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EFFECT OF PHOSPHORUS AND POTASSIUM ON GROWTH FLOWERING AND BULB YIELD OF TUBEROSE

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EFFECT OF PHOSPHORUS AND POTASSIUM ON GROWTH FLOWERING AND BULB YIELD OF TUBEROSE

BY

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CERTIFICATE

This is to certify that the thesis entitled, "**EFFECT OF PHOSPHORUS AND POTASSIUM ON GROWTH FLOWERING AND BULB YEILD OF TUBEROSE**" submitted to the Department of Horticulture, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka. In partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE in HORTICULTURE**, embodies the result of a piece of bona-fide research work carried out by **MD. FARIDUJJAMAN**, Registration No. 08-03228 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: 31.06.10
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Dedicated to

My

Beloved Parents

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EFFECT OF PHOSPHORUS AND POTASSIUM ON GROWTH FLOWERING AND BULB YIELD OF TUBEROSE

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ABSTRACT

The experiment was conducted at the Horticultural farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, during the period from April, 2009 to March, 2010 to investigate the effect phosphorus and potassium on growth, flowering and bulb yield of tuberose. The experiment consisted of two factors. Factor A: Four levels of phosphorus i.e. P_0: 0, P_1: 135, P_2: 145 and P_3: 155 kg P_2O_5/ha and Factor B: Four levels of potassium i.e. K_0: 0, K_1: 170, K_2: 180 and K_3: 190 kg K_2O/ha respectively. The experiment was laid out with Randomized Complete Block Design with three replications. In case of Phosphorus, the highest flower (19.25 t/ha) and bulb (24.66 t/ha) yield was recorded from P_3 and the lowest flower (9.60 t/ha) and bulb (14.51 t/ha) yield was recorded from $P_{0.}$ In case of Potassium, the highest flower (16.39 t/ha) and bulb (21.99 t/ha) yield was noted from K_3 and the lowest flower (11.48 t/ha) and bulb (17.17 t/ha) yield was recorded from $K_{0.}$ For combined effect the highest flower (22.27 t/ha) and bulb (27.57 t/ha) yield was noted from P_3K_3 and the lowest flower (6.94 t/ha) and bulb (12.22 t/ha) yield was recorded from $P_0K_{0.}$ So, it may be concluded that 155 kg P_2O_5/ha with 190 kg K_2O/ha was found suitable for growth, flowering and bulb yield of tuberose.

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ABBREVIATIONS AND ACRONYMS

%	=	Percent
AEZ	=	Agro-Ecological Zone
ANOVA	=	Analysis of Variance
cm	=	Centimeter
CV	=	Coefficient of Variance
DAP	=	Days After Planting
DMRT	=	Duncan's Multiple Range Test
et al.	=	and others
g	=	Gram
ha	=	Hectare
K	=	Potassium
Kg	=	Kilogram
LSD	=	Least Significant Difference
m^2	=	Square Meter
Max.	=	Maximum
Min.	=	Minimum
MoP	=	Muriate of Potash
N	=	Nitrogen
No.	=	Number
P	=	Phosphorus
RCBD	=	Randomized Complete Block Design
SAU	=	Sher-e-Bangla Agricultural University
SRDI	=	Soil Resources Development Institute
t	=	Ton
TSP	=	Triple Super Phosphate
Viz.	=	Namely

CHAPTER I

INTRODUCTION

Tuberose (*Polianthes tuberosa* L.) belonging to the family Amaryllidacaae, produce attractive, elegant and fragrant white flowers. It occupies a very selective and special position to flower loving people because of its prettiness, elegance and sweet pleasant fragrance. It has a great economic potential for cut flower trade and essential oil industry. The flowers remain fresh for quite a long time and stand distance transportation and fill a useful place in the flower market (Patel *et al.*, 2006).

The long spikes of tuberose are used for vase decoration and bouquet preparation and the florets for making artistic garlands, ornaments and buttonhole use. The flowers emit a delightful fragrance and are the source of tuberose oil. The natural flower oil of tuberose is one of the most expensive perfumer’s raw materials.

Tuberose is a half-hardy bulbus perennial multiplying itself through the bulblets. Roots are mainly adventitious and shallow, the leaves are long, narrow, linear grass like, green and arise in rosette, the flowers have a funnel shaped perianth, waxy white in colour and born in a spike.

In Bangladesh, for the last few years, tuberose has become a popular cutflower for its attractive fragrance and beautiful display in the vase. Now, it is one of the most important commercial cutflowers. Tuberose has high demand in the market and its production is highly profitable.

There are three types of tuberose: single with one row of corolla segments, semi- double bearing flowers with two to three rows of corolla segments and double having more than three rows of corolla segments.

In Bangladesh, its commercial cultivation was introduced during 1980 by some pioneer and innovative farmers at Panishara union of Jhikorgacha thana under Jessore district. Due to multi use, it holds a high demand in the market and its production is appreciable (Aditya, 1992). Although tuberose is now cultivation in the country, very little knowledge of production technology is hand to the growers (Ahmed, 1985).

The growing period of tuberose in normally one year or more. Therefore, a high amount of organic and inorganic fertilizers are needed to maintain sustainable growth and flowering over a long period. There are many factors which affect plant growth and economic cultivation of tuberose. Tuberose is a gross feeder and requires a large quantity of NPK, both in the form of organic and inorganic fertilizers (Amarjeet *et al*., 2000).

Fertilizers have great influence on growth, building and flower production in tuberose (Yadav *et al*, 1985; Polara *et al*., 2004). Effect of NPK on tuberose production has been reported by several authors for different geographical region (Cirrito, 1975; Singh *et al*, 1976; Mitra *et al*, 1979; Nanjan *et al*, 1980; Yadav *et al*, 1985; Singh *et al*., 2005). Phosphorus has a significant effect on spike production and floret quality (Jana *et al*, 1974; Banker and Mukhopadhyay, 1985; Singh *et al.*, 2002). Potash appears to help in increasing the number of spike, flower per spike and number of flowers per hill (Singh *et al*, 1976; Bose and Yadav, 1998; Singh *et al.*, 2004). Duration of flowering in the field was improved through using potassium fertilizer.
However, under Bangladesh condition a few reports are available regarding the fertilizers requirement of this economically important cutflowers.

Considering the above mentioned facts, the present investigations were undertaken with the following objectives:

I. To determine the effects of phosphorus and potassium on growth, bulb and flower production of tuberose; and

II. To determine the suitable combination of phosphorus and potassium for ensuring the higher yield of bulb and flower production of tuberose.

CHAPTER II

REVIEW OF LITERATURE

Tuberose (*Polianthes tuberosa* L.) is an important cutflower in the world trade. It is a gross feeder and requires judicial application of manures and fertilizers. The requirements of manures and fertilizers for optimum growth and development of a crop depends upon the climatic and soil conditions. A few reports are available regarding the requirement of fertilizers for growth, flowering and bulb production of tuberose. The N, P and K levels on tuberose has 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 potassium requirement. A brief review of these pertinent to the present study has been given below:

2.1 Influence of phosphorus on growth, bulb and flower yield of tuberose

An experiment was conducted by Yadav (2007) in Bikaner, Rajasthan, India, 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 (*Polianthes tuberosa*) 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.

A field trial on tuberose was undertaken at the Floriculture field of Horticultural Research Centre, BARI, Joydebpur, Gazipur, Bangladesh during the summer seasons of 2003 and 2004 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. (Sultana *et al*. 2006)

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* were studied under greenhouse conditions by Mohanasundaram *et al.* (2003). 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 (*Polianthes tuberosa*) 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 x15 cm and 30 cm x 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^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.

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^2 is recommended.

The response of *Polianthes tuberosa* cv. “Single” to high doses of NPK. N, P_2O_5 and/or K_2O were applied at plant and floral characteristics. N had a significantly beneficial effect on all of the parameters studied where as P had a significant effect on floret quality only. K had no appreciable effect was investigated by Banker *et al*. (1985)

2.2 Influence of potassium on growth, bulb and flower yield of tuberose

Sultana *et al.* (2006) conducted a field trial on tuberose at the Floriculture field of Horticultural Research Centre, BARI, Joydebpur, Gazipur, Bangladesh during the summer seasons of 2003 and 2004 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 authors reported that 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.

Singh *et al.* (2005) studied the effect of varying levels of N (10,20 and 30 g/m^2), P_20_5 (10,20 and 30 g/m^2) and K_20 (10 and 20 g/m^2) on the growth and flowering of tuberose (*Polianthes tuberosa* cv. Single) at Faizabad, Uttar Pradesh, India. The authors reported that application of NPK increased sprouts per bulb, leaves per plant, leaf length, spike length, flowering duration, forets/100 g and spikes per clump.

A field experiment was conducted by Pal and Biswas (2005) in Nadia , West Bengal, India, during 1999-2000 to 2000-01 to investigate the effect of N, P and K on the growth the flowering of tuberose (*Polianthes. tuberosa*) cv. Calcutta Single. The application of 20 g each of N, P_20_5 and K_20/m^2 recorded the highest plant height, leaf number and spike length. However application of N, P_2O_5 and K_20 at 20, 15 and 20g/m^2, respectively, improved spike weight and yield, and number of florets per spike for the first year. Application of 15 g each of N, P_20_5 and K_20/m^2 improved plant height and leaf number in ratoon crop. The spike production was highest with N, P_20_5 and K_20 at 20, 15 and15g/m^2, respectively, in ratoon crop. The lower doses of fertilizer produced poor quality plant and yield of flower. Thus, application of N, P_20_5 and K_20 at 15, 15 and 20/m^2, respectively for ratoon crop recommended to produce good quality plant and improve yield of flower spike in the plains of West Bengal.

Singh and Sangama (2000) studied the N, P and K uptake by *Polianthes tuberosa* cv. Single conducted in Bapatla, Andhra Pardesh, India. Treatments consisted of 4 NPK application rates (100 kg N+ 50 kg P_20_5 + 50 kg K_20/ha (F1). 175 kg N+ 75 kg P_20_5 + 75 kg K_20/ha (F2), 250kg N + 100 kg P_20_5+ 100kg K_20/ha (F3), and 325 kg N + 125kg P_20_5 + 125 kg K_20/ha (F4).

The authors reported that the treatments F_4, F_3 and its combinations resulted in the highest N, P and K uptake , both at 50% flowering stage and harvesting stage.

Patil *et al.* (1999) conducted an experiments 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 and reported that 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. Application of 250:200:200 kg NPK/ha on 3 tuberose tubers per hill resulted in the highest flower and spike yields (7.86 t/ha, 3.33 spikes/ha, respectively) and plant growth (43.72 cm).

In a 2-year trial by Amarjeet and Godara (1998) at Hisar, India, N was applied at 0, 100, 200, 300 or 400 kg/ha and P and K each at 0, 100 or 200 kg/ha to tuberose cv. Single and reported that increasing P rate also increased flower yield but K application had only a slight effect. Roy (1992) investigated the effect of two doses of potash (250 and 500 kg potash per hectare) on growth and yield of tuberose and reported that plant characters were greater in 500 kg potash/ha than in 250 kg potash/ha.

Bankar (1988) studied in 2-year field trials , plants received N at 0, 5, 10, 15 or 20 g/m^2, and P_20_5 and K_20 each at 0, 20 or 40 gm^2, giving 45 treatments altogether. Data are tabulated on plant height number of leaves /plant , days to spike emergence , number of spikes/plant , spike length, rachis length, number of spikes/plant , spike length, rachis length, number of flowers/spike, duration of flowering, and number and weight of bulbs/plant. P and K improved vegetative growth, flowering and bulb production in the first year. P and K increased spike number, rachis length and duration of flowering only in the second year (the ratoon crop crop). The optimum fertilizer application rate was determined as 15 g N + 40 g P_20_5 + 40 g K_20/m^2.

Patel *et al.* (1997) conducted with 4 fertilizer rates (5 kg organic manure/msuperscript 2 or NPK at 100+50+0, 200+100+50 or 300+ 200+100 kg/ha) were compared in trials in Navsari, Gujarat, India , in 1992-95 with Polianthes tuberosa (cv. Double) grown for cut flower. Neither plant height nor leaf width was affected by the different fertilizer treatments. Leaf number was highest with highest NPK fertilizer rate. Flower spike length and the number of florets/spike were highest with the highest NPK rate.

An experiment was studied by Bhuyan *et al.* (1996) at Jorhat, Assam, India, during 1992 and 1993 to study the effect of applying K at o-120 g K_20/msuperscript 2 on growth, flowering and bulb production in tuberose for cut flowers. The number and weight of spikes, floret size, shelf- life and vase–life increased as K rate increased up to 60 g/msuperscipt 2. Bulb production was also greatest with 60 g K_20/ msuperscript2.

A trials at Hisar, Haryana, was undertaken by Singh *et al*. (1996), in 1991 and 1992, N was applied at 0, 10, 20, 30, 40 g / msuperscript 2, P at 0,10 or 20 g P_20_5 /msuperscript 2 and K at 0,10 or 20 g K_20 / msuperscript 2. P and K rates had little effect on bulb yield.

Amarjeet *et al.* (1996) studied with 5 rates of N (0,100,200,300 and 400 gk/ha) and 3 rates each of P and K (0, 100 and 200 kg/ha) was conducted with P. tuberosa cv. Single on a sandy loam soil in 1991 and 1992. Application of high rates of N, P and K delayed spike emergence and considerably prolonged the flowering period and shelf-life of florets in both years. Length of spike and rachis increased significantly in both years at both development stages (opening of first floret and last floret) with increasing doses of N and P fertilizer, increasing K application increased rachis length at opening of the last floret but not the first floret.

An experiment was conducted by Bhuyan *et al.* (1996) at Jorhat, Assam, India, during 1992 and 1993 to study the effect of applying K at 0-120 g K 20/ msuperscript 2 on growth flowering and bulb production in tuberose for cut flowers. The number and weight of spikes, floret size shelf-life and vase –life increased as K rate increased up to 60 g/msuperscript 2. Bulb production was also greater with 60 g K_20/msuperscript 2.

Amarjeet and Godara (1998) in plots of *Polianthes tuberosa* cv. Single received N fertilizer at 0, 100, 200, 300 or 400 kg/ha and P and K fertilizer each at 0, 100 or 200 kg/ha. Increasing rates of N, P and K increased the number of leaves per plant and plant height significantly. Increasing rates of N and P reduced the number of days for sprouting of rhizomes but K had no significant effect.

Parthiban *et al.* (1992) worked on *Polianthes tuberosa* cv. Single plants were supplied with 50, 75, 100 or 125 kg N/ha, 25, 50, 75kg P/ha and 37.5, 62.5 or 87.5 kg k/ha . The maximum plant height (58.93 cm) was obtained with the 125 kg N + 50 P kg/ha + 62.5 kg K/ha treatment combination. The highest mean number of leaves (41.34) and number of side suckers/clump were obtained with the 100 kg N + 75 kg P + 62.5 kg K/ha treatment combination.

Gowda *et al*. (1991) carried out an experiment at the farm under Horticulture Division , University of Agriculture, Banglore, India, with three rates of N application (100, 150 and 200 kg /ha), 3 of P_20_5 (50, 75 and 100 kg) and 3 of K_20 (100 , 125 and 150 kg) were compared for a cut-flower crop of *Polianthes tuberosa* L. grown at a spacing of 30 × 30 cm. All the P_20_5 and K_20 and half the N were applied as a basal dressing ; the remaining N was applied as a top dressing 30 days after planting. Increasing N significantly increased plant height. Both N and K_20 significantly influenced the number of days required for flower spike emergence. Increasing P and K_20 rates resulted in a greater number of flower spikes and number of flowers/spike.

