	3750	6380	99790
P_2G_0	16000	6000	52000	3000	5000	4160	4750	3750	0	94660
P_2G_1	16000	6000	52000	3000	5000	4160	4750	3750	5060	99720
P_2G_2	16000	6000	52000	3000	5000	4160	4750	3750	6380	101040
P_3G_0	16000	6000	52000	3000	5000	4160	6000	3750	0	95910
P_3G_1	16000	6000	52000	3000	5000	4160	6000	3750	5060	100970
P_3G_2	16000	6000	52000	3000	5000	4160	6000	3750	6380	102290

B. Overhead cost (Tk. ha-1), Cost of production (Tk. ha-1), Gross return (Tk. ha-1), Net return (Tk. ha-1) and BCR

Treatments	Overhead cost (Tk. ha^{-1})				Subtotal (A)	Total cost of production (A+B)	Spike yield ha^{-1} (No.) ('000')	Bulb yield ha^{-1} (ton)	Bulblet yield ha^{-1} (ton)	Gross return (Tk. ha^{-1})	Net return (Tk. ha^{-1})	BCR
	Cost of leased land for 6 months (13% of value of land Tk. 10,00,000/-	Miscellaneous cost (Tk. 5% of the input cost)	Interest on running capital for 6 month (13% of cost $year^{-1}$)	Subtotal (B)								
P_0G_0	65000	4495.5	10361	79856.86	89910	169767	189.60	14.57	9.05	227470	57703	1.34
P_0G_1	65000	4748.5	10707	80455.2	94970	175425	241.80	16.44	10.07	269890	94465	1.54
P_0G_2	65000	4814.5	10797	80611.29	96290	176901	292.40	18.70	10.94	313100	136199	1.77
P_1G_0	65000	4670.5	10600	80270.73	93410	173681	267.50	17.54	10.54	291690	118009	1.68
P_1G_1	65000	4923.5	10946	80869.08	98470	179339	345.80	21.89	12.82	368340	189001	2.05
P_1G_2	65000	4989.5	11036	81025.17	99790	180815	357.70	22.25	13.57	380200	199385	2.10
P_2G_0	65000	4733	10686	80418.55	94660	175079	321.50	19.82	11.65	337920	162841	1.93
P_2G_1	65000	4986	11031	81016.89	99720	180737	378.70	26.38	14.97	422480	241743	2.34
P_2G_2	65000	5052	11121	81172.98	101040	182213	405.60	31.45	16.01	471550	289337	2.59
P_3G_0	65000	4795.5	10771	80566.36	95910	176476	332.50	20.86	12.01	351460	174984	1.99
P_3G_1	65000	5048.5	11116	81164.7	100970	182135	369.80	23.90	14.23	399450	217315	2.19
P_3G_2	65000	5114.5	11206	81320.79	102290	183611	393.60	29.11	15.48	448860	265249	2.44

- Selling cost of spike = Tk. 500/- per 1000 spike
- Selling cost of bulb = Tk. 6000/- per ton
- Selling cost of bulblet = Tk. 5000/- per ton

Plate 1: Growth stage of tuberose

Plate 2: Flower initiation of tuberose

Plate 3: Flowering of tuberose

Plate 4: Data recording on plant height