GROWTH AND YIELD OF TUBEROSE AS INFLUENCED BY GIBBERELLIC ACID AND POTASSIUM

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CERTIFICATE

This is to certify that thesis entitled, "GROWTH AND YIELD OF TUBEROSE AS INFLUENCED BY GIBBERELLIC ACID AND POTASSIUM" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of MASTER OF SCIENCE (MS) IN HORTICULTURE, embodies the result of a piece of bona-fide research work carried out by NILUFA AKTAR, Registration no. 07-02234 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.

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TO MY

BELOVED PARENTS

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ABSTRACT

The experiment was conducted at the Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka during the period from April, 2013 to March 2014. The experiment consisted of two factors. Factor A: Four levels of potassium i.e. K_0: 0, K_1: 125 K_2: 145 and K_3: 165 kg K_2O/ha and Factor B: three levels of GA_3 i.e. G_0: 0. G_1: 100 and G_2: 200 ppm GA_3 respectively. The experiment was conducted in a Randomized Complete Block Design with three replications. The maximum number of spike (309 thousand/ha), yield of bulb (19 t/ha) and bulblets (22.85 t/ ha) was recorded from K_2 and lowest from $K_{0.}$ In case of $GA_{3,}$ the maximum number of spike (325 thousand/ha), yield of bulb (20.24 t/ha) and bulblets (22.94 t/ha) was obtained from G_2 and lowest from G_0. In respect of combined effect, K_2G_2 produced the maximum number of spike (350 thousand/ha), yield of bulb (21.72 t/ha) and bulblets (26.95 t/ha) and lowest from K_0G_0. The maximum benefit cost ratio (2.24) was obtained from K_2G_2 and minimum from $K_0G_{0.}$ So the present investigation indicates that, combined effect of 200 ppm GA_3 with 145 kg K_2O/ha is suitable for growth, flowering, bulb and bulblets yield of tuberose.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

ABBREVIATIONS AND ACRONYMS

AEZ	=	Agro-Ecological Zone
ANOVA	=	Analysis of Variance
CCC	=	Chlormequat
CV	=	Coefficient of Variance
DAP	=	Days after planting
Ed.	=	Edition
et al.	=	and others
Fig.	=	Figure
GA_3	=	Gibberellic Acid
ha	=	Hectare
K	=	Potassium
LSD	=	Least Significant Difference
Max.	=	Maximum
Min.	=	Minimum
MOP	=	Muriate of Potash
No.	=	Number
P	=	Phosphorus
PH	=	Hydrogen ion concentration
ppm	=	Parts Per Million
RCBD	=	Randomized Complete Block Design
RH	=	Relative Humidity
SAU	=	Sher-e-Bangla Agricultural University
SRDI	=	Soil Resources Development Institute
TSP	=	Triple Super Phosphate
Viz.	=	Namely

CHAPTER I

INTRODUCTION

Tuberose (*Polianthes tuberosa* L.) is one of the most popular cut flower. Tuberose belongs to family Amaryllidaceae. Tuberose is a native of Mexico from where it spreads to other parts of the world. In the orient white goes for virtue and purity, tuberose is much adored for its color, elegance and fragrance. Tuberose occupies a very selective and special position to flower loving people. It has a great economic potential for cut flower trade and essential oil industry (Sadua and Bose, 1973).

Tuberose is a half-hardy bulbus perennial multiplying itself through bulb and 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.

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 the source of tuberose oil. The natural flower oil of tuberose is one of the most expensive perfumer's raw materials.

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

The growing period of tuberose is 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).

For the last few years, tuberose has become a popular cutflower for its attractive fragrance and beautiful display in the vase in Bangladesh. Now, it is one of the most important commercial cutflower.

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 our country, very little knowledge of production technology is hand to the growers (Ahmed, 1985).

There are many factors which can affect plant growth and economic cultivation of tuberose, such as size of bulb and bulblet, depth of planting, optimum level of fertilizer, appropriate concentration of growth regulating chemicals etc. The number of florets per spike, flower quality, daughter bulb production etc are related to application of appropriate level of fertilizer and growth regulating chemicals.

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). Potassium (K) is an essential mineral element for plants as it involved in many biochemical and physiological processes vital to plant growth, yield, quality and stress (Cakmak, 2005). It is also involved in stomatal regulation of transpiration and photosynthesis, photophosphorylation, transportation of photoassimilates from source tissues via the phloem to sink tissues, enzyme activation, turgor maintenance and stress tolerance (Marschner, 1995). Potash appears to help in increasing the number of spike, flower per spike and number of flowers per hill (Singh *et al.*, 1976; Yadav *et al.,* 1989; Singh *et al.,* 2004). Duration of flowering in the field was improved through using potassium fertilizer.

Normal plant growth and development are regulated by naturally produced chemicals or phytohormones. Their role can often be substituted by application of synthetic growth regulating chemicals. These are becoming extremely important and valuable in the commercial control of crop growth in both agriculture and horticulture (Nickell, 1982). The potential use of growth regulators in flower production has created considerable scientific interest in recent years. Many studies have indicated that the application of growth regulators can affect the growth and development of flowers.

Application of certain growth substance has been found to influence the growth and flowering of tuberose (Bose and Yadav, 1998). Mukhopadhyay and Banker (1983) sprayed the plants of cv. single with GA_3 and observed that GA_3 increased spike length and number of floret per spike. Duration of flower in the field was improved with GA_3. According to Dhua *et al.,* (1987) treatment with GA_3 caused earliest flowering and gave the highest yield of spikes and flowers.

In Bangladesh, a few studies have been done regarding use of GA_3 and potassium (K) for tuberose cultivation. So research work is so lack about the production technique of tuberose. Such research is very important for the greater interest of the scientist as well as the grower of our country.

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

1. To find out the optimum level of potassium for maximum growth, flowering, bulb production and higher yield of tuberose.

2. To determine the appropriate concentration of GA_3 on growth, flowering, bulb production and higher yield of tuberose.

3. To find out the suitable combination of GA_3 and potassium (K) for ensuring the growth, flowering, bulb production and higher yield of tuberose.

CHAPTER II

REVIEW OF LITERATURE

Tuberose is one of the most important cut flower in the world. Many research works have been done on various aspects of this important cut flower in different countries of the world. But very limited research works have been carried out on this flower under Bangladesh condition. However, the available research findings relevant to the present study have been reviewed in this chapter.

2.1 Effect of growth regulator (GA_3) on the growth, flowering and bulb production of tuberose

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

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

A field experiment was conducted by Bharti and Ranjon (2009) during 2008-09 and 2009-10 to find out the effect of foliar spray of growth regulators in three doses each in GA_3 (50, 00 and 150 ppm), Kinetin (50, 100 and 150 ppm), NAA (50, 100 and 150 ppm), Ethrel (100, 200 and 300 ppm) and SADH (100, 200 and 300 ppm) on the flowering of two cultivars of tuberose viz., Shringer and Kalyani Double. Cultivar Shringar was superior in inducing early spike emergence, first floret opening and also produced maximum number of spikes/m^2. However, cv. Kalyani Double showed maximum number of florets and spike length and flowering duration. Among various treatment, GA_3 (150 ppm) was observed best in inducing early spike emergence, opening of first floret, 50 percent floret opening and maximum spike yield per sq. meter. The spike characteristics, such as length of rachis and spike, number of florets per spike, increased significantly with the application GA_3 (100 ppm). Maximum days to withering of first opened floret and flowering duration were observed with Kinetin (150 ppm). However, Ethrel (300 ppm) exhibited delayed flowering, maximum flowering duration and reduced length of spike characters.

Jitendra *et al.* (2009) to study the effect of vitalizer (GA_3) and nitrogenous fertilizer (urea) on growth and floral parameters in tuberose cv. Pearl Double. The experiment was conducted at Horticultural Research Farm, Department of Horticulture, C.C.S. University campus, Meerut, consisting of two levels of GA_3 (100 ppm and 200 ppm) and two levels of urea (55 and 110 g/m^2). There are 4 treatment combinations, replicated three times and laid out in factorial randomized block design. The results revealed that combined application of gibberellic acid and nitrogenous fertilizer (urea) at different doses showed the beneficial effect in different growth and flowering attributes viz., days taken for bulb sprouting, plant height, number of leaves/plant, number of floret/spike, rachis length, spike length and floret length but delay in appearance of initial spike and opening of first florets was recorded by the individual application of gibberellic acid at higher concentration (GA_3 @ 200 ppm).

Padaganur *et al*. (2005) studied the effects of gibberellic acid (GA₃; 50, 100 or 150 ppm), paclobutrazol (500, 1000 or 1500 ppm) and maleic hydrazide (500, 1000 or 1500 ppm) on the growth and yield of tuberose (*Polianthes tuberoae* cv. Single) in Dharwad, Karnataka, India, during 2001-02. GA ₃ increased plant height, number of leaves, number of shoots and leaf area. Paclobutrazol and maleic hydrazide reduced plant height, number of leaves, leaf area and spike length. Early flowering was obtained by 150 ppm GA<sub>3</ sub>, 1500 ppm maleic hydrazide and 1500 ppm paclobutrazol. Plant treated with 150 ppm GA <sub>3</ sub > exhibited the earliest flowering (137.67 days), and recorded the greatest spike length (86.01 cm), spike weight (28.09 g), spike girth (0.630 cm), floret diameter (0.817 cm), floret length (5.69 cm), and loose flower yield per plot (3.66 kg) and hectare (6.35 t). The increase in the concentration of the growth regulators increased the spike yield per hectare.

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

Sanap *et al.* (2004) conducted a field experiment during 1996/97 at Pune, Maharashtra, Indiamto evaluate the effects of GA₃ (100, 150 and

200 ppm) and CCC [chlormequat] (100, 200 and 300 ppm) on tuberose cv. Single. Foliar spraying of the growth regulators was performed at 40, 55 and 70 days after planting. Data were recorded for various growth (number of leaves, leaf length and leaf breath) and flowering characters (days to flower spike emergence, days to flowering and days from spike emergence to flower harvest). All growth regulator treatments were significantly superior to the control (water spray), with GA_3 ₃ at 150 ppm and CCC at 200 ppm sprays giving optimum growth and earliest flowering.

Singh *et al.* (2003) conducted an experiment in Meerut, Uttar Pradesh, India during 1997-98 on tuberose (*polianthes tuberosa* L) cv. Double. The treatments comprised of water dipping (control); dipping in GA_3 , IAA and NAA at 50 and 100 ppm each; spraying GA_3 and 100 ppm each; spraying $GA_{3,}$ IAA and NAA; and dipping + spraying GA_3, IAA and NAA. The number of flowers, flower length and longevity of the whole spike were highest for bulbs dipped in 100 ppm Ga_3 for 24 hours before planting + spraying with 100 ppm GA_3 at 30 days after planting. Spike length and rachis length were also highest in bulbs dipped and sprayed with 100 ppm GA_3 at 100 ppm (dipping + spraying) increased the number (28.4), weight (90.52gm), diameter (4.20cm) and yield (305.25 g/ha) of tuberose.

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

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

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

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

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

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

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

An experiment was conducted by Devendra *et al.* (1999) to study the effect of foliar applied plant growth regulators on the flowering and vase life of tuberose. The treatment comprised: 50, 100 and 150 ppm GA ₃; 100, 150 and 200 ppm NAA; 1000, 1500 and 2000 mg thiourea /litre. Foliar application was conducted at 30, 60 and 90 days after planting. GA₃ at 150 ppm gave the earliest number of days required for spike emergence (43.48) and longest vase life (11.35 days). Further, GA₃ gave maximum spike length (6.65cm) and floret diameter (3.88 cm).

Singh (1999) noted the effects of gibberellic acid (GA_3 at 100 and 200 ppm), ethephon (200 and 400 ppm) and kinetin (50 and 100 ppm) on the growth, flowering and yield of tuberose(*Polianthes tuberosa*) cv. Double were investigated in Medziphema, Nagaland, India during 1998. The plant growth regulators were applied as foliar sprays 40 days after planting. The second application was conducted 3 weeks after the initial spraying. All growth regulators improved the performance of tuberose compared with the control. GA_3 at 200 ppm produced the tallest plants (35.87 cm) with the highest number of leaves per plant (27.41), spike length (63.17 cm), number of florets per spike (35.99) and floret weight per plant (52.16 g). This treatment likewise resulted in the longest flowering duration (17.33 days). The number of bulbs per plant (9.74) and bulb weight per plant (76.95 g) were highest in plants treated with 100 ppm kinetin. Plants treated with ethephon (400 ppm) exhibited the earliest flowering (117 days).

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

Nagaraja *et al.* (1999) conducted an experiment to investigate the effect of growth regulators on the growth and flowering of tuberose. The tuberose bulbs were soaked for 24 hour in solutions of $GA_{3,}$ Ethrel (ethephon) or BA each at 100, 500, 1000 and 1500 ppm and then planted in a randomized block design. All treatments influenced growth and flowering characteristics. All treatments resulted in earlier plant emergence, a higher percentage of sprouting and earlier flowering compared to the control with GA_3 at 500 and 1500 ppm being particularly effective. Plant height was greatest with GA_3 at 100 ppm while ethrel at all concentrations reduced plant height compared to the control. The number of spikes/plant and floret/spike were enhanced by GA_3 at 500 and 1500 ppm. All GA_3 treatments increased flower, spike length and rachis length. Length of flowering was greatest with ethrel at 1000 ppm. All GA_3 treatments and ethrel at 100 ppm increased bulb number where as all other ethrel and all BA treatments reduced bulb number.

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

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

Belorkar *et al.* (1993) studied a field experiment during 1991, to study the effect of soaking the bulbs [rhizomes] for 24 h in gibberellic acid (0, 10, 20 or

40 ppm) followed by N fertilizer treatment (0, 50, 60 or 70 kg/ha) in the field. N at 70 kg/ha produced the highest number of rachises/ha (132444), flowers/stalk (40.65) and flower yield (63.1 q/ha). Gibberellic acid soak at 45 ppm with 70kg N/ha was the best combination yielding 163555 rachises/ha, 50.6 flowers/stalk and 81.77 q flowers/ha. For number of flowers/stalk and flower yield, there was a distinct positive interaction between gibberellic acid and N.

Leena *et al.* (1992) carried out an experiment in Kerala, India on Gladiolus (cv. Friendship) during 1989-90 with TIBA (150 or 300 ppm), NAA (100 and 200 ppm), CCC (Cholormequat 250 or 500 ppm) or GA_3 (50 or 100 ppm) applied a foliar spray at 4.6 and 8 weeks after planting. Control plants were sprayed with distilled water. The 100 ppm GA_3 treatment resulted with the greatest plant growth and earliest flowering. The greatest flower spike length, rachis length and number of floret/spike were obtained with the 50 ppm GA_3 treatment. The greatest corm weight (70.20 g) and size (71.00 cm^2) were obtained with the 100 ppm NAA treatment. The greatest number and weight of cormels (93.33 and 17.57 g, respectively) were obtained with 500 ppm CCC treatment.

Dhua *et al*. (1987) reported that tuberose (*Polianthes tuberosa*) is an important cut flower crop. Using bulbs with a diameter between 1.50-2.0 cm. storage of bulbs at 4-10^0C for 10-30 days and soaking in GA_3 (200 mg/L) or thiourea (2000 mg/L) solution for 6 hours improved plant growth and increased the yield of spikes and flower spikes and improved flower quality.

Gowda (1985) concluded that GA_3 spray on rose cv. Super star resulted in more number of flowers and longer stems which are the important characters of a good cut flower.

According to Biswas *et al.* (1983) the highest number of flower spikes 6/clump was obtained after foliar application of GA_3 at 1000 mg/litre, CCC at 0.2 ml/litre and the highest number of flower/spike (46) was on plant sprayed with GA_3 at 100 mg/litre.

Mukhopadhyay and Banker (1983) sprayed the plants cv. Single 40 days after planting and twice at fortnightly interval with GA_3 at 25-100 ppm or Ethephon at 500 to 2000 ppm observed that increasing concentration reduced the plant height. GA_3 increased the spike length and flower/spike. Duration of flowering in the field was improved with GA_3 at 100 mg/ litre.

Jana and Biswas (1982) reported that the shortest time of flower opening 97 days occurred in plants treated with 10 ppm GA_3 and the greatest of flower/spike 3.5-5 was on plants treated with 1000 ppm SADH.

Bose *et al*. (1980) conducted an experiment by soaking bulbs of *Hippeastrum hybridum (cyclamen)* in three concentrations of indolacetic acid, gibberellic acid, cycocel or ethrel and they showed various responses on growth and flowering as observed. GA_3 at 1000 ppm promoted the number of leaves. But other treatments did not exert any significant effect. Ethrel at 1000 ppm resulted in the maximum length of flower stalks, while higher concenteations of GA_3 increased the stalk length.

Pathak *et al.* (1980) found that soaking of bulb in GA_3, ethrel, kinetin and thiourea solutions before planting improved the growth and flowering of tuberose among the different chemicals used GA_3 and thiourea proved more effective than others. Thiourea promoted plant height and leaf number while GA_3 improved flowering. Treatments with GA_3 at 200 mg/litre caused earliest flowering and gave the maximum yield of spikes and flowers.

According to Ramaswamy *et al.* (1979) application of certain growth substance has been found to influence the growth and flowering of tuberose. Soaking of sprouting bulbs for 1 hour in solution of 100 ppm GA_3 or 400 ppm CCC advanced the flowering by 17 and 15 days respectively.

El-shafie (1978) reported that spraying of GA_3 on rose four (4) times at monthly intervals at 250 ppm on cv. Montezuma increased the number of flower and the length, thickness of flower stems compared to other concentration (50, 100, 150 and 200 ppm).

Rees (1975) noted that growth and development behaviour of bulbous plant is also regulated either by a single or by a interaction of several endogenous hormone like gibberellins, auxin, cytokinin, ethylene and abscisic acid. They play a major role in directing the movement of organic metabolites in establishing.