The highest yield of flowers (40.20/spike) the longest spikes (81.28 cm) and the longest duration of flowering (29.75 days) were obtained with 200 kg N + 75 kg P_20_5 + 125 kg K_20/ha .

Parthiban and Khader (1991) studied in an experiment aimed at determining the fertilizer requirements of *Polianthes tuberosa* cv. Single. N was applied at 50, 75,100 kg, P at 25,50 or 75 kg and K at 37.5, 62.5 or 87.5 kg/ha. Application of 100 kg N + 75 Kg P + 62.5 kg K/ha resulted the highest number of spikes/plant (1.72), number of flowers/spike (39.67) and the highest flower yield (3578.6 kg/ha).

Polianthes tuberosa cv. “Single” to high doses of NPK. N, P_2O_5 and/ or K_2O were applied at plant and floral characteristics which were assessed by Banker and Mukhopadhyay (1985). N had a significantly beneficial effect on all of the parameters studied where as P had a significant effect on floret quality only. K had no appreciable effect.

From the review of literature, it is observed that application of phosphorus and potassium has tremendous effect on growth and yield of tuberose.

CHAPTER III

MATERIALS AND METHODS

This chapter deals with the materials and methods that were used in execution of the experiment.

3.1 Experimental site

The experiment was conducted at Horticulture farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh during the period from April, 2009 to March, 2010.The location of the site in 23.774^0 N latitude and 90.335^0 E longitudes with an elevation of 8.2 m from sea level. The experimental field was medium high land belonging to the Chhiata series of Grey Terrace Soil (AEZ-28, Madhupur Tract). The morphological characteristics of the land are presented in (Appendix II.), and the physical and chemical characteristics of the soil are presented in(Appendix III.)

Plate:1 Experimental field, SAU, Dhaka

3.2 Climate

The experimental field is under subtropical climate characterized by heavy rainfall during the month of April to September and scanty rainfall during October to March. The monthly means of daily maximum,Minimum and average temperature, relative humidity, total rainfall and sunshine hours received at the experimental site during the period from April 2009 to March 2009 are presented in (Appendix I.)

3.3 Soil

The soil of the experimental area was non-calcarious dark grey and belongs to the Madhupur Tract (Anonymous, 1988) under AEZ 28. The selected plot was medium high land and soil series was Tejgoan (Anonymous, 1988) with a pH of 5.6. The analytical data of the soil sample collected from the experimental area were analyzed in the SRDI, Soil Testing Laboratory, Khamarbari, Dhaka and details of the soil characteristics are presented in (Appendix III.)

3.4 Land preparation

The land was first open by ploughing in the month of April, 2009 with the help of power tiller and then it kept open to sun for seven days prior to further ploughing. Afterwards it was prepared by ploughing and cross ploughing followed by laddering. The weeds and stubbles were removed after each laddering. Simultaneously the clods were broken and the soil was made into good tilth. The basal dose of manures and fertilizers were mixed into the soil during final land preparation.

3.5 Treatment(s) of the experiment

The experiment was designed to study the effect of phosphorus and potassium on growth, flower and bulb yield of tuberose.

The experiment consisted of two factors, which are as follows:

Factor A: Phosphorus (P)	Factor B: Potassium (K)
K_0 = 0 kg K_2O/ha	P_0 = 0 kg P_2O_5/ha
K_1 = 170 kg K_2O/ha	P_1 = 135 kg P_2O_5/ha
K_2 = 180 kg K_2O/ha	P_2 = 145 kg P_2O_5/ha
K_3 = 190 kg K_2O/ha	P_3 = 155 kg P_2O_5/ha

There were altogether 16 treatment combinations such as: P_0K_0, P_0K_1, P_0K_2, P_0K_3, P_1K_0, P_1K_1, P_1K_2, P_1K_3, P_2K_0, P_2K_1, P_2K_2, P_2K_3, P_3K_0, P_3K_1, P_3K_2 and P_3K_3.

3.6 Design of layout of the experiment

The two factors experiment was laidout in Randomized Complete Black Design (RCBD) with 3 replications. Each block was divided into 16 plots, where treatments were allotted at random. Thus, there were 48 (16×3) unit plots altogether in the experiment. The size of each plot was 2 m x 1.5 m. The distance between blocks 1m and 0.5 m wide drains were made between the plots. Every unit plot had 6 rows with 48 plants each. Row to row and plant to plant distance was 25 cm both and 48 bulbs were planted in each plot. The detailed lay-out is present in Fig. 1.

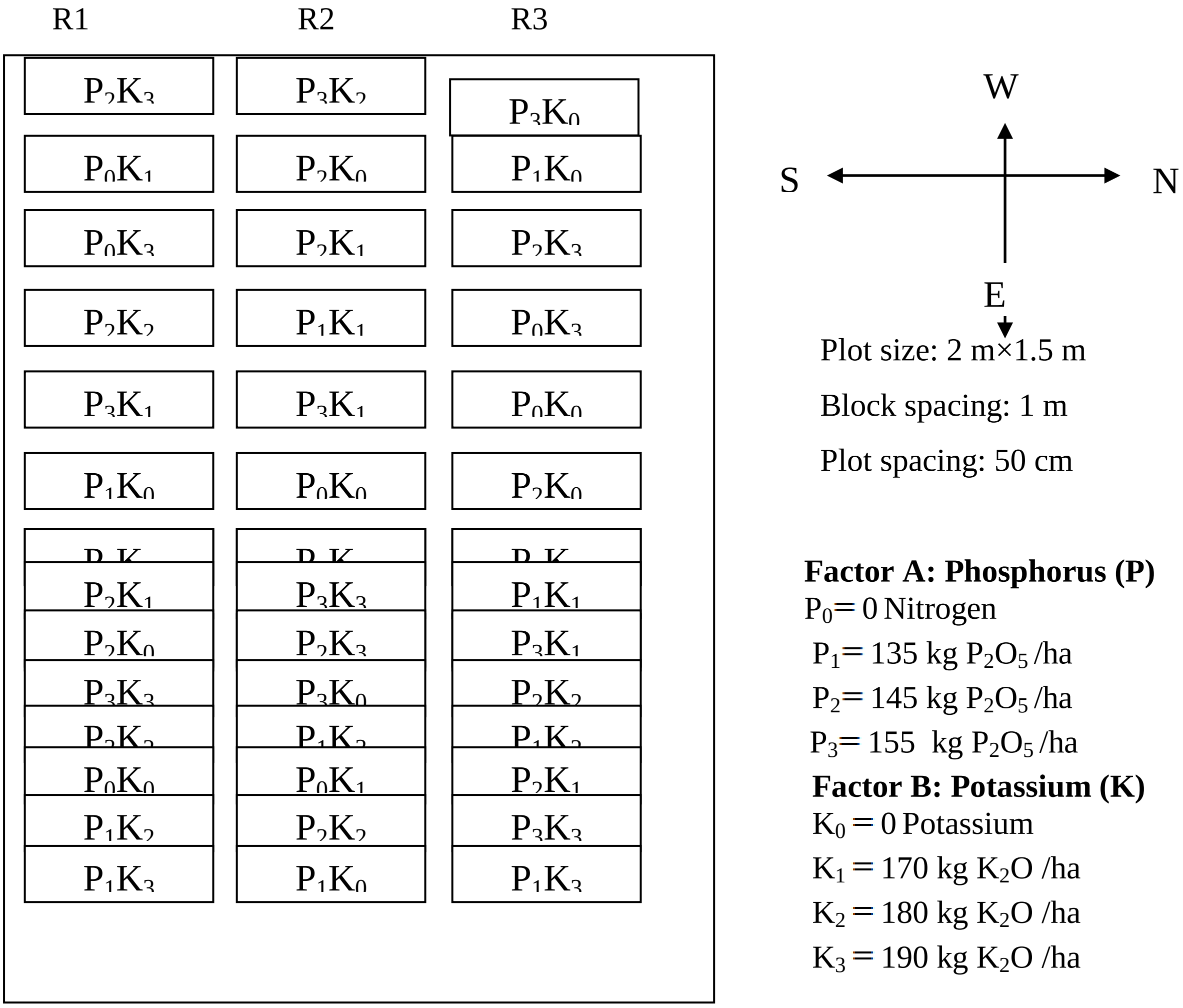

Figure. 1 Field layout of the two factors experiment in the Randomized Complete Block Design (RCBD)

3.7 Planting materials

The bulbs of tuberose cv. Double were collected from Horticulture Farm of Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla Nagar, Dhaka-1207.

3.8 Manures, fertilizers and their application methods

Urea, Triple Super Phosphate (TSP) and Muriate of Potash (MoP) were used as source of nitrogen, phosphorus and potassium respectively. Full dose of cow dung (20 t/ha), and TSP (as per treatment) were incorporated during final land preparation. The total dose of nitrogen and potash (as per treatment) were applied in three equal installments. The first installment was applied at 30 days after planting. The second and third installments were applied at 65 and 100 days respectively after planting.

3.9 Planting of bulbs

Uniform bulbs (2.0 to 3.0 cm in diameter) of tuberose cv. Double were selected for planting separately. Uniform bulbs were planted in each unit plot at a depth of 6 cm on April 20, 2009. The planting distance was 25 cm x 25 cm between row to row and plant to plant. Just after planting a light irrigation was given with the hose pipe, so that irrigation water could not move from unit plot.

3.10 Weeding and mulching

The plots were kept weed free by regular weeding. The soil was mulched frequently after irrigation by breaking the crust for easy aeration and to conserve soil moisture.

3.11 Irrigation

The experimental plots were irrigated as and when necessary during the crop period.

3.12 Staking

For staking bamboo stick was placed and spike was tied with the rope.

3.13 Selection and tagging of plants

Ten plants from each of the plots were selected randomly for recording data for different characters.

3.14 Pest management

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

3.15 Disease management

Dithane M-45 @ 0.2% was sprayed to check the fungal infection.

3.16 Harvesting

The spikes of tuberose were harvested when the first floret in the rachis opened. Harvesting was done during 22 August to 14 January, 2010 and bulb and bulblet were harvested on 16 March, 2010.

3.17 Collection of data

3.17.1 Plant height

Plant height refers to the length of the plant from ground level upto shoot apex of the plant. It was measured three times at an interval of 30 days from 30 DAP to 90 DAP and at harvest.

3.17.2 Number of leaves/plant (mother bulb)

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 three times at an interval of 30 days starting from 30 DAP to 90 DAP.

3.17.3 Maximum length of leaves

Maximum length of leaves was measured from the base to the tip of the longest leaf at an interval 30 days starting from 30 days after planting
(DAP) till 90 days.

3.17.4 Breadth of leaves

The breadth of leaves was taken from one leaf margin (side) to another. Data were recorded as the average of 10 leaves selected at10 random plants at 30 days interval starting from 30 days after planting till 90 days.

3.17.5 Number of side shoot

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 30 days starting from 30 days after planting (DAP) till 90 days.

3.17.6 Length of spike

Length of the spike was measured from the base to the tip of the spike.

3.17.7 Length of rachis

Length of rachis refers to the length from the axil of first floret upto the tip of the inflorescence.

3.17.8 Diameter of a single spike

Ten spikes were cut from randomly selected plants from each unit plot and the diameter of spikes was taken at 30 cm from the soil surface and their mean was calculated.

3.17.9 Number of florets per spike

All the florets of the spike were counted from ten randomly selected plants and their mean was calculated.

3.17.10 Weight of a single spike

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

3.17.11 Spike yield per plot

Spike yield per plot was computed from weight of spike per plot.

3.17.12 Flower yield

Yield of flower per hectare was computed from weight of spike per plot and converted to hectare.

3.17.13 Length of bulb

A slide calipers was used to measure the length of the bulb.

3.17.14 Diameter of bulb

A slide calipers was used to measure the diameter of the bulb.

3.17.15 Fresh weight of bulb per hill

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

3.11.16 Number of side bulb per plant

Number of side bulb per plant was taken from ten random sample plants at harvest and average was recorded.

3.17.17 Yield of bulb

It was calculated by converting the yield of bulb per plot to per hectare.

3.18 Statistical analysis

The collected data were analyzed statistically following the analysis of variance (ANOVA) technique and the mean differences were adjudged by Duncan’s Multiple Range Test (DMRT) using the statistical computer package program, MSTAT (Russell, 1988).

CHAPTER IV

RESULTS AND DISCUSSION

The results of the study regarding the effect of phosphorous and potassium rate on crop characters of tuberose have been presented and possible interpretations have been made in this chapter.

4.1 Effect of phosphorus and potassium and their interaction on morphological characters in tuberose

4.1.1 Plant height (cm)

Mean effect of phosphorus and potassium: The mean effect of phosphorus and potassium on plant height at 30, 60, 90 days after planting (DAP) and at harvest was significant (Fig. 2). Result revealed that the influence of phosphorus on plant height was greater than potassium at all growth stages. This result is supported by Sultana *et al*. (2006) in tuberose who reported that phosphorus had much more influence on plant growth and development in tuberose than potassium.

Effect of phosphorus: The effect of phosphorus rate on plant height at different days after planting was statistically significant at $P \leq 0.05$ in tube rose (Appendix IV). Result showed that plant height increased with increasing phosphorus rate up to 155 kg P_2O_5 ha^{-1} (Fig. 3). The tallest plant was recorded in 155 kg P_2O_5 ha^{-1} at all growth stages followed by 145 kg P_2O_5 ha^{-1}. In contrast, the phosphorous at the rate of 0 kg ha^{-1} (P_0) had the shortest plant height at all growth stages. This result indicates that phosphorous has tremendous effect on growth and development in tuberose.

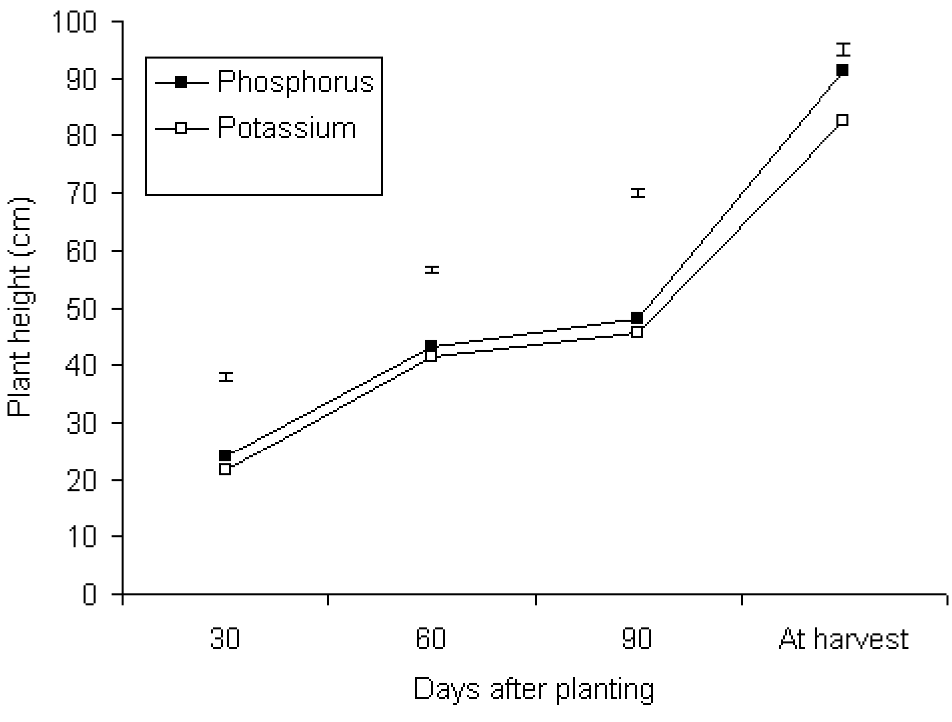

Fig. 2. Mean effect of phosphorus and potassium on plant height at different plant age of tuberose. Vertical bars represent LSD (0.05).

