GROWTH, FLOWERING AND YIELD OF BULB OF TUBEROSE AS INFLUENCED BY POTASSIUM AND GIBBERELLIC ACID

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Dedicated to

My

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CERTIFICATE

*This is to certify that the thesis entitled "**GROWTH, FLOWERING AND YIELD OF BULB OF TUBEROSE AS INFLUENCED BY POTASSIUM AND GIBBERELLIC ACID**" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE (MS) in HORTICULTURE, embodies the results of a piece of bona fide research work carried out by **FARJANA NIPA, Registration No. 17-08309** under my supervision and guidance. No part of this 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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ABSTRACT

An experiment was conducted at Horticulture Farm of Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla Nagar, Dhaka-1207 during the period from August, 2017 to October, 2018 to find out the effect of potassium and Gibberellic Acid (GA_3) on growth, flowering and yield of bulb of tuberose. The experiment consisted of two factors namely. Factor A: levels of Potassium (K_0= Control; 0 kg K_2O /ha, K_1 = 130 kg K_2O/ha, K_2 = 150 kg K_2O/ha, K_3 = 170 kg K_2O/ha) and Factor B: Concentration of Gibberellic Acid (G_0 = Control, G_1 = 120 ppm, G_2 = 150 ppm) with three replications. The experiment was laid out in Randomized Complete Block Design (RCBD). At 75 days the maximum plant height, number of leaves per plant, number of spike per plant and side shoot per plant 63.50 cm, 10.22, 16.09 and 1.90 was found from K_2 (150 kg K_2O/ha) respectively and also 62.55 cm, 9.16, 12.67 and 1.45 was found from G_1 (120 ppm) respectively that was significantly influenced due to the effect of potassium and Gibberellic Acid (GA_3). The highest number of floret per spike 43.00 and 38.93 were found from K_2 (150 kg K_2O/ha) and G_1 (120 ppm) respectively. The highest yield of bulb (18.86 t/ha) and bulblets (20.70 t/ha) was found from K_2 (150 kg K_2O/ha) and the lowest from K_0 (control, 0 kg K_2O/ha). On the other hand the highest yield of bulb (17.21 t/ha) and bulblets (17.86 t/ha) was obtained from G_1 (120 ppm) and the lowest from G_0 (control). In respect of combined effect, K_2G_1 produced maximum yield of bulb (19.36 t/ha) and bulblets (21.99 t/ha) and the lowest from K_0G_0. So the present investigation exhibits that, combined effect of 150 kg K_2O/ha with 120 ppm GA_3 is suitable for growth, flowering and yield of bulb of tuberose.

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ABBREVIATIONS AND ACRONYMS

The following abbreviations were used throughout this thesis:

ANOVA :	Analysis of Variance
LSD :	Least Significant Difference
DMRT :	Duncan's Multiple Range Test
Cont'd. :	Continued
RCBD :	Randomized Complete Block Design
CV :	Coefficient of Variation
Wt. :	Weight
% :	Percentage
e.g. :	*Exempli gratia* (by way of example)
Et al. :	And others
g :	Gram
i.e. :	*Edest* (means that is)
AEZ :	Agro-ecological Zone
SRDI :	Soil Resources Development Institute
DAP :	Days After Planting
Kg :	Kilogram

CHAPTER I

INTRODUCTION

Tuberose (*Polianthes tuberosa* L.) is one of the most important ornamental bulbous flowering plants cultivated for production of long lasting flower spikes. It is popularly known as Rajanigandha or Nishigandha. Tuberose is one of the most popular bulbous ornamental plants of tropical and sub-tropical areas in the family Amaryllidaceae, produces attractive, elegant and fragrant white flowers. The flowers having excellent keeping quality and are widely used as cut flowers. The flowers remain fresh for quite a long time and stand long distance transportation and fill a useful place in the flower market (Patel *et al.,* 2006). It is used as vase decoration, bouquets, making veni, garland, button-holes or crown and frequently used during marriage or religious ceremonies (Randhawa and Mukhopadhyay, 1986). The long flower spikes of tuberose are excellent as cut flowers for table decoration when arranged in bowls and vases. The flowers emit a delightful fragrance and are the source of tuberose oil. The natural flower oil of tuberose remains today as one of the most expensive of the perfumes raw materials.

Tuberose is a native of Mexico from where it spreads to the different parts of the world during 16 century. Now a day, it is cultivated on large scale in France, Italy, South Africa, USA, and in many tropical and subtropical areas, including India and Bangladesh. It is cultivated on a large scale in India and its commercial importance is mainly confined to Karnataka, Uttar Pradesh, West Bengal, Tamil Nadu, Maharashtra, Andhra Pradesh, Gujarat, Haryana, Punjab and Delhi including low mid hill areas of Himachal Pradesh, Uttrakhand and Jammu & Kashmir. In India, about 3500 ha area is under bulbous ornamentals and out of this 800 ha area is under tuberose cultivation (Desh Raj, 2011). The statistics shows that the area and production of flowers in Bangladesh during 2008-09 were 520.64 ha and 4308 MT, respectively (BBS, 2008). How and when the tuberose found its entrance to India, Ceylon and elsewhere in the orient is probably an unanswerable question (Yadav *et al*., 1982). In Bangladesh, for the last few years, tuberose has become a popular cutflower for its attractive fragrance and beautiful display in the vase. In Bangladesh, its commercial cultivation was introduced during 1980 by some pioneer and innovative farmers at Panishara union of Jhikorgacha thana under Jessore district near the Benapol border.

Although tuberose is now grown in the country, very little is known about production technology in Bangladesh condition. In Bangladesh, for the last few years, tuberose has become a popular cut flower for its attractive fragrance and beautiful display in the vase. Now, it is one of the most important commercial cut flowers. Tuberose has high demand in the market and its production is highly profitable. Although tuberose is now grown in the country, very little is known about production technology in Bangladesh condition. Tuberose is a half-hardy bulbus perennial multiplying itself through the bulblets. Roots are mainly adventitious and shallow, the leaves are long, narrow, linear grass like, green and arise in rosette, the flowers have a funnel shaped perianth, waxy white in color and borne in a spike. There are three types of tuberose: single with one row of corolla segments, semi-double bearing flowers with two to three rows of corolla segments and double having more than three rows of corolla segments.

Tuberose is known to be thermo photo sensitive crop and grown in Bangladesh all the year round. The role of mulching is well known on the growth and production of plants. Its vegetative growth, flower and bulb development are greatly influenced by growing environment. Due to long growing period it requires several irrigations. The increased production of quality flowers and bulbs plant is the main objective to be reckoned in commercial flower production of tuberose. Though, the quality of cut flowers is primarily a varietal trait, but is greatly influenced by climatic, geographical and nutritional factors among which the nutrition plays a very crucial role. The nutritional requirements of tuberose vary with the prevailing climatic conditions and soil types besides the availability of nutrients in the soil. The information regarding nutrition of tuberose is very scanty and exhibited wide variation in terms of quantity of nutrients to be applied for different tuberose growing areas (Singh *et al*., 1995; Singh *et al*., 1976; Yadav *et al*., 1985).

The tuberose is a voracious feeder of NPK and responds well to the organic and inorganic nutrient application particularly nitrogenous fertilizers (Sadhu and Bose, 1973). Among the major nutrients required for the optimum growth, development and flowering of tuberose, nitrogen (N) has greater influence right from cell division to the development of vegetative and reproductive organs. It is an integral component of nucleic acids, proteins, protoplasm and chlorophyll.

It is one of the most mobile of all the mineral nutrients absorbed by the plants. Nitrogen has significant effect on bulb production of tuberose. It also increases plant height, number of leaves, spike per hill, earlier flowering and higher number of flowers per spike (Mukhopahyay and Banker, 1986; Roy, 1992). Phosphorus has a significant effect on spike production and floret quality (Jana et al, 1974; Banker and Mukhopadhyay, 1985). Potash appears to help increasing the number of spike, flower per spike and number of flowers per hill (Cirrito, 1975; Singh *et al*., 1976). In determining the yields of flower crops, phosphorus (P) is also one of the major and crucial limiting factors. Thus, it has been called as "the key to life" because it is directly involved in most life processes. It is an essential part of many sugar phosphates involved in photosynthesis, respiration and other metabolic processes.

Deficiency of phosphorus may adversely affect the plant in maintaining the full supply of N and K and excess application of P may result in various nutritional problems including Ca and Zn deficiency. Application of certain growth substance has been found to influence the growth and flowering of tuberose (Bose and Yadav, 1989). Mukhopadhyay and Banker (1986) 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 used earliest flowering and gave the highest yield of spikes and flowers. In Bangladesh, a few studies have been done regarding use of growth regulators and fertilizers ensure better yield 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 facts, the present investigations were undertaken with the following objectives:

i. to find out the optimum level of Potassium for maximum growth, flowering, bulb production and higher yield of tuberose.

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

iii. to find out the suitable combination of Potassium and GA_3 for ensuring the growth, flowering, bulb production and higher yield of tuberose.

CHAPTER II

REVIEW OF LITERATURE

Tuberose was referred to as "omixochitl", meaning bone white flower. The Spaniards described it as pleasing odor, fragrant, sweet (Trueblood, 1973). Fifteen species of *Polianthes* have been discovered in Mexico with flower colour in white, orange-red, red or striped (Barba-Gonzalez, *et al*., 2012; Sheela, 2008). Tuberose was discovered in the 16th century by the early Spaniards who had traveled to Mexico to document plants of medicinal interest. Trueblood (1973) reviewed the ethno botanical data in the Aztec Nahuatl language. The development of new cultivars has not been very successful. There are three types tuberose: single semi –double and double but only the single and double are cultivated, both of them have white flowers (Sheela, 2008). These two varieties single and double have flowers with white petals. In India where it an important flower for cultural festivities a variety of colours are obtained by use of colouring agents to induce colours such as red, scarlet, rose to yellow (Sambandamurthi, and Appavu, 1980). Other efforts to diversify tuberose colours were by irradiation but no colour mutation of flower has been possible (Abraham and Desai, 1976). The flower is used by florists in bouquets as accents, corsages and boutonnieres. It is an important flower whose fresh petals when processed produce an essential oil that is used in the preparation of high-grade perfumes and cosmetics (Trueblood, 1973; Asif *et al*., 2001).