2.2 Influence of potassium on growth, flowering and bulb production 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_2O_5 (10, 20 and 30 g/m^2) and K_2O (10 and 20 g/m^2) on the growth and flowering of tuberose (*Polianthes tuberose)* 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, florets/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 growth of flowering of tuberose (*Polianthes. tuberosa*) cv. Calcutta

Single. The application of 20 g each of N, P_2O_5 and K_2O /m^2 recorded the highest plant height, leaf number and spike length. However application of N, P_2O_5 and K_2O 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_2O_5 and K_2O /m^2 improved plant height and leaf number in ratoon crop. The spike production was highest with N, P_2O_5 and K_2O at 20, 15 and15g/m^2, respectively, in ratoon crop. Thus, application of N, P_2O_5 and K_2O 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.

The experiment was carried out by Rajib and Misra (2003) to study the effects of nitrogens (0, 20 40, 60 or 80 g/m^2), phosphorus (0, 5, 10 or 20 gm/m^2) and potassium (0, 15, 20 or 25 gm/m^2) on growth, flowering and yield in Gladiolus cv. Jester Gold in new Delhi, India, during 2000-01 and 2001-02. Application of 60 g N/m^2 resulted in maximum leaves per shoot (6.0), leaf area per plant (330.83cm^2), plant height (80.6cm), diameter of first floret on third day of opening (9.7 cm), durability of first floret (3.8 days) and whole spike (12.4 days), florets per spike (15.7), spike length (58.8cm), rachis length (44.7 days) and useful life of spike (7.2 days). N at 20 gm/m^2 resulted in earliest 50% heading (95.6 days) and first floret showing colour (114.3days), while 40 gm/m^2 resulted in earlier 50% sprouting (7.9 days). Higher dose of nitrogen (80g/m^2) resulted in maximum corms per plant (1.8), corm size (5.3 cm), corm weight (44.8 gm), cormel weight (5.0gm), cormels per plant (19.3) and propagating coefficient (315.2%)

The nutrient status of *Polianthes tuberosa* plants treated with different N, P and K levels (0, 10, 20, 30 and 40 kg N/ha; 0, 10 and 20 kg P/ha; and 0,10 and 20 kg K/ha) was determined. The N, P and K contents of leaves significantly increased with the increase in rate of N, P and K fertilizers, respectively. Leaf P and K concentrations decreased with increasing N fertilizer rate. N, P and K contents in leaves were higher than those in bulbs (rhizomes). Bulb N increased with increasing rates of all fertilizers. Bulb P content also increased with increasing rates of all fertilizers. (Singh *et al.*, 2001).

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_2O_5 + 50 kg K_2O /ha (F1). 175 kg N+ 75 kg P_2O_5 + 75 kg K_2O /ha (F2), 250kg N + 100 kg P_2O_5+ 100kg K_2O /ha (F3), and 325 kg N + 125kg P_2O_5 + 125 kg K_2O /ha (F4). The authors reported that the treatments F4, F3 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).

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.

Patel *et al.* (1997) conducted with 4 fertilizer rates (5 kg organic manure/m superscript 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 0-120 g K_2O /m^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/m. Bulb production was also greatest with 60 g K_2O / m^2.

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 / m^2, P at 0, 10 or 20 g P_2O_5/m^2 and K at 0,10 or 20 g K_2O / m^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 kg/ha) and 3 rates each of P and K (0, 100 and 200 kg/ha) was conducted with *Polianthes. 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.

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.

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.

Gowda *et al*. (1991) carried out an experiment at the farm under Horticulture Division, University of Agriculture, Bangalore, India, with three rates of N application (100, 150 and 200 kg /ha), 3 of P_2O_5 (50, 75 and 100 kg) and 3 of K_2O (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_2O_5 and K_2O 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_2O significantly influenced the number of days required for flower spike emergence. Increasing P and K_2O 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_2O_5 + 125 kg K_2O /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).

Bankar (1988) studied in 2-year field trials, plants received N at 0, 5, 10, 15 or 20 g/m, and P_20_5 and K_20 each at 0, 20 or 40 g, 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 bulb/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). The optimum fertilizer application rate was determined as 15 g N + 40g P_2O_5 + 40 g K_2O/m^2.

Gowda *et al.* (1988) carried out in studies with this cv. grown for cut flowers, the plants received N and P, each at 20, 30 or 40 g/m^2; K at 20 g/m^2 was applied as a basal dressing. A high number of spikes/plant, a large florets diameter (9 cm), the highest number of florets/plant (14.6) and the greatest spike length (89.7 cm) were obtained with the highest N and K rates.

Mukhopadhyay *et al.* (1986) studied nutritional requirement of tuberose cv. Single in a trail over two years. The plants growing on 2m x 1m plots received N: P_2O_5: K_2O at 0-20; 0-40 g/m^2 giving 45 treatment combinations. Of the three nutrients only N, especially at the highest rate, improved plant growth, spike yield and flower quality.

Mukhopadhyay and Banker (1986) conducted a fertilizer experiment for two years with tuberose cv. Single and reported that the yield of bulb and bulblets as influenced by the different fertilizer levels, it was found that only the number of bulblets got increased by adding nitrogen, while the number of flowering size bulbs was not affected by N levels. These showed positive interaction and maximum bulblet production was recorded in the treatment comprising 20g P_2O_5 and 40 g K_2O/m^2. In the case of bulblets production, phosphorus and potassium bulbs and bulblets were also havier than those under control. Apparently P and K fertilization had no appreciable effect on bulb yield,

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.

Banker *et al.* (1985) investigated response of *Polianthes tuberose* cv. "Single" to high doses of NPK. N, P_2O_5 and /or K_2O were applied at plant and floral characteristics were assessed. 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. Survival of spike in the field was longest (22.8 days) with highest N rate.

Nanjan *et al.* (1980) studied the effects of nitrogen, phosphorus and potash on the production on tuberose cv. Single in a neutral clay soil having high amount of potassium. They recommended a nutrient combination of 200 kg nitrogen, 60 kg phosphorus and 50 kg potash/ha of soils low in potassium.

In an alkaline and nitrogen deficient soil, application of 20 kg N, 40 kg P_2O_5 and 20 kg K_2O over a basal dose of 2.5 kg of FYM/m^2 was recommended year. Full dose of P_2O_5 and K_2O and half dose of nitrogen is to be applied as basal dressing, while the remaining half dose of N is to be applied 20 days after planting (Bhattacharjee *et al.*, 1979).

Singh *et al.* (1976) reported that flower yield of tuberose depends upon the dose of nitrogen, phosphorus and potash. They recommended a dose of 80 kg nitrogen, 60 kg phosphorus and 40 kg potash per hectare, respectively under Uttar Pradesh. India conditions to have an optimum flower yield. According to them potash increased the yield of fresh flowers through increasing the number of spike number and weight of flower per hill and also the weight of flowers per spike.

Application of 200 kg nitrogen, 400 kg phosphorus and 600 kg potash per hectare increased the weight of both saleable and individual bulbs of tuberose (Cirrito, 1975).

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

CHAPTER III

MATERIALS AND METHODS

The materials and methods that were used for conducting the experiment are presented in this chapter under the following headings:

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 16th April, 2013 to March, 2014.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).

3.2 Characteristics of soil

The soil of the experimental area was non-calcarious dark grey and belongs to the Modhupur Tract under AEZ No. 28 (UNDP 1988). The selected experimental plot was medium high land and the soil series was Tejgaon (FAO 1988) with a p^{H} 6.1. The components of the soil were analyzed in the SRDI, Soil testing Laboratory, Farmgate, Dhaka and presented in Appendix I.

3.3 Weather condition of the experimental site

The climate of experimental site was under the subtropical, characterized by three distinct seasons, the monsoon or the winter season from November to February and the pre-monsoon period or hot season from March to April and the monsoon period from May to October. Meteorological data related to the temperature, relative humidity, rainfalls and sunshine during the period of the experiment was collected from the Bangladesh Meteorological Department, Sher-e-Bangla Nagar, Dhaka and presented in Appendix II.

3.4 Planting materials

Bulbs of tuberose were used as planting materials and they were collected from Horticulture farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh

3.5 Treatment of the experiment

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

The experiment had two factors, which are as follows:

Factor A: Potassium (Levels of K_2O): 4 levels

i. K_0 = 0 kg K_2O (Control)

ii. K_1 = 125 kg K_2O/ha

iii. K_2 = 145 kg K_2O /ha

iv. K_3 = 165 kg K_2O/ha

Factor B: Gibberellic acid (GA_3): 3 levels

i. G_0 = Control treatment (Water spray)

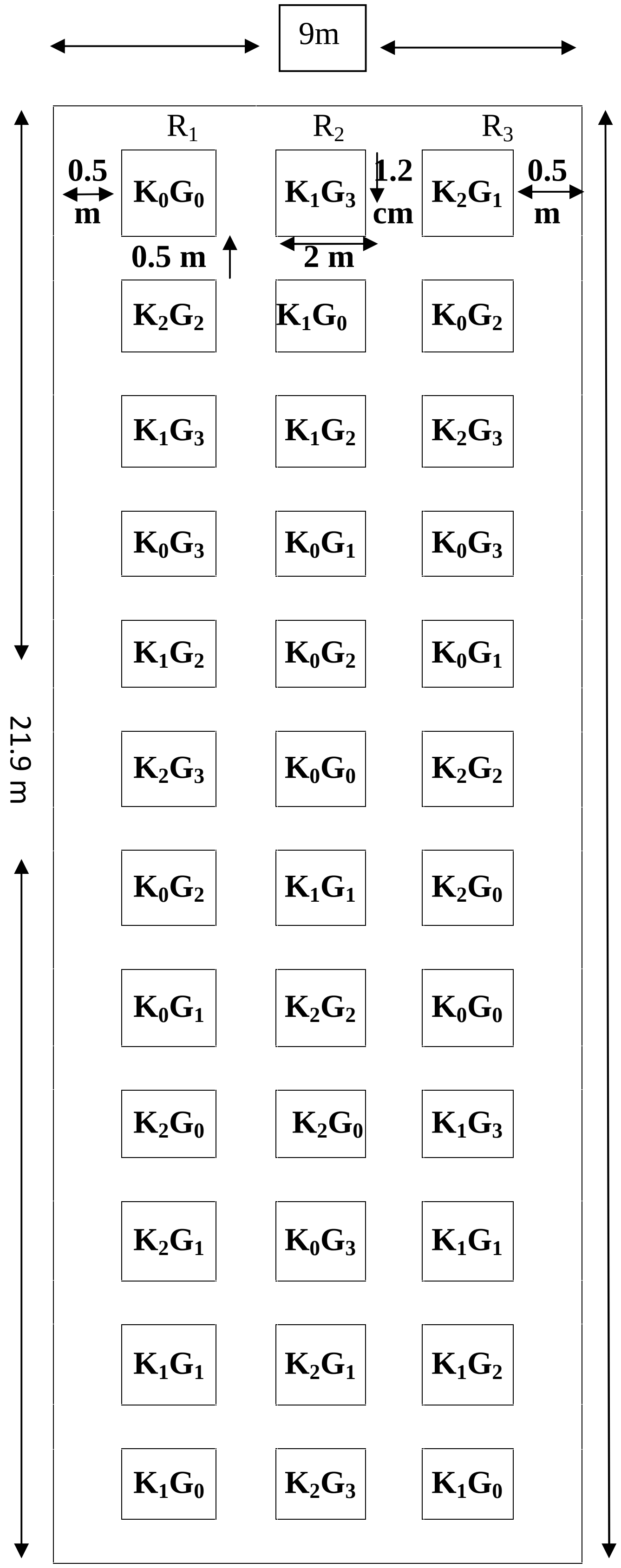
ii. G_1 = 100 ppm

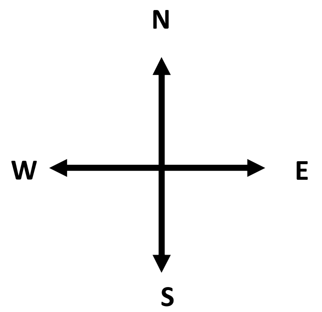
iii. G_2 = 200 ppm

There were 12 (3 x 4) treatment combinations such as K_0G_0, K_0G_1, K_0G_2, K_1G_0, K_1G_1, K_1G_2, K_2G_0, K_2G_1, K_2G_2, K_3G_0, K_3G_1, K_3G_2.

3.6 Experimental design and layout

The experiment was laid out following Randomized Complete Block Design (RCBD) with three replications. An area of 21.9 m x 9.0 m was divided into three equal blocks and each block was divided into 12 plots for distribution 12 treatments randomly. There were 36 unit plots, the size of each plot was 2 m x 1.2 m with a plant spacing 30 cm x 25 cm. Two adjacent unit plots and block will be separated by 0.5 m and 0.75 m space, respectively. The layout of the experiment is shown in Fig.1.





Plot size: 2 m x 1.2m

Spacing between plot: 50 cm
Spacing between replication: 75 cm

Row to row distance: 30 cm

Plant to plant distance: 25 cm

Factors: A
K_0 = Control
K_1 = 125 kg K_2O/ha
K_2 = 145 kg K_2O/ha
K_3 = 165 kg K_2O/ha
Factor: B
G_0 = Control treatment (water spray)
G_1 = 100 ppm GA_3
G_2 = 200 ppm GA_3

Fig. 1: Field layout of the two factors experiment

3.7 Land preparation

The experimental plot was opened in the 16th April 2013, with a power tiller and left exposed to the sun for a week. After one week the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain good tilth. Weeds and stubbles were removed and finally obtained desirable tilth of soil.

3.8 Manure, fertilizers and their application methods

The crop was fertilized with the following doses of manure and fertilizers as recommended by Anonymous (2002).

Table 1: Doses of manure and fertilizers in tuberose field

Manures	Dose/ha	Dose/plot
Cow dung	5 t/ha	2.75 kg
Urea	260kg	142 gm
TSP	200kg	109 gm
MP	K_0= 0 kg/ha	-
	K_1= 125 kg/ha	68.43 gm
	K_2= 145 kg/ha	79.38 gm
	K_3= 165 kg/ha	90.33 gm

Urea, Triple Super Phosphate (TSP) and Muriate of Potash (MP) were used as source of nitrogen, phosphorus and potassium respectively. Full dose of cow dung (5 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 bulb

The bulbs were planted in 4 cm depth in furrows on 30th April, 2013 with a distance on 30 cm x 25 cm and the number of bulb/plot was 32.

3.10 Preparation of Gibberellic acid (GA_3) and Control solution

GA_3 in different concentrations viz. 0, 100, and 200 ppm were prepared following the procedure mentioned below and spraying was done using hand sprayer. GA_3 was used in three times in 20,40 and 60 days after planting . 1000 ppm stock solution of GA_3 was prepared by dissolving 1 g of it in a small quantity of ethanol prior to dilution with distilled water in one litre of volumetric flask. The stock solution was used to prepare the required concentration for different treatment i.e. 100 ml of this stock solution was diluted in 1L of distilled water to get 100 ppm GA_3 solution. In a similar way 200 concentrations were made. Control plots were treated only with water.

3.11 Intercultural operation

When the seedlings started to emerge in the beds it was always kept under careful observation. After emergence of seedlings, various intercultural operations, weeding, top dressing was accomplished for better growth and development of tuberose seedlings.

3.11.1 Irrigation and drainage

Over-head irrigation was provided with a watering can to the plots once immediately after germination in every alternate day in the evening. Further irrigation was done when needed. Stagnant water was effectively drained out at the time of heavy rains.

3.11.2 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. It was done for 2 times at 30 DAP and 50 DAP.

3.11.3 Top Dressing

After basal dose, the remaining doses of urea were top-dressed in 3 equal installments. The fertilizers were applied on both sides of plant rows and mixed well with the soil by hand. Earthing up was done with the help of nirani immediately after top-dressing of nitrogen fertilizer.

3. 11.4 Earthing up

Earthing up was done during growing period when necessary.

3.11.5 Staking

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

3.11.6 Selection and tagging of plants

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

3.11.7 Plant Protection

For controlling leaf caterpillars Nogos @ 1 ml/L water was applied 2 times at an interval of 10 days starting soon after the appearance of infestation. No remarkable attack of disease was found.

3.11.8 Harvesting

The spikes of tuberose were harvested when the first floret in the rachis opened. Harvesting was done during 5th August to 20 October, 2013 and bulbs were harvested on 20 March, 2014.

3.12 Data collection

Data were recorded on the following parameters from ten randomly selected plants during the course of experiment.

3.12.1 Plant height

The height of plant was recorded in centimeter (cm) at 20, 40, 60, 80 and 100 days after planting (DAP) in the experimental plots. The height was measured from the ground level up to the tip of the growing point of the plant.

3.12.2 Number of leaves per plant

All the leaves of ten plants were counted at an interval of 20 days at 20, 40, 60, 80 and 100 days after planting (DAP) in the experimental plots.

3.12.3 Number of side shoot per plant

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 15 days at 30, 45, 60, 75 and 90 days after planting in the experimental plots.

3.12.4 Number of spike per plant

It was measured at an interval of 15 days at 30, 45, 60, 75 and 90 days after planting (DAP) in the experimental plots. All the spikes of the plant were counted from ten randomly selected plants and their mean was calculated.

3.12.5 Days required to emergence of spike

It was achieved by recording the days taken for first emergence of spike from each unit plot

.3.12.6 Diameter of the 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. A slide calipers was used to measure the diameter of the spike and expressed in centimeter and mean of 10 spikes was calculated.

3.12.7 Length of spike

Length of spike refers to the length from the base to the tip of the spike and expressed in centimeter.

3.12.8 Weight of the single spike

It was determined by weighing the spike with the help of digital weight machine from the ten randomly selected plants and mean weight was calculated and expressed in gram.

3.12.9 Length of rachis at harvest

Length of rachis refers to the length from the axil of first floret up to the tip of the inflorescence and expressed in centimeter.

3.12.10 Number of floret per spike

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

3.12.11 Dry weight of florets (%)

100gm of fresh weight of florets were taken after harvesting. Then the florets sample was put in the sun to dry. The florets sample were sliced into very thin pieces, put into envelop and placed in oven maintained at 60^0C for 72 hours. The sample was then transferred into desiccators and allowed to cool down to the room temperature. The final weight of the sample was taken with the help of digital weight machine and it was expressed in gram. Dry weight of florets in percent was calculated within the following formula:

$$\text{Dry weight of florets (\%)} = \frac{\text{Dry weight of florets}}{\text{Fresh weight of florets}} \times 100$$

3.12.12 Dry weight of leaves (%)

100 gm of fresh leaves were harvested from the experimental plot and put in the sun to dry. The leaves sample were sliced into very thin pieces, put into envelop and placed in oven maintained at 60^0C for 72 hours. The sample was then transferred into desiccators and allowed to cool down to the room temperature. The final weight of the sample was taken with the help of digital weight machine and it was expressed in gram. Dry weight of leaves in percent was calculated within the following formula:

$$\text{Dry weight of leaves (\%)} = \frac{\text{Dry weight of leaves}}{\text{Fresh weight of leaves}} \times 100$$

3.12.13 Number of spike per hectare (‘000)

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

3.12.14 Diameter of single bulb

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

3.12.15 Single bulb weight

It was determined by weighing the bulb from the ten randomly selected plants and mean weight was calculated and expressed in gram.

3.12.16 Diameter of single bulblet

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

3.12.17 Single bulblet weight

It was determined by weighing the bulblet with the help of digital weight machine from the ten randomly selected plants and mean weight was calculated and expressed in gram.

3.12.18 Yield of bulb per plot and hectare

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

3.12.19 Yield of bulblets per plot and hectare

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

3.13 Statistical Analysis

The collected data on various parameters were statically analyzed using MSTAT package program. The mean for all the treatment was calculated and analyses of variances of all the characters were performed by F-variance test. The significant of difference between the pairs of treatment means was evaluated by the least significant difference (LSD) test at 5% and at 1% levels of probability (Gomez and Gomez, 1984).

3.14 Economic analysis

The cost of production was analyzed in order to find out the most economic treatment of nutrient sources . All input cost were considered in computing the cost of production. The market price of spike, bulb and bulblet was considered for estimating the return. The benefit cost ratio (BCR) was calculated as follows:

$$\text{Benefit cost ratio} = \frac{\text{Gross return per hectare (Tk.)}}{\text{Total cost of production per hectare (Tk.)}}$$

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was carried out to find out the influences of potassium levels and GA_3 on growth and yield of tuberose. The analysis of variance (ANOVA) of the data on different growth parameter and yield of flower and bulb are presented in Appendix III-IX. The results have been presented and discussed, and possible interpretations given under the following headings:

4.1 Plant height

Plant height of tuberose was showed statistically significant differences due to different potassium levels at 20, 40, 60, 80 and 100 DAP (Appendix III). The tallest plant height 30.4, 42.7, 43.8, 50.0 and 52.4 cm was recorded from K_2 at 20, 40, 60, 80 and 100 days after planting (DAP). Again, at the same DAP the shortest plant height 22.4, 28.6, 35.4, 38.9 and 35.2 cm was recorded from K_0 , respectively (Fig. 2). Potassium has great influence on growth in tuberose (Yadav *et al*., 1985).

Plant height of tuberose differed significantly due to the application of different concentrations of GA_3 at 20, 40, 60, 80 and 100 DAP (Appendix III). At 20, 40, 60, 80 and 100 DAP the tallest plant height 23.1, 38.5, 44.5, 47.5 and 51.5 cm was found from G_2 whereas, the shortest plant height 20.4, 24.8, 32.6, 35.7 and 40.3 cm was observed from G_0 for the same DAP, respectively (Fig. 3). The observed results are in agreement with the findings of Nagaraja *et al.* (1999) and Wankhade *et al.* (2002a).

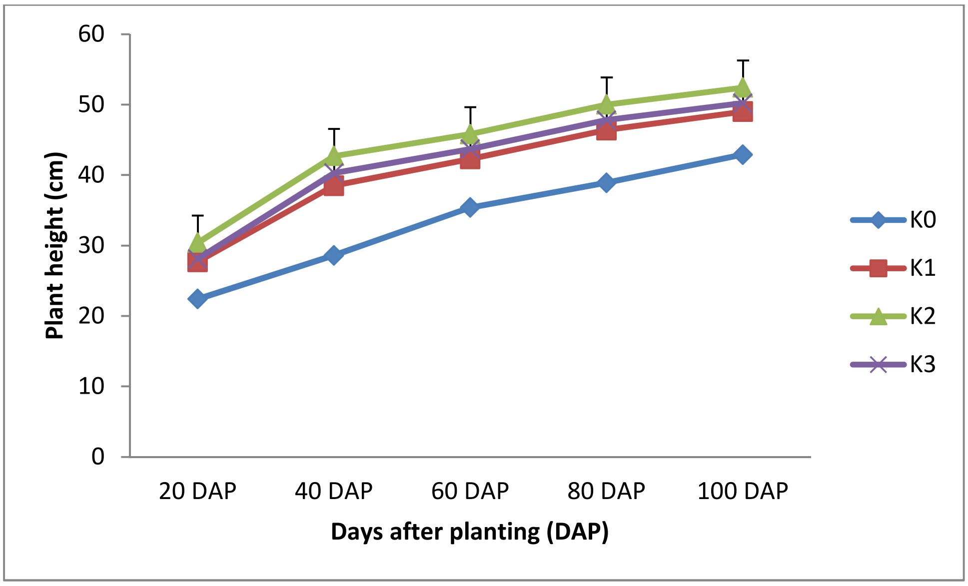


Fig. 2: Effect of different levels of potassium on plant height of tuberose

K_0: Control: No potassium
K_1: 125 kg K_2O ha^{-1}
K_2: 145 kg K_2O ha^{-1}
K_3: 165 kg K_2O ha^{-1}

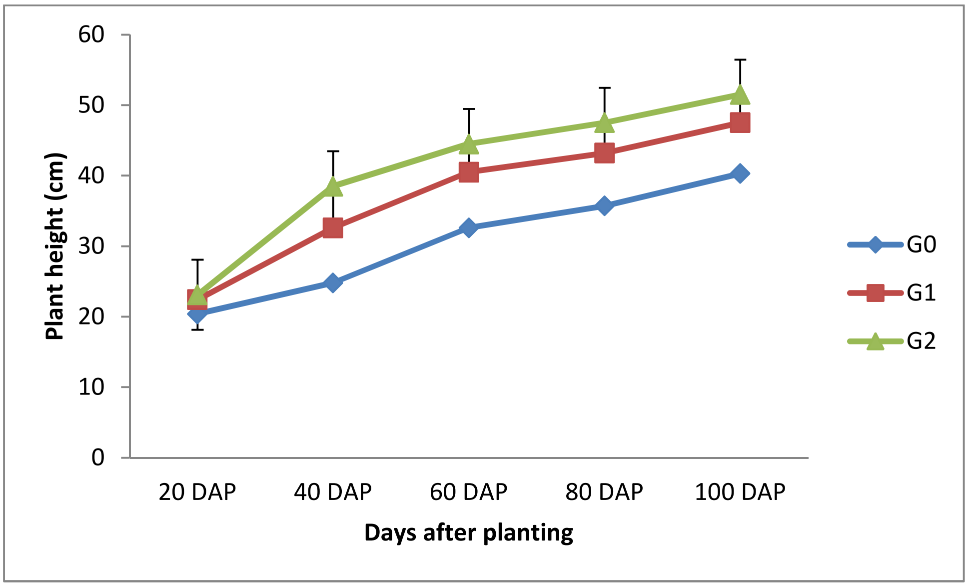


Fig. 3: Effect of different concentrations of GA_3 on plant height of tuberose

G_0: Control treatment
G_1: GA_3 100 ppm
G_2: GA_3 200 ppm

Table 2. Combined effect of potassium and GA_3 on plant height of tuberose

Treatment	Plant height (cm) at				
	20 DAP	40 DAP	60 DAP	80 DAP	100 DAP
K_0G_0	17.0 f	34.6 g	41.3 c	43.3 d	46.97 f
K_0G_1	18.6 de	38.6 b-e	46.0 bc	55.0 b-d	57.19 de
K_0G_2	18.6 de	38.6 b-e	46.3 bc	55.0 b-d	57.59 de
K_1G_0	18.0 ef	36.0 fg	45.6 bc	55.0 b-d	57.40 d
K_1G_1	19.0 c-e	36.3 e-g	45.0 bc	55.6 bc	57.89 de
K_1G_2	19.6 b-d	38.6 b-e	47.0 bc	55.0 b-d	57.05 cd
K_2G_0	20.3 b	40.0 bc	47.0 bc	56.6 b	60.61 a
K_2G_1	20.6 b	40.3 b	48.0 b	56.3 b	57.47 bc
K_2G_2	22.6 a	44.0 a	47.0 a	55.0 a	60.73 a
K_3G_0	19.6 b-d	36.6 d-g	44.3 c	52.0 cd	55.72 bc
K_3G_1	19.0 c-e	37.6 c-f	45.0 bc	52.6 cd	54.15 cd
K_3G_2	20.0 bc	39.0 b-d	45.3 bc	56.3 b	55.47 c
$LSD_{(0.05)}$	1.1	2.1	3.0	3.4	1.75
Level of significance	**	**	**	*	*
CV (%)	6.4	6.3	6.9	6.7	6.02

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

K_0: Control: No potassium
K_1: 125 kg K_2O ha^{-1}
K_2: 145 kg K_2O ha^{-1}
K_3: 165 kg K_2O ha^{-1}

G_0: Control treatment
G_1: GA_3 100 ppm
G_2: GA_3 200 ppm

Significant variation was recorded due to combined effect of potassium and GA_3 in terms of plant height of tuberose at 20, 40, 60, 80 and 100 days after planting (DAP) (Appendix III). The tallest plant height 22.6, 44.0, 47.0, 55.0 and 60.73 cm was observed from K_2G_2 (145 kg K_2O ha^{-1} with 200 ppm GA_3) at 20, 40, 60, 80 and 100 DAP, respectively whereas the shortest plant 17.0, 34.6, 41.3, 43.3 and 46.97cm was recorded from K_0G_0 at same DAP, respectively (Table 2). It was revealed that K_2G_2 ensure maximum vegetative growth of plants and the ultimate results was the highest plant height of tuberose.

4.2 Number of leaves per plant

Statistically significant differences was recorded on number of leaves per plant by applying potassium at 20, 40, 60, 80 and 100 DAP (Appendix IV). At 20, 40, 60, 80 and 100 days after planting (DAP), the highest number of leaves per plant 4.7, 9.4, 12.2, 13.3 and 15.7 was found from K_2 and the lowest 4.3, 7.5, 9.7, 11.4 and 12.0 was observed from K_0 (Fig. 4). Amarjeet *et al.* (2000) found 11-12 leaves from 140 kg K_2O/ ha at 100 DAP which was almost similar to the present study.

Different concentrations of GA_3 showed variation on number of leaves per plant of tuberose at 20, 40, 60, 80 and 100 days after planting (DAP) (Appendix IV). At 20, 40, 60, 80 and 100 DAP the highest number of leaves per plant 5.33, 10.7, 14.3, 15.0 and 15.8 was recorded from G_2 whereas, the lowest 4.66, 7.6, 9.4, 11.0 and 12.9 was found from G_0 as no GA_3 i.e. control for the same DAP, respectively (Fig. 5). The results of the experiment comply with the findings of Wankhade *et al.* (2002b).

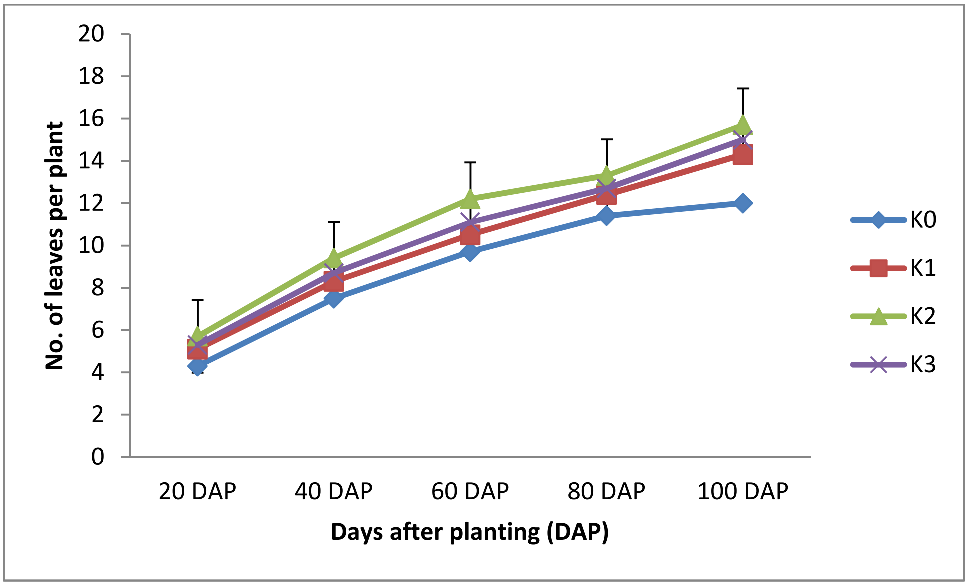


Fig. 4: Effect of different levels of potassium on number of leaves per plant of tuberose

K_0: Control: No potassium
K_1: 125 kg K_2O ha^{-1}
K_2: 145 kg K_2O ha^{-1}
K_3: 165 kg K_2O ha^{-1}

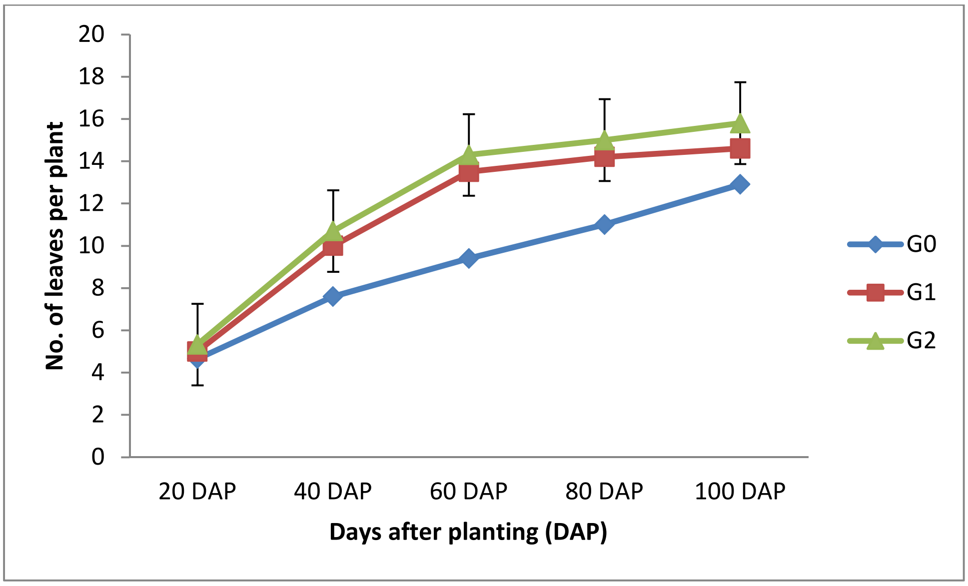


Fig. 5: Effect of different concentrations of GA_3 on number of leaves per plant of tuberose

G_0: Control treatment
G_1: GA_3 100 ppm
G_2: GA_3 200 ppm

Table 3. Combined effect of potassium and GA_3 on number of leaves per plant of tuberose

Treatment	Number of leaves at				
	20 DAP	40 DAP	60 DAP	80 DAP	100 DAP
K_0G_0	4.3	5.3 g	9.3 g	14.3 f	17.52 i
K_0G_1	4.6	6.3 ef	10.0 fg	14.6 ef	20.03 f
K_0G_2	5.3	6.3 ef	10.3 ef	15.3 d-f	19.42 f
K_1G_0	4.3	6.0 f	10.3 ef	15.3 d-f	20.79 g
K_1G_1	4.6	6.6 de	10.6 d-f	15.6 d-f	21.70 e
K_1G_2	5.3	7.0 cd	11.3 cd	16.0 c-e	21.99 e
K_2G_0	6.0	7.6 b	11.6 bc	17.0 bc	27.02 b
K_2G_1	5.6	7.3 bc	12.3 ab	17.3 b	25.51 c
K_2G_2	6.3	8.6 a	13.0 a	19.0 a	28.35 a
K_3G_0	5.3	7.0 cd	11.3 cd	15.6 c-f	25.22 c
K_3G_1	5.6	7.0 cd	11.0 c-e	15.6 d-f	18.21 h
K_3G_2	5.6	7.0 cd	11.0 c-e	16.3 b-d	23.16 d
$LSD_{(0.05)}$	2.9	0.363	0.810	1.201	0.656
Level of significance	NS	**	**	**	*
CV (%)	8.4	8.11	8.4	8.4	10.12

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

K_0: Control: No potassium
K_1: 125 kg K_2O ha^{-1}
K_2: 145 kg K_2O ha^{-1}
K_3: 165 kg K_2O ha^{-1}

G_0: Control treatment
G_1: GA_3 100 ppm
G_2: GA_3 200 ppm

Significant variation was recorded due to combined effect of potassium and GA_3 in terms of number of leaves per plant of tuberose except 20 DAP (Appendix IV). However at 20, 40, 60, 80 and 100 days after planting (DAP), the highest number of leaves per plant 6.3, 8.6, 13.0, 19.0 and 28.35 was observed from the treatment combination of K_2G_2 (145 kg K_2O ha^{-1} with 200 ppm GA_3) whereas, the lowest 4.3, 5.3, 9.3, 14.3 and 17.52 was found from K_0G_0 (control combination) at same DAP (Table 3).

4. 3 Number of side shoot per plant

A significant variation was observed in terms of days required for number of side shoot per plant (Appendix V). Different levels of potassium showed a gradual increasing trend in terms of number of side shoot per plant of tuberose under the study at 30, 45, 60, 75 and 90 DAP (Fig. 6). The maximum (2.37) number of side shoot per plant at 90 DAP was recorded from K_2 and the minimum (0.76) was obtained from K_0. Parthiban *et al.* (1992) agreed to the finding of present trial.

Different concentrations of GA_3 showed a statistically significant difference on number of side shoot per plant at 30, 45, 60, 75 and 90 DAP under the present study (Appendix V). The maximum (2.23) number of side shoot per plant at 90 DAP was obtained from G_2. On the other hand, the minimum (1.01) number of side shoot per plant was observed G_0 (Fig. 7). Pathak *et al.* (1980) found similar trend of results in their trail which is support to the present finding by using GA_3.

Combined effect of potassium and GA_3 did not show the significant variation in all the data of value recorded in terms of number of side shoot per plant of tuberose (Appendix V). But the maximum (2.58) number of side shoot per plant was produced by the treatment combination of K_2G_2 at 90 DAP and the minimum (0.42) was recorded from K_0G_0 (Table 4).

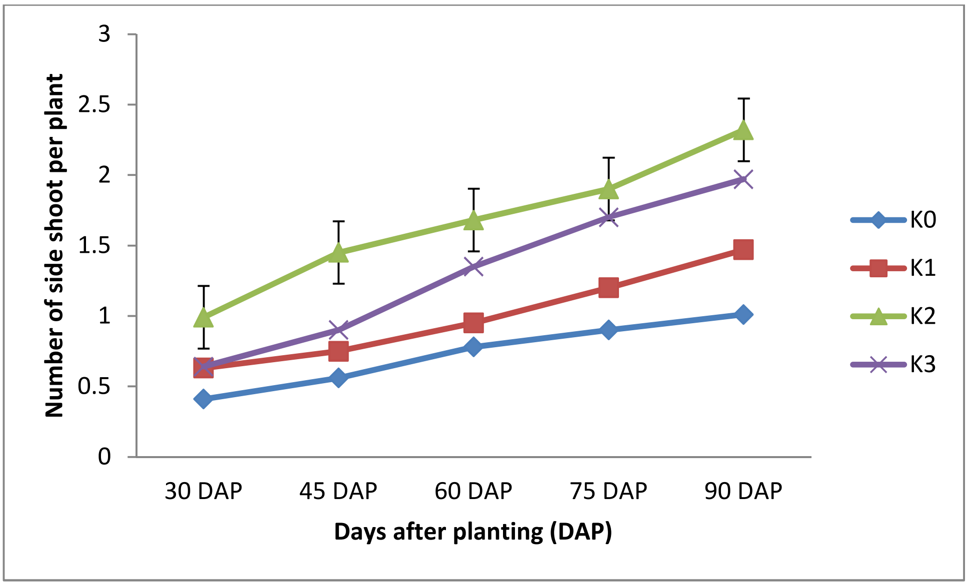


Fig. 6: Effect of different levels of potassium on number of side shoot per plant of tuberose

K_0: Control: No potassium
K_1: 125 kg K_2O ha^{-1}
K_2: 145 kg K_2O ha^{-1}
K_3: 165 kg K_2O ha^{-1}

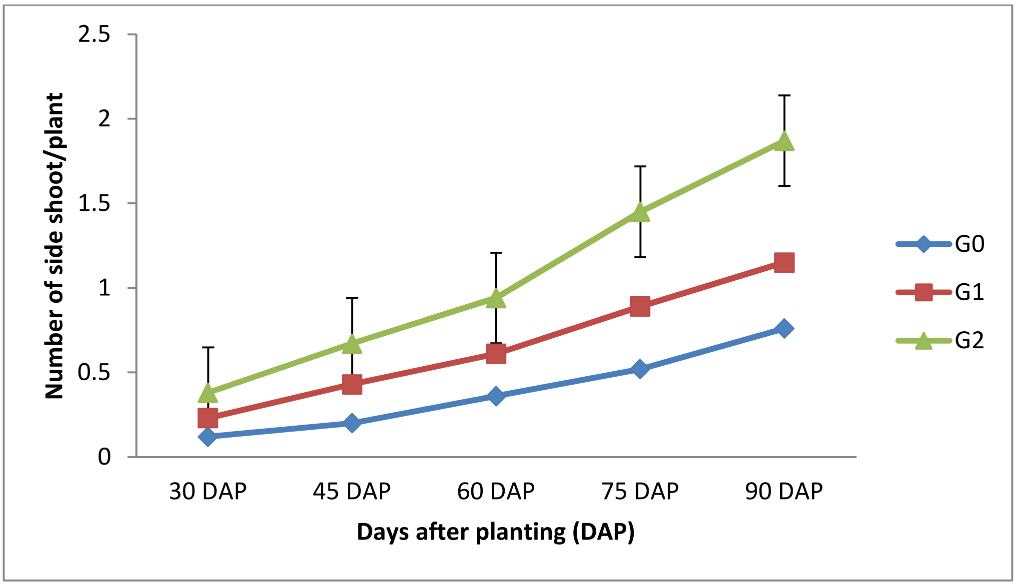


Fig. 7: Effect of different concentrations of GA_3 on number of side shoot per plant of tuberose

G_0: Control treatment
G_1: GA_3 100 ppm
G_2: GA_3 200 ppm

Table 4. Combined effect of potassium and GA_3 on number of side shoot per plant of tuberose

Treatment	Number of side shoot at				
	30 DAP	**45 DAP**	**60 DAP**	**75 DAP**	**90 DAP**
K_0G_0	0.19	0.24	0.30	0.38	0.42
K_0G_1	0.20	0.44	0.52	0.67	0.73
K_0G_2	0.39	0.57	0.77	0.85	0.88
K_1G_0	0.48	0.62	0.76	0.80	0.92
K_1G_1	0.38	0.57	0.71	0.92	0.97
K_1G_2	0.70	0.87	0.97	1.03	1.13
K_2G_0	0.75	0.83	0.95	1.09	1.11
K_2G_1	0.84	0.96	1.09	1.22	1.25
K_2G_2	0.95	1.36	1.57	1.98	2.58
K_3G_0	0.85	0.99	1.34	1.38	1.45
K_3G_1	0.90	1.07	1.49	1.62	1.78
K_3G_2	0.93	1.23	1.57	1.88	1.90
$LSD_{(0.05)}$	0.532	0.616	0.821	0.778	0.869
Level of significance	NS	NS	NS	NS	NS
CV (%)	7.37	8.29	8.36	9.17	8.75

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

K_0: Control: No potassium
K_1: 125 kg K_2O ha^{-1}
K_2: 145 kg K_2O ha^{-1}
K_3: 165 kg K_2O ha^{-1}

G_0: Control treatment
G_1: GA_3 100 ppm
G_2: GA_3 200 ppm

4. 4 Number of spike per plant

A significant variation was found on number of spike per plant due to the application of different levels of potassium at different days after planting (DAP) (Appendix VI). Different levels of potassium showed a gradual increasing trend in terms of number of spike per plant of tuberose up to 145 kg K_2O/ha then decreasing with increasing potassium level at 30, 45, 60, 75 and 90 DAP (Fig. 8). At, 30, 45, 60, 75 and 90 DAP the maximum number of spike per plant 6.34, 10.2, 12.6, 15.6 and 17.9 was obtained from K_2 (145 kg K_2O ha^{-1}) and the minimum (5.12, 7.77, 10.35, 12.5 and 14.2 was found from K_0 (control treatment). Gowda *et al.* (1991) stated that potassium also helps to increase the number of spikes upto a certain level.

Different concentrations of GA_3 showed a statistically significant difference on number of spike per plant at 30, 45, 60, 75 and 90 DAP under the present study (Appendix VI). Number of spike per plant was increase with increasing concentration of GA_3. The maximum 5.64, 7.84, 11.63, 14.74 and 17.84, number of spike per plant at 30, 45, 60, 75 and 90 DAP was recorded from G_2. On the other hand, the minimum 3.41, 5.83, 8.86, 11.74 and 14.04 was observed G_0 (Fig. 9).Application of gibberellic acid at different concentration showed beneficial effect on spikes per plant. (Tiwari and Singh, 2002).

Combined effect of potassium levels and GA_3 did not show the significant variation in all observation in terms of number of spike per plant of tuberose (Appendix VI). But the maximum 7.44, 10.36, 11.57, 13.98 and 16.58, number of spike per plant at 30, 45, 60, 75 and 90 DAP was counted from the treatment combination K_2G_2 (145 kg K_2O ha^{-1} with 200 ppm GA_3) and the minimum 6.19, 6.14, 7.15, 10.78 and 12.92 was recorded from K_0G_0 (control combination) (Table 5).

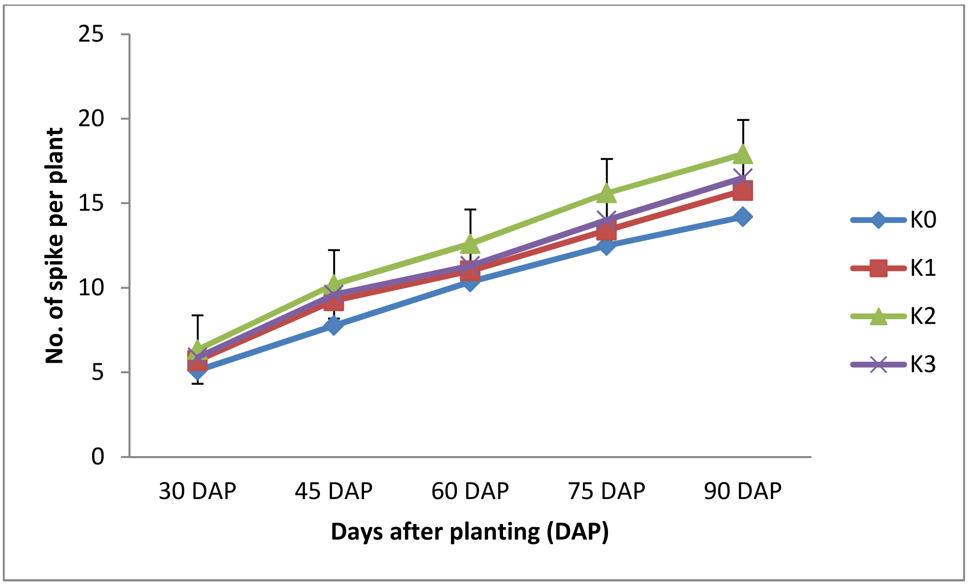


Fig. 8: Effect of different levels of potassium on number of spike per plant of tuberose

K_0: Control: No potassium
K_1: 125 kg K_2O ha^{-1}
K_2: 145 kg K_2O ha^{-1}
K_3: 165 kg K_2O ha^{-1}

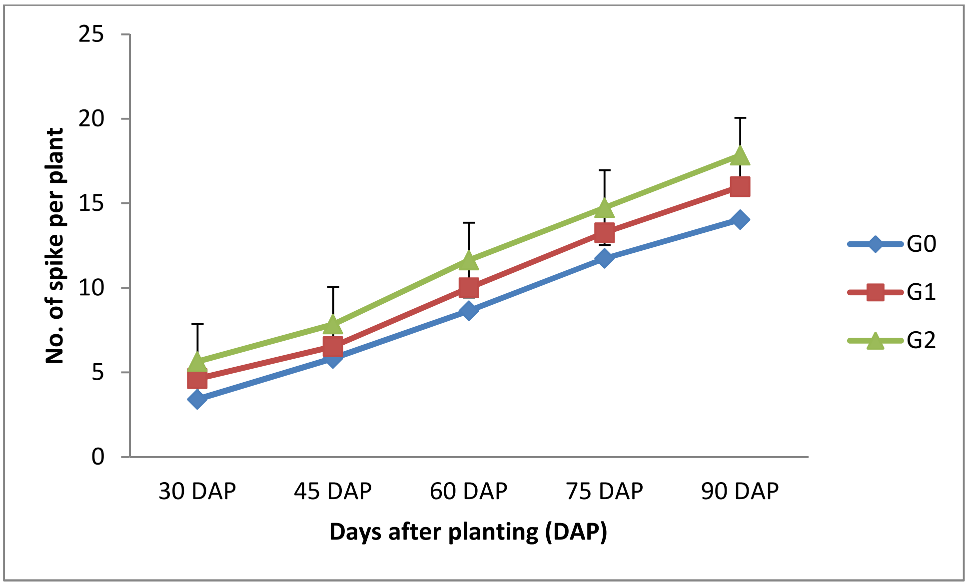


Fig. 9: Effect of different concentrations of GA_3 on number of spike per plant of tuberose

G_0: Control treatment
G_1: GA_3 100 ppm
G_2: GA_3 200 ppm

Table 5. Combined effect of potassium and GA_3 on number of spike per plant of tuberose

Treatment	Number of spike plant^{-1} at				
	30 DAP	**45 DAP**	**60 DAP**	**75 DAP**	**90 DAP**
K_0G_0	6.19	6.14	7.15	10.78	12.92
K_0G_1	6.20	6.84	8.12	11.07	13.23
K_0G_2	6.39	8.27	10.17	12.65	15.48
K_1G_0	6.68	9.32	10.56	13.01	15.56
K_1G_1	6.38	6.99	8.71	11.22	13.40
K_1G_2	7.13	7.77	9.67	11.83	13.83
K_2G_0	7.27	8.37	9.94	12.42	15.08
K_2G_1	7.38	10.33	11.49	13.90	16.50
K_2G_2	7.44	10.36	11.57	13.98	16.58
K_3G_0	7.06	9.83	11.07	13.49	16.11
K_3G_1	7.01	9.76	10.99	13.42	16.05
K_3G_2	7.15	6.69	9.68	12.18	14.85
$LSD_{(0.05)}$	3.138	4.961	3.992	5.659	4.666
Level of significance	NS	NS	NS	NS	NS
CV (%)	6.23	6.79	6.83	8.68	8.04

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

K_0: Control: No potassium
K_1: 125 kg K_2O ha^{-1}
K_2: 145 kg K_2O ha^{-1}
K_3: 165 kg K_2O ha^{-1}

G_0: Control treatment
G_1: GA_3 100 ppm
G_2: GA_3 200 ppm

4.5 Days required to emergence of spike

Days required to emergence of spike showed significant differences due to application of different levels of potassium (Appendix VII). Days required to emergence of spike was decrease with increasing the potassium levels up to 145 kg K_2O ha^{-1}. The longest days (81.60 days) were required to spike emergence from K_0 treatment while the treatment K_2 took the minimum (77.8 days) period to emergence of spike (Table 6). Bankar (1988) showed the similar trends of result which is agreed to the present study.

Different concentrations GA_3 also showed significant variation on days required to emergence of spike (Appendix VII). Days required to emergence of spike was decrease with increasing the concentration GA_3. The highest period (82.90 days) was required for G_0 treatment and the lowest (77.80 days) was observed from G_2 treatment (Table 6).

The combined effect of different levels of potassium and GA_3 showed significant differences on days required to emergence of spike (Appendix VII). However, the treatment combination of K_0G_0 took the highest days (84.60 day) for spike emergence and the lowest (75.30 days) from K_2G_2 (Table 7).

4.6 Diameter of spike

There was no significant difference on diameter of spike due to the effect of different levels of potassium (Appendix VII). However, the maximum diameter of spike (0.79 cm) was recorded in K_2 and the minimum (0.70 cm) was recorded in K_0 (Table 6). Rajiv and Mirsa (2003) found similar trends of result in their trail which is support the present findings by using potassium upto a certain level.

Table 6. Main effect of Potassium and GA_3 on days required to emergence of spike and diameter of spike of tuberose

Treatment	Days required to emergence of spike	Diameter of spike (cm)
Effect of potassium		
K_0	81.60 a	0.70
K_1	80.02 a	0.75
K_2	77.80 b	0.79
K_3	78.50 ab	0.77
$LSD_{(0.05)}$	1.542	0.214
Level of significance	*	NS
Effect of GA_3		
G_0	82.90 a	0.70
G_1	79.23 b	0.74
G_2	77.80 c	0.77
$LSD_{(0.05)}$	1.021	0.301
Level of significance	*	NS
CV (%)	7.81	8.53

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

K_0: Control: No potassium
K_1: 125 kg K_2O ha^{-1}
K_2: 145 kg K_2O ha^{-1}
K_3: 165 kg K_2O ha^{-1}

G_0: Control treatment
G_1: GA_3 100 ppm
G_2: GA_3 200 ppm

Statistically significant variation did not show on diameter of spike due to the effect of different concentrations of GA_3 (Appendix VII). The highest diameter of spike (0.77 cm) was recorded in G_2 treatment whereas, the lowest (0.70 cm) was found in G_0 treatment (Table 6). The present results are in agreement the findings of Mukhopandhay and Bankar (1983).

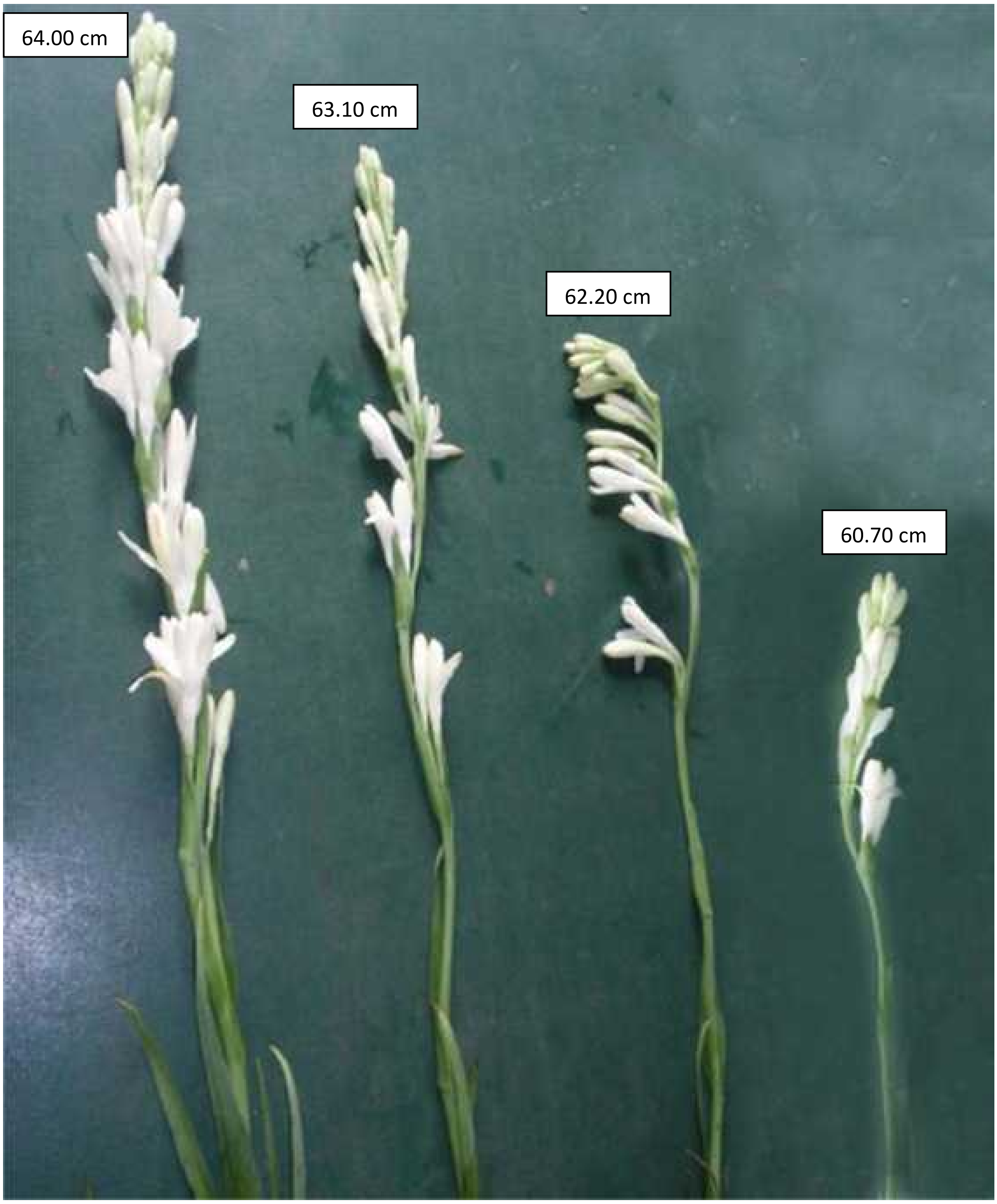
Combined effect of different levels of potassium and GA_3 did not show significant variation in terms of diameter of spike (Appendix VII). But, the maximum diameter of spike (0.91 cm) was recorded in K_2G_2 treatment. On the other hand, the minimum diameter of spike (0.72 cm) was recorded in K_0G_0 treatment (Table 7).

4. 7 Length of spike

The length of spike varied significantly due to the effect of application different levels of potassium (Appendix VII). The highest spike length (64.00 cm) was observed from K_2 and the shortest spike (60.70 cm) was recorded from K_0 (Fig. 10 and plate 1). The results also agreed with the findings of Kabir *et. al.* (2011) who concluded that the increased spike length was due to use of potassium.

Different concentrations of GA_3 showed statistically variation on spike length under the present trial (Appendix VII). The maximum spike length (66.50 cm) was recorded from G_2 while the minimum spike length (58.30 cm) was recorded from G_0 (Fig. 11 and plate 2). Singh (1999) reported similar results in tuberose plant.

Combined effect of potassium and GA_3 showed significant difference on spike length of tuberose (Appendix VII). The longest spike (72.03 cm) was recorded from K_2G_2 and the shortest (60.29 cm) was obtained from K_0G_0 (Table 7).



K_2 K_3 K_1 K_0

Plate 1: Effect of potassium (K_2O) on length of spike

Plate 2: Effect of gibberellic acid (GA_3) on length of spike

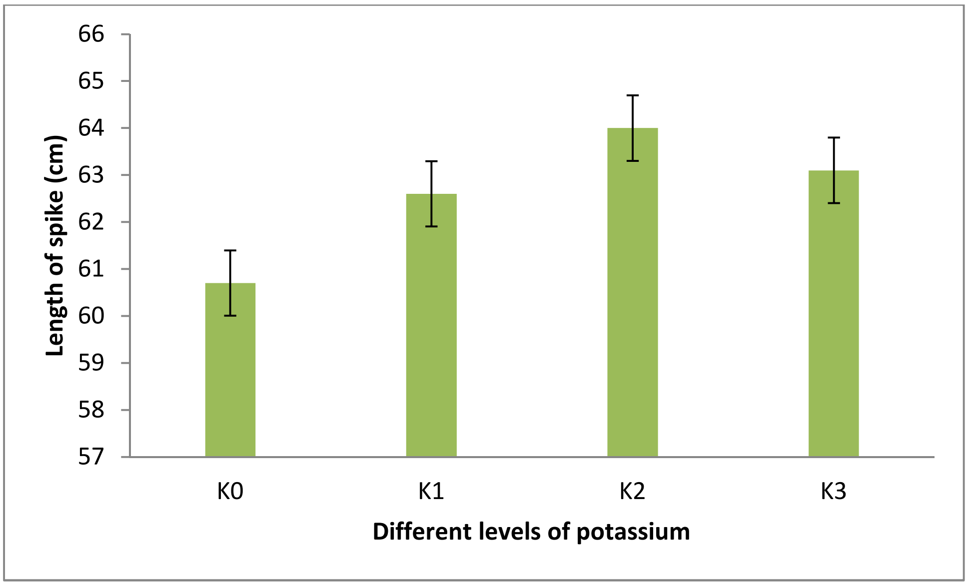


Fig. 10: Effect of different levels of potassium on length of spike of tuberose

K_0: Control: No potassium
K_1: 125 kg K_2O ha^{-1}
K_2: 145 kg K_2O ha^{-1}
K_3: 165 kg K_2O ha^{-1}

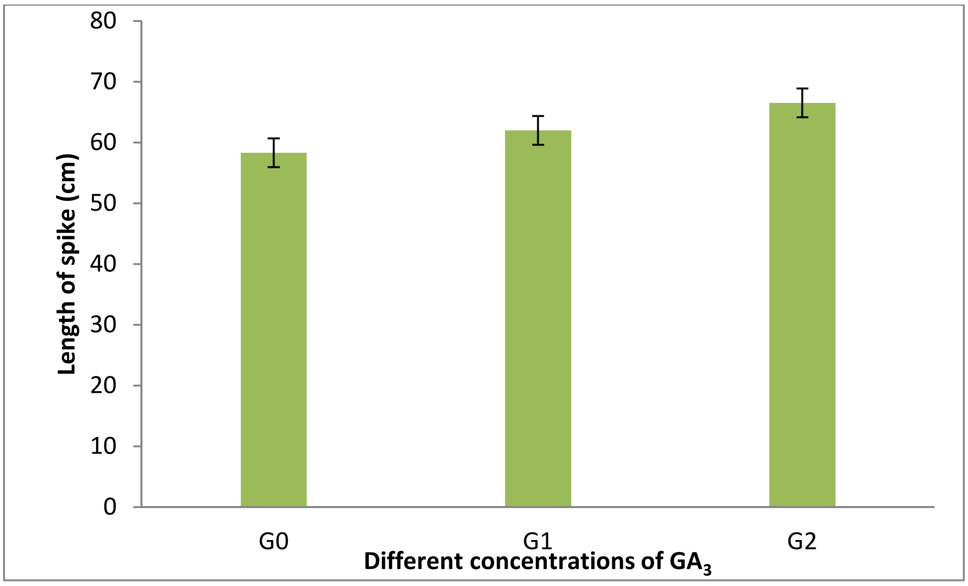


Fig. 11: Effect of different concentrations of GA_3 on length of spike of tuberose

G_0: Control treatment
G_1: GA_3 100 ppm
G_2: GA_3 200 ppm

4.8 Weight of single spike

Different levels of potassium showed a statistically significant variation in terms of weight of single spike under the trial (Appendix VII). The highest weight of single spike (45.40 g) was recorded from K_2 and K_0 performed the lowest (37.98 g) weight of single spike (Fig. 12). The K_2 was showed the highest weight of single spike and control was showed lowest result.

Statistically significant variation was recorded of weight of single spike due to the application of different concentrations of GA_3 under the trial (Appendix VII). Increasing the concentration of GA_3 on weight of single spike represent an increasing trend. The highest weight of single spike (46.00 g) was recorded from G_2 which was followed by G_1 (41.82 g) and the lowest (38.05 g) weight of single spike was obtained from G_0 treatment (Fig. 13). This result is consistent with Bharti and Ranjan (2009) reported that weight of single spike increased with increasing concentration of $GA_{3.}$

Combined effect of different levels of potassium and GA_3 showed significant variation on weight of single spike (Appendix VII). The maximum weight of single spike (49.83 g) was observed from K_2G_2 and the minimum weight of single spike (33.93 g) was recorded from K_0G_0 (Table 7).

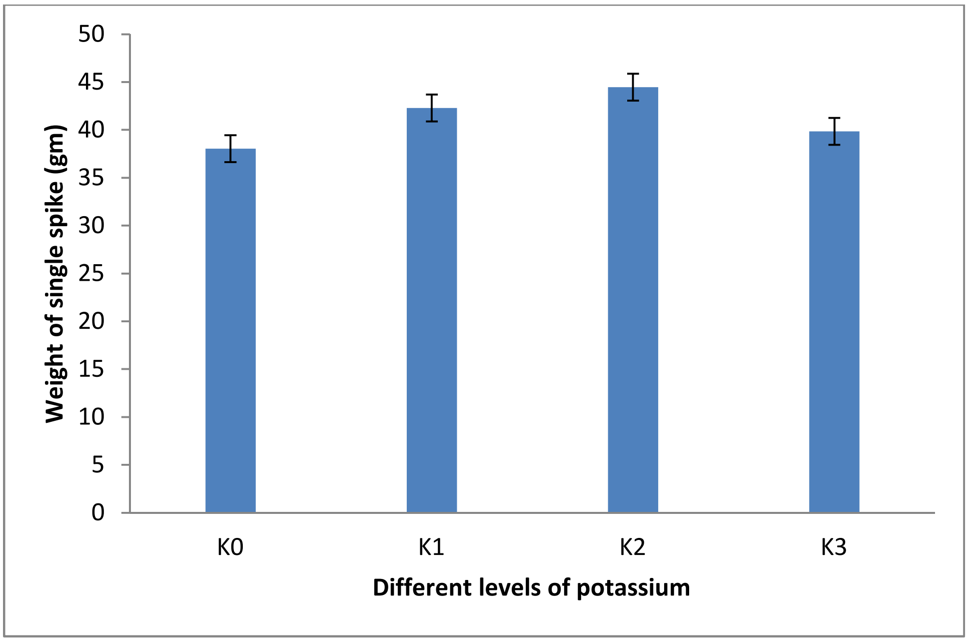


Fig. 12: Effect of different levels of potassium on weight of single spike of tuberose

K_0: Control: No potassium
K_1: 125 kg K_2O ha^{-1}
K_2: 145 kg K_2O ha^{-1}
K_3: 165 kg K_2O ha^{-1}

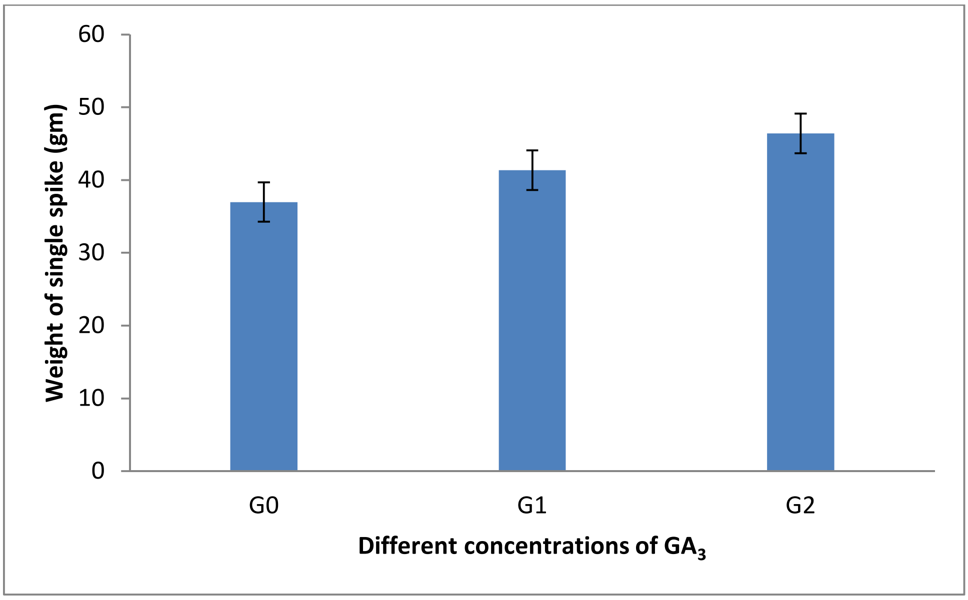


Fig. 13: Effect of different concentrations of GA_3 on weight of single spike of tuberose

G_0: Control treatment
G_1: GA_3 100 ppm
G_2: GA_3 200 ppm

4.9 Length of rachis at harvest

Statistically significant difference was found on length of rachis at harvest for the application different levels of potassium (Appendix VII). The highest length of rachis at harvest (27.7 cm) was recorded from K_2 which was closely followed by K_3 (26.83 cm) and K_1 (26.13 cm). The lowest (25.00 cm) was recorded from K_0 (Fig. 14). Yadav (2007) reported that length of rachis was remarkably increased with potassium application, alone and in combination.

Length of rachis at harvest of tuberose varied significantly due to the application of different concentrations of GA_3 (Appendix VII). The highest length of rachis at harvest (33.50 cm) was found from G_2 whereas, the lowest (22.51 cm) was found from G_0 treatment (Fig. 15). Manisha *et al.* (2002) found similar result.

Length of rachis at harvest of tuberose showed significant variation due to combined effect of potassium and GA_3 (Appendix VII). The maximum length of rachis at harvest (35.57 cm) was recorded from the treatment combined of K_2G_2 (145 kg K_2O ha^{-1} with 200 ppm GA_3) whereas, the minimum (23.70 cm) was recorded from the combination treatment of K_0G_0 which statistically similar to K_0G_1 (25.10 cm), K_0G_2 (24.03) and K_1G_0 (24.50cm) (Table 7).

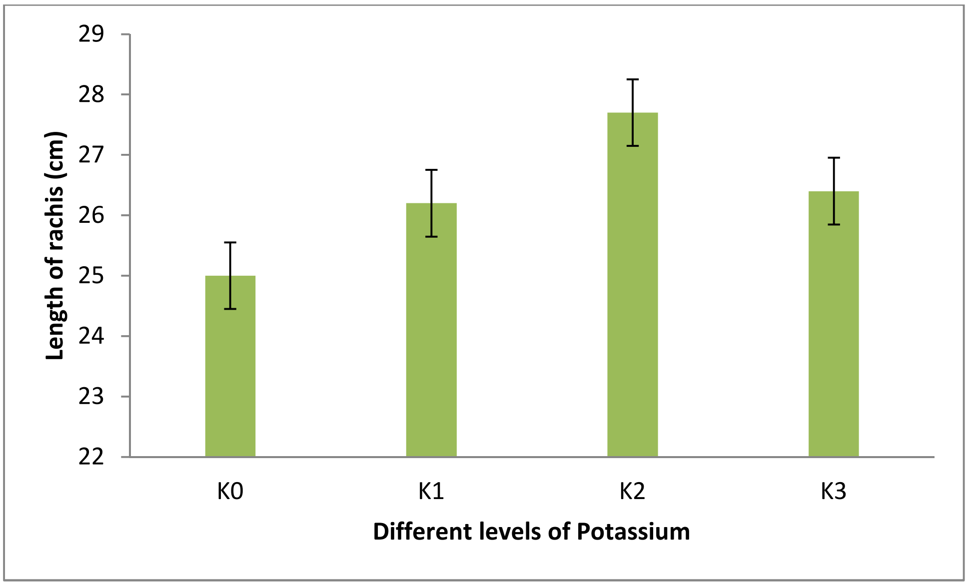


Fig. 14: Effect of different levels of potassium on length of rachis of tuberose

K_0: Control: No potassium
K_1: 125 kg K_2O ha^{-1}
K_2: 145 kg K_2O ha^{-1}
K_3: 165 kg K_2O ha^{-1}

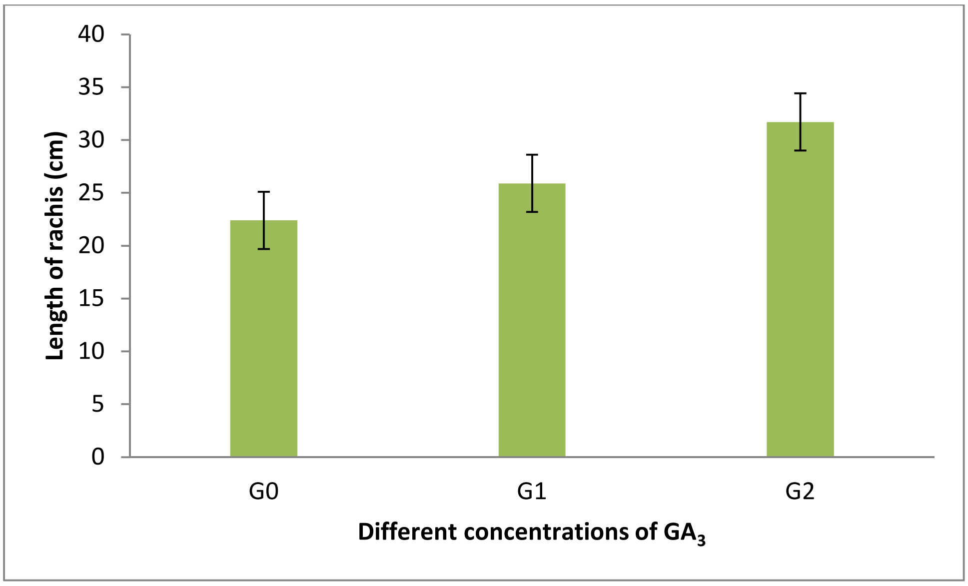


Fig. 15: Effect of different concentrations of GA_3 on length of rachis of tuberose

G_0: Control treatment
G_1: GA_3 100 ppm
G_2: GA_3 200 ppm

4.10 Number of florets per spike

Significant difference was recorded on number of florets per spike due to the application of different levels of potassium (Appendix VII). The highest number of florets per spike (43.00) was performed by K_2 and the lowest (35.00) was found from K_0 (Fig.16).

Different concentrations of GA_3 differed significantly on number of florets per spike of tuberose (Appendix VII). The highest number of florets per spike (41.20) was found from G_2 and the lowest (32.00) was recorded from G_0 (Fig. 17). Preeti *et al.* (1997) found similar trends of results.

Significant variation was recorded due to combined effect of potassium and GA_3 in terms of number of florets per spike of tuberose (Appendix VII). The maximum number of florets per spike (47.80) was found from K_2G_2 treatment whereas, the minimum (32.90) was recorded from K_0G_0 treatment (Table 7). Yadav (2007) reported that number of floret per spike was remarkably increased with potassium application, alone and in combination.

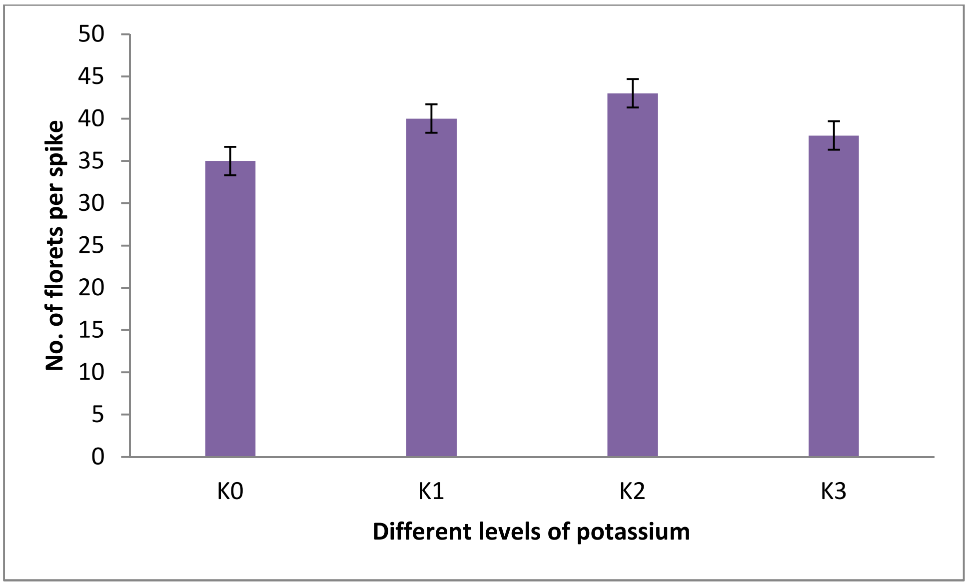


Fig. 16: Effect of different levels of potassium on number of floret per spike of tuberose

K_0: Control: No potassium
K_1: 125 kg K_2O ha^{-1}
K_2: 145 kg K_2O ha^{-1}
K_3: 165 kg K_2O ha^{-1}

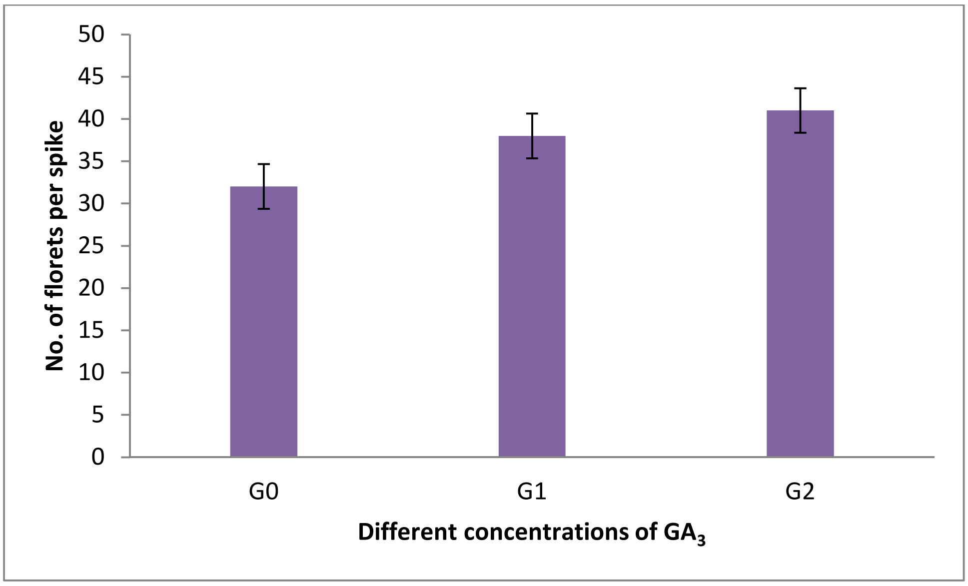


Fig. 17: Effect of different concentrations of GA_3 on number of floret per spike of tuberose

G_0: Control treatment
G_1: GA_3 100 ppm
G_2: GA_3 200 ppm

Table 7. Combined effect of potassium and GA_3 on growth parameter of tuberose

Treatment	Days required for emergence of spike	Diameter of single Spike (cm)	Length of single spike (cm)	Weight of single spike (g)	Length of rachis (cm)	Number of floret per spike
K_0G_0	84.6 a	0.72	60.29 d	33.93 i	23.70 f	32.90 i
K_0G_1	81.6 b	0.80	60.33 d	35.43 h	25.10 ef	34.40 h
K_0G_2	81.6 b	0.79	59.58 d	39.67 f	24.03 f	38.64 f
K_1G_0	81.3 b	0.74	61.05 d	37.00 g	24.50 f	36.01 g
K_1G_1	79.6 bc	0.75	63.35 cd	37.90 g	27.40 cd	36.87 g
K_1G_2	81.0 b	0.83	63.10 cd	39.60 f	26.59 de	38.57 f
K_2G_0	78.3 cd	0.85	67.65 b	42.70 e	32.52 b	42.87 d
K_2G_1	78.0 bc	0.87	66.63 bc	44.47 c	33.00 b	41.65 e
K_2G_2	75.3 e	0.91	72.03 a	49.83 a	35.57 a	47.80 a
K_3G_0	81.0 b	0.85	63.35 cd	42.33 e	29.01 c	41.30 e
K_3G_1	78.2 bc	0.82	66.33 bd	43.91 d	28.25 cd	42.88 d
K_3G_2	80.6 b	0.84	58.62 b	47.20 b	32.53 b	46.15 b
$LSD_{(0.05)}$	1.573	3.40	0.962	0.897	1.782	0.879
Level of significance	**	*	NS	*	*	*
CV (%)	7.81	9.62	8.35	8.38	9.96	7.79

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

K_0: Control: No potassium
K_1: 125 kg K_2O ha^{-1}
K_2:145 kg K_2O ha^{-1}
K_3: 165 kg K_2O ha^{-1}

G_0: Control treatment
G_1: GA_3 100 ppm
G_2:GA_3 200 ppm

4.11 Dry weight of florets (%)

There were no significant differences on percent dry weight of florets due to the effect of different levels of potassium (Appendix VIII). However, the highest dry weight of florets (6.56%) was recorded in K_2 and the lowest (4.83%) was recorded in K_0 (Table 8).

Statistically significant variation did not show on percent dry weight of florets due to the effect of different concentrations of GA_3 (Appendix VIII). The highest dry weight of florets in percent (6.34%) was recorded in G_2 treatment whereas, the lowest (5.42%) was found in G_0 treatment (Table 8). Singh *et al.* (2003) stated that gibberellic acid also helps to increase dry weight of florets.

Combined effect of different levels of potassium and GA_3 did not show significant variation in terms of percent dry weight of florets (Appendix VIII). But the highest dry weight of florets (7.73%) was recorded in K_2G_2 treatment whereas, the lowest dry weight of florets (4.67%) was recorded in K_0G_0 treatment (Table 9).

4.12 Dry weight of leaves (%)

There were no significant differences on dry weight of leaves in percent due to the effect of different levels of potassium (Appendix VIII). However, the maximum dry weight of leaves in percent (9.65%) was recorded in K_2 and the minimum (6.53%) was recorded in K_0 (Table 8). This result is consistent with Singh *et al.* (2005) who reported that dry weight of leaf was higher in potassium applied plants than control plants.

Statistically significant variation did not show on dry weight of leaves due to the effect of different concentrations of GA_3 (Appendix VIII). The maximum dry weight of leaves in percent (10.83%) was recorded in G_2 treatment whereas, the minimum (6.72%) was found in G_0 treatment (Table 8). Nagar and Saraf (2002) found similar trends of result in their trail which is supported to the present finding by using GA_3

Combined effect of potassium and GA_3 did not show significant variation in terms of dry weight of leaves in percent (Appendix VIII). But, the maximum dry weight of leaves in percent (12.26%) was recorded in K_2G_2 treatment while the minimum dry weight of leaves in percent (5.50%) was recorded in K_0G_0 treatment (Table 9).

4. 13 Number of spike per hectare ('000)

A statistically significant variation was recorded on spike in thousand per hectare due to the application of different levels of potassium (Appendix IX). The maximum number of spike per hectare (309.10) was recorded from K_2 whereas, the minimum (269.50) was recorded from K_0 (Fig. 18).

Due to the application of different concentrations of GA_3 on number of spike in thousand per hectare showed significant variation (Appendix IX). Increases of concentration of GA_3 number of spike per hectare represent an increasing trend under the present investigation. The maximum number of spike per hectare (325.00) was recorded from G_2 while, the minimum (264.50) was recorded from G_0 (Fig. 19). The present results are in agreement the findings of Dhua *et al.* (1987) and Pathak *et al.* (1980).

Combined effect of different levels of potassium and GA_3 showed significant variation on number of spike in thousand per hectare (Appendix IX). The maximum number of spike per hectare (350.00) was recorded from K_2G_2 treatment whereas, the minimum (250.31) was recorded from K_0G_0 treatment (Table 11).

Table 8. Main effect of potassium and GA_3 on dry weight of florets in percent and dry weight of leaves in percent of tuberose

Treatment	Dry weight of florets (%)	Dry weight of leaves (%)
Effect of potassium		
K_0	4.83	6.53
K_1	6.05	8.46
K_2	6.56	9.65
K_3	5.66	8.28
$LSD_{(0.05)}$	2.992	3.892
Level of significance	NS	NS
Effect of GA_3		
G_0	5.42	5.72
G_1	5.93	8.28
G_2	6.34	9.83
$LSD_{(0.05)}$	2.051	4.627
Level of significance	NS	NS
CV (%)	5.09	8.092

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

K_0: Control: No potassium
K_1: 125 kg K_2O ha^{-1}
K_2: 145 kg K_2O ha^{-1}
K_3: 165 kg K_2O ha^{-1}

G_0: Control treatment
G_1: GA_3 100 ppm
G_2: GA_3 200 ppm

Table 9. Combined effect of potassium and GA_3 on dry weight of florets in percent and dry weight of leaves in percent of tuberose

Treatment	Dry weight of florets (%)	Dry weight of leaves (%)
K_0G_0	4.67	5.50
K_0G_1	4.74	6.60
K_0G_2	4.85	7.50
K_1G_0	5.04	5.72
K_1G_1	6.58	8.90
K_1G_2	6.04	9.91
K_2G_0	5.78	5.64
K_2G_1	6.39	9.13
K_2G_2	7.73	12.26
K_3G_0	5.23	5.85
K_3G_1	5.98	8.50
K_3G_2	6.48	10.10
$LSD_{(0.05)}$	3.332	5.278
Level of significance	NS	NS
CV (%)	5.09	8.092

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

K_0: Control: No potassium
K_1: 125 kg K_2O ha^{-1}
K_2: 145 kg K_2O ha^{-1}
K_3: 165 kg K_2O ha^{-1}

G_0: Control treatment
G_1: GA_3 100 ppm
G_2: GA_3 200 ppm

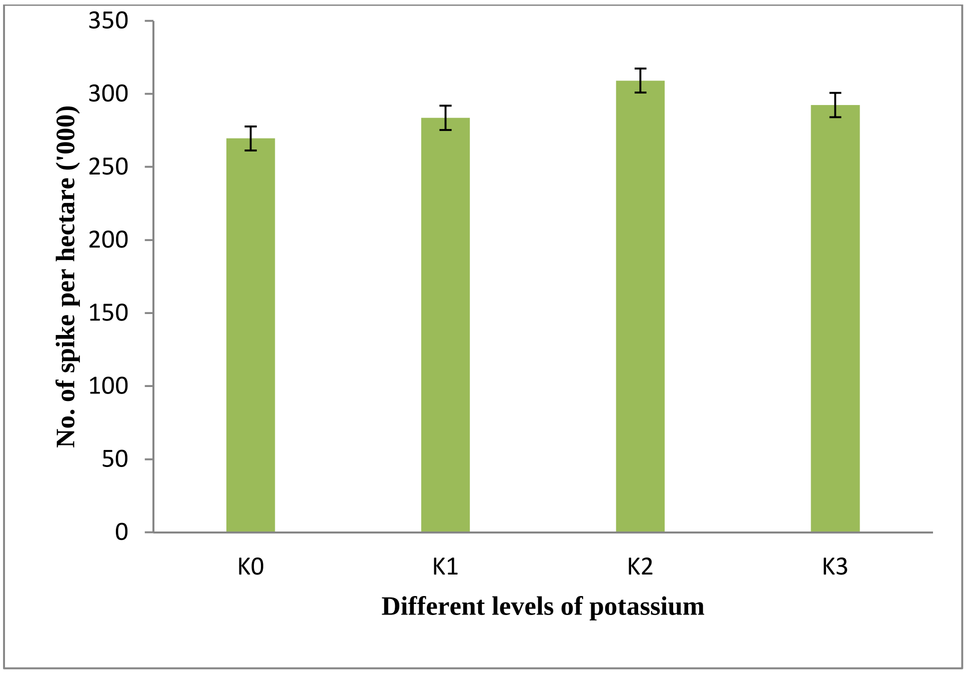


Fig. 18: Effect of different levels of potassium on number of spikes per hectare (in thousand) of tuberose

K_0: Control: No potassium
K_1: 125 kg K_2O ha^{-1}
K_2: 145 kg K_2O ha^{-1}
K_3: 165 kg K_2O ha^{-1}

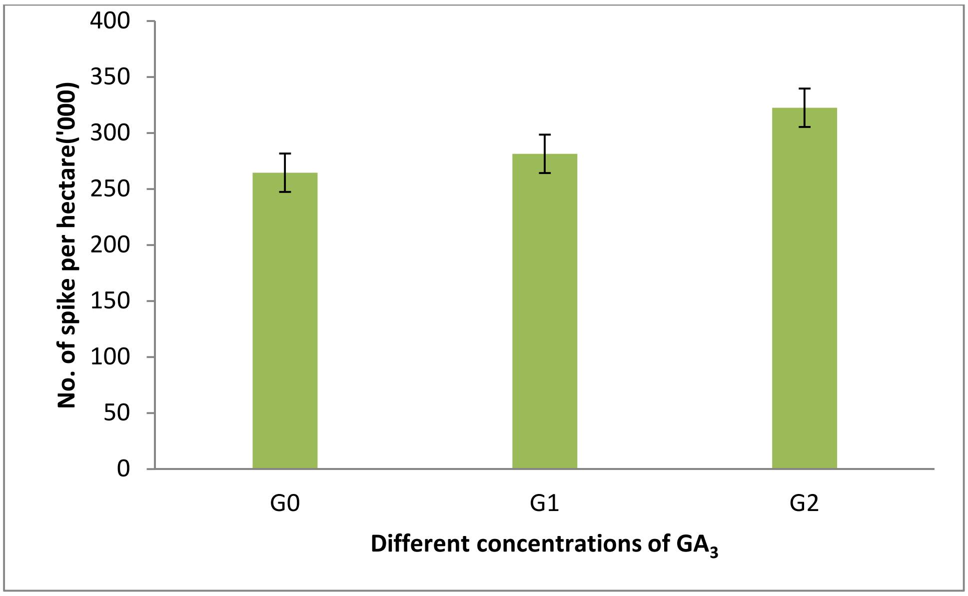


Fig. 19: Effect of different concentrations of GA_3 on number of spike per hectare (in thousand) of tuberose

G_0: Control treatment
G_1: GA_3 100 ppm
G_2: GA_3 200 ppm

4.14 Diameter of single bulb

Significant difference was found on diameter of single bulb for the application of different levels of potassium (Appendix IX). But numerically, the highest diameter of individual bulb (2.03 cm) was found from K_2 treatment and lowest (1.75 cm) was recorded from K_0 treatment (Tabel 10). Banker and Mukhopadhyay (1985) reported that bulb diameter was higher in potassium applied plants than control plants that supported the present experimental result.

Different concentrations of GA_3 showed significant difference on diameter of single bulb of tuberose (Appendix IX). The highest diameter of single bulb (2.35 cm) was found from G_2 treatment (200 ppm GA_3) whereas, the lowest (2.10 cm) was observed from G_0 as no GA_3 i.e. control treatment (Table 10).

There was no significant variation was recorded due to combined effect of different levels of potassium and GA_3 on diameter of single bulb of tuberose (Appendix IX). However, the maximum diameter of single bulb (2.53 cm) was recorded from the treatment combination of K_2G_2 whereas, the minimum diameter of single bulb (1.92 cm) was recorded from K_0G_0 (Table 11).

4.15 Single bulb weight

Single bulb weight showed statistically significant difference due to the application of different levels of potassium (Appendix IX). The highest weight of single bulb (30.40 g) was observed in K_2 and the lowest (25.60 g) was found from K_0 (Table 10). Bankar (1988) showed similar trends of result which is agreed to the present study.

Different concentrations of GA_3 differed significantly on the weight of single bulb of tuberose (Appendix IX). The highest weight of single bulb (31.90 g) was observed in G_2 whereas, the lowest (25.30 g) was found from G_0 as no GA_3 i.e. control treatment (Table 10).

Combined effect of different levels of potassium and GA_3 varied significantly on weight of single bulb of tuberose (Appendix IX). The maximum weight of single bulb (35.35 g) was observed in K_2G_2 treatment (145 kg K_2O ha^{-1} with 200ppm GA_3) whereas, the minimum (24.78 g) was obtained from K_0G_0 treatment (Table 11).

4.16 Diameter of single bulblet

Diameter of single bulblet did not show the significant differences due to the application of different levels of potassium (Appendix IX). The maximum diameter of single bulblet (0.95 cm) was found from K_2 (145 kg K_2O ha^{-1}) treatment while, minimum (0.33 cm) was observed from K_0 treatment (Table 10).

Different concentrations of GA_3 did not show the significant difference on diameter of single bulblet of tuberose (Appendix IX). The highest diameter of single bulblet (1.10 cm) was found from G_2 treatment (200 ppm GA_3) whereas, the lowest (0.60 cm) was observed from G_0 as (control treatment) (Table 10).

There was no significant variation was recorded due to combined effect of potassium and GA_3 on diameter of single bulblet of tuberose (Appendix IX). The highest diameter of single bulblet (1.16 cm) was recorded from the treatment combination of K_2G_2 whereas, the lowest diameter of single bulb (0.43 cm) was recorded from K_0G_0 (Table 11).

4.17 Single bulblet weight

Single bulblet weight showed the statistically significant variation due to the application of different levels of potassium (Appendix IX). The highest weight of single bulblet (5.50 g) was observed in K_2 which was followed by K_3 (5.10 g) and the lowest (4.20 g) was found from K_0 (Table 10).

Different concentrations of GA_3 differed significantly on the weight of single bulblet of tuberose (Appendix IX). The highest weight of single bulblet (5.00

g) was observed in G_2 whereas, the lowest (4.00 g) was found from G_0 as no GA_3 i.e. control treatment (Table 10).

Combined effect of different levels of potassium and GA_3 varied significantly in terms of weight of single bulblet of tuberose (Appendix IX). The maximum individual bulblet weight (5.50 g) was observed in K_2G_2 treatment (145 kg K_2O with 200ppm GA_3) whereas, the minimum (4.00 g) was observed from K_0G_0 treatment (Table 11).

4.18 Yield of bulb (t ha^{-1})

Yield of bulb showed statistically significant difference due to the application of different levels of potassium (Appendix IX). The highest yield of bulb (19.00 t ha^{-1}) was recorded from K_2 treatment and the lowest (15.39 t ha^{-1}) was recorded from K_0 treatment (Fig. 20). Sultana *et al.* (2006) reported that bulb yield was higher in potassium applied plants than control plants that supported the present experimental result.

Significant difference was found different concentrations of GA_3 on yield of bulb of tuberose (Appendix IX). The highest yield of bulb (20.24 t ha^{-1}) was observed from G_2 treatment whereas, the lowest (15.67 t ha^{-1}) was found from G_0 treatment (Fig. 21).

Combined effect of different levels of potassium and GA_3 varied significantly on yield of bulb of tuberose (Appendix IX). The maximum yield of bulb (21.72 t ha^{-1}) was observed from K_2G_2 treatment whereas, the minimum (15.17 t ha^{-1}) was recorded from K_0G_0 treatment (Table 11).

Table 10. Main effect of potassium and GA_3 on bulb parameter of tuberose

Treatment	Diameter of single bulb (cm)	Single bulb Weight (g)	Diameter of single bulblet (cm)	Single bulblet weight (g)
Effect of potassium				
K_0	1.75 b	25.60 c	0.33	4.20 d
K_1	1.96 ab	27.13 b	0.56	4.90 c
K_2	2.03 a	30.40 a	0.95	5.50 a
K_3	2.00 a	28.26 ab	0.66	5.10 b
$LSD_{(0.05)}$	0. 153	2.560	0.661	0.028
Level of significance	*	*	NS	*
Effect of GA_3				
G_0	2.10 b	25.30 c	0.60	4.00 c
G_1	2.17 ab	28.27 b	0.80	4.31 b
G_2	2.35 a	31.90 a	1.10	5.00 a
$LSD_{(0.05)}$	0.291	2.030	0.965	0.173
Level of significance	*	**	NS	*
CV(%)	7.23	7.99	8.52	9.25

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

K_0: Control: No potassium
K_1: 125 kg K_2O ha^{-1}
K_2: 145 kg K_2O ha^{-1}
K_3: 165 kg K_2O ha^{-1}

G_0: Control treatment
G_1: GA_3 100 ppm
G_2: GA_3 200 ppm

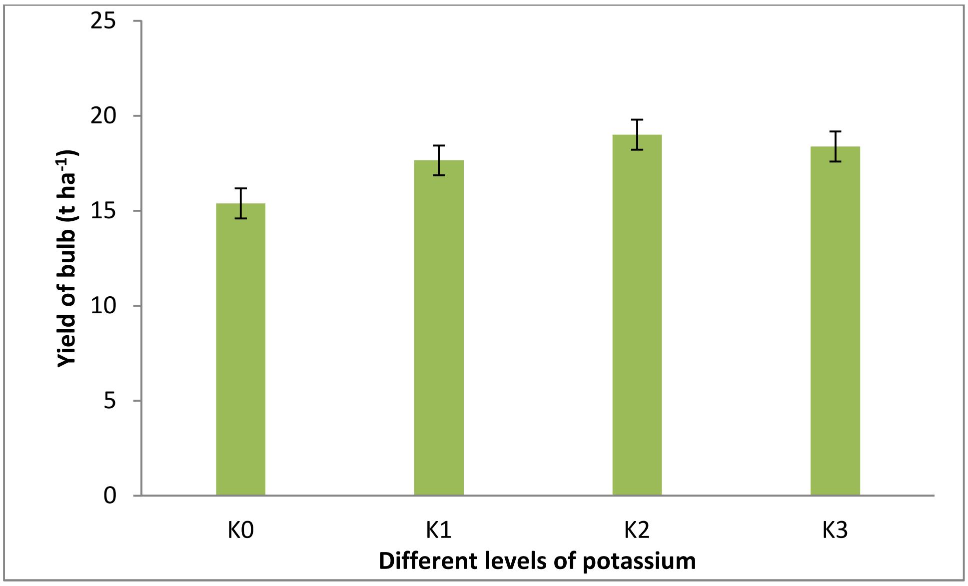


Fig. 20: Effect of different levels of potassium on bulb yield ($t\ ha^{-1}$) of tuberose

K_0: Control: No potassium
K_1: 125 kg K_2O ha^{-1}
K_2: 145 kg K_2O ha^{-1}
K_3: 165 kg K_2O ha^{-1}

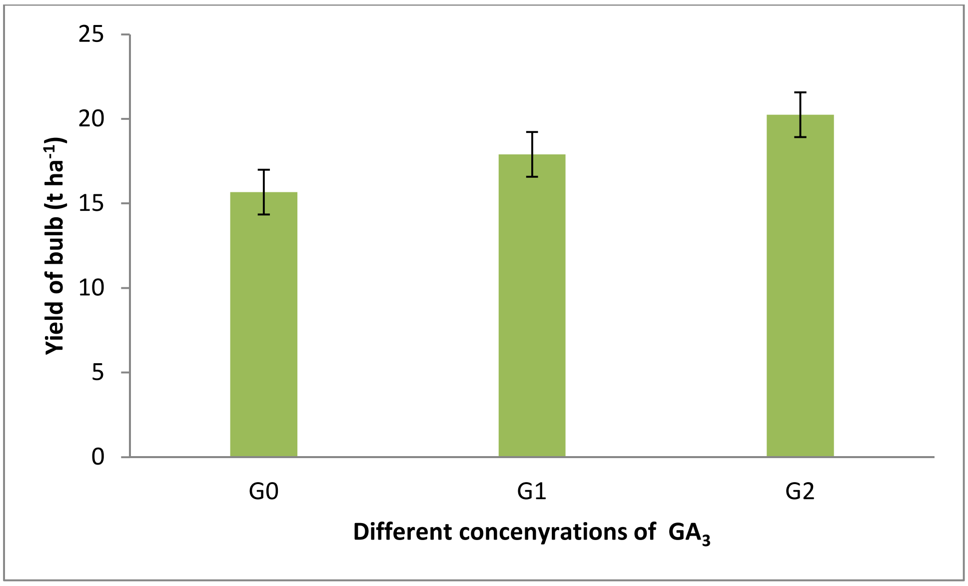


Fig. 21: Effect of different concentrations of GA_3 of bulb yield ($t\ ha^{-1}$) of tuberose

G_0: Control treatment
G_1: GA_3 100 ppm
G_2: GA_3 200 ppm

4.19 Yield of bulblets (t ha^{-1})

Significant difference was recorded on yield of bulblets due to the application of different levels of potassium (Appendix IX). The highest yield of bulblets (22.85 t ha^{-1}) was found from K_2 treatment (145 kg K_2O ha^{-1}) and the lowest (15.39 t ha^{-1}) was recorded from K_0 (control treatment) (Fig. 22). Mukhopadhyay and Banker (1986) reported that bulblets production was higher in potassium applied plants than control plants that supported the present experimental result.

Yield of bulblets of tuberose was showed significance variation for the application of different concentrations of GA_3 (Appendix IX). The highest yield of bulblets (22.94 t ha^{-1}) was found from G_2 treatment (200 ppm GA_3) whereas, the lowest (17.20 t ha^{-1}) was found from G_0 (control treatment) (Fig. 23).

Statistically significant variation was recorded due to combined effect of potassium levels and GA_3 in terms of yield of bulblets of tuberose (Appendix IX). The maximum yield of bulblets (26.95 t ha^{-1}) was observed from the combination treatment of K_2G_2 (145 kg K_2O ha^{-1} with 200 ppm GA_3) whereas, the minimum (11.00 t ha^{-1}) was observed from the combination treatment of K_0G_0 (control treatment) (Table 11).

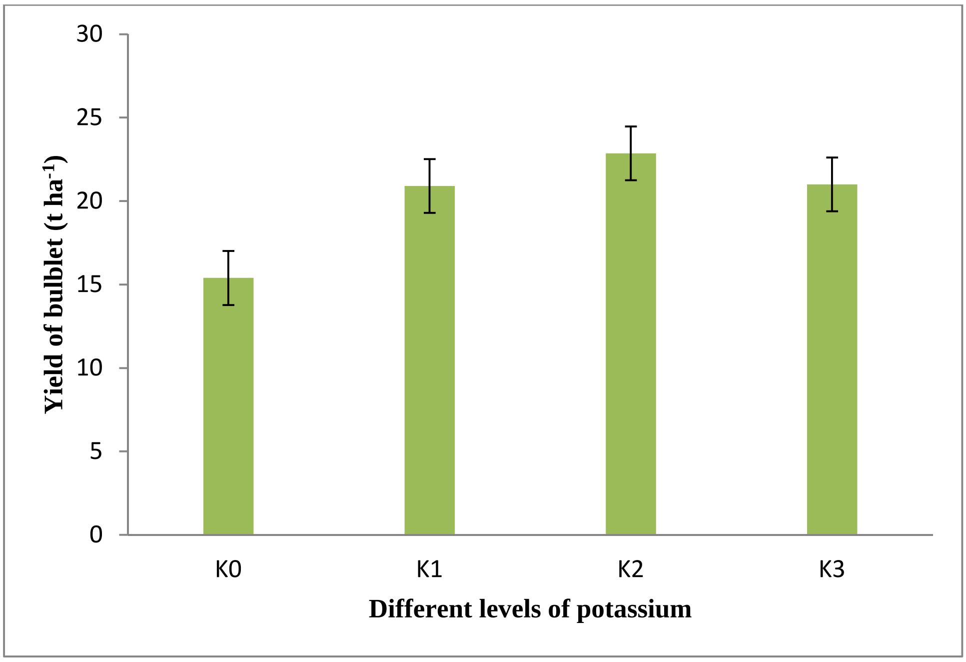


Fig. 22: Effect of different levels of potassium on bulblets yield (t ha^{-1}) of tuberose

K_0: Control: No potassium
K_1: 125 kg K_2O ha^{-1}
K_2: 145 kg K_2O ha^{-1}
K_3: 165 kg K_2O ha^{-1}

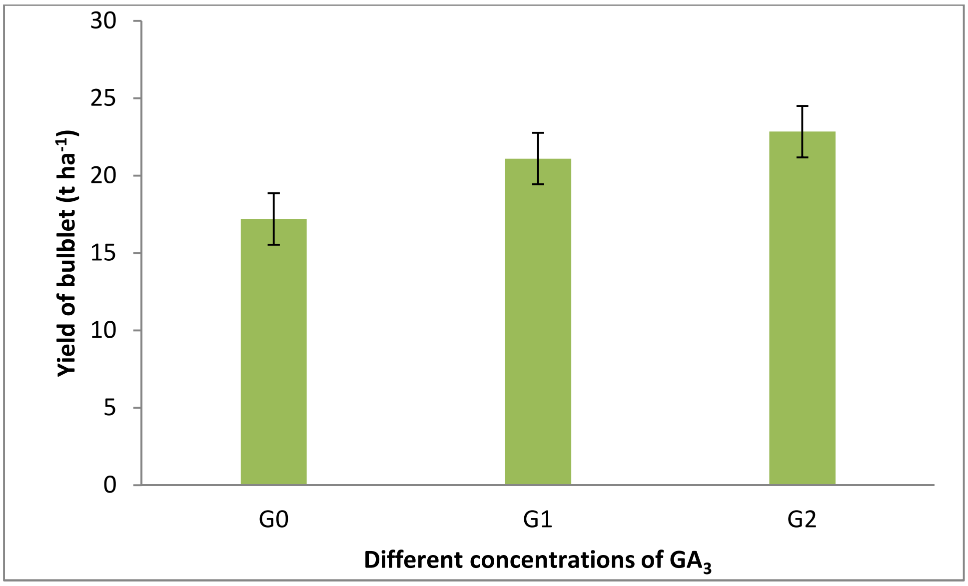


Fig. 23: Effect of different concentrations of GA_3 on bulblets yield (t ha^{-1}) of tuberose

G_0: Control treatment
G_1: GA_3 100 ppm
G_2: GA_3 200 ppm

Table 11. Combined effect of potassium and GA_3 on yield parameter of tuberose

Treatment	Number of spike per hectare('000)	Diameter of singlebulb (cm)	Singlebulb Weight (g)	Diameter of single bulblet (cm)	Single bulblet weight (g)	Yield of bulb (t/ha)	Yield of bulblets (t/ha)
K_0G_0	250.3 l	1.92	24.78 i	0.43	4.00 j	15.17 k	11.00 e
K_0G_1	270.3 i	1.95	25.80 h	0.56	4.20 h	16.33 i	17.95 d
K_0G_2	278.6 g	2.04	26.46 g	0.59	4.40 g	17.28 g	18.67 cd
K_1G_0	258.6 j	1.91	26.27 g	0.72	4.10 i	16.50 h	17.20 d
K_1G_1	258.3 k	2.02	29.00 f	0.82	4.20 h	15.78 j	19.22 cd
K_1G_2	278.3 h	2.28	31.51 d	0.92	4.70 e	17.28 g	22.76 a-c
K_2G_0	330.0 b	2.29	32.37 c	0.82	5.00 c	17.59 f	22.90 a-c
K_2G_1	350.0 c	2.27	34.35 b	1.03	5.20 b	18.84 d	22.60 a-c
K_2G_2	350.0 a	2.53	35.35 a	1.16	5.50 a	21.72 a	26.95 a
K_3G_0	298.6 e	2.45	26.65 g	0.56	4.50 f	18.33 e	20.24 b-d
K_3G_1	290.3 f	2.44	30.44 e	0.61	4.70 e	19.33 c	22.67 ab
K_3G_2	300.0 d	2.46	32.85 c	0.73	4.80 d	20.43 b	24.46 a-c
$LSD_{(0.05)}$	5.35	1.062	0.574	1.962	0.05	4.336	4.067
Level of significance	**	NS	**	NS	*	*	*
CV (%)	8.9	7.23	7.99	8.52	9.25	8.52	7.04

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

K_0: Control: No potassium
K_1: 125 kg K_2O ha^{-1}
K_2: 145 kg K_2O ha^{-1}
K_3: 165 kg K_2O ha^{-1}

G_0: Control treatment
G_2: GA_3 200 ppm
G_1: GA_3 100 ppm

4.20 Economic analysis

Input costs for land preparation, bulb, organic manure, GA_3, irrigation and manpower required for all the operations from planting to harvesting of tuberose flower, bulb and bulblet were recorded for unit plot and converted into cost per hectare. Price of tuberose flower, bulb and bulblet was considered as per market rate. The economic analysis presented under the following headings-

4.20.1 Gross return

The combination of different levels of potassium (K_2O) and GA_3 showed different gross return. The highest gross return (Tk. 4,55,195) was obtained from K_2G_2 and the second highest gross return (Tk.4,40,540) was found in K_2G_1. The lowest gross return (Tk. 3,21,030) was obtained from K_0G_0 (Table 12 and appendices X).

4.20.2 Net return

In case of net return different treatment combination showed diff erent concentration of net return. The highest net return (Tk. 2,52,114.176) was found from K_2G_2 and the second highest net return (Tk. 2,39,191.269) was obtained from K_2G_1. The lowest (Tk. 1,31,469.36) net return was obtained K_0G_0 (Table 12 and Appendices X).

4.20.3 Benefit cost ratio

In the combination of different levels of potassium (K_2O) and GA_3, highest benefit cost ratio (2.24) was noted from K_2G_2 and the second highest benefit cost ratio (2.19) was estimated from K_2G_1. The lowest benefit cost ratio (1.81) was obtained from K_0G_0 (Table 12). From economic point of view, it was apparent from the above results that the combination of K_2G_2 was more profitable than rest of the combination.

Table 12. Cost and return of tuberose cultivation as influenced by potassium fertilizer and GA_3

Treatment	Cost of production (Tk./ha)	Yield of bulb (t/ha)	Price of bulb (Tk.)	Yield of Bulblet (t/ha)	Price of bulblet (Tk.)	Tuberose (1000)	Price of cut flower (Tk.)	Gross return (Tk./ha)	Net return (Tk./ha)	Benefit cost ratio
K_0G_0	189560.64	15.17	15170	11	5500	250.3	300360	321030	131469.36	1.69
K_0G_1	192793.94	16.33	16330	17.95	8975	270.3	324360	349665	156871.06	1.81
K_0G_2	198026.06	17.28	17280	18.67	9335	278.6	334320	360935	162908.94	1.82
K_1G_0	194935.522	16.5	16500	17.2	8600	258.6	310320	335420	140484.478	1.72
K_1G_1	197168.822	15.78	15780	19.22	9610	258.3	309960	335350	138181.178	1.70
K_1G_2	205400.942	17.28	17280	22.76	11380	278.3	333960	362620	157219.058	1.77
K_2G_0	198115.404	17.69	17690	22.9	11450	336	403200	432340	234224.596	2.18
K_2G_1	201348.704	18.84	18840	22.6	11300	342	410400	440540	239191.296	2.19
K_2G_2	203080.824	21.72	21720	26.95	13475	350	420000	455195	252114.176	2.24
K_3G_0	197295.64	18.33	18330	20.24	10120	298.6	358320	386770	189474.36	1.96
K_3G_1	202528.94	19.33	19330	22.67	11335	310	372000	402665	200136.06	1.99
K_3G_2	207761.06	20.43	20430	24.46	12230	300	360000	392660	184898.94	1.89

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

K_0: Control: No potassium
K_1: 125 kg K_2O ha^{-1}
K_2: 145 kg K_2O ha^{-1}
K_3: 165 kg K_2O ha^{-1}

G_0: Control
G_1: GA_3 100 ppm
G_2: GA_3 200 ppm

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted at the farm of Sher-e-Bangla Agriculture University, Dhaka to study the effect of GA_3 and potassium on the growth and yield contributing characters of tuberose during the period from April 2013 to March 2014. The experiment included two factors namely. Factor A: levels of Potassium (0, 125, 145, 165 kg/ha) and Factor B: concentration of Gibberellic Acid (0, 100, 120 pmm GA_3). The trail was laid out in a randomized complete block design with three replications. Data were taken on plant height, number of leaves per plant, number of side shoot, number of spike per plant, days required to emergence of spike, diameter of the spike, length of spike at harvest, , weight of the single spike, length of rachis at harvest, number of floret per spike, dry weight of florets (%), dry weight of leaves(%), number of spike per hectare, diameter of single bulb, single bulb weight, diameter of single bulblet, single bulblet weight, bulb yield per hectare and bulblets yield per hectare. The analysis of variance for the characters under study were performed by using least significant difference (LSD) test at 5% and at 1% levels of probability.

The longest (30.4 cm) plant height was found from K_2 (145 kg K_2O) and shortest (22.40 cm) was observed from K_0 at 20 DAP. Similar trend was followed at 40, 60, 80 and 100 days after planting. The highest (15.7) number of leaves per plant at 100 DAP was observed due to the application of 145 kg K_2O/ha. The maximum (2.37) number of side shoot at 90 DAP was observed from K_2. The maximum (17.9) number of spike per plant was recorded from K_2 and minimum (14.2) was obtained from K_0 (control treatment). The longest days (81.6 days) were required to spike emergence from K_0 treatment while the shortest (77.8 days) were recorded for K_2 treatment. The maximum diameter of single spike (0.79 cm) was recorded in K_2 and the minimum (0.70 cm) was recorded in $K_{0.}$. The highest spike length (64 cm) was observed from K_2. On the other hand, the shortest spike (60.70 cm) was recorded from $K_{0.}$ The highest weight of single spike (45.40 g) was recorded from K_2 and K_0 performed the lowest (37.98 g) weight of single spike. The highest length of rachis at harvest (27.70 cm) was recorded from K_2 while, the lowest (25 cm) was recorded from $K_{0.}$ The highest number of florets per spike (43) was performed by K_2 and the lowest (35.00) was found from $K_{0.}$ The highest dry weight of floret (6.56 %) and leaves (9.65 %) was recorded in K_2 and the lowest (4.83%) and (6.53 %) was recorded in $K_{0.}$ The maximum number of spike per hectare (309.10) was recorded from K_2. The highest diameter of single bulb (2.03 cm) was found from K_2 treatment while, lowest (1.75 cm) was observed from K_0 treatment. The highest weight of single bulb (30.40 g) and bulblet (5.50 g) was observed in K_2 and the lowest (25.60 g) and (4.20 g) was found from $K_{0.}$ Maximum diameter of single bulblet (0.95 cm) was found from K_2 (145 kg K_2O ha^{-1}) treatment while, minimum (0.33 cm) was observed from K_0 treatment. The highest yield of bulb (19 t ha^{-1}) and bulblets (4.20 g) was recorded from K_2 treatment.

The longest (23.1cm) plant height was found from 200 ppm GA_3 and shortest (20.4 cm) was observed from control treatment at 20 DAP. Similar trend was followed at 40, 60, 80 and 100 days after planting. The highest (15.8) number of leaves per plant at 100 DAP was observed due to the application of 200 ppm of GA_3. The highest (2.23) number of side shoot at 90 DAP was observed due to application of 200 ppm GA_3. The maximum (17.84) number of spike per plant at 90 DAP was observed from G_2 and minimum (14.04) was obtained from G_0 at same DAP. The highest period (82.9 days) was required for G_0 treatment and the lowest (77.8 days) was observed from G_2 treatment. The highest diameter of single spike (0.77 cm) was recorded in G_2 treatment whereas, the lowest (0.70 cm) was found in G_0 treatment. The maximum spike length (66.50 cm) was recorded from G_2. One the other hand, the minimum spike length (58.30 cm) was recorded from $G_{0.}$ Increases of concentration of GA_3 weight of single spike represent an increasing trend. The highest weight of single spike (46.00 g) was recorded from G_2 and G_0 performed the lowest (38.05 g) weight of single spike. The highest length of rachis at harvest (33.50 cm) was found from G_2 whereas, the lowest (22.51 cm) was found from G_0 treatment. The highest number of florets per spike (41.20) was performed by G_2 and the lowest (32) was recorded from G_0. The highest dry weight of florets (6.34 %) was recorded in G_1 treatment whereas, the lowest (5.42 %) was found in G_0 treatment. The maximum dry weight of leaves (9.83 %) was recorded in G_2 treatment whereas, the minimum (5.72 %) was found in G_0 treatment. The maximum number of spike per hectare (325) was recorded from G_2 while, the minimum (264.50) was recorded from G_0. Highest diameter of single bulb (2.35 cm) was found from G_2 and the lowest (2.10 cm) was observed from G_0. The highest weight of single bulb (31.90 g) was observed in G_2 and the lowest (25.30 g) was found from G_0. The highest diameter of single bulblet (1.10 cm) was found from G_2 and lowest (0.60 cm) was observed from G_0. The highest weight of single bulblet (5 g) was observed in G_2 treatment and the lowest (4 g) was found from G_0. The highest yield of bulb (20.24 t ha^{-1}) was observed from G_2 treatment whereas, the lowest (15.67 t ha^{-1}) was found from G_0 treatment. The highest yield of bulblets (22.94 t ha^{-1}) was found from G_2 treatment (200 ppm GA_3) while the lowest (17.20 t ha^{-1}) was found from G_0.

Significant variation on plant height and number of leaves per plant was observed due to combined effect of GA_3 and different levels of K_2O. The longest plant height (60.73 cm) and highest (28.35) number of leaves per plant at 100 DAP was produced K_2G_2 (200 ppm GA_3 with 145 kg K_2O). The maximum (16.58) number of spike per plant at 90 DAP was found K_2G_2 and the minimum (12.92) was recorded from K_0G_0 at same DAP. The combination effect of potassium and GA_3 showed significant differences on date of emergence of spike. The highest days (84.6 day) were counted for spike emergence the treatment combination of K_0G_0 and the lowest (75.3 days) from K_2G_2. Combined effect of potassium and GA_3 showed significant difference on spike length, weight of single spike, length of rachis and number of florets per spike. The maximum spike length (72.03 cm), weight of single spike (49.83 g), length of rachis (35.57 cm) and number of florets per spike (47.80) was recorded from K_2G_2. The combination effect of potassium and GA_3 showed significant differences on number of spike per hectare, weight of single bulb, single bulb weight and yield of bulb and bulblet. The maximum yield of bulb (21.72 t ha^{-1}) and bulblets (26.95 t ha^{-1}) was recorded from K_2G_2.

Gross return of tuberose ranged from TK 3,21030 in control to TK 4,55,195 in K_2G_2. Total cost of production of tuberose ranged from TK 1,89,560.64 in control to TK 203080.824 in K_2G_2. Net return of tuberose from TK 1,31,469.36 in control to TK 2,52,114.176 in 200 ppm GA_3 with 145 kg K_2O/ha. The highest (2.24) benefit cost ratio was obtained due to the application of 200 ppm GA_3 combined with 145 kg K_2O/ha while the lowest (1.69) in control.

Among various levels of combination of K and GA_3, 145 kg K_2O/ha with 200 ppm GA_3 performed the best result in all observations. So it may be concluded that 145 kg K_2O with 200 ppm GA_3 is the suitable combination for growth, flowering and yield of tuberose.

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 potassium i.e. >145 kg K_2O/ha may be used in the treatments for further study for identify better performance.
3. Higher levels of gibberellic acid i.e. > 200 ppm GA_3 may be used for further study to get better result.

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APPENDICES

Appendix I. Characteristics of Horticulture Farm soil is analyzed by Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka

A. Morphological characteristics of the experimental field

Morphological features	**Characteristics**
Location	Horticulture Garden, SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping Pattern	Fallow- Tuberose

B. Physical and chemical properties of the initial soil

Characteristics	Value
% Sand	27
% Silt	43
% clay	30
Textural class	Silty-clay
pH	6.1
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.077
Available P (ppm)	20.00
Exchangeable K (meq/ 1 00 g soil)	0.10
Available S (ppm)	45

Source : SRDI, 2013

Appendix II. Monthly record of air, temperature, rainfall, relative humidity, soil temperature and sunshine of the experimental site during the period from April 2013 to January 2014

Month	Average air temperature (°C)			Average relative humidity (%)	Total rainfall (mm)	Total sunshine per day (hrs)
	Maximum	Minimum	Mean			
April, 2013	33.7	23.8	28.81	69	185	7.8
May, 2013	36.7	20.3	28.5	70	205	7.7
June, 2013	35.4	22.5	28.95	80	577	4.2
July, 2013	36.0	24.6	30.3	83	563	3.1
August, 2013	36.0	23.6	29.8	81	319	4.0
September, 2013	34.8	24.4	29.6	81	279	4.4
October, 2013	34.8	18.0	26.4	77	227	5.8
November, 2013	29.7	20.1	24.9	65	5	6.4
December, 2013	26.9	15.8	21.35	68	0	7.0
January, 2014	24.6	12.5	18.7	66	0	5.5

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

Appendix III. Analysis of variance of the data on plant height of tuberose as influenced by potassium and GA_3

Source of variation	Degrees of freedom	Mean square				
		Plant height (cm) at				
		20 DAP	40 DAP	60DAP	80 DAP	100 DAP
Replication	2	1.863	2.164	4.224	0.302	0.264
Potassium (A)	3	43.346**	56.761**	95.643**	95.362*	224.794*
Gibberellic acid (B)	2	84.086**	81.107**	128.127**	71.901*	73.655*
Interaction (AxB)	6	3.407**	13.26**	15.03**	11.60*	3.660*
Error	22	0.452	1.61	3.35	4.23	2.752

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

Appendix IV. Analysis of variance of the data on number of leaves per plant of tuberose as influenced by potassium and GA_3

Source of variation	Degrees of freedom	Mean square				
		Number of leaves				
		20 DAP	40 DAP	60DAP	80 DAP	100 DAP
Replication	2	0.005	0.128	0.058	0.269	8.337
Potassium (A)	3	0.429**	0.323**	1.087**	3.480**	771.500*
Gibberellic acid(B)	2	0.794**	3.980**	11.576**	14.424**	149.357*
Interaction (AxB)	6	0.083^NS	1.574**	1.743**	3.694**	10.350*
Error	22	0.055	0.046	0.241	0.505	5.722

* *: Significant at 0.01 level of probability:
*: Significant at 0.05 level of probability
NS: Non-significant

Appendix V. Analysis of variance of the data on number of side shoot per plant of tuberose as influenced by potassium and GA_3

Source of variation	Degrees of freedom	Mean square				
		Number of side shoot				
		30 DAP	45 DAP	60DAP	75 DAP	90 DAP
Replication	2	0.008	0.612	0.401	0.737	0.136
Potassium (A)	3	3.909*	8.810*	12.801*	6.418*	8.048*
Gibberellic acid (B)	2	0.268*	13.934*	9.808*	7.435*	10.310*
Interaction (AxB)	6	0.087^NS	0.679^NS	0.368^NS	0.081^NS	0.252^NS
Error	22	0.185	0.350	0.481	0.522	0.591

*: Significant at 0.05 level of probability
NS: Non-significant

Appendix VI. Analysis of variance of the data on number of spike per plant of tuberose as influenced by potassium and GA_3

Source of variation	Degrees of freedom	Mean square				
		Number of spike per plant				
		30 DAP	45 DAP	60DAP	75 DAP	90 DAP
Replication	2	3.250	2.698	1.234	4.235	7.024
Potassium (A)	3	0.814*	1.884*	2.505*	8.470*	12.705*
Gibberellic acid (B)	2	2.645*	12.540*	7.515*	14.705*	19.729*
Interaction (AxB)	6	2.153^{NS}	4.725^{NS}	15.030^{NS}	13.257^{NS}	8.220^{NS}
Error	22	0.491	2.616	1.660	3.251	1.196

*: Significant at 0.05 level of probability

NS: Non-significant

Appendix VII. Analysis of variance of the data on yield and yield contributing characters of tuberose as influenced by potassium and GA_3.

Source of variation	Degrees of freedom	Mean square					
		Days required to emergence of spike	Diameter of Spike (cm)	Length of spike	Weight of single spike	Length of rachis at harvest	Number of floret per spike
Replication	2	3.934	4.369	0.147	4.369	0.143	0.001
Potassium (A)	3	266.883*	125.561^{NS}	200.952 *	125.561*	61.398**	631.212*
Gibberellic acid (B)	2	430.93*	119.904^{NS}	3.892*	119.904*	47.212*	100.080*
Interaction (AxB)	6	37.58**	19.984^{NS}	10.50*	19.984*	6.758*	6.407*
Error	22	4.153	2.985	5.380	2.985	2.421	4.576

* *: Significant at 0.01 level of probability:

*: Significant at 0.05 level of probability

NS: Non-significant

Appendix VIII. Analysis of variance of the data on dry weight of florets and dry weight of leaves of tuberose as influenced by potassium and GA_3

Source of variation	Degrees of freedom	Mean square	
		Dry weight of florets	Dry weight of leaves
Replication	2	7.122	18.634
Potassium (A)	3	87.778^{NS}	55.902^{NS}
Gibberellic acid (B)	2	58.493^{NS}	64.768^{NS}
Interaction (AxB)	6	3.805^{NS}	25.598^{NS}
Error	22	1.902	2.458

*: Significant at 0.05 level of probability

NS: Non-significant

Appendix IX. Analysis of variance of the data on yield and yield contributing characters of tuberose as influenced by potassium and GA_3

Source of variation	Degrees of freedom	Mean square						
		Number of spike per hectare ('000)	Diameter of single bulb (cm)	single bulb weight (g)	Diameter of single bulblet (cm)	Single bulblet weight (g)	Yield of bulb (t/ha)	Yield of bulblets (t/ha)
Replication	2	10.441	0.020	12.433	0.0001	0.001	0.07	0.084
Potassium (A)	3	41.6032*	1.305*	285.135 *	0.082*	0.041*	18.12*	24.583*
Gibberellic acid (B)	2	75.00*	0.081*	34.395*	0.034*	0.026*	0.33*	25.527*
Interaction (AxB)	6	37.05**	0.003^{NS}	0.641**	0.008^{NS}	0.007*	21.103*	17.441*
Error	22	2.251	0.006	2.839	0.003	0.002	3.360	4.476

* *: Significant at 0.01 level of probability:

*: Significant at 0.05 level of probability

NS: Non-significant

Appendix X. Production cost of Tuberose per hectare

A. Input cost

Treatment combination	Labor cost	Ploughing cost	Bulb cost	Irrigation cost	Manure and fertilizers				GA_3	Miscelloneous Cost	Subtotal (A)
					Cowdung	Urea	TSP	K_2O (as MP)			
K_0G_0	15000	5000	50288	3000	5000	1560	3000	0	0	10000	92848
K_0G_1	15000	5000	50288	3000	5000	1560	3000	0	4435	10000	97283
K_0G_2	15000	5000	50288	3000	5000	1560	3000	0	8869	10000	101717
K_1G_0	15000	5000	50288	3000	5000	1560	3000	6249.9	0	10000	99098
K_1G_1	15000	5000	50288	3000	5000	1560	3000	6249.9	4435	10000	103533
K_1G_2	15000	5000	50288	3000	5000	1560	3000	6249.9	8869	10000	107967
K_2G_0	15000	5000	50288	3000	5000	1560	3000	7249.8	0	10000	100098
K_2G_1	15000	5000	50288	3000	5000	1560	3000	7249.8	4435	10000	104533
K_2G_2	15000	5000	50288	3000	5000	1560	3000	7249.8	8869	10000	108967
K_3G_0	15000	5000	50288	3000	5000	1560	3000	8250	0	10000	101098
K_3G_1	15000	5000	50288	3000	5000	1560	3000	8250	4435	10000	105533
K_3G_2	15000	5000	50288	3000	5000	1560	3000	8250	8869	10000	109967

Labor 250 @ Tk. 60/Capita/Day
Bullock 50 pairs @ Tk. 100/Pair/Day

Cowdung 5 ton @ Tk. 1000/ton
Urea 260 Kg @ Tk. 6/kg
TSP 200 Kg @ Tk. 15/kg
MP 200 Kg @ Tk. 12/kg
GA_3 @ Tk. 500/g

B. Overhead Cost

Treatment combination	Cost of lease of land for 6 months (13% of value of land Tk. 6,00,000/year)	Miscellaneous Cost (Tk. 5% of the input cost)	Interest on running capital for 6 months (Tk. 13% of the cost/year)	Subtotal (Tk) (B)	Total cost of production (Tk/ha) (A+B)
K_0G_0	78000	5242.4	13470.24	96712.64	189560.6
K_0G_1	78000	4864.15	12646.79	95510.94	192793.9
K_0G_2	78000	5085.85	13223.21	96309.06	198026.1
K_1G_0	78000	4954.895	12882.73	95837.62	194935.5
K_1G_1	78000	4276.645	11359.28	93635.92	197168.8
K_1G_2	78000	5398.345	14035.7	97434.04	205400.9
K_2G_0	78000	5604.89	14412.71	98017.6	198115.4
K_2G_1	78000	5226.64	13589.26	96815.9	201348.7
K_2G_2	78000	4448.34	11665.68	94114.02	203080.8
K_3G_0	78000	5054.9	13142.74	96197.64	197295.6
K_3G_1	78000	5276.65	13719.29	96995.94	202528.9
K_3G_2	78000	5498.35	14295.71	97794.06	207761.1

Appendix XI. Agro-Ecological Zone of Bangladesh