This result is in agreement with that of Gupta *et al.* (2006) who reported that plant height increased with increased phosphorus rate of tuberose till 200 P_2O_5 ha^{-1}.

Effect of potassium: The plant height varied significantly due to different doses of potassium at different days after planting of tuberose (Appendix IV). Result showed that plant height increased with increasing potassium rate up to 190 kg K_2O ha^{-1}. The tallest plant was recorded in 190 kg K_2O ha^{-1} at all growth stages followed by 180 kg K_2O ha^{-1} with same statistical rank (Fig. 4). In contrast, the shortest plant was recorded in control plant at all growth stages. This result indicates that potassium has tremendous effect on growth and development in tuberose. This result is consistent with Sultana *et al.* (2006) in tuberose who reported that plant height increased with increased potassium rate of tuberose till 160 K_2O ha^{-1}.

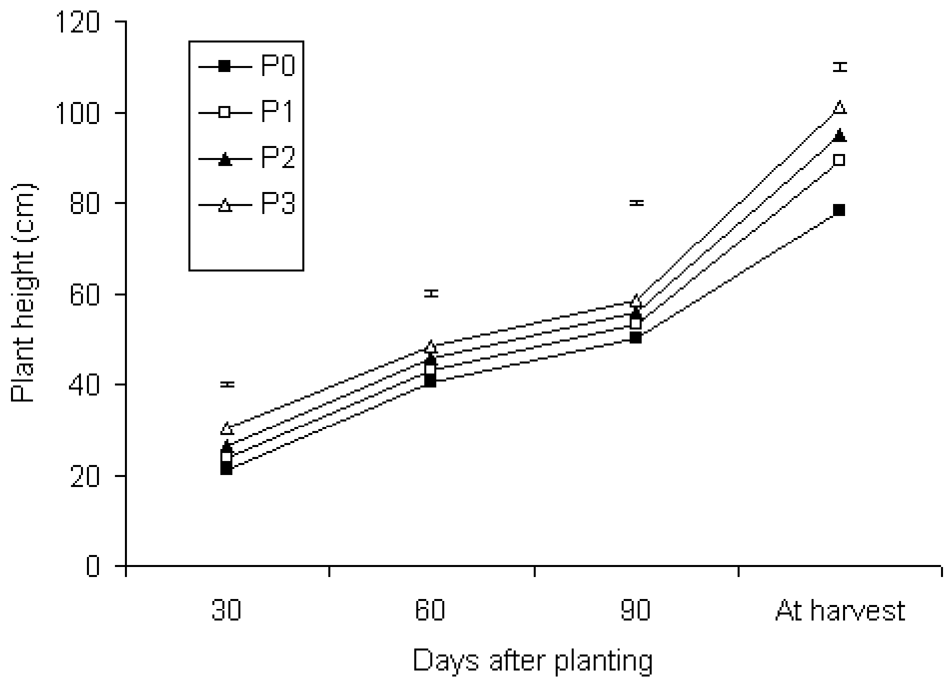

Fig. 3. Effect of different levels of phosphorus fertilizer on plant height at different plant age. Vertical bars represent LSD (0.05).

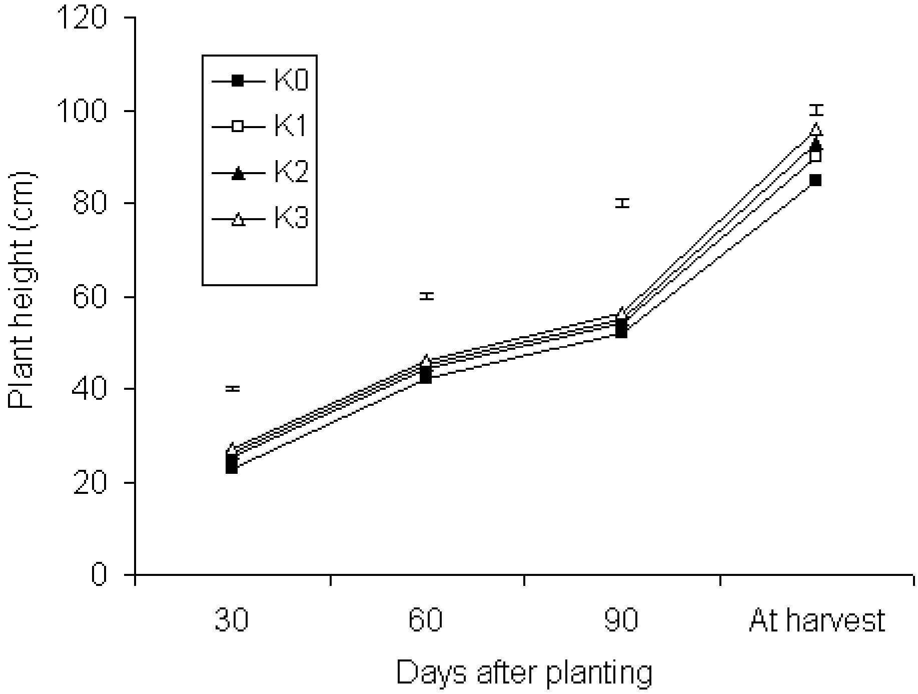

Fig. 4. Effect of different levels of potassium fertilizer on plant height at different plant age. Vertical bars represent LSD (0.05).

Interaction effect: The interaction effect of phosphorus and potassium level had significant effect on plant height in tuberose (Appendix IV). The highest plant height was recorded in the treatment combination of 155 kg P_2O_5 ha^{-1} with 190 kg K_2O ha^{-1} at all growth stages followed by the treatment combination of 155 kg P_2O_5 with 180 kg K_2O ha^{-1} with same statistical rank (Table 1). In contrast, the lowest plant height was recorded in the treatment combination of P_0K_0 at all growth stages of tuberose.

4.1.2 Leaf production

Mean effect of phosphorus and potassium: There was significant variation in leaf number of tuberose due to phosphorus and potassium application (Fig. 5). Results revealed that leaf production was greater in phosphorus applied plant than potassium applied plant. This result indicates that the influence of phosphorus on leaf production was higher than potassium at all growth stages. Mohanasundaram *et al.* (2003) reported that leaf production was higher in phosphorus applied plant than potassium applied plants that supported the present experimental result.

Effect of phosphorus: Different levels of phosphorus application on tuberose had significant effect on leaf production (Fig. 6). 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.

Table 1. Interaction effect of phosphorus and potassium levels on plant height at different days after planting of tuberose

Interaction	Plant height (cm) at days after planting of			
	30	60	90	At harvest
P_0K_0	19.12 i	38.50 h	44.17 h	64.78 i
P_0K_1	21.00 hi	40.92 gh	44.85 gh	77.31 h
P_0K_2	21.25 hi	41.08 gh	45.43 fgh	82.36 gh
P_0K_3	22.50 gh	42.13 fg	46.74 e-h	87.64 efg
P_1K_0	21.95 ghi	41.12 gh	45.58 fgh	86.40 fg
P_1K_1	24.07 fgh	43.17 efg	48.25 d-g	89.29 ef
P_1K_2	24.62 efg	43.58 efg	48.75 def	90.17 ef
P_1K_3	24.75 efg	44.58 def	49.67 cde	91.92 def
P_2K_0	23.46 fgh	43.25 efg	48.67 def	90.67 ef
P_2K_1	26.50 def	45.95 b-e	50.83 bcd	92.88 cde
P_2K_2	27.29 cde	46.50 b-e	51.42 bcd	97.67 bc
P_2K_3	27.96 cd	47.08 bcd	51.75 bcd	98.52 b
P_3K_0	26.67 def	45.75 cde	50.03 cde	96.89 bcd
P_3K_1	30.00 bc	48.00 abc	52.83 bc	100.8 ab
P_3K_2	31.72 ab	49.20 ab	54.33 ab	102.2 ab
P_3K_3	33.25 a	50.72 a	56.42 a	105.3 a
F-test	*	*	*	**
CV (%)	6.76	4.02	3.95	3.39

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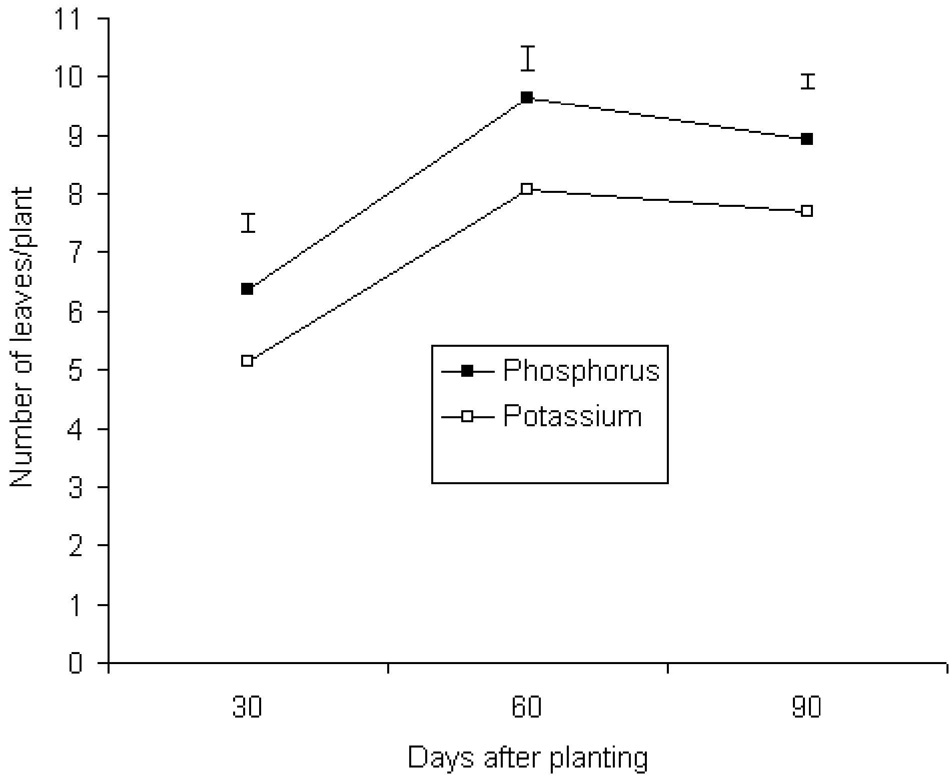

Fig. 5. Mean effect of phosphorus and potassium on leaf production at different plant age of tuberose. Vertical bars represent LSD (0.05).

The maximum leaf production was recorded in 155 kg P_2O_5 ha^{-1} at all growth stages followed by 145 kg P_2O_5 ha^{-1}. The minimum leaf production was recorded in control plant where no phosphorus was applied. Kumar *et al.* (2002) observed that application of phosphorous fertilizer increased leaf production in tuberose that supported the present experimental result.

Effect of potassium: In potassium rates, leaf production varied significantly (Fig. 7). The highest leaf production was recorded in 190 kg K_2O ha^{-1} followed by 180 kg K_2O with same statistical rank. In contrast, control plant produced the lowest number of leaves $plant^{-1}$ at all growth stages. This result is consistent with Singh *et al.* (2005) who reported that leaf production was higher in potassium applied plants than control plants.

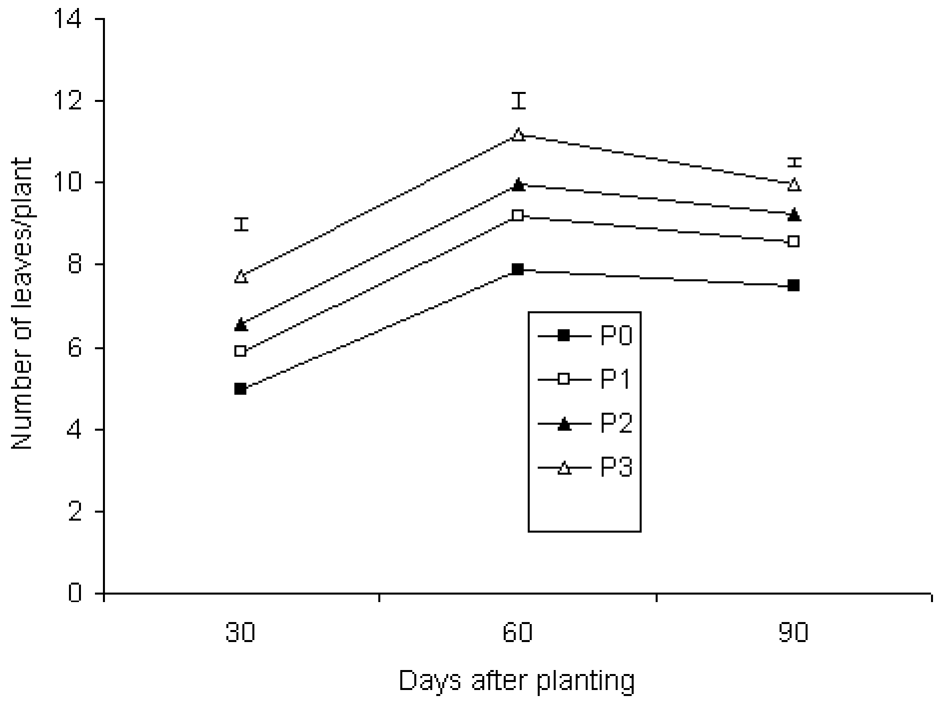

Fig. 6. Effect of different levels of phosphorus fertilizer on leaf production at different plant age. Vertical bars represent LSD (0.05).

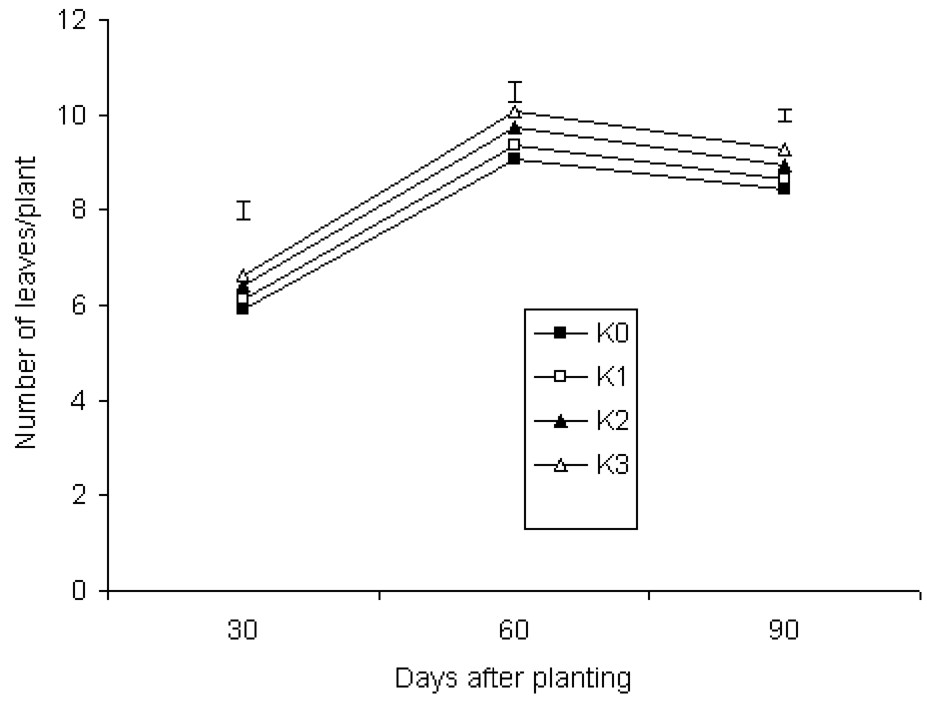

Fig. 7. Effect of different levels of potassium fertilizer on leaf production at different plant age. Vertical bars represent LSD (0.05).

Interaction effect: The interaction effect of phosphorus and potassium level had significant effect on leaf production in tuberose (Appendix V). The maximum leaf production was recorded in the treatment combination of 155 kg P_2O_5 ha^{-1} with 190 kg K_2O ha^{-1} at all growth stages followed by the treatment combination of 155 kg P_2O_5 with 180 kg K_2O ha^{-1} with same statistical rank (Table 1). In contrast, the lowest plant height was recorded in the treatment combination of P_0K_0 at all growth stages of tuberose.

4.1.3 Leaf length

Mean effect of phosphorus and potassium: Figure 8 showed that Leaf length was higher phosphorus applied plant than potassium applied plant. This result indicates that the influence of phosphorus on leaf growth and development was higher than potassium at all growth stages.

Effect of phosphorus: The effect of phosphorus level on leaf length in tuberose was significant (Fig. 9). Result revealed that leaf length increased with increasing phosphorus level. The maximum leaf length (47.58 cm) was recorded in 155 kg P_2O_5 ha^{-1} followed by 135 kg P_2O_5 ha^{-1}. The minimum leaf length (38.92 cm) was recorded in control plant where no phosphorus was applied. Gowda *et al.* (1991) observed that application of phosphorous fertilizer increased leaf length of tuberose that supported the present experimental result.

Table 2. Combined effect of phosphorus and potassium on leaf production at different days after planting of tuberose

Interaction	Number of leaves/plant at days after planting of		
	30	60	90
P_0K_0	4.50 j	7.25 i	6.83 h
P_0K_1	4.75 ij	7.83 hi	7.33 gh
P_0K_2	5.25 hij	8.08 ghi	7.66 fg
P_0K_3	5.42 ghij	8.33 fghi	8.08 ef
P_1K_0	5.66 fghi	8.91 efgh	8.16 ef
P_1K_1	5.83 efgh	9.00 efg	8.50 de
P_1K_2	5.92 efgh	9.33 def	8.58 de
P_1K_3	6.08 efgh	9.58 cde	9.00 cd
P_2K_0	6.33 defg	9.75 cde	9.08 cd
P_2K_1	6.50 cdef	9.85 cde	9.17 cd
P_2K_2	6.50 cdef	10.0 cde	9.25 cd
P_2K_3	6.83 cde	10.2 cd	9.42 c
P_3K_0	7.16 bcd	10.3 cd	9.58 bc
P_3K_1	7.42 abc	10.8 bc	9.58 bc
P_3K_2	8.00 ab	11.5 ab	10.2 ab
P_3K_3	8.25 a	12.1 a	10.6 a
F-test	*	*	**
CV (%)	8.42	6.61	4.56

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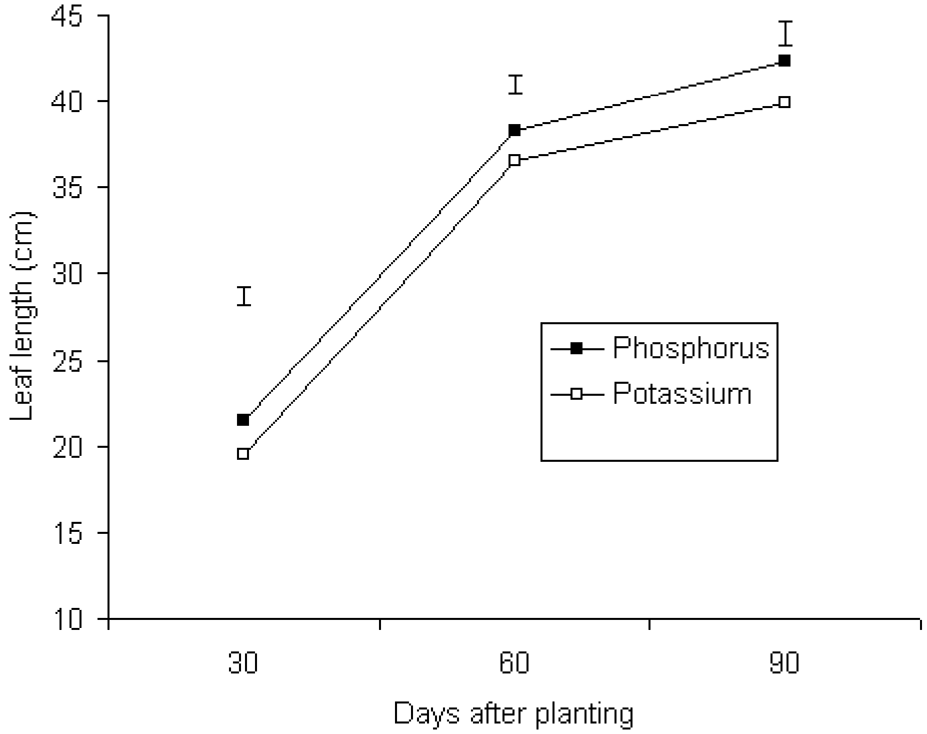

Fig. 8. Mean effect of phosphorus and potassium on leaf length at different plant age of tuberose. Vertical bars represent LSD (0.05).

Effect of potassium: The leaf length varied significantly due to different doses of potassium at different days after planting of tuberose (Appendix VI). Results showed that leaf length increased with increasing potassium rate up to 190 kg K_2O ha^{-1}. The highest leaf length was recorded in 190 kg K_2O ha^{-1} at all growth stages followed by 180 kg K_2O ha^{-1} with same statistical rank (Fig. 10). In contrast, the shortest leaf length was recorded in control plant at all growth stages. This result indicates that potassium has tremendous effect on leaf growth and development in tuberose. Singh *et al.* (2005) who reported that leaf length was higher in potassium applied plants than control plants.

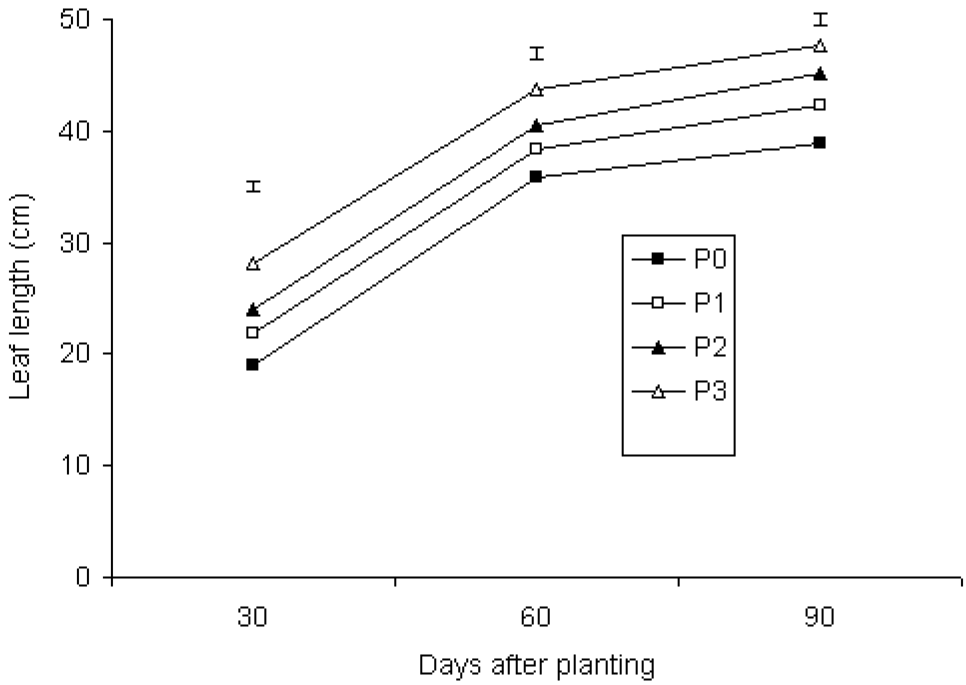

Fig. 9. Leaf length influenced by different levels of phosphorus fertilizer at different plant age. Vertical bars represent LSD (0.05).

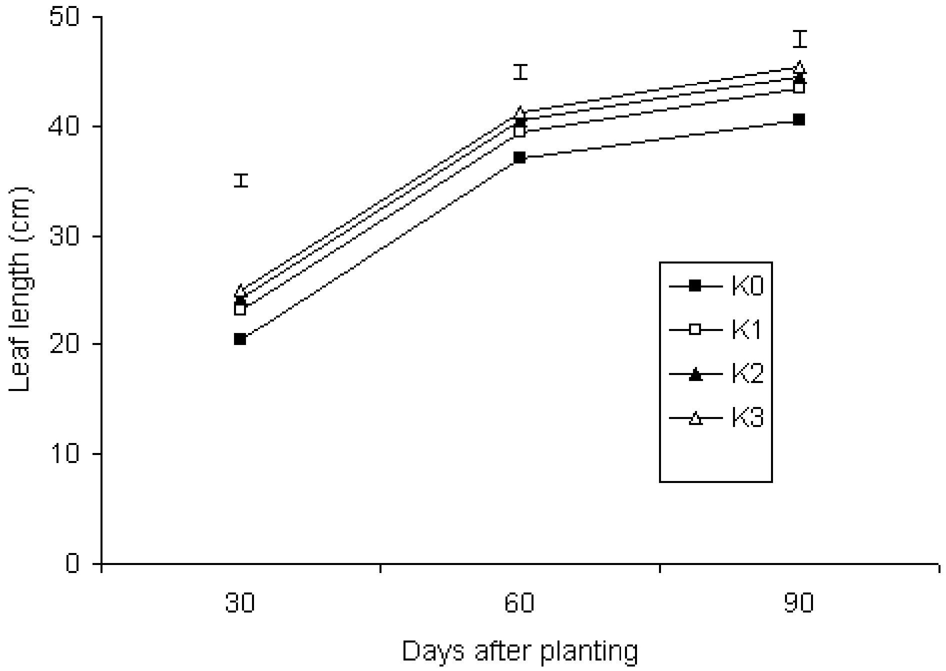

Fig. 10. Leaf length influenced by different levels of potassium fertilizer at different plant age. Vertical bars represent LSD (0.05).

Interaction effect: The interaction effect of phosphorus and potassium rate had significant effect on leaf length in tuberose (Table 3). The highest leaf length was recorded in the treatment combination of 155 kg P_2O_5 with 190 kg K_2O at all growth stages followed by the treatment combination of 155 kg P_2O_5 with 180 kg K_2O with same statistical rank.

4.1.4 Leaf breadth

Mean effect of phosphorus and potassium: The mean effect of phosphorus and potassium on leaf breadth at 30 and 90 DAP was significant but non-significant at 60 DAP (Fig. 11). Result revealed that the influence of phosphorus on leaf breadth was greater than potassium at all growth stages. This result is supported by Sultana *et al.* (2006) in tuberose who reported that phosphorus had much more influence on plant growth and development in tuberose than potassium.

Effect of phosphorus: The effect of phosphorus rate on leaf breadth at different days after planting was statistically significant at $P \leq 0.05$ in tube rose (Appendix VII). Result showed that leaf breadth increased rapidly till 60 DAP followed by slowly increased (Fig. 12). Results further revealed that leaf breadth increased with increasing phosphorus rate (Fig. 12). The widest leaf was recorded in 155 kg P_2O_5 ha^{-1} at all growth stages followed by 145 kg P_2O_5 ha^{-1}. In contrast, the phosphorous at the rate of 0 kg P_2O_5 ha^{-1} (P_0) had the narrowest leaves at all growth stages. This result indicates that phosphorous has tremendous effect on growth and development of tuberose leaves. This result is in agreement with that of Gupta *et al.* (2006) who reported that leaf breadth increased in phosphorus applied plants than control plants.

Table 3. Combined effect of phosphorus and potassium on leaf length at different days after planting of tuberose

Interaction	Leaf length (cm) at days after planting of		
	30	60	90
P_0K_0	17.59 g	33.29 j	35.83 i
P_0K_1	18.58 g	35.92 hij	39.00 hi
P_0K_2	19.67 fg	36.58 g-j	40.17 gh
P_0K_3	20.21 efg	37.25 f-i	40.67 fgh
P_1K_0	19.54 fg	35.67 ij	39.25 hi
P_1K_1	22.08 def	38.21 e-i	42.17 e-h
P_1K_2	22.42 def	39.50 d-h	43.58 c-g
P_1K_3	23.37 cde	39.83 c-g	44.50 b-f
P_2K_0	20.58 efg	38.17 e-i	42.75 d-h
P_2K_1	24.17 cd	40.37 c-f	45.17 b-e
P_2K_2	25.50 bcd	41.42 b-e	45.92 b-e
P_2K_3	26.17 bc	42.33 a-d	46.67 a-d
P_3K_0	24.29 cd	41.10 b-e	44.25 b-f
P_3K_1	27.71 ab	43.25 abc	47.58 abc
P_3K_2	29.79 a	44.45 ab	48.33 ab
P_3K_3	30.54 a	45.75 a	50.17 a
F-test	*	*	*
CV (%)	7.93	4.85	4.99

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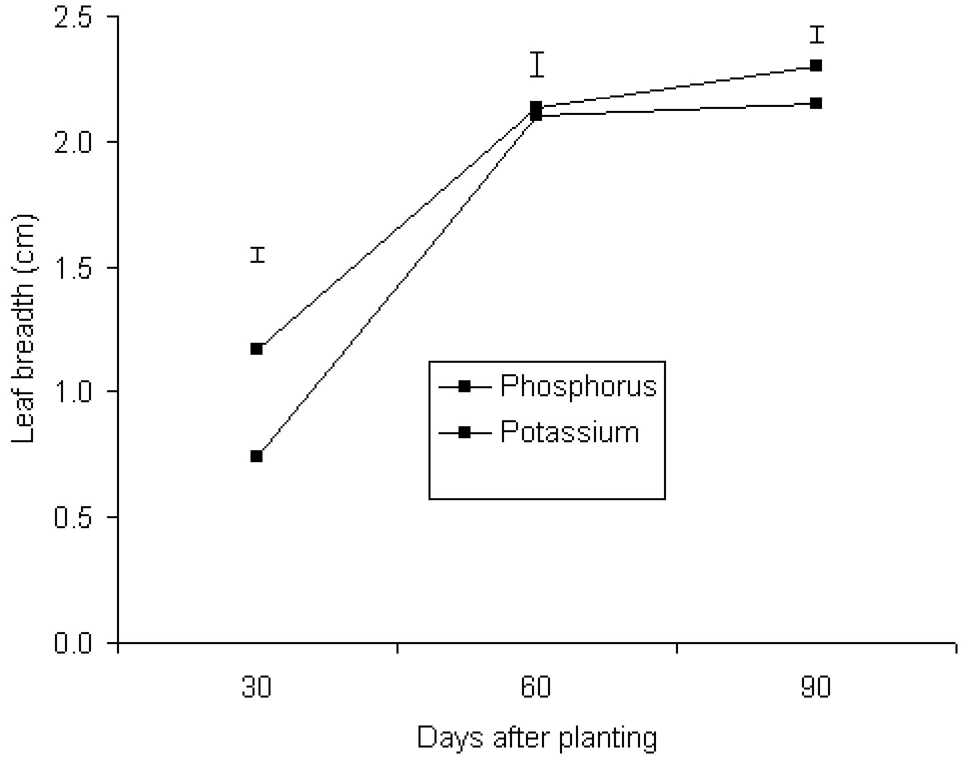


Fig. 11. Mean effect of phosphorus and potassium on leaf breadth at different plant age of tuberose. Vertical bars represent LSD (0.05).

Effect of potassium: The leaf breadth varied significantly due to different doses of potassium at different days after planting of tuberose (Appendix VII) but there had no significant different among the potassium doses at 30 and 60 DAP. Result showed that leaf breadth increased with increasing potassium rate up to 190 kg K_2O ha^{-1}. The widest leaf was recorded in 190 kg K_2O ha^{-1} at all growth stages followed by 180 kg K_2O ha^{-1} with same statistical rank (Fig. 13). In contrast, the narrowest leaf was recorded in control plant at all growth stages. This result indicates that potassium had effect on growth and development of leaves in tuberose. This result is consistent with Sultana *et al.* (2006) in tuberose who reported that leaf breadth was greater in potassium applied plant than control plants.

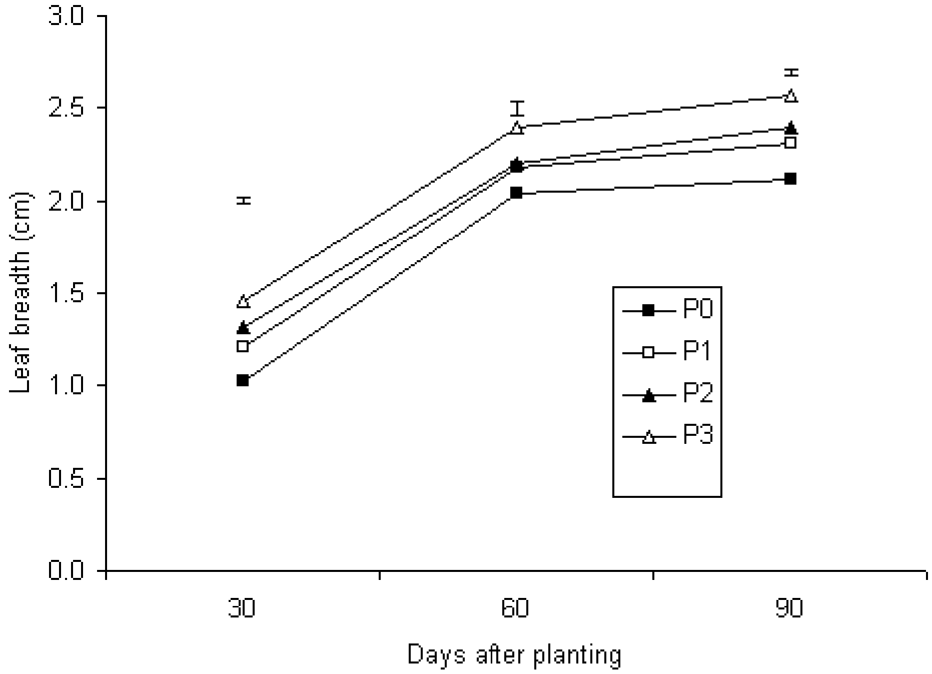


Fig. 12. Leaf breadth as influenced by different levels of phosphorus fertilizer at different plant age. Vertical bars represent LSD (0.05).

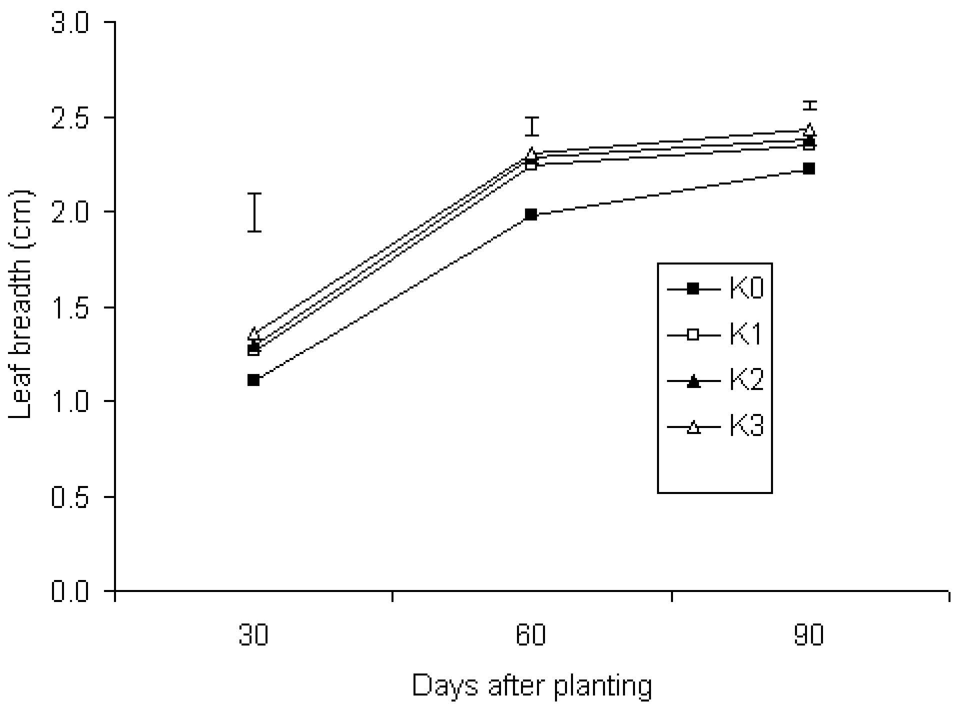


Fig. 13.Leaf breadth as influenced by different levels of potassium fertilizer at different plant age. Vertical bars represent LSD (0.05).

Interaction effect: The interaction effect of phosphorus and potassium level had significant effect on leaf breadth in tuberose (Appendix VII). The highest leaf breadth was recorded in the treatment combination of 155 kg P_2O_5 ha^{-1} with 190 kg K_2O ha^{-1} at all growth stages followed by the treatment combination of 155 kg P_2O_5 with 180 kg K_2O ha^{-1} with same statistical rank (Table 4). In contrast, the lowest leaf breadth was recorded in the treatment combination of P_0K_0 at all growth stages of tuberose.

4.1.5 Number of side shoots plant^{-1}

Mean effect of phosphorus and potassium: The mean effect of phosphorus and potassium on side shoot production was presented in Fig. 14. Results showed that side shoot production was higher in phosphorus applied plants than potassium applied plants. This result indicates that phosphorus has more effect on side shoot production in tuberose than potassium. This result is consistent with Parthiban and Khader (1991) in tuberose who reported that side shoots production was greater in phosphorus applied plants than potassium.

Effect of phosphorus: There was a significant different in side shoot production due to different levels of phosphorus application in tuberose (Appendix VIII). Result showed that side shoot production increased with age till 60 DAP followed by a decline due to some side shoots died at later growth stages (Fig. 15). Result further showed that side shoot number increased with increasing phosphorus levels. The highest number of side shoots plant^{-1} was recorded in 155 kg P_2O_5 ha^{-1} followed by 145 kg P_2O_5 ha^{-1} at all growth stages.

Table 4. Combined effect of phosphorus and potassium on leaf breadth at different days after planting of tuberose

Interaction	Leaf breadth (cm) at days after planting of		
	30	60	90
P_0K_0	0.89 j	1.86 fg	2.00 g
P_0K_1	1.03 i	2.08 def	2.08 fg
P_0K_2	1.07 i	2.11 cdef	2.13 f
P_0K_3	1.12 hi	2.12 cdef	2.24 de
P_1K_0	1.08 i	2.06 ef	2.19 ef
P_1K_1	1.23 g	2.20 bcde	2.32 cd
P_1K_2	1.25 efg	2.22 bcde	2.35 bcd
P_1K_3	1.28 efg	2.23 bcde	2.37 bc
P_2K_0	1.20 gh	1.79 g	2.31 cd
P_2K_1	1.33 def	2.31 abcde	2.41 bc
P_2K_2	1.35 de	2.33 abcde	2.42 bc
P_2K_3	1.39 cd	2.36 abcd	2.45 b
P_3K_0	1.24 fg	2.20 bcde	2.40 bc
P_3K_1	1.45 bc	2.39 abc	2.60 a
P_3K_2	1.49 b	2.47 ab	2.63 a
P_3K_3	1.62 a	2.53 a	2.67 a
F-test	*	*	*
CV (%)	4.45	6.67	2.81

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

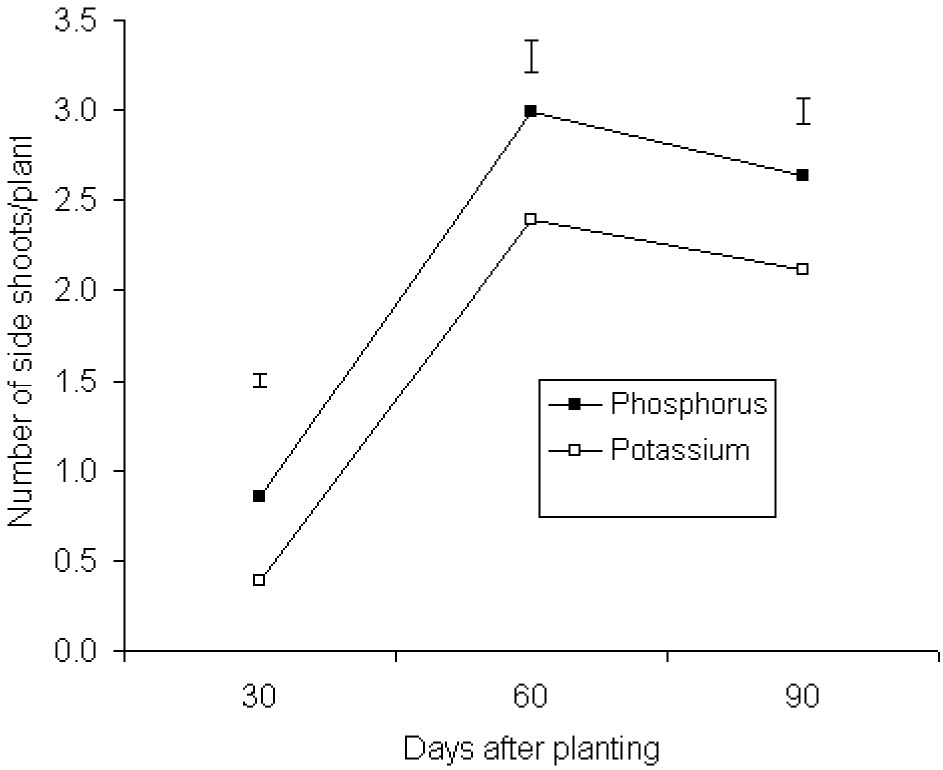


Fig. 14. Mean effect of phosphorus and potassium on side shoot production at different plant age of tuberose .Vertical bars represent LSD (0.05).

In contrast, the control plot (P_0) produced the lowest number of side shoots plant $^{-1}$ at all growth stages. 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.

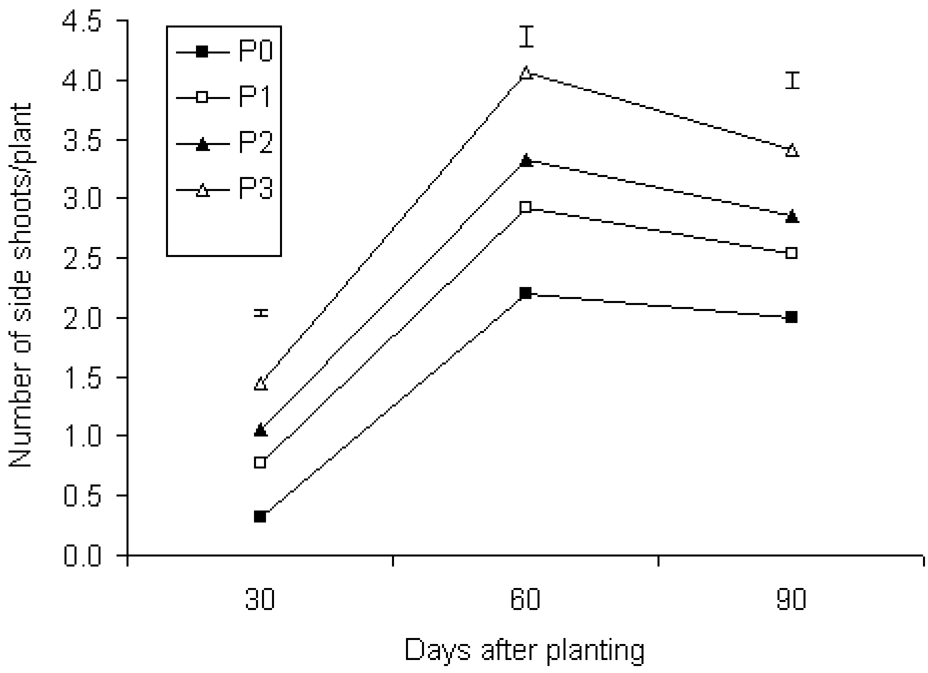


Fig.15. Effect of different levels of phosphorus fertilizer on side shoot production at different plant age. Vertical bars represent LSD (0.05).

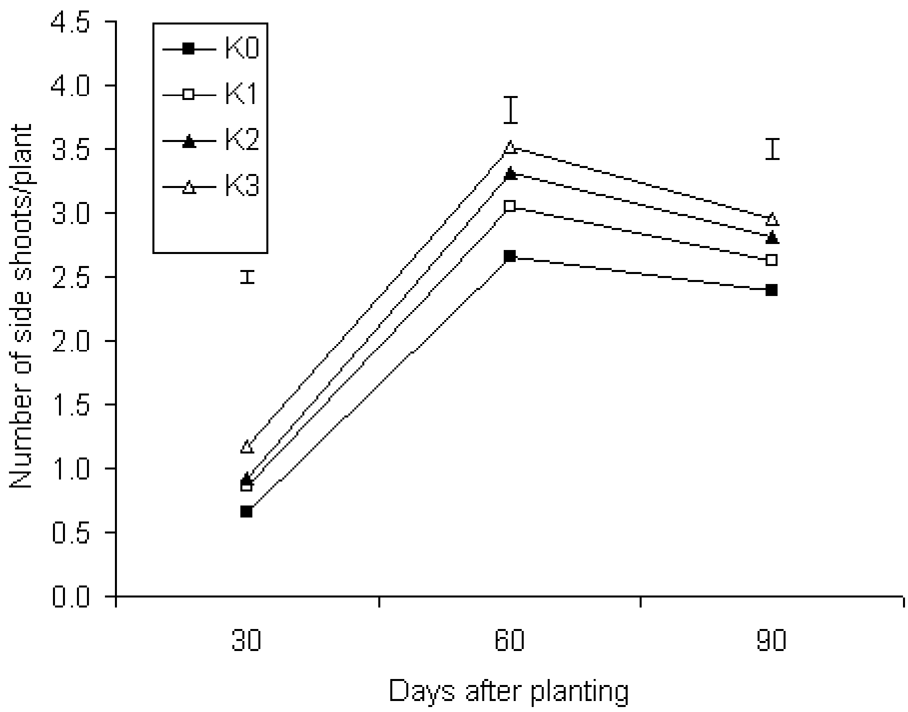


Fig. 16. Effect of different levels of potassium fertilizer on side shoot production at different plant age. Vertical bars represent LSD (0.05).

Effect of potassium: Different levels of potassium application had significant influenced on side shoot production in tuberose (Appendix VIII). The highest number of side shoots plant^{-1} was recorded in 190 kg K_2O ha^{-1} followed by 180 kg K_2O ha^{-1} at all growth stages (Fig. 16). The lowest side shoots plant^{-1} was recorded in control plant. Variation in shoots plant^{-1} due to different levels of potassium was observed by Pal and Biswas (2005) in tuberose that also supported the present experimental result.

Interaction effect: The interaction effect of phosphorus and potassium level for side shoot number was also significant (Appendix VIII). The highest number of shoots plant^{-1} was recorded in the treatment combination of 155 kg P_2O_5 ha^{-1} with 190 kg K_2O ha^{-1} at all growth stages followed by the treatment combination of 155 kg P_2O_5 with 180 kg K_2O ha^{-1} with same statistical rank (Table 5). In contrast, the lowest number of side shoots plant^{-1} was recorded in the treatment combination of P_0K_0 at all growth stages of tuberose.

4.2 Effect of phosphorus and potassium and their interaction on bulb characters in tuberose

4.2.1 Number of side bulbs

Mean effect of phosphorus and potassium: The mean effect of phosphorus and potassium on side bulb production plant^{-1} was significant (Appendix IX). Result revealed that side bulb number was greater in phosphorus applied plants (12. 13 plant^{-1}) than potassium applied plants (10.64 plant^{-1}) (Table 6). This result is supported by Sultana *et al.* (2006) in tuberose who reported that phosphorus had much more influence on plant growth and development in tuberose than potassium.

Table 5. Interaction effects of phosphorus and potassium on side shoot production at different days after planting of tuberose

Interaction	Number of side shoots at days after planting of		
	30	60	90
P_0K_0	0.083 j	1.67 i	1.67 j
P_0K_1	0.330 i	2.00 i	1.83 ij
P_0K_2	0.330 i	2.50 h	2.17 hi
P_0K_3	0.500 hi	2.66 fgh	2.33 gh
P_1K_0	0.580 gh	2.55 gh	2.32 gh
P_1K_1	0.750 fg	2.92 efgh	2.50 fgh
P_1K_2	0.833 ef	3.08 defg	2.66 efg
P_1K_3	0.916 def	3.17 def	2.66 efg
P_2K_0	0.916 def	3.07 defg	2.56 fgh
P_2K_1	1.000 de	3.33 de	2.83 def
P_2K_2	1.080 cd	3.33 de	2.83 def
P_2K_3	1.250 bc	3.58 cd	3.17 bcd
P_3K_0	1.050 d	3.37 de	3.05 cde
P_3K_1	1.330 b	3.92 bc	3.33 abc
P_3K_2	1.420 b	4.33 ab	3.58 ab
P_3K_3	2.000 a	4.67 a	3.67 a
F-test	**	*	*
CV (%)	12.43	9.35	8.95

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

Table.6 Effect of phosphorus and potassium on bulb characters and bulb yield of tuberose

Treatments	Side bulbs/ plant (no.)	Bulb length (cm)	Bulb diameter (cm)	Bulb weight/ plant (g)	Bulb yield (t/ha)
Nutrients (mean effect)					
Phosphorus	12.13 a	6.50 a	3.12 a	135.2 a	18.82 a
Potassium	10.64 b	5.83 b	2.91 b	109.1 b	15.27 b
F-test	**	**	*	**	**
Phosphorus levels					
P_0	9.81 d	5.64 d	2.84 d	103.6 d	14.51 d
P_1	11.64 c	6.33 c	3.13 c	128.9 c	18.04 c
P_2	13.52 b	6.77 b	3.37 b	152.3 b	21.82 b
P_3	15.53 a	7.39 a	3.68 a	176.4 a	24.66 a
F-test	**	**	**	**	**
Potassium levels					
K_0	10.93 b	6.15 c	3.00 b	123.2 c	17.17 d
K_1	12.65 a	6.47 b	3.26 a	137.6 b	19.31 c
K_2	13.25 a	6.69 ab	3.36 a	145.0 ab	20.56 b
K_3	13.69 a	6.82 a	3.40 a	155.3 a	21.99 a
F-test	**	**	**	**	**
CV (%)	9.44	4.65	5.78	8.14	6.52

In a column, figure (s) bearing same letter do not differ significantly at $P \leq 0.05$ by DMRT; *, ** indicate significant at 5% and 1% level of probability, respectively.

Effect of phosphorus: The effect of phosphorus rate on side bulb production was statistically significant at $P \leq 0.05$ in tube rose (Appendix IX). Results showed that side bulb production increased with increasing phosphorus rate up to 155 kg P_2O_5 ha^{-1} (Table 6). The highest number of side bulb was recorded in 155 kg P_2O_5 ha^{-1} (15.53 $plant^{-1}$) followed by 145 kg P_2O_5 ha^{-1} (13.52 $plant^{-1}$). In contrast, the lowest side bulb was recorded in control plant (9.81 $plant^{-1}$). This result indicates that phosphorous has tremendous effect on side bulb production in tuberose. This result is in agreement with that of Gupta *et al.* (2006) who reported that plant height increased with increased phosphorus rate of tuberose till 200 P_2O_5 ha^{-1}.

Effect of potassium: The side bulb number varied significantly due to different doses of potassium of tuberose (Appendix IX). Results showed that side bulb number increased with increasing potassium rate (Table 6). The highest number of side bulb was recorded in 190 kg K_2O ha^{-1} (13.69 $plant^{-1}$) followed by 180 (13.25 $plant^{-1}$) and 170 kg K_2O ha^{-1} (12.65 $plant^{-1}$) with same statistical rank. The lowest number of side bulb was recorded in control plant (10.93 $plant^{-1}$). This result indicates that potassium has tremendous effect on side bulb production in tuberose. This result is consistent with Sultana *et al.* (2006) in tuberose who reported that side bulb production increased in potassium applied plants than control plants.

Interaction effect: The interaction effect of phosphorus and potassium level had significant effect on side bulb production in tuberose (Appendix IX). The highest number of side bulb was recorded in the treatment combination of 155 kg P_2O_5 ha^{-1} with 190 kg K_2O ha^{-1} (17.0 $plant^{-1}$) followed by the treatment combination of 155 kg P_2O_5 with 180 kg K_2O ha^{-1} (15.83 $plant^{-1}$) and the treatment combination of 155

Table.7 Interaction effect of phosphorus and potassium on bulb characters and bulb yield of tuberose

Interaction	Side bulbs/ plant (no.)	Bulb length (cm)	Bulb diameter (cm)	Bulb weight/ plant (g)	Bulb yield (t/ha)
P_0K_0	7.33 h	5.09 j	2.63 h	87.33 h	12.22 j
P_0K_1	9.75 g	5.59 ij	2.84 gh	104.0 gh	14.55 i
P_0K_2	11.00 fg	5.91 hi	2.93 e-h	108.9 g	15.25 hi
P_0K_3	11.17 fg	5.98 ghi	2.97 e-h	114.3 fg	16.00 hi
P_1K_0	10.41 fg	6.03 ghi	2.87 fgh	108.9 g	15.25 hi
P_1K_1	11.83 efg	6.35 fgh	3.18 c-g	121.9 fg	17.07 gh
P_1K_2	12.00 def	6.42 e-h	3.22 c-f	133.7 ef	18.71 fg
P_1K_3	12.33 def	6.50 d-g	3.26 cde	150.9 cde	21.13 de
P_2K_0	12.08 def	6.40 e-h	3.11 d-g	142.5 de	19.95 ef
P_2K_1	13.58 cde	6.72 c-f	3.40 bcd	153.1 cde	21.43 de
P_2K_2	14.17 bcd	6.93 cde	3.45 bcd	154.5 cde	22.63 cd
P_2K_3	14.25 bcd	7.04 bcd	3.51 bc	158.9 cd	23.25 cd
P_3K_0	13.90 b-e	7.07 bc	3.38 bcd	154.2 cde	21.25 de
P_3K_1	15.42 abc	7.23 abc	3.63 ab	171.3 bc	24.20 bc
P_3K_2	15.83 ab	7.52 ab	3.84 a	183.1 ab	25.63 ab
P_3K_3	17.00 a	7.75 a	3.86 a	196.9 a	27.57 a
F-test	*	*	*	*	*
CV (%)	9.44	4.65	5.78	8.14	6.52

In a column, figure (s) bearing same letter do not differ significantly at $P \leq 0.05$ by DMRT; * indicates significant at 5% level of probability, respectively kg P_2O_5 with 170 kg K_2O ha^{-1} (15.42 $plant^{-1}$) with same statistical rank (Table 7). On the other hand, the lowest number of side bulb was recorded in the treatment combination of P_0K_0 (7.33 $plant^{-1}$) in tuberose.

4.2.2 Bulb length

Mean effect of phosphorus and potassium: Table 6 showed that bulb length was higher in phosphorus applied plant than in potassium applied plant. This result indicates that the influence of phosphorus on bulb growth and development was higher than potassium in tuberose.

Effect of phosphorus: The effect of phosphorus level on bulb length in tuberose was significant (Appendix IX). Results revealed that bulb length increased with increasing phosphorus level (Table 6). The maximum bulb length (7.39 cm) was recorded in 155 kg P_2O_5 ha^{-1} followed by 135 kg P_2O_5 ha^{-1} (6.77 cm). The minimum bulb length (5.64 cm) was recorded in control plant. Gowda *et al.* (1991) observed that application of phosphorous fertilizer increased bulb length of tuberose that supported the present experimental result.

Effect of potassium: The bulb length varied significantly due to different doses of potassium in tuberose (Appendix IX). Results showed that bulb length increased with increasing potassium rate. The highest bulb length was recorded in 190 kg K_2O ha^{-1} (6.82 cm) which was statistically similar to 180 kg K_2O ha^{-1} (6.69 cm). In contrast, the lowest bulb length was recorded in control plant (6.15 cm). This result indicates that potassium has tremendous effect on bulb growth and development in tuberose. Singh *et al.* (2005) reported that bulb length was higher in potassium applied plants than control plants that supported the present experimental result.

Interaction effect: The interaction effect of phosphorus and potassium rate had significant effect on bulb length in tuberose (Appendix IX). The highest bulb length was recorded in the treatment combination of 155 kg P_2O_5 with 190 kg K_2O (7.75 cm) followed by the treatment combination of 155 kg P_2O_5 with 180 kg K_2O (7.52 cm) with same statistical rank (Table 7).

4.2.3 Bulb diameter

Mean effect of phosphorus and potassium: Result showed that the influence of phosphorus on bulb diameter was greater than potassium in tuberose (Table 6). This result is consistent with Singh and Sangama (2000) who reported that bulb diameter was higher in phosphorus applied plants than potassium applied plants.

Effect of phosphorus: Significant variation was observed in bulb diameter for different levels of phosphorus (Appendix IX). Result showed that bulb diameter was higher in phosphorus applied plants than control plants (Table 6).The highest bulb diameter was recorded in 155 kg P_2O_5 ha^{-1} (3.68 cm) and the lowest was recorded in control plant (2.84 cm). Patil *et al.*(1999) reported that 150 kg P_2O_5 ha-

$^{-1}$ showed that the highest bulb diameter. In the present experiment, 155 kg P_2O_5 ha^{-1} showed the highest bulb diameter.

Effect of potassium: The effect of potassium on bulb diameter was significant (Appendix IX). Results showed that bulb diameter increased with increasing potassium rate. The highest bulb diameter was recorded in 190 kg K_2O ha^{-1} (3.40 cm) which was statistically similar to other doses of potassium.

The lowest bulb diameter was recorded in control plant (3.00 cm). Banker and Mukhopadhyay (1985) reported that bulb diameter was higher in potassium applied plants than control plants that supported the present experimental result.

Interaction effect: The interaction effect of phosphorus and potassium rate on bulb diameter was significant (Appendix IX). The highest bulb diameter was recorded in the treatment combination of 155 kg P_2O_5 with 190 kg K_2O (3.86 cm) followed by the treatment combination of 155 kg P_2O_5 with 180 kg K_2O (3.84 cm) and 155 kg P_2O_5 with 170 kg K_2O (3.63 cm) with same statistical rank (Table 7).

4.2.4 Bulb yield

Mean effect of phosphorus and potassium: Both bulb weight plant^{-1} and bulb yield in tons ha^{-1} were greater in phosphorus applied plot than potassium applied plot indicating phosphorus has more effect in increasing grain yield than potassium (Table 6).

Effect of phosphorus: Bulb yield both per plant and per hectare was significantly influenced by different levels of phosphorus application (Table 6). Result showed that grain yield was greater in phosphorus applied plot than in control plot where no phosphorus was applied. Again, bulb yield increased with increasing phosphorus levels. The highest bulb yield was recorded in 155 kg P_2O_5 ha^{-1} (176.4 g plant^{-1} and 24.66 t ha^{-1}) due to production of higher number of side bulb with larger bulb.

The lowest bulb yield (103.6 g plant^{-1} and 14.51 t ha^{-1}) was recorded in control because of fewer side bulb with smaller size bulb. These results are consistent with Yadav(2007) who reported that application phosphorus increased bulb yield in tuberose.

Effect of potassium: The effect of potassium on bulb yield both per plant and per hectare was significant (Appendix IX). Results showed that bulb yield both per plant and per hectare increased with increasing potassium rate. The highest bulb yield was recorded in 190 kg K_2O ha^{-1} (155.3 g $plant^{-1}$ and 21.99 t ha^{-1}) followed 180 kg K_2O ha^{-1} (145.0 g $plant^{-1}$ and 20.56 t ha^{-1}). The lowest bulb yield was recorded in control plant (123.2 g $plant^{-1}$ and 17.17 t ha^{-1}) due to fewer productions of side bulb as well as smaller bulb size. Sultana *et al.* (2006) reported that bulb yield was higher in potassium applied plants than control plants that supported the present experimental result.

Interaction effect: The interaction effect of phosphorus and potassium rate on bulb yield was significant (Appendix IX). The highest bulb yield was recorded in the treatment combination of 155 kg P_2O_5 with 190 kg K_2O (196.9 g $plant^{-1}$ and 27.57 t ha^{-1}) followed by the treatment combination of 155 kg P_2O_5 with 180 kg K_2O (183.1 g $plant^{-1}$ and 25.63 t ha^{-1}) with same statistical rank (Table 7). The lowest bulb yield was recorded in control plant (87.33 g $plant^{-1}$ and 12.22 t ha^{-1}).

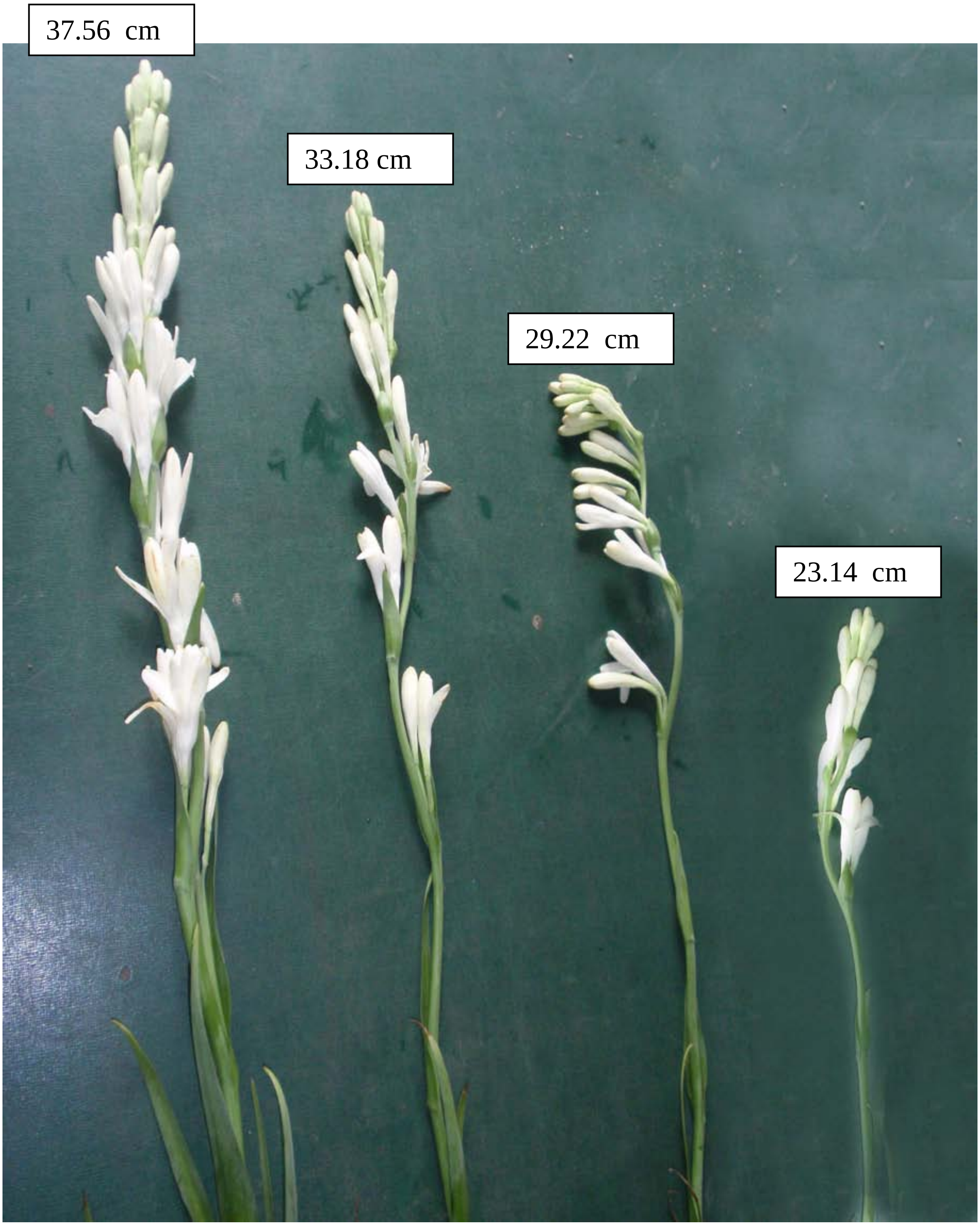
4.3 Effect of phosphorus and potassium and their interaction on reproductive characters in tuberose

4.3.1 Spike length

Mean effect of phosphorus and potassium: The mean effect of phosphorus and potassium on spike length was significant (Table 8). Spike length was higher in phosphorus (30.18 cm) than potassium (24.76 cm). This result indicates that phosphorus has more influence in spike growth and development than potassium. This result is supported by Patel *et al.* (2006) in tuberose who reported that phosphorus had much more influence on plant growth and development in tuberose than potassium.

Effect of phosphorus: Various levels of phosphorus significantly influence the spike length (Appendix X). Results showed that spike length increased with increasing phosphorus rate (Table 8).

The longest spike was recorded in 155 kg P_2O_5 ha^{-1} (37.56 cm) followed by 145 kg P_2O_5 ha^{-1} (33.18 cm). In contrast, the shortest spike was recorded in control plant (23.14 cm). This result indicates that phosphorous has tremendous effect on spike growth and development in tuberose. Reduced spike length under no phosphorus application might be due to less P-uptake by the plant and resulted in insufficiency of enough assimilates to normal growth and development. This result is in agreement with that of Gupta *et al.* (2006) who reported that spike length increased with increased phosphorus rate of tuberose till 150 P_2O_5 ha^{-1}.



P_3 P_2 P_1 P_0

Plate 2. Effect of Phosphorus on length of spike of tuberose

Table. 8 Effect of phosphorus and potassium on yield attributes and flower yield of Tuberose

Treatments	Rachis length (cm)	Spike length (cm)	Spike diameter (cm)	Florets/ spike (no.)	Weight/ spike (g)	Flower yield (t/ha)
Nutrients (mean effect)						
Phosphorus	10.21 a	30.18 a	0.81	21.99 a	64.34 a	12.99 a
Potassium	9.36 b	24.76 b	0.81	18.86 b	54.10 b	10.49 b
F-test	**	**	NS	**	**	**
Phosphorus levels						
P_0	9.10 d	23.14 d	0.78 d	17.77 d	49.55 d	9.60 d
P_1	9.91 c	29.22 c	0.85 c	21.45 c	63.00 c	12.23 c
P_2	10.60 b	33.18 b	0.91 b	24.78 b	70.19 b	15.50 b
P_3	12.24 a	37.56 a	0.98 a	29.19 a	80.14 a	19.25 a
F-test	**	**	**	**	**	**
Potassium levels						
K_0	9.74 c	27.21 c	0.78 c	20.12 b	57.24 c	11.48 d
K_1	10.16 b	30.30 b	0.89 b	23.46 a	65.07 b	13.73 c
K_2	10.37 ab	31.58 b	0.92 ab	24.44 a	68.92 a	14.98 b
K_3	10.58 a	34.02 a	0.93 a	25.17 a	71.65 a	16.39 a
F-test	**	**	**	**	**	**
CV (%)	3.92	5.25	2.65	7.47	4.45	6.93

In a column, figure (s) bearing same letter do not differ significantly at $P \leq 0.05$ by DMRT; ** indicates significant at 5 1% level of probability; NS = Not significant

Plate 3. Effect of Potassium on length of spike of tuberose

Effect of potassium: Significant increased was found in spike length with increased levels of potassium in tuberose (Appendix X). Longest spike was observed in 190 kg K_2O ha^{-1} (34.02 cm) followed by 180 kg K_2O ha^{-1} (31.58 cm) (Table 9). The shortest spike was recorded in control plant (27.21 cm). Pal and Biswas (2005) reported that spike length increased with increasing potassium levels till 200 kg K_2O in tuberose that supported the present experimental results.

Interaction effect: The interaction effect of phosphorus and potassium levels had significant effect on spike length in tuberose (Appendix X). The longest spike was recorded in the treatment combination of 155 kg P_2O_5 ha^{-1} with 190 kg K_2O ha^{-1} (41.50 cm) followed by the treatment combination of 155 kg P_2O_5 with 180 kg K_2O ha^{-1} (37.71 cm) (Table 8). On the other hand, the shortest spike was recorded in the treatment combination of P_0K_0 (18.28 cm) in tuberose.

4.3.2 Spike diameter

Mean effect of phosphorus and potassium: The mean effect of phosphorus and potassium on spike diameter was non-significant (Table 8). This result disagrees with Parthiban and Khader (1991) in tuberose who reported that spike diameter increased more phosphorus applied plants than potassium applied plants.

Effect of phosphorus: The effect of phosphorus level on spike diameter in tuberose was significant (Appendix X). Results revealed that spike diameter increased with increasing phosphorus level (Table 8). The maximum spike diameter (0.98 cm) was recorded in 155 kg P_2O_5 ha^{-1} followed by 145 kg P_2O_5 ha^{-1} (0.91 cm). The minimum spike diameter (0.78 cm) was recorded in control plant. Sultana *et al.* (2006) observed that application of phosphorous fertilizer increased spike diameter that supported the present experimental result.

Table.9 Interaction effect of phosphorus and potassium on yield attributes and flower yield of tuberose

Interaction	Rachis length (cm)	Spike length (cm)	Spike diameter (cm)	Florets/ spike (no.)	Flower weight/ spike (g)	Flower yield (t/ha)
P_0K_0	7.31 j	18.28 l	0.71 j	14.50 j	35.92 j	6.94 j
P_0K_1	9.08 i	22.55 k	0.78 hi	18.39 i	48.05 i	9.26 i
P_0K_2	9.43 hi	24.77 jk	0.83 fgh	18.97 hi	55.17 h	10.89 ghi
P_0K_3	9.58 ghi	26.97 ij	0.83 fgh	19.22 ghi	59.07 gh	11.32 gh
P_1K_0	9.55 hi	26.11 j	0.75 ij	18.80 hi	56.40 h	10.33 hi
P_1K_1	9.92 fgh	29.02 hi	0.86 efg	21.72 fgh	62.61 fg	11.53 gh
P_1K_2	10.07 fg	29.76 ghi	0.89 de	22.32 efg	65.58 ef	12.30 fg
P_1K_3	10.11 ef	32.00 efg	0.90 cde	22.97 def	67.39 def	14.78 de
P_2K_0	10.42 def	30.25 fgh	0.81 gh	22.17 efg	65.01 f	13.46 ef
P_2K_1	10.58 cde	32.80 def	0.93 cd	25.00 de	70.50 cde	15.07 de
P_2K_2	10.66 cd	34.08 cde	0.94 bcd	25.77 cd	71.17 cd	16.27 cd
P_2K_3	10.73 cd	35.60 bcd	0.95 bc	26.17 cd	74.09 c	17.19 c
P_3K_0	10.67 cd	34.19 cde	0.87 ef	25.00 de	71.62 cd	15.19 de
P_3K_1	11.05 bc	36.83 bc	0.99 ab	28.73 bc	79.14 b	19.04 b
P_3K_2	11.33 b	37.71 b	1.02 a	30.71 ab	83.75 ab	20.48 b
P_3K_3	11.92 a	41.50 a	1.04 a	32.33 a	86.06 a	22.27 a
F-test	*	*	*	*	**	**
CV (%)	3.92	5.25	2.63	7.47	4.45	6.93

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

Effect of potassium: The spike diameter varied significantly due to different doses of potassium in tuberose (Appendix X). Results showed that spike diameter increased with increasing potassium rate. The highest spike diameter was recorded in 190 kg K_2O ha^{-1} (0.93 cm) which was statistically similar to 180 kg K_2O ha^{-1} (0.92 cm). In contrast, the lowest spike diameter was recorded in control plant (0.78 cm). This result indicates that potassium has tremendous effect on spike growth and development in tuberose. Singh *et al.* (2005) reported that spike diameter was higher in potassium applied plants than control plants that supported the present experimental result.

Interaction effect: The interaction effect of phosphorus and potassium rate on spike diameter was significant in tuberose (Appendix X). The highest spike diameter was recorded in the treatment combination of 155 kg P_2O_5 with 190 kg K_2O (1.04 cm) followed by the treatment combination of 155 kg P_2O_5 with 180 kg K_2O (1.02 cm) and the treatment combination of 155 kg P_2O_5 with 170 kg K_2O (0.99 cm) with same statistical rank (Table 9).

4.3.3 Rachis length

Mean effect of phosphorus and potassium: Result showed that the influence of phosphorus on rachis length was greater than potassium in tuberose (Table 8). This result is consistent with Singh and Sangama (2000) who reported that rachis length was higher in phosphorus applied plants than potassium applied plants.

Effect of phosphorus: Significant variation was observed in rachis length for different levels of phosphorus (Appendix X). Result showed that rachis length was higher in phosphorus applied plants than control plants (Table 8).
The highest rachis length was recorded in 155 kg P_2O_5 ha^{-1} (12.24 cm) and the lowest was recorded in control plant (9.10 cm). This result is consistent with Singh and Sangama (2000) who reported that rachis length increased with increasing K level till 125 kg K_2O ha^{-1} in tuberose.

Effect of potassium: The effect of potassium on rachis length was significant (Appendix X). Results showed that rachis length increased with increasing potassium rate. The highest rachis length was recorded in 190 kg K_2O ha^{-1} (10.58 cm) which was statistically similar to 180 kg K_2O ha^{-1} (10.37 cm).

The lowest rachis length was recorded in control plant (27.21 cm). Bankar (1988) reported that rachis length was higher in potassium applied plants than control plants that supported the present experimental result.

Interaction effect: The interaction effect of phosphorus and potassium rate on rachis length was significant (Appendix X). The highest rachis length was recorded in the treatment combination of 155 kg P_2O_5 with 190 kg K_2O (11.92 cm) and the lowest was recorded in the treatment combination of K_0P_0 (7.31 cm).

4.3.4 Number of flowers spike^{-1}

Mean effect of phosphorus and potassium: The number of flower spike^{-1} was greater in phosphorus applied plot than potassium applied plot indicating phosphorus has more effect in increasing flower production than potassium

Effect of phosphorus: Phosphorus fertilization had significant effect on the number of flowers spike $^{-1}$ in tuberose (Appendix X). Result revealed that flower number spike^{-1} increased with increasing phosphorus level (Table 8).
The highest number of flowers spike $^{-1}$ was observed in 155 kg P_2O_5 ha^{-1} (29.19) followed by 145 kg P_2O_5 ha^{-1} (24.78). In contrast, the lowest number of flowers spike^{-1} was recorded in control plant (17.77) that was significantly different than the other treatments. Reduced number of flowers spike^{-1} under no phosphorus application might be due to less P-uptake by the plant and resulted in insufficiency of enough assimilates to produce potential number of flowers. These results are in conformity with Pal and Biswas (2005) who reported that zero or lesser amount of P application had the lowest number of flowers spike^{-1} compared to higher doses in tuberose.

Effect of potassium: The flower number varied significantly due to different doses of potassium of tuberose (Appendix X). Results showed that flower number spike^{-1} increased with increasing potassium rate but the increscent was not significant among the potassium levels (Table 8). The highest number of flowers spike^{-1} was recorded in 190 kg K_2O ha^{-1} (25.17 spike^{-1}) and the lowest was recorded in control plant (20.12 spike^{-1}).This result is consistent with Sultana *et al.* (2006) in tuberose who reported that side bulb production increased in potassium applied plants than control plants.

Interaction effect: The interaction effect of phosphorus and potassium level had significant effect on flower production in tuberose (Appendix X). The highest number of flowers spike^{-1} was recorded in the treatment combination of 155 kg P_2O_5 ha^{-1} with 190 kg K_2O ha^{-1} (32.33 spike^{-1}) followed by the treatment combination of 155 kg P_2O_5 with 180 kg K_2O ha^{-1} (30.71 spike^{-1}) with same statistical rank.

4.3.5 Flower yield

Mean effect of phosphorus and potassium: The flower yield both per spike and per hectare was greater in phosphorus applied plot than potassium applied plot indicating phosphorus has more effect in increasing flower production than potassium (Table 8).

Effect of phosphorus: Flower yield both per spike and per hectare was significantly influenced by different levels of phosphorus application (Table 8). Result showed that grain yield was greater in phosphorus applied plot than in control plot where no phosphorus was applied indicating application of phosphorus had effect on flower yield. Result revealed that flower yield increased with the increasing amount of phosphorus application till 155 kg P_2O_5 ha^{-1}. The highest flower yield was observed in 155 kg P_2O_5 ha^{-1} followed by 145 kg P_2O_5 ha^{-1} (80.14 g spike^{-1} and 19.25 t ha^{-1}). The flower yield was the higher in 155 kg P_2O_5 ha^{-1} because of production of higher number of flowers spike^{-1} compared to other treatments (Table 8). On the contrary, control plot (P_0) produced the lowest flower yield (49.55 g spike^{-1} and 9.60 t ha^{-1}) due to production of lesser flowers spike^{-1}. Considering flower yield increased over control, result showed that the highest percentage of grain yield increased in the treatment of 155 kg P_2O_5 ha^{-1} (100%) followed by 145 kg P_2O_5 ha^{-1} (61.5%). The lowest percent increased over control was recorded in 135 kg P_2O_5ha^{-1} (27.4%). Flower yield variations in tuberose due to phosphorus application was also observed by many researchers (Kumar *et al.*, 2002; Mohanasundaram *et al.*, 2003; Gupta *et al.*, 2006; Patel *et al.*, 2006; Sultana *et al.*, 2006; Yadav, 2007).

Effect of potassium: The effect of potassium on flower yield both per spike and per hectare was significant (Appendix X). Results showed that flower yield both per spike and per hectare increased with increasing potassium rate. The highest flower yield was recorded in 190 kg K_2O ha^{-1} (71.65 g spike^{-1} and 16.39 t ha^{-1})

followed 180 kg K_2O ha^{-1} (68.92 g $spike^{-1}$ and 14.98 t ha^{-1}). The lowest flower yield was recorded in control plant (57.24 g $spike^{-1}$ and 11.48 t ha^{-1}) due to production of fewer flowers $spike^{-1}$. Many workers reported that flower yield increased due to potassium application in tuberose (Amarjeet and Godara, 1998; Patil *et al.,* 1999; Singh and Sangama, 2000; Pal and Biswas, 2005; Singh *et al.*, 2005) that supported the present experimental result.

Interaction effect: The interaction effect of phosphorus and potassium rate on flower yield both per spike and per hectare was significant (Appendix X). The highest flower yield both per spike and per hectare was recorded in the treatment combination of 155 kg P_2O_5 with 190 kg K_2O (86.06 g $spike^{-1}$ and 22.27 t ha^{-1}) (Table 9). The lowest flower yield was recorded in control plant (35.92 g $spike^{-1}$ and 6.94 t ha^{-1}).

CHAPTER V
SUMMARY AND CONCLUSION

The experiment was conducted at the field Laboratory of the Horticultural farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, during the period from April, 2009 to March, 2010 to investigate the effect of different levels of phosphorus and potassium and their combined effect on growth, yield attributes, bulb and flower yield of tuberose *cv.* single. The soil belongs to the Chhiata series of Grey Terrace Soil (AEZ-28, Madhupur Tract). The experiment comprised four levels of phosphorus application like i) P_0 = Control (0 kg P_2O_5 ha^{-1}); ii) P_1 = 135 kg P_2O_5 ha^{-1}; iii) P_2 = 145 kg P_2O_5 ha^{-1}; iv) P_3 = 155 kg P_2O_5 ha^{-1} and four levels of potassium like i) K_0 = 0 kg K_2O ha^{-1}; ii) K_1 = 170 kg K_2O $ha^{-}1$; iii) K_2 = 180 kg K_2O ha^{-1} and iv) K_3 = 190 kg K_2O ha^{-1}. Phosphorus and potassium were applied from TSP and MP, respectively to the experimental plot during final land preparation as per treatments. The experiment was laid out in a two factor Randomized Complete Block Design with three replications. The collected data were analyzed statistically and means were adjudged by DMRT at 5% level of probability.

Results revealed that the influence of phosphorus on morphological, growth, bulb and flower characters was greater than potassium in tuberose.

The effect of phosphorus levels on morphological characters such as plant height, leaves production, leaf length and breadth and side shoot production was significant at three growth stages of 30, 60 and 90 days after planting (DAP). Results revealed that plant height, leaf number $plant^{-1}$, leaf length and breadth and number of side shoots $plant^{-1}$ increased with increasing phosphorus levels till 155 kg P_2O_5 ha^{-1}.

The longest plant, maximum leaf production, larger leaf and the highest number of side shoot production was recorded in 155 kg P_2O_5 ha^{-1} at all growth stages followed by 145 kg P_2O_5 ha^{-1}**.** In contrast the above studied parameters were recorded in control plant. These results indicate that application of 155 kg P_2O_5 ha^{-1} may be optimum dose for plant growth and development of tuberose.

Bulb characters such as bulb production plant-1, bulb length, bulb diameter and bulb yield both per plant and per hectare were significantly influenced by different levels of phosphorus application. Results showed that bulb production, bulb length, bulb diameter and bulb yield both per plant and per hectare were increased with increasing phosphorus levels till 155 kg P_2O_5 ha^{-1}. These results indicate that application of 155 kg P_2O_5 ha^{-1} may be the optimum dose for maximizing tuber yield. On the other hand, the lowest bulb production, bulb size and bulb yield was recorded in control plant.

There were significant differences in floral characters such as rachis length, spike length and diameter, number of flowers $spike^{-1}$ and flower yield both per spike and per hectare due to different levels of phosphorus application. Results revealed that rachis length, spike length and diameter, number of flowers $spike^{-1}$ and flower yield increased with increasing phosphorus levels till 155 kg P_2O_5 ha^{-1}. The highest flower yield was recorded in 155 kg P_2O_5 ha^{-1} due to increased flowers $spike^{-1}$. In contrast, the lowest flower yield was recorded in control plant due to fewer flowers $spike^{-1}$.

The effect of potassium levels on morphological characters such as plant height, leaves production, leaf length and breadth and side shoot production was significant at three growth stages of 30, 60 and 90 days after planting (DAP). Results revealed that plant height, leaf number $plant^{-1}$, leaf length and breadth and number of side shoots $plant^{-1}$ increased with increasing potassium levels till 190 kg K_2O ha^{-1}. The longest plant, maximum leaf production, larger leaf and the highest number of side shoot production was recorded in 190 kg K_2O ha^{-1} at all growth stages followed by 180 kg K_2O ha^{-1}**.** In contrast, the shorter plant, lower leaf and side shoot production and leaf size were recorded in control plant. These results indicate that application of 190 kg K_2O ha^{-1} may be optimum dose for plant growth and development of tuberose.

Bulb characters such as bulb production plant-1, bulb length, bulb diameter and bulb yield both per plant and per hectare were significantly influenced by different levels of potassium application. Results showed that bulb production, bulb length, bulb diameter and bulb yield both per plant and per hectare were increased with increasing potassium levels till 190 kg K_2O ha^{-1}.
These results indicate that application of 190 kg K_2O ha^{-1} may be the optimum dose for maximizing tuber yield. On the other hand, the lowest bulb production, bulb size and bulb yield was recorded in control plant. .

There were significant differences in floral characters such as rachis length, spike length and diameter, number of flowers $spike^{-1}$ and flower yield both per spike and per hectare due to different levels of potassium application. Results revealed that rachis length, spike length and diameter, number of flowers $spike^{-1}$ and flower yield increased with increasing phosphorus levels till 190 kg K_2O ha^{-1}. The highest flower yield was recorded in 190 kg K_2O ha^{-1} due to increased flowers $spike^{-1}$. In contrast, the lowest flower yield was recorded in control plant due to fewer flowers $spike^{-1}$.
The interaction effect of phosphorus and potassium level on plant characters as well as bulb and flower yield was significant. The highest bulb and flower yield was observed in the treatment combination of 155 kg P_2O_5 ha^{-1} with 190 kg K_2O ha^{-1}. These results indicate that 155 P_2O_5 $ha^{-1}$with 190 kg K_2O ha^{-1} might be the optimum combination of P and K for maximizing flower production in tuberose. Further, results indicated that combined application of P and K was more effective than single application of P and K.

From the results, it may be concluded that growth, bulb and flower yield of tuberose were influenced by different levels of phosphorus and potassium application. Among the treatment combinations, application of phosphorus @ 155 kg P_2O_5 ha^{-1} along with potassium dose of 190 kg K_2O ha^{-1} appeared to be the best suited dose for optimizing bulb and flower yield of tuberose in the AEZ-28.

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

1. Such study is needed in different agro ecological zones (AEZ) of Bangladesh for regional adaptability and other performances.
2. Higher levels of Phosphorus i.e. >155 kg P_2O_5/ha may be used in the treatments for further study for identify better performance.
3. Higher levels of potassium i.e. >190 kg K_2O /ha may be used for further study to get better result.

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APPENDICES

Appendix I. Average monthly rainfall, air temperature and relative humidity during the experimental period between April 2009 to March, 2010 at the SAU area, Dhaka

Month	Monthly average air temperature (^{0}C)			Average rainfall (mm)	Average relative humidity (%)	Average daily sunshine (hrs)
	Maximum	Minimum	Average			
April	30.56	22.14	26.35	96.6	78.57	7.42
May	32.80	23.34	28.07	266	82.50	5.66
June	31.27	26.46	29.09	153.4	86.29	6.20
July						
August						
September						
October	31.27	24.14	27.71	18.0	86.2	8.65
November	29.49	19.55	24.52	00.0	84.3	8.45
December	26.52	13.19	19.85	00.0	80.8	6.67
January	23.43	12.93	18.18	00.0	78.0	7.20
February	27.34	16.41	21.87	06.6	73.9	8.18
March	29.61	20.57	25.09	13.6	80.6	7.66

Source: Weather Yard, SAU, Dhaka

Appendix II. Morphological characteristics of the experiment field

Characters	SAU farm
Locality	SAU, Dhaka
Geographic position	24.09^{o} North Latitude 90.5^{o} Eeast Longitude 8.2 m height above the mean sea level
Agro-ecological zone (FAO and UNDP, 1988)	Madhupur Tract (AEZ-28)
General soil type	Shallow Grey Terrace Soil
Taxonomic soil classification: Order Sub-order Sub-group Soil series	 Inceptisols Aquept Aeric Albaquept Chhiata
Parent material	Madhupur terrace
Topography	Fairly level
Drainage	Well drained
Flood level	Above Flood level

Appendix III. Physical and chemical characteristics of the soils

Characteristics	SAU farm
Mechanical fractions:	
% Sand (0.2-0.02 mm)	27.4
% Silt (0.02-0.002 mm)	33.3
%Clay (< 0.002 mm)	39.3
Textural class	Clay loam
Colour	Grey
Consistency	Sticky and mud when wet
pH (1:2.5 Soil-Water)	6.2
CEC (cmol kg^{-1})	18.4
Exchangeable K (meq/100 g)	0.39
Exchangeable Ca (meq/100 g)	3.20
Exchangeable Mg (meq/100 g)	1.34
Exchangeable Na (meq/100 g)	0.16
Organic C (%)	0.99
Total N (%)	0.052
Available P (mg kg^{-1})	13.1
Available S (mg kg^{-1})	8.51
Available Zn (mg kg^{-1})	1.52
Available Cu (mg kg^{-1})	0.66
Available Fe (mg kg^{-1})	16.8
Available Mn (mg kg^{-1})	3.1
Available boron (mg kg^{-1})	0.33

Source : SRDI, Soil Testing Laboratory, Khamarbari, Dhaka

Appendix IV. Analysis of variance (mean square) on plant height of tuberose at different days after planting

Source of variation	df	Plant height (cm) at days after planting of			
		30	60	90	At harvest
Replication		0.524	6.924	1.034	4.641
Phosphorus level (A)		191.85 **	133.84 **	145.02 **	1170.2 **
Potassium level (B)		41.48 **	33.97 **	34.59 **	274.52 **
A×B		2.95 *	8.417 *	3.805 *	36.01 **
Error		1.731	3.193	1.871	9.517

*, ** indicate significant at 5% and 1% level of probability, respectively

Appendix V. Analysis of variance (mean square) on leaf production of tuberose at different days after planting

Source of variation	df	Number of leaves plant^{-1} at different days after planting of		
		30	60	90
Replication		0.51	1.69	0.231
Phosphorus level (A)		15.87 **	22.83 **	13.50 **
Potassium level (B)		1.233 *	2.27 **	1.620 **
A×B		0.279 *	0.59 *	0.315 *
Error		0.097	0.20	0.162

*, ** indicate significant at 5% and 1% level of probability, respectively

Appendix VI. Analysis of variance (mean square) on leaf length of tuberose at different days after planting

Source of variation	df	Leaf length (cm) at different days after planting of		
		30	60	90
Replication		26.628	10.817	25.099
Phosphorus level (A)		175.97 **	134.72 **	166.294 **3
Potassium level (B)		48.41 **	40.53 **	55.49 **
A×B		3.401 *	3.684 *	9.471 *
Error		1.944	0.176	4.711

*, ** indicate significant at 5% and 1% level of probability, respectively

Appendix VII. Analysis of variance (mean square) on leaf breadth of tuberose at different days after planting

Source of variation	df	Leaf breadth (cm) at different days after planting of		
		30	60	90
Replication		0.001	0.080	0.047
Phosphorus level (A)		0.387 **	0.257 **	0.443 **
Potassium level (B)		0.137 **	0.282 **	0.096 **
A×B		0.014 *	0.063 *	0.013 *
Error		0.003	0.022	0.004

*, ** indicate significant at 5% and 1% level of probability, respectively

Appendix VIII. Analysis of variance (mean square) on side shoot production of tuberose at different days after planting

Source of variation	df	Number of side shoots plant^{-1} at different days after planting of		
		30	60	90
Replication		0.038	0.785	0.118
Phosphorus level (A)		2.771 **	7.258 **	4.154 **
Potassium level (B)		0.530 **	1.643 **	0.705 **
A×B		0.053 **	0.294 *	0.068 *
Error		0.012	0.086	0.025

*, ** indicate significant at 5% and 1% level of probability, respectively

Appendix IX. Analysis of variance (mean square) on bulb characters of tuberose.

Source of variation	df	Side bulbs/ plant (no.)	Bulb length (cm)	Bulb diameter (cm)	Bulb weight/ plant (g)	Bulb yield (t/ha)
Replication		0.100	0.196	0.104	1.98	0.16
Phosphorus level (A)		72.64**	6.516 **	1.497 **	11675.4 **	235.3 **
Potassium level (B)		17.57**	1.034 **	0.394 **	2181.2 **	50.07 **
A×B		1.422*	0.092 *	0.055 *	304.56 *	3.42 *
Error		0.651	0.035	0.015	130.36	1.66

*, ** indicate significant at 5% and 1% level of probability, respectively

Appendix X. Analysis of variance (mean square) on floral characters of tuberose.

Source of variation	df	Rachis length (cm)	Spike length (cm)	Spike diameter (cm)	Florets / spike (no.)	Weight / spike (g)	Flower yield (t/ha)
Replication		0.085	5.55	0.001	23.72	19.44	0.12
Phosphorus level (A)		10.12**	450.0**	0.079 **	283.7**	1987.3**	208.5**
Potassium level (B)		1.58 **	96.44**	0.053 **	59.87**	471.04**	52.1**
A×B		0.258 *	5.79 *	0.003 *	8.54 *	24.49 **	1.76 **
Error		0.080	2.61	0.001	3.03	8.56	0.96

*, ** indicate significant at 5% and 1% level of probability, respectively