Tuberose is grown in the tropical and subtropical areas as a cut flower and for fragrance (Benschop, 1993; Huang *et al.*, 2001). The crop is a day neutral bulbous perennial and grows well in the field at a temperature range of 20 - 30°C with no shading or plant support (Anon, 2001; 2004; Watako, 2005). Tuberose is vegetative propagated and bulbs are commercially used with tissue culture being experimented within Kenya (Hutchinson *et al*., 2004). Flowering performance of tuberose has been demonstrated to vary according to the temperature regime (Watako, 2005). Nutrition studies show that 42.5 kg N ha^{-1} was optimum for good quality cut flowers (Ngamau, 1992). The quality of tuberose cut flowers grown in Kenya by smallholder farmers remains low (Muriithi *et al*., 2011).

Double tuberose varieties acquire a reddish pink colour on the outer florets preferred by the consumers (Huang *et al*., 2001 a, b).

Tuberose (*Polianthes tuberosa* L.) is one of the most popular cut flower of the world as well as Bangladesh and received much attention to the researchers of different countries including Bangladesh. Like many other cut flowers; the growth, bulb and flower yield of tuberose are influenced by bulb size and potassium fertilizer and GA_3. A number of factors like temperature, soil moisture are involved with the absorption of potassium fertilizer and bulb emergence which ultimately influence the growth and yield of a crop. Bulb of tuberose is also known to be a heavy absorber of soil moisture as well as potassium fertilizer. There is a little or no combined research work to the effect of bulb size and potassium and also GA_3 on growth and yield of bulb and flower in Bangladesh.

2.1 Botanical classification

Tuberose is half-hardy, herbaceous perennial, bulbous plant. It is classed as a monocotyledon, leaves often lighter green in colour. It is an erect herb, 60-120 cm high with stout and short bulbs. Tuberose is classified in the Agavaceae family the genus Polianthes (Hutchinson, 1959; Trueblood, 1973; Barba-Gonzalez *et al*., 2012). However some taxonomists (Shah and Gopal, 1970) placed it in the Amaryllidaceae family supported with cytological studies of shared characteristics in vegetative and floral organs. The Agavaceae family is characterized by a rosette of basal leaves, flowers on a raceme or panicle with bracts along its length subtending the flowers. The petals are nearly free, generally being joined at the base (Hutchinson, 1959; Barba-Gonzalez *et al*., 2012).

Polianthes tuberosa Linn. is the only species cultivated as an ornamental cut flower in tropical and subtropical areas. Bulbs are made of scales and leaf bases and stem remains concealed within scales. Fibrous roots are mainly adventitious and shallow. Leaves are basal, 6-9 in number, 30-45 cm long, about 1.3 cm wide, linear, grass like foliage, bright green, reddish near the base. The foliage is narrow at the base and wider at the top and is arranged in a rosette at the base. Tuberose inflorescences (spikes) bear 25 ± 10 pairs of florets which open acropetally (i.e., from base to top of the spike). Tuberose is a cross pollinated crop.

Polianthes genus contains three types of flowers. One of them is single flower type having basic chromosome number n = x = 30 and 2n = 60, which is female fertile used in perfumery industry and breeding programme as female parent. The other two are semi -double and double flower types and generally used as cut flower. The flower colour of all known cultivars of *Polianthes tuberosa* is white; however, many attempts have been made to introduce colours from related species (*Polianthes* has 15 species all from Mexico). Most of the species have white flowers except P. geminiflora with reddish orangen and *P.howardi* purple and *P. densiflora* yellow (Rocha *et al*., 2006; Barba Gonzalez *et al*., 2012). *Polianthes* is characterized by twin flowers, which arise from a single bract along the flower spike. There are three types of tuberose: single, semi–double and double.

The single have one row of corolla segments shown in semi double‘with two to three rows of corolla segments and refers to a flower having the outermost stamens converted into petals; while double which is also referred to as the 'Pearl Double', has four rows of corolla, the inner ones remain perfect, while double-flower forms often arise when some or all of the stamens in a flower are replaced by petals (Barba-Gonzalez, *et al*., 2012). This mainly arises from mutations, where one organ in a developing organism is replaced with another, generally known as homeotic mutations. In Kenya, the double and semi double varieties are grown without market preference.

2.2 Tuberose cultivation

Tuberose is a bulbous perennial that grows well in open fields with temperatures ranging from 20–30°C (Huang *et al*., 2001); it requires neither shading nor plant support structures. Tuberose does well in altitude between 1200 and 1800 metres above sea level. The major production areas in Kenya are Limuru and Maragua (Anon, 2000; Muriithi *et al*., 2011). Tuberose grows well in loam and sandy loam with a soil pH range of 6.5 to 7.5 (Asif *et al*., 2001; Singh, 2006). Commercial propagation is mainly by bulbs (Singh, 2006). However, efforts to propagate using tissue culture have been undertaken extensively using various explants such as: the bulb scale (Nazneen *et al*., 2003; Mishra *et al*., 2006), stem disc (Gajbhiye *et al*., 2011), shoot tips (Hutchinson *et al*, 2004), and rhizome (Sangavai and Chellapandi, 2008). The stage for harvest is related to the number of opened florets showing sufficient accumulation of carbohydrates that enhance petal opening after harvesting (Varu and Barad, 2010). Cut flowers are graded based on length of the spike, the longer the spike the longer the vase life (Anon 2001). Tuberose evolves minimum endogenous ethylene and the use of ethylene synthesis and receptor inhibitors such silver thiosulphate (STS) do not delay flower senescence of *P. tuberosa* (Waithaka *et al.,* 2001; Abbasi and Hassanpour, 2011). However, preservative solutions consisting of gibberellic acid (GA_3) at 40ppm (Abbasi and Hassanpour, 2011) or citric acid in the form of hydroxy quinine citrate (8-HQC) at 250ppm and 2% sucrose (Waithaka *et al.,* 2001) have been shown to increase vase life. Tuberose florets were not sensitive to ethylene exposure. From the survey, tuberose growers harvest and transport immediately to the market, they do not use preservatives (Muriithi *et al*., 2011). Harvesting of tuberose bulbs is done when the older leaves dry, plant growth ceases and bulbs are almost dry.

Bulbs are harvested 18–24 months after planting. Planting varies according to temperatures experienced during the growth period (Anon, 2001). The distribution, production and quality characteristics of tuberose in Kenya were established in this study. Areas of concern in production include: provision of good quality, adequate and affordable planting material; employing appropriate crop production management practices such as the use of recommended inputs, control of pests and diseases; postharvest handling and access to markets.

The survey looked at all links in the tuberose value chain thus these findings bring out the gaps that need intervention. For example, it was clear that smallholder growers lack a system for producing and bulking high-quality planting material to satisfy the needs of commercialized farmers. There was also inability by smallholder farmers to access high-quality planting material because of high costs a fact which led to most farmers accessing them from their neighbors. Currently, there is need for certification and a regulatory provision for tuberose bulbs to curb widespread distribution of poor quality material which contribute to the dissemination of pests. Further, there is need for germplasm conservation and production of certified clean planting material which is the basis for good quality cut flowers (Muriithi *et al*., 2011). Other interventions require building capacity of farmers in sorting and grading, packaging, postharvest handling, and marketing.

Some of the data adduced from this study may be used towards the formulation of the floriculture policy. The cause of decline in tuberose export volumes was due to high rejections of poor quality cut flowers. Low productivity can be attributed to poor quality bulbs infested with nematodes. Abandonment of tuberose enterprises was in areas with other flower choices caused in the reduction of tuberose acreage (Muriithi *et al*., 2011).

2.3 Effect of growth regulator (GA_3) on the growth, flowering and higher yield of bulb production of tuberose

Nejad and Etemadi (2010) conducted a study to evaluate the effects of Gibberellic acid (GA3) on flower quality and flowering date of tuberose (*Polianthes tuberosa*). Double cultivar tuberose bulbs, ranging from 6 to 7 cm in diameter used. GA_3 solutions were used 100, 200 and 300 ppm. At two stages of plant development the bulbs were soaked before cultivation and bud sprouts were sprayed with GA_3 solutions. GA_3 application methods did not show any significant differences on the evaluated characters, while significant variations were observed among various GA_3 concentrations. Comparing with the date of flowering harvest indicated that the highest number of flowers was picked 3 to 4 weeks after flowering for both GA_3 application methods. Soaking the bulbs before cultivation, application of GA_3 (300 ppm) increased significantly the number of flowering shoots and flowering time.

Asil *et al*. (2011) reported that the effect of different chemical treatments on quantitative characteristics of *Polianthes tuberosa* L. (cv. Goldorosht Mahallat) was investigated. A factorial experiment based on Randomized Block design with 3 replications was conducted in this research. The flowers were sprayed with various concentration of Gibberellic acid (GA_3) and Benzyladenine (BA) (0, 50 and 100 ppm) at 40 and 50 days after planting. The results indicated that flowering, stem length and leaves length were greatest with GA_3 at 100 ppm while BA had no increased 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 field experiment was trial 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, 100 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 better in inducing early spike emergence, first floret opening and also produced maximum number of spikes/m^2. However, cv. Kalyani Double gave maximum number of florets and spike length and flowering duration. Among various treatment, GA_3 (150 ppm) was performed 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, was increased significantly with the application GA_3 (100 ppm).

Maximum days to withering of first opened floret and flowering duration were trial with Kinetin (150 ppm). However, Ethrel (300 ppm) showed delayed flowering, maximum flowering duration and reduced length of spike characters. Jitendra *et al.*, (2009) to observe the effect of vitalizer (GA_3) and nitrogenous fertilizer (urea) on growth and floral parameters in tuberose cv. Pearl Double. The experiment was trial 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, which was replicated three times and laid out in factorial randomized block design. The finding 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) observed the effects of gibberellic acid (GA_3; 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 which increased plant height, number of leaves, number of shoots and leaf area. Paclobutrazol and maleic hydrazide decreased plant height, number of leaves, leaf area and spike length. Early flowering was found by 150 ppm GA_3, 1500 ppm maleic hydrazide and 1500 ppm paclobutrazol. Plant treated with 150 ppm GA_3 showed 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 spike yield per hectare was increased in the concentration of the growth regulators. Padaganur *et al*. (2005) reported that the effect of bulb size (<2, 2-3, and 3 cm, corresponding to small, medium and large bulbs) and pretreatment of bulbs with CCC (chlormequat) and GA_3 (gibberellic acid) on the yield of *Polianthes tuberosa* were studied in Bakewar, Etawah, Uttar Pradesh, India. The maximum 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) trialed a field experiment during 1996/97 at Pune, Maharashtra, Indiamto evaluate the effects of GA_3 (100, 150 and 200 ppm) and CCC (chlormequat) (100, 200 and 300 ppm) on tuberose cv. Single. Foliar spraying of the growth regulators which was performed at 40, 55 and 70 days after planting. Data were collected 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 higher to the control (water spray), with GA_3 at 150 ppm and CCC at 200 ppm sprays giving optimum growth and earliest flowering. An experiment was conducted by Singh (2003) in Meerut, Uttar Pradesh, India during 1997-98 on tuberose (*Polianthes tuberosa* L) cv. Double. The treatments made 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 best 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 maximum in bulbs dipped and sprayed with 100 ppm GA_3 at 100 ppm (dipping + spraying) increased the number (28.4), weight (90.52 gm), diameter (4.20 cm) and yield (305.25 g/ha) of tuberose. Manisha *et al*. (2002) observed tuberose (*P. tuberosa* 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 increased the height of the plants and increased the number of leaves/plant, being highest (55.50 cm 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 recorded with this treatment. GA_3 at all concentration significantly trend increased the number of spike/plant, number of flowers/spike and yield/ha. All these characters were the biggest in plants applied with GA_3 at 150 ppm.

Nagar and Saraf (2002) trial 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. tuberosa* cv. Double) in Alexandria, Egypt during the summer seasons of 2000 and 2001. After planting roots are soaked in GA_3 for 24 months twice within the following 42 days. The application of 200 mg GA_3 /litre + 30 kg N/faddan which 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 best average floret dry weight (4.47 gm) was obtained with 300 mg GA_3 /litre + 550 kg N/Feddan. In the contribution ratio of soil N decreased with increasing N fertilizer rate but increased with increasing GA_3 rate. Tiwari and Singh (2002), trial an experiment to identify the effects of bulb size, i.e. large (>1.5 cm diameter), medium (1.0-1.5 cm), and small (<1.00 cm), 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 increased 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 which showed significant increase in growth flowering and bulb production. Wankhede *et al*. (2002) observed 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 showed that higher concentration of GA_3 (150 ppm) for bulb soaking treatment and 200 ppm of GA_3 as a foliar spray indicated 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 observed 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. tuberosa* before planting soaked bulbs with GA_3 (40 and 80 ml/litre) at 40 C for 30 days or at 300 C for 15 days. Bulbs which were planted in October, November and December. The tubers that treated with low temperature and planted in October had high spouting rates.

The low temperature that combined with gibberellic acid increased the flowering rate. The highest flowering rate which was over 95% with an average of 62%. Dalal *et al*. (1999) observed 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 better N application rate was 70 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 30.93 cm, 91.06 cm, 106.14 gm/plan and 12.94 days, respectively. The interaction between N and GA_3 that was significant only in respect of weight of flowers per plant.

An experiment was conducted by Devendanam *et al*. (2007) to observe 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 which was conducted at 30, 60 and 90 days after planting. GA_3 at 150 ppm which gave the earliest number of days required for spike emergence (43.48) and longest vase life (11.35 days). Further, GA_3 gave highest spike length (6.65 cm) and floret diameter (3.88 cm). Singh (1999) noted the effects of gibberellic acid (GA_3 at 100 and 200 ppm), ethephon (200 and 400 ppm) and kinetin (50 and 100 ppm) on the growth, flowering and yield of tuberose (*Polianthes tuberosa*) cv. Double were investigated in Medziphema, Nagaland, India during 1998. The plant growth regulators that were applied as foliar sprays 40 days after planting. The second application which was conducted 3 weeks after the initial spraying. All growth regulators increased 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 that 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) which were highest in plants treated with 100 ppm kinetin. Plants treated with ethephon (400 ppm) showed the earliest flowering (117 days).

Singh and Manoj (1999) observed an experiment in Meerut, Uttar Pradesh, India during 1997-98 on tuberose (*Polianthes tuberosa*) cv. Double. The treatments made 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 and spraying with 100 ppm GA_3 at 30 days after planting. Spike length and rachis length were also best in bulbs dipped and sprayed with 100 ppm GA_3 at 100 ppm (dipping + spraying) increased the number (28.4), weight (90.52 g), diameter (4.20 cm) and yield (305.25 g/ha) of tuberose. Nagaraja *et al*. (1999) trialed 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 which 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 that 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 which 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 ether and all BA treatments decreased bulb number. Preeti *et al*. (1997) conducted a field experiment during 1993-94 at Biswanath college of Agriculture, Sonitpur, Assam, India, to study the effects of preplanting treatment of bulbs of *P. tuberosa* 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 increased the number of flower spikes, but reduced the number of bulbs production/plant. Ethrel-treated plants gave a mixed response; flower production trended to decrease with increasing concentration of Ethrel. Treatment with GA_3 at 200 ppm produced the maximum 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 maximum (2.15 g) and largest (6.42 cm diameter) flowers. Nagaraja *et al*. (1999) observed a field experiment during 1991, to study the effect of soaking the bulbs rhizomes for 24 h in gibberellic acid (0, 10, 20 or 12 40 ppm) followed by N fertilizer treatment (0, 50, 60 or 70 kg/ha) in the field. N at 70 kg/ha which produced the maximum number of rachises/ha (132444), flowers/stalk (40.65) and flower yield (63.1 q/ha). Gibberellic acid soak at 45 ppm with 70 kg N/ha was good combination yielding 163555 rachis/ha, 50.6 flowers/stalk and 81.77 q flowers/ha. The number of flowers/stalk and flower yield, there was a distinct positive interaction between gibberellic acid and nitrogen.

Leena *et al*. (1992) conducted 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 showed the greatest plant growth and earliest flowering. The greatest flower spike length, rachis length and number of floret/spike were found from the 50 ppm GA_3 treatment. The greatest corm weight (70.20 g) and size (71.00 cm^2) were found from the 100 ppm NAA treatment. The greatest number and weight of cormels (93.33 and 17.57 g, respectively) were found from 500 ppm CCC treatment. Dhua *et al*. (1987) also 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 4-100C for 10-30 days and soaking in GA_3 (200 mg/L) or thiourea (2000 mg/L) solution for 6 hours that improved plant growth and increased the yield of spikes and flower spikes and improved flower quality. Super star resulted in high number of flowers and longer stems which are the important characters of a good cut flower. According to Biswas *et al*. (1983) the maximum 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) reported that 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 that increasing concentration reduced the plant height. GA_3 which 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) observed 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) trialed 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 which increased the stalk length. Pathak *et al.* (1980) found that soaking of bulb in GA_3, ethrel, kinetin and thiourea solutions before planting that 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 that 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 increase the growth and flowering of tuberose. Soaking of sprouting bulbs for 1 hour in solution of 100 ppm GA_3 or 400 ppm CCC in the flowering by 17 and 15 days respectively. El-shafie (1978) showed that spraying of GA_3 on rose four (4) times at monthly intervals at 250 ppm on cv. Montezuma which increased the number of flower and the length, thickness of flower stems compared to other concentration (50, 100, 150 and 200 ppm). Rees (1975) reported 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. The movement of organic metabolites in establishing they play a major role.

2.4 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 period 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 dose of 10 t/ha cowdung. The authors noted that application of NPK significantly influenced the growth, flowering and flower quality of tuberose.

Except plant height all the parameters were the highest with 200 kg N, 45 kg P and 80 kg K/ha along with 10 t/ha cowdung. Singh *et al.* (2001) observed the effect of varying levels of N (10, 20 and 30g/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 tuberosa*) cv. Single at Faizabad, Uttar Pradesh, India. The authors noted 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 studied 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 showed the highest plant height, leaf number and spike length. However spray of N, P_2O_5 and K_2O at 20, 15 and 20 g/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 increased plant height and leaf number in ratoon crop. The spike production which was highest with N, P_2O_5 and K_2O at 20, 15 and 15 g/m^2, respectively, for ratoon crop. Thus, spraying of N, P_2O_5 and K_2O at 15, 15 and 20/m^2, respectively for ratoon crop recommended producing good quality plant and improving yield of flower spike in the plains of West Bengal. The experiment was carried out by Rajiv and Misra (2003) to observe the effects of nitrogens (0, 20 40, 60 or 80 g/m2), 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 highest 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 showed 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 (80 g/m^2) showed maximum corms per plant (1.8), corm size (5.3 cm), corm weight (44.8 gm), cormel weight (5.0 gm), 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 investigated. The N, P and K contents of leaves significantly improved with the increase in rate of N, P and K fertilizers, respectively. Leaf P and K concentrations lower with increasing N fertilizer rate. N, P and K contents in leaves were higher than those in bulbs (rhizomes). Bulb N improved with increasing rates of all fertilizers. Bulb P content also increased with increasing rates of all fertilizers. (Sing *et al*., 2001). Singh and Sangama (2000) observed 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+100 kg K_2O /ha (F3), and 325 kg N + 125 kg P_2O_5+ 125 kg K_2O /ha (F4).

The authors noted 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) observed 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 maximum flower and spike yields (7.86 t/ha, 3.33 spikes/ha, respectively) and plant growth (43.72 cm). Amarjeet and Godara (1998) conducted an experiment 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 improved the number of leaves per plant and plant height significantly. Increasing rates of N and P decreased 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 test in Navsari, Gujarat, India , in 1992-95 with *Polianthes tuberosa* (cv. Double) grown for cut flower. Neither plant height nor leaf width was reponsed by the different fertilizer treatments. Leaf number was maximum with highest NPK fertilizer rate. Flower spike length and the number of florets/spike were maximum with the highest NPK rate.

An experiment was observed 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 improved to 60 g/m. Bulb production was also highest 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 reposed on bulb yield. Amarjeet *et al*. (1996) observed 5 rates of N (0, 100, 200, 300 and 400kg/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 maximum 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 which 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) studied on *Polianthes tuberosa* cv. Single plants were supplied with 50, 75, 100 or 125 kg N/ha, 25, 50, 75 kg P/ha and 37.5, 62.5 or 87.5 kg k/ha.

The highest plant height (58.93 cm) was obtained with the 125 kg N + 50 P kg/ha + 62.5 kg K/ha treatment combination. The maximum 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) studied 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) conducted 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_20_5 and K_2O and half the N were sprayed 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 was significantly influenced the number of days required for flower spike emergence. Increasing P and K_2O rates resulted in maximum 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) which were obtained with 200 kg N + 75 kg P_20_5 + 125 kg K_2O /ha. Parthiban *et al*. (1992) conducted an experiment aimed at determining the fertilizer requirements of Polianthes tuberosa cv. Single. N was sprayed 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 found the highest number of spikes/plant (1.72), number of flowers/spike (39.67) and the highest flower yield (3578.6 kg/ha). Bankar *et al. (*1985) investigated in 2-year field trials, plants received N at 0, 5, 10, 15 or 20 g/m, and P_2O_5 and K_2O each at 0, 20 or 40 g, giving 45 treatments altogether. Data are recorded on plant height number of leaves /plant , days to spike emergence, number of spikes/plant, spike length, rachis length, number of spikes/plant, number of flowers/spike, duration of flowering, and number and weight of bulb/plant.

P and K increased vegetative growth, flowering and bulb production in the first year. P and K improved spike number, rachis length and duration of flowering only in the second year (the ratoon crop). The optimum fertilizer application rate was found as 15g N + 40g P_2O_5 + 40 g K_2O /m^2. To investigated 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 because of application N and K. Mukhopadhyay *et al*. (1986) studied nutritional requirement of tuberose cv. Single in a trail in two years. The plants growing on 2 m × 1 m plots which 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) observed 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. This value showed positive interaction and maximum bulblet production was recorded in the treatment comprising 20 g P_2O_5 and 40 g K_2O/m^2. In the case of bulblets production, phosphorus and potassium bulbs and bulblets were also heavier than those under control.

Apparently P and K fertilization had no appreciable effect on bulb yield, *Polianthes tuberosa* cv. "Single" to high rate 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 advantage effect on all of the parameters studied whereas P had a significant effect on floret quality only. K had no appreciable effect. Banker et al. (1985) studied a response of *Polianthes tuberosa* cv. "Single" to high doses of NPK. N, P_2O_5 and /or K_2O were applied at plant and floral characteristics were assessed. N had a significantly advantage effect on all of the parameters studied whereas 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. Nazneen *et al.* (2003) observed 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 that low in potassium. In an alkaline and nitrogen lacking's 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. Parthiban *et al.* (1992) noted full dose of P_2O_5 and K_2O and half dose of nitrogen are to be applied as basal dressing, while the remaining half dose of N is to be applied 20 days after planting. Singh *et al*. (1976) noted 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 that are good. India conditions to have an optimum flower yield. According to them potash increased the yield of fresh flowers through improving 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 improved 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 present research work was conducted at the Horticulture Farm, Department of Horticulture, Sher-e-Bangla Agricultural University (SAU), Dhaka during August, 2017 to October, 2018. The location of the experiment, materials used and methods followed in different operations during the experiment as well as in data collection are described here under the following sub- heads:

3.1 Experimental site

The site is situated between 23°74' N latitude and 90^0 $35^{'}$ F longitude with an elevation 8.2 m from sea level (Anonymous, 1989).

3.2 Climate

The experimental area is situated in the subtropical zone, characterized by heavy rainfall during Kharif season (April to September), and scanty in Rabi season (October to March). Rabi season is characterized by plenty of sunshine. Information regarding average monthly maximum and minimum temperature, rainfall and relative humidity, soil temperature as recorded by the Dhaka meteorology centre, Agagoan. Dhaka, during the period of study has been presented in Appendix 1.

3.3 Soil

The soil of the experimental area was non-calcarious dark grey and belongs to the Madhupur Tract (UNDP, 1988) under AEZ 28. The selected plot *was* medium high land and soil series was Tejgoan (FAO, 1988) with a pH of 5.6. The analytical data of the soil sample collected from the experimental area were analyzed in the SRDI, Soil Testing 1aboratoiy, Khamarbari, Dhaka and details of the soil characteristics are presented in Appendix II.

3.4 Treatments

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 = 130 kg K_2O /ha

iii. K_2 = 150 kg K_2O /ha

iv. K_3 = 170 kg K_2O /ha

Factor B: Gibberellic acid (GA_3): 3 levels

i. G_0 = Control treatment (Water spray)

ii. G_1 = 120 ppm

iii. G_2 = 150 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.

3.5 Design and layout

The experiment was laid out following Randomized Complete Block Design (RCBD) with three replications. The total area of the experimental plot was 230.3 m^2 (24.5 m x 9.4 m) which 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 1.8 m x 1.25 m with a plant spacing 30 cm × 25 cm. Two adjacent unit plots and block separated by 0.5 m and 1 m space, respectively.

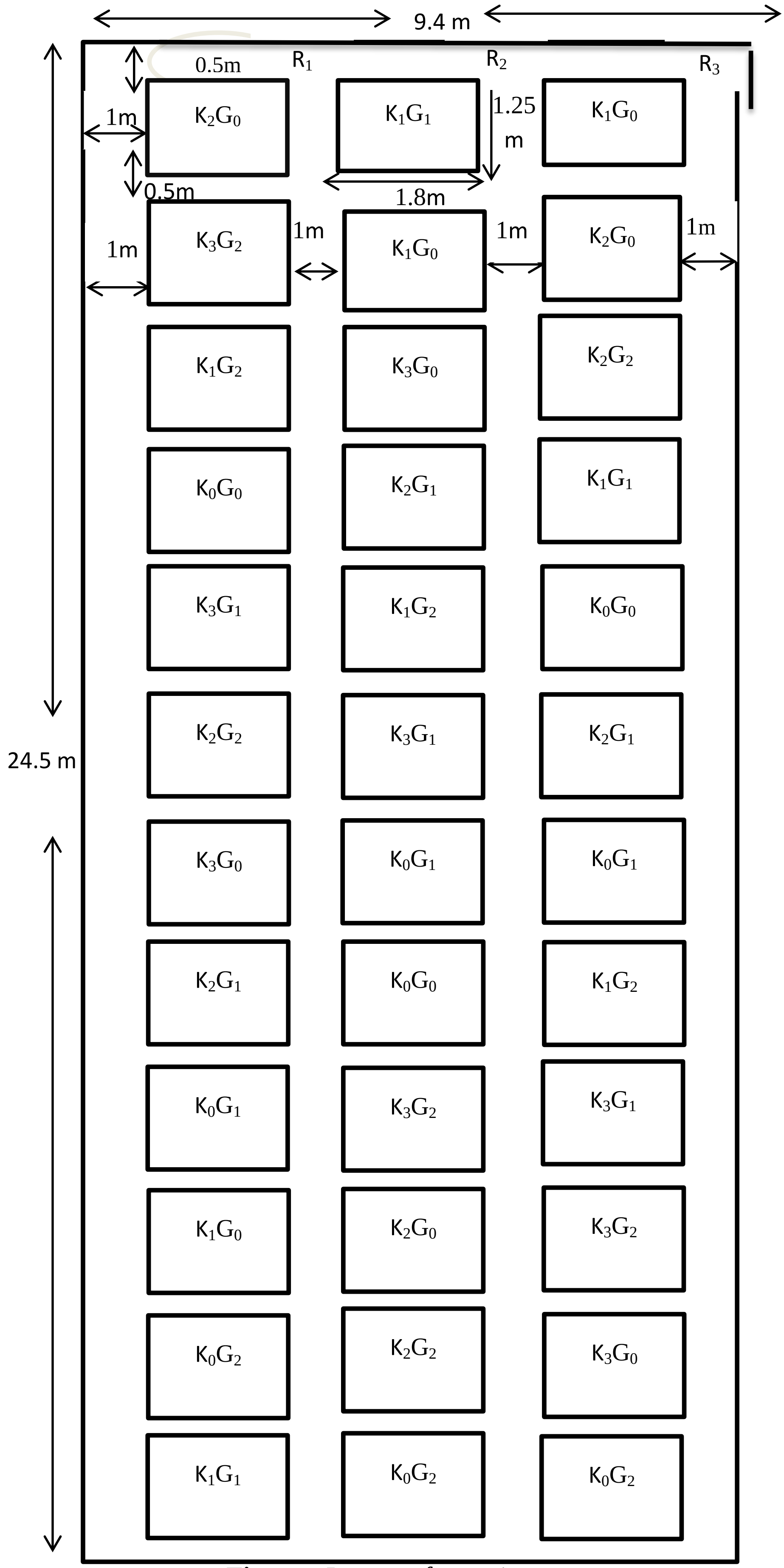
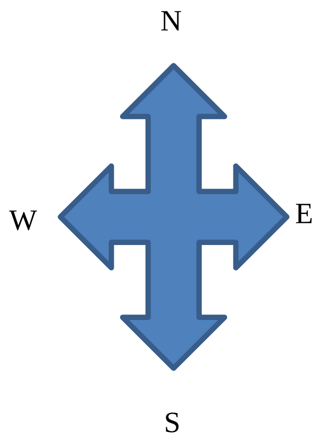


Figure : Layout of experiment

Area of the field

24.5 m × 9.4 m

= 230.3 m^2



Plot size: 1.8 m × 1.25 m

Spacing between plot:
= 0.5m

Spacing between replication: 1m

Row to row distance= 30cm

Plant to plant distance= 25cm

Factors: A

K_0 = Control

K_1 = 130kg K_2O/ha

K_2 = 150kg K_2O/ha

K_3 = 170kg K_2O/ha

Factors: B

G_0 = Control

G_1 = 120ppm

G_2= 150ppm

3.6 Land preparation

The land which was selected to conduct the experiment was opened on 8 August, 20017 with the help of a power tiller and then it *was* kept open to sun for 7 days prior to further ploughing. Afterwards it was prepared by ploughing and cross ploughing followed by laddering. Deep ploughing was done to have a good tilth, which was necessary for getting better yield of this crop. The weeds and stubbles were removed after each laddering. Simultaneously the clods were broken and the soil was magic until good tilth.

3.6.1 Planting of bulb

The bulbs were planted on 16 August, 2017 to make shallow furrows with 2 cm depth to keep at a row to row distance 30 cm and bulb to bulb distance at 25 cm. Each unit plot (1.8 m × 1.25 m) was accumulated with 30 numbers of plants.

3.6.2 Application of manure and fertilizers

The following doses of manures and fertilizers recommended by Rashid, (1999) were applied to the experimental plots to grow the crop as below:

Table 1: Doses of manure and fertilizers in tuberose field

Manures/Fertilizers	Dose/ha	Dose/plot *
Well decomposed cow dung	15 tons	3.37 Kg
Urea	260 Kg	58.50 gm
Triple Super Phosphate (TSP)	200 Kg	45.00 gm
Potassium	As per treatment	

*Unit plot size was 1.8 m x 1 .25 m = 2.25 m^2

3.7 Intercultural operations

3.7.1 Weeding

Plots were kept from weeds by regular weeding. The weeds were eradicated very carefully with roots were done as per necessity.

3.7.2 Irrigation and drainage

Irrigation and drainage were done as necessity.

3.7.3. Pest management

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

3.7.4 Diseases management

The crop was healthy and disease free and no fungicide were used.

3.7.5 Selections and tagging of plants and spikes

Ten plants from each plot were selected randomly for recording plant height, number of leaves per plant, number of side shoot per plant, number to days to first flowering, weight of bulb. Ten spikes from each plot were labeled with details of date of first flowering and after opening of basal fiord, to each spike. Spikes were labeled again with date for recording duration of flowering on plant. Ten spikes of each plot were selected randomly for three times for throughout the season for recording the length of spike, length of rachis, number of florets per spike and weight of spike.

3.8 Harvesting

The spikes were harvested from 30 November, 2017 and continued upto 10 April, 2018 when the basal fioret opened and data were recorded for number spike per hectare and yield per hectare. After that time, the spikes were found sporadically in the field that was not counted. Then after the plants were allowed for bulb maturity and were harvested on 20 July, 2018.Then bulbs were measured also with the help of digital weighing machine.

3.9 Data collection

Data on the following parameters were recorded from the sample plants during the course of experiment. Ten plants were sampled randomly from each unit plot for collection of per plant data. The whole plot was harvested to record per plot data. Data were collected on different growth and yield component and yield. The plants in the outer rows and at the extreme end of the middle rows were excluded from the random selection to avoid the border effect. The following observations were made regarding plant growth, yield and yield attributes as affected by different sizes bulbs and levels of potassium. The following parameters were recorded.

3.9.1 Plant height (cm)

Plant height was measured in centimeter (cm) by a meter scale at 30, 45, 60 and 75 DAP from the point of attachment of the leaves to the bulb (ground level) up to the tip of the longest leaf.

3.9.2 Number of leaves per plant

Number of leaves per plant of ten random selected plants was counted at 30, 45, 60 and 75 DAP. All the leaves of each plant were counted separately.

3.9.3 Number of spikes per plant

Total number of spikes was counted for each plant

3.9.4 Number of side shoots per plant

Side shoot refers to those plants, which developed from the mother bulb, all the green shoot above the soil surface and adjoined to the mother plant were counted as side shoot. Number of side shoot per plant was taken from ten random sample plants at 30, 45, 60 and 75 DAP and average was recorded.

3.9.5 Days of emergence of spike

Days of emergence spike was counted in time and recorded.

3.9.6 Diameter of spike (cm)

Diameter of spike from ten selected plants were measured with the help of a slide calipers after harvest and expressed in centimeter. Mean diameter was taken from top, middle and bottom portion of the harvested spikes.

3.9.7 Weight of single spike (g)

After harvested spikes from ten selected plants were weighed and average was considered as weight of single spike which expressed in gram (g).

3.9.8 Length of rachis (cm)

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

3.9.9 Number of florets per spike

The total number of florets per spikes was counted and average was recorded.

3.9.10 Diameter of single bulb (cm)

Diameter of single bulb from ten selected plants were measured with the help of a slide calipers after harvest and expressed in centimeter.

3.9.11 Yield of bulbs per hectare (tha^{-1})

The yield of bulbs per hectare was calculated in ton by converting the total yield of bulbs per plot.

3.9.12 Yield of bulblet per hectare (tha^{-1})

The yield of bulbs per hectare was calculated in ton by converting the total yield of bulbs per plot.

3.10 Statistical analysis

The data collected from the experimental plots were statistically analyzed. The mean value for all the treatments was calculated and the analysis of variance for most, of the characters was accomplished by F variance test. The significance of difference between pair of means was tested by the Duncan's Multiple Range 'Pest (DMRT) test at 5% probability (Gomez and Gomez; 1984).

CHAPTER IV

RESULTS AND DISCUSSION

The results of the analyses of variance in respect of all the parameters studied in the present investigation are presented and discussed in this chapter. The results on the different parameters are presented in Tables and Appendices for ease of discussion under the following sub-headings and possible interpretations are also given whenever necessary. A summary of the analyses of variance of the data in respect of all the parameters studied are shown in the Appendices.

4.1 Plant height

Plant height showed significance variation due to application of different levels of potassium at different days after planting except 75 days (Figure 1 and Appendix III). However, K_2 (150 kg K_2O/ha) performed the longest plant height at observation. At 75 days the longest plant (63.50 cm) was obtained from K_2 whereas the shortest plant (59.22 cm) was provided by K_0 (Control condition). Sultan *et al.* (2006) observed the effect of potassium on plant height.

Plant height of Tuberose showed significance due to the application of different concentrations of GA_3 at 30, 45, 60 and 75 days after planting (Appendix III). At 30, 45, 60, and 75 DAP the highest plant height 31.87, 41.9, 51.95 and 62.55 cm was found from G_1 (120 ppm) whereas, the shortest plant height 27.89, 38.94, 48.97 and 59.30 cm was observed from G_0 (control condition) for the same DAP, respectively (Figure 2). Padaganur *et al*. (2005) studied the effect of GA_3 on plant height and reported that Gibberellins help to cell elongation and division that stimulates elongation and resulted in increased plant height.

Combined effect of Potassium and GA_3 showed the significant variation on plant height of tuberose (Appendix III). The maximum plant height 35.14, 45.18, 55.22 and 66.59 cm was found in K_2G_1 at 30, 45, 60 and 75 DAP and the minimum 27.01, 37.08, 47.16 and 57.99 cm was recorded from K_0G_2 at 30, 45, 60 and 75 DAP (Table 2). Singh *et al.* (2005) noted that combined effects were increased gradually at days after planting.

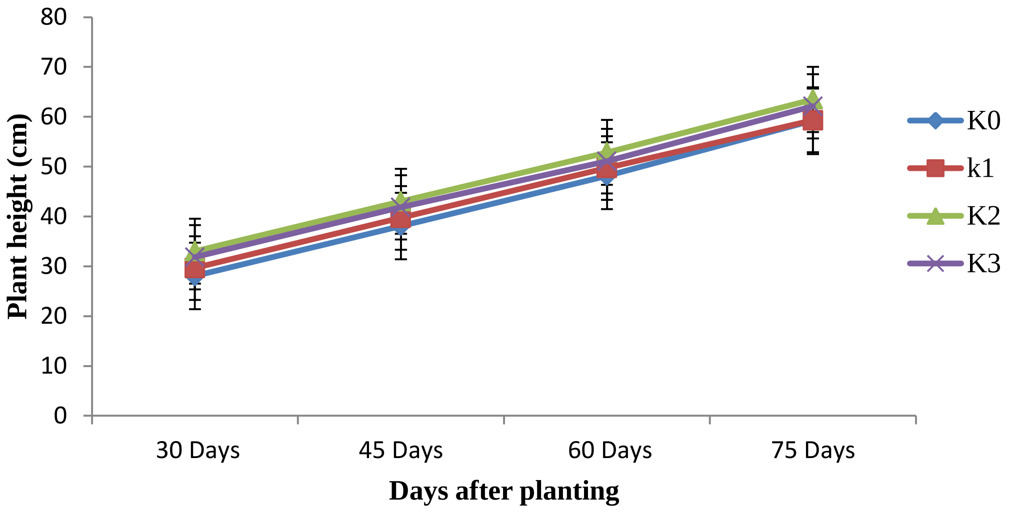


Figure 1: Effect of Potassium on plant height of tuberose at different days after planting at 5% levels of probability and vertical bar represents standard error,

K_0= control 0 kg K_2O/ha, K_1 = 130 kg K_2O/ha, K_2 = 150 kg K_2O/ha, K_3 = 170 kg K_2O/ha.

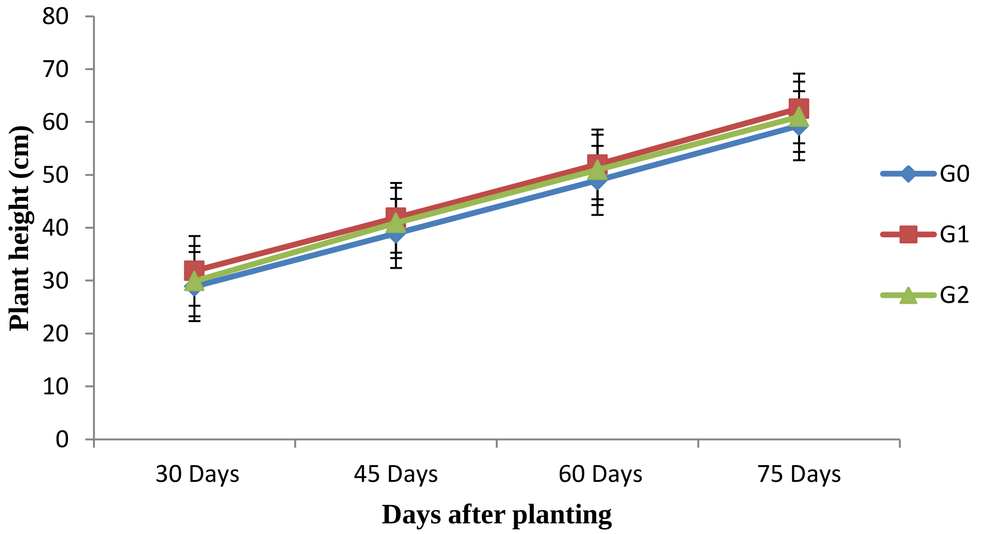


Figure 2: Effect of GA_3 on plant height of tuberose at different days after planting at 5% levels of probability and vertical bar represents standard error,

G_0 = control, G_1 = 120 ppm, G_2 = 150 ppm.

Table 2: Combined effects of Potassium and GA_3 on plant height of tuberose

Treatments $\times GA_3$	Plant height (cm) at different Days			
	30 days	45 days	60 days	75 days
K_0G_0	28.02j	38.07j	48.16i	60.55cde
K_0G_1	29.06i	39.08i	49.20h	58.61de
K_0G_2	27.10k	37.08k	47.16j	57.99e
K_1G_0	29.36h	39.45h	49.45g	58.51de
K_1G_1	30.20f	40.24f	50.25e	59.81cde
K_1G_2	29.44g	39.48h	49.49g	60.08cde
K_2G_0	30.14f	40.16g	50.18f	59.78cde
K_2G_1	35.14a	45.18a	55.22a	66.59a
K_2G_2	33.17c	43.20c	53.18c	62.95abc
K_3G_0	32.06e	42.08e	52.10d	62.91abc
K_3G_1	33.10d	43.12d	53.14c	62.58bcd
K_3G_2	33.94b	43.94b	54.00b	65.02ab
Level of Significance	*	*	*	*
CV (%)	1.02	0.10	0.06	3.42
LSD at 5%	0.05474	0.05474	0.05474	0.09744

* Significant at 5% level of probability, CV= Coefficient of variation, (K_0= control 0 kg K_2O/ha, K_1 = 130 kg K_2O/ha, K_2 = 150 kg K_2O/ha, K_3 = 170 kg K_2O/ha, G_0 = control, G_1 = 120 ppm, G_2 = 150 ppm)

4.2 Number of leaves per plant

Number of leaves per plant of tuberose showed statistically significance due to the effect of different levels of potassium except 75 days (Appendix IV). After 30 days the highest number of leaves (6.11) was found in K_2 (150 kg K_2O/ha) and the lowest number of leaves (4.00) was found in K_0 (control 0 kg K_2O/ha). Number of leaves per plant was increasing days to days. At 75 days the highest number of leaves (10.22) was found in K_2 (150kg k_2o/ha) and the lowest number of leaves (8.00) was found in K_0 (control 0kg/ha) (Figure 3). Sultan *et al*. (2006) reported that number of leaves of tuberose increase with increasing day.

Number of leaves of tuberose showed significance due to the application of different concentrations of GA_3 at 30, 45, 60, and 75 days after planting (Appendix IV). At 30, 45, 60, and 75 DAP the highest number of leaves 5.08, 6.58, 8.08 and 9.16 was found from G_1 (120 ppm) and the lowest number of leaves 5.00, 6.50, 7.50 and 8.50 was observed from G_0 (control condition) for the same DAP, respectively (Figure 4). Same result was found by Padaganur *et al*. (2005) in tuberose. Treatment combination of K_2G_1 gave the maximum number of leaves at all observations (Table 3, Appendix IV). However, at 75 DAP the maximum number of leaves (10.66) was obtained from K_2G_1 and the lowest (8.00) was found from control treatment (K_0G_0). Singh *et al.* (2005) noted that combined effects were increased gradually at days after planting.

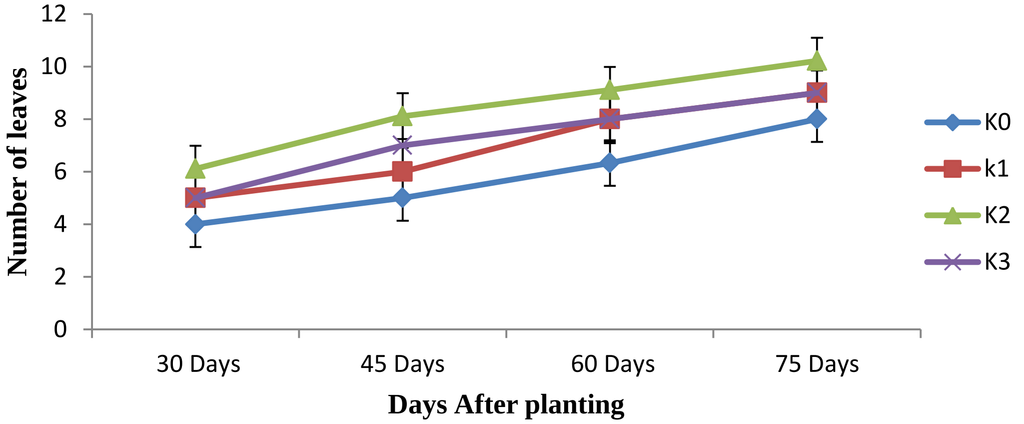


Figure 3: Effect of Potassium on number of leaves of tuberose at different days after planting at 5% levels of probability and vertical bar represents standard error,

K_0= control 0 kg K_2O/ha, K_1 = 130 kg K_2O/ha, K_2 = 150 kg K_2O/ha, K_3 = 170 kg K_2O/ha.

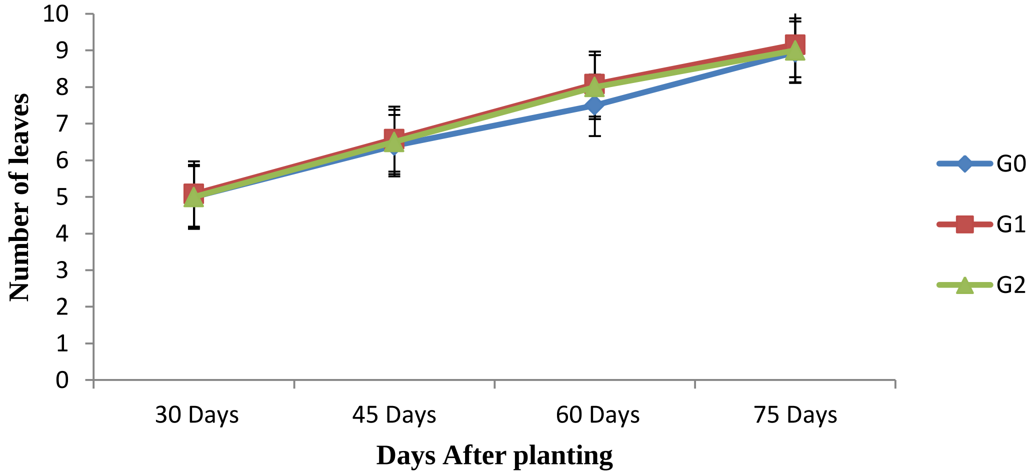


Figure 4: Effect of GA_3 on number of leaves of tuberose at different days after planting at 5% levels of probability and vertical bar represents standard error,

G_0 = control, G_1 = 120 ppm, G_2 = 150 ppm.

Table 3: Combined effects of Potassium and GA_3 on number of leaves of tuberose

Treatments ×GA_3 concentration	Number of leaves at different Days			
	30 days	45 days	60 days	75 days
K_0G_0	4.00d	5.00e	6.00e	8.00d
K_0G_1	4.00d	5.00e	7.00d	8.00d
K_0G_2	4.00d	5.00e	6.00e	8.00d
K_1G_0	5.00c	6.00d	7.00d	9.00c
K_1G_1	5.00c	6.00d	8.00c	9.00c
K_1G_2	5.00c	6.00d	9.00b	9.00c
K_2G_0	6.00b	8.00b	9.00b	10.00b
K_2G_1	6.33a	8.33a	9.33a	10.66a
K_2G_2	6.00b	8.00b	9.00b	10.00b
K_3G_0	5.00c	7.00c	8.00c	9.00c
K_3G_1	5.00c	7.00c	8.00c	9.00c
K_3G_2	5.00c	7.00c	8.00c	9.00c
Level of Significance	*	*	*	*
CV (%)	3.31	2.55	2.12	3.68
LSD at 5%	0.2896	0.2896	0.2896	0.5767

* Significant at 5% level of probability, CV= Coefficient of variation, (K_0= control 0 kg K_2O/ha, K_1 = 130 kg K_2O/ha, K_2 = 150 kg K_2O/ha, K_3 = 170 kg K_2O/ha, G_0 = control, G_1 = 120 ppm, G_2 = 150 ppm)

4.3 Number of spike per plant

Spike per plant of tuberose showed statistically due to the effect of different levels of potassium and it was significance at 5% level (Figure 5 and Appendix V). At 30 DAP the highest value (6.33) was found in K_2 (150 kg K_2O/ha) and the lowest value (4.60) was found in K_0 (control 0 kg K_2O/ha). At 75 DAP highest value (16.09) was found in K_2 (150 kg K_2O/ha) and the lowest value (9.19) was found in K_0 (control 0 kg K_2O/ha. Rajib and Misra (2003) found the same result.

Spike per plant of tuberose showed significance due to the application of different concentrations of GA_3 at 30, 45, 60, and 75 days after planting (Appendix V). At 30, 45, 60, and 75 DAP the highest spike per plant 5.52, 7.17, 9.91 and 12.67 was found from G_1 (120 ppm) and also the shortest spike per plant 5.42, 6.85, 8.77 and 11.22

was observed from G_0 (control) for the same DAP, respectively (Figure 6). Singh *et al.* (2003) reported that number of leaves was increased with the use of GA_3.

The maximum number of spike per plant was obtained from K_2G_1 at all observations (Table 4, Appendix V). However, at 75 DAP the highest number of spike per plant (16.99) was found from K_2G_1 whereas the lowest (9.35) was found from control treatment (K_0G_0). Singh *et al.* (2005) found the same trend of results.

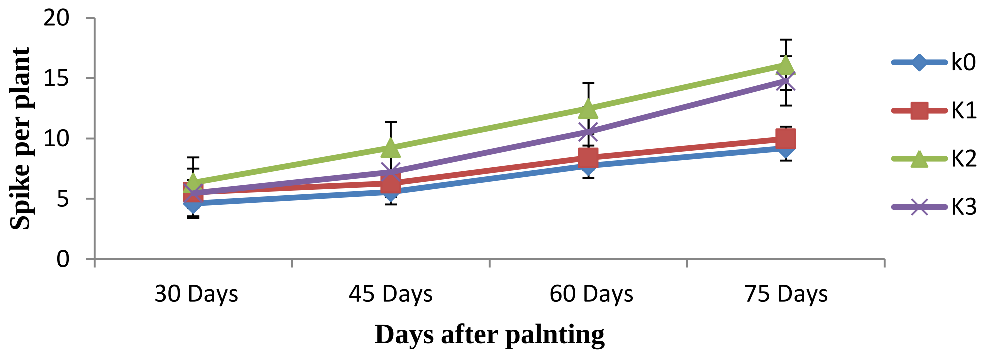


Figure 5: Effect of Potassium on spike per plant of tuberose at different days after planting at 5% levels of probability and vertical bar represents standard error,

K_0= control 0 kg K_2O/ha, K_1 = 130 kg K_2O/ha, K_2 = 150 kg K_2O/ha, K_3 = 170 kg K_2O/ha.

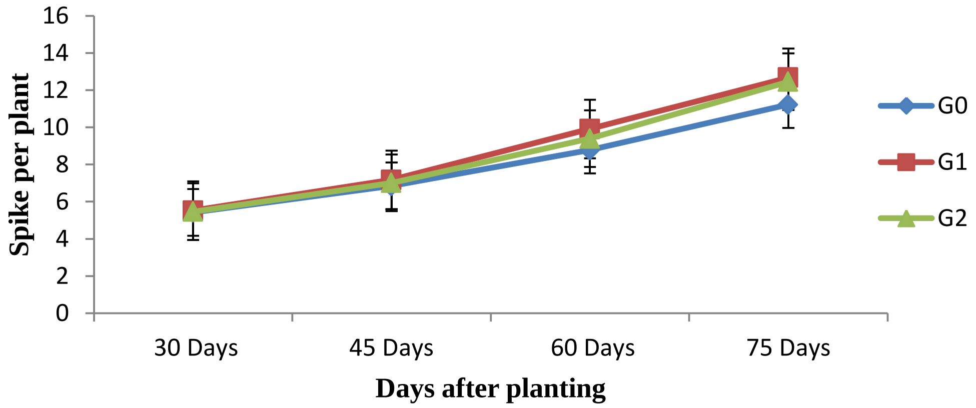


Figure 6: Effect of GA_3 on spike per plant of tuberose at different days after planting at 5% levels of probability and vertical bar represents standard error,

G_0 = control, G_1 = 120 ppm, G_2 = 150 ppm.

Table 4: Combined effects of Potassium and GA_3 on spike per plant of tuberose

Treatments ×GA_3 concentration	Spike per plant at different Days			
	30 days	45 days	60 days	75 days
K_0G_0	5.22g	6.13i	8.34h	9.35j
K_0G_1	4.46i	5.45j	7.56j	8.79k
K_0G_2	4.14j	5.14k	7.34k	9.45i
K_1G_0	5.52f	6.32h	8.36h	10.03f
K_1G_1	5.16g	6.19i	8.24i	9.90h
K_1G_2	5.93d	6.38g	8.59g	9.97g
K_2G_0	6.32b	8.90b	12.15b	15.25c
K_2G_1	6.43a	9.99a	13.25a	16.99a
K_2G_2	6.24c	8.80c	12.04c	16.04b
K_3G_0	5.05h	7.22e	10.24f	14.26e
K_3G_1	5.80e	7.07f	10.59e	15.03d
K_3G_2	5.50f	7.37d	10.80d	14.99d
Level of Significance	*	*	*	*
CV (%)	0.08	0.08	0.07	0.05
LSD at 5%	0.05474	0.05474	0.05474	0.05474

* Significant at 5% level of probability, CV= Coefficient of variation, (K_0 = control 0 kg K_2O/ha, K_1 = 130 kg K_2O/ha, K_2 = 150 kg K_2O/ha, K_3 = 170 kg K_2O/ha, G_0 = control, G_1 = 120 ppm, G_2 = 150 ppm)

4.4 Number of side shoots per plant

Different levels of potassium showed significant influenced on number of side shoot per plant (Figure 7 and Appendix VI). At 30 DAP the highest value (1.12) was found in K_2 (150 kg K_2O/ha) and the lowest value (0.62) was found in K_0 (control 0 kg K_2O/ha). At 75 days the highest number of side shoot (1.90) was found in K_2 (150 kg K_2O/ha) and the lowest value (0.89) was found in K_0 (control 0 kg K_2O/ha). Bankar and mukhopadhyay *(*1985) studied in 2-year field trials and found the same result that side shoots was increasing with days after planting.

Side shoot per plant of tuberose showed significant variation due to the application of different concentrations of GA_3 at 30, 45, 60, and 75 days after planting (Appendix VI). At 30, 45, 60, and 75 DAP the highest side shoot per plant 0.89, 1.03, 1.28 and 1.45 was found from G_1 (120 ppm) and also the shortest side shoot per plant 0.82, 0.98, 1.10 and 1.18 was observed from G_0 (control) for the same DAP respectively

(Figure 8). GA_3 increased the side shoots and flower/spike which is noted by Mukhopadhyay and Banker (1983).

The highest number of side shoot per plant was obtained from K_2G_1 at all observations (Table 5, Appendix VI). However, at 75 DAP the highest number of side shoot per plant (2.69) was found from K_2G_1 whereas the lowest (0.80) was found from control treatment (K_0G_0). Singh *et al.* (2005) found the same trend of results.

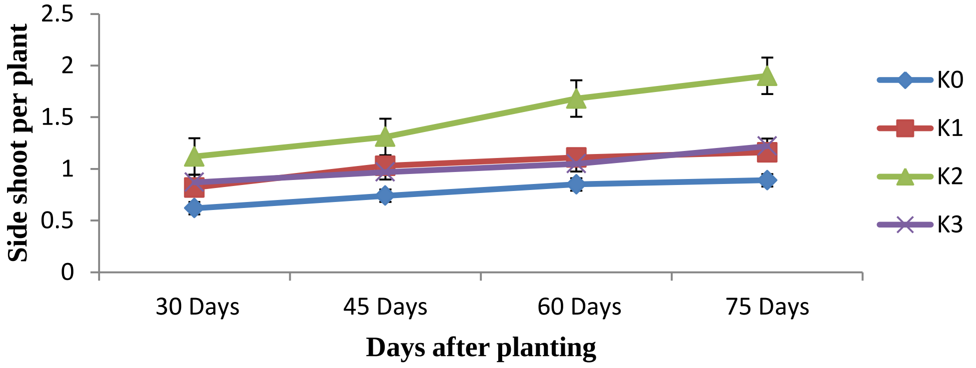


Figure 7: Effect of Potassium on side shoot per plant of tuberose at different days after planting at 5% levels of probability and vertical bar represents standard error,

K_0= control 0 kg K_2O/ha, K_1 = 130 kg K_2O/ha, K_2 = 150 kg K_2O/ha, K_3 = 170 kg K_2O/ha.

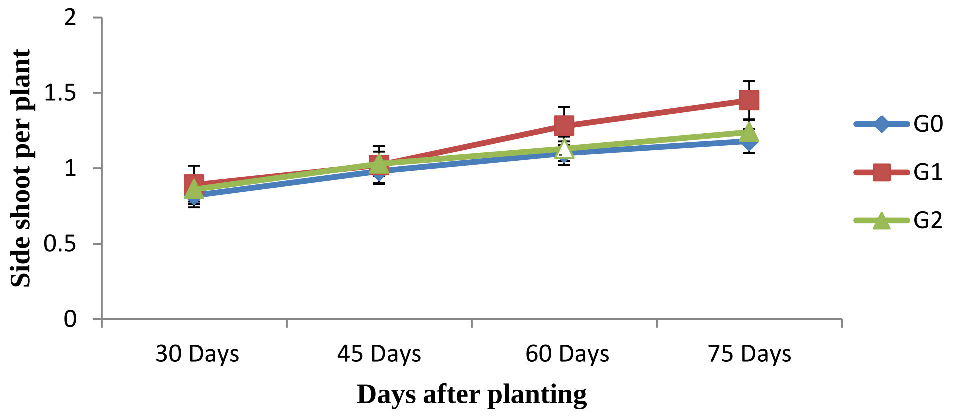


Figure 8: Effect of GA_3 on side shoot per plant of tuberose at different days after planting at 5% levels of probability and vertical bar represents standard error,

G_0 = control, G_1 = 120 ppm, G_2 = 150 ppm.

Table 5: Combined effects of Potassium and GA_3 on side shoot per plant of tuberose

Treatments ×GA_3 concentration	Side shoot at different Days			
	30 days	45 days	60 days	75 days
K_0G_0	0.51f	0.64j	0.72j	0.80i
K_0G_1	0.63e	0.73i	0.89hi	0.91gh
K_0G_2	0.73d	0.86fg	0.95fg	0.96g
K_1G_0	0.86c	0.90ef	0.93gh	0.95g
K_1G_1	0.86c	0.82g	0.87i	0.88h
K_1G_2	0.76d	1.37b	1.54c	1.64c
K_2G_0	1.06b	1.41b	1.68b	1.79b
K_2G_1	1.23a	1.60a	2.33a	2.69a
K_2G_2	1.08b	0.91def	1.04de	1.24e
K_3G_0	0.87c	0.96cd	1.09d	1.20e
K_3G_1	0.83c	0.95cde	1.06de	1.32d
K_3G_2	0.89c	0.99c	1.00ef	1.14f
Level of Significance	*	*	*	*
CV (%)	0.82	0.65	0.06	0.44
LSD at 5%	0.05474	0.05474	0.05474	0.09744

* Significant at 5% level of probability, CV= Coefficient of variation, (K_0 = control 0 kg K_2O/ha, K_1 = 130 kg K_2O/ha, K_2 = 150 kg K_2O/ha, K_3 = 170 kg K_2O/ha, G_0 = control, G_1 = 120 ppm, G_2 = 150 ppm)

4.5 Days of emergence of spike

Effect of different levels of potassium showed significant effect on spike emergence of tuberose (Figure 9 and Appendix VII). The highest period was required (72.66 days) in K_0 (control) and the lowest (65.33 days) was required in case of K_2 treatment K_3 gave the value 69.55 days that was close to the K_0 value. Patil *et al.* (1999) conducted experiments and find that application of potassium fertilizer also helps to the emergency spike of tuberose.

Spike emergence of tuberose was showed highly significant due to the effect of different concentrations of GA_3 (Figure 10 and Appendix VII). The highest days (69.66) was required to emerged in G_0 treatment and the lowest (68.70 days) was found in G_1 (120 ppm). Preeti *et al*. (1997) reported that the early appearance of spikes was occurred when application of GA_3.

The highest days for emergence spike were obtained from K_0G_0 at all observations (Table 6, Appendix VII). However, at 75 DAP the highest days for emergence spike (74.00) was found from K_0G_0 whereas the lowest (63.00 days) was found from control treatment (K_2G_1). Amarjeet and Godara (1998) found the same trend of results.

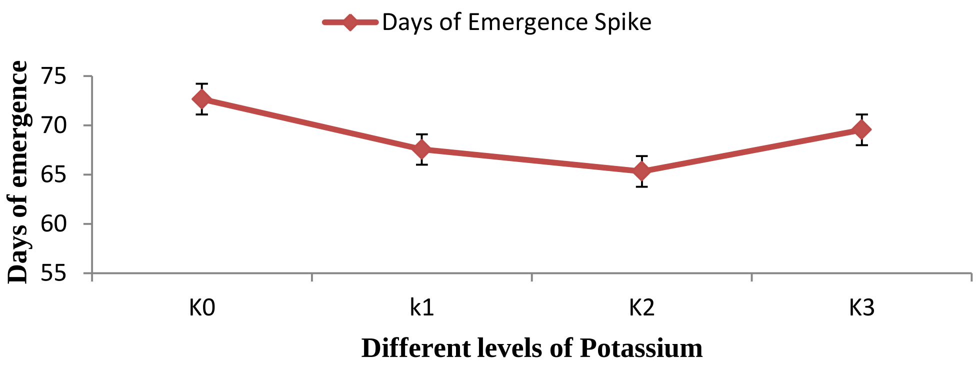


Figure 9: Effect of Potassium on emergence spike of tuberose at different days after planting at 5% levels of probability and vertical bar represents standard error,

K_0= control 0 kg K_2O/ha, K_1 = 130 kg K_2O/ha, K_2 = 150 kg K_2O/ha, K_3 = 170 kg K_2O/ha.

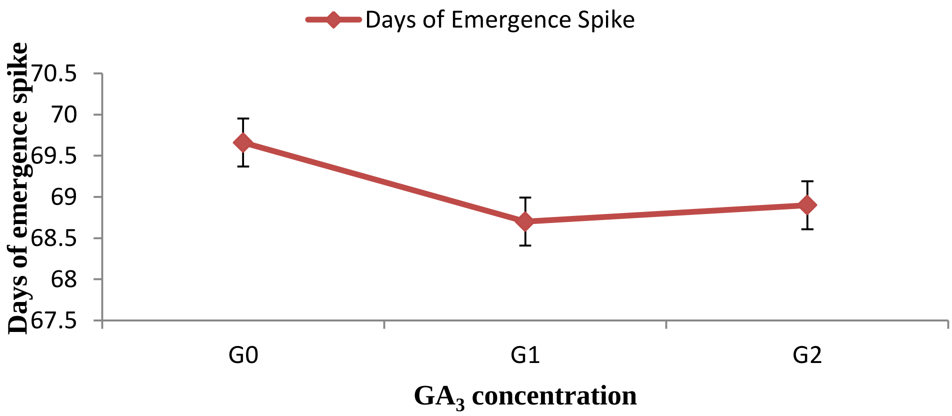


Figure 10: Effect of GA_3 on emergence spike of tuberose at different days after planting at 5% levels of probability and vertical bar represents standard error,

G_0 = control, G_1 = 120 ppm, G_2 = 150 ppm.

Table 6: Combined effects of Potassium and GA_3 on emergence of spike of tuberose

Treatments × GA_3	Days of emergence spike
K_0G_0	74.00a
K_0G_1	66.00de
K_0G_2	67.00d
K_1G_0	65.00e
K_1G_1	69.00c
K_1G_2	68.66c
K_2G_0	73.00b
K_2G_1	63.00f
K_2G_2	71.00bc
K_3G_0	71.33bc
K_3G_1	68.66c
K_3G_2	68.66c
CV (%)	0.91
Level of significance	*
LSD at 5%	1.080

* Significant at 5% level of probability, CV= Coefficient of variation, (K_0 = control 0 kg K_2O/ha, K_1 = 130kg K_2O/ha, K_2 = 150 kg K_2O/ha, K_3 = 170 kg K_2O/ha, G_0 = control, G_1 = 120 ppm, G_2 = 150 ppm)

4.6 Diameter of spike

Due to the effect of different levels of potassium showed significant effect on diameter of spike of tuberose (Table 7). The highest diameter of spike (1.85 cm) was found in K_2 (150 kg K_2O/ha) and the lowest result (1.47 cm) was found in K_0. Singh *et al*. (1976) reported that diameter of spike tuberose depends upon dose of potassium and found increased spike number, rachis length and duration of flowering and also diameter of spike.

Diameter of spike showed significant variation due to the effect of different concentrations of GA_3 (Table 7). The highest diameter of spike (1.68 cm) was found in G_1 (120 ppm) and the lowest (1.50 cm) was found in G_0 (control). Padaganur *et al*. (2005) studied the effects of gibberellic acid and found the same result.

Combined effect of potassium and GA_3 on diameter of spike showed significance variation (Table 7). However, the maximum diameter of spike (1.77 cm) was observed in treatment combination of K_2G_1 and the minimum (1.48 cm) was obtained from control treatment combination (K_0G_0). Singh *et al.* (2005) found the same trend of results which support present study.

4.7 Weight of single spike

Due to the effect of different levels of potassium showed significant effect on weight of singles spike of tuberose (Table 7). The maximum weight (42.94 g) was found in K_2 ((150 kg K_2O/ha) and the minimum weight (32.78 g) was found in K_0. Banker and Mukhopadhyay (1985) were also found the same result.

Weight of single spike showed significant due to the effect of different concentrations of GA_3 (Table 7). The maximum weight (39.08 g) was found in G_1 (120 ppm) and the lowest (36.73 g) was found in G_0 (control). Preeti *et al*. (1997) reported that weight of single spikes was increased when application of GA_3.

Combined effect of potassium and GA_3 on weight of single spike showed significance variation (Table 7). However, the maximum weight of single spike (44.27 g) was observed in treatment combination of K_2G_1 and the minimum weight (31.21 g) was obtained from control treatment combination (K_0G_0). Singh *et al.* (2005) found the same trend of results which support present study.

4.8 Length of rachis

Length of rachis of tuberose showed significant due to the effect of different levels of potassium (Table 7). The maximum length of rachis (27.22 cm) was found in K_2 (150 kg K_2O/ha) and minimum length of rachis (25.67 cm) was found in K_0. K_3 gave 26.31cm and K_1 gave 26.34cm length of rachis. Bankar *et al. (*1985) found same result which partially supports the present study.

Different concentrations of GA_3 showed the significant effect on length of rachis (Table 7). The highest rachis length (26.46 cm) was found in G_1 (120 ppm) and the lowest length (26.24 cm) was found in G_0 (control). Ramaswamy et al. (1979) application of certain growth substance has been found to influence the growth and flowering of tuberose that supported present study.

Combined effect of Potassium and GA_3 on length of rachis showed significance variation (Table 7). However, the highest length of rachis (27.36 cm) was found in treatment combination of K_2G_1 and the lowest length of rachis (25.25 cm) was obtained from control treatment combination (K_0G_0). Singh *et al.* (2005) found the same trend of results which support present study. The present results are in agreement the findings of Singh and Sangama (2000).

4.9 Number of florets per spike

Number of florets per spike of tuberose was showed significant due to the effect of different levels of potassium (Table 7). The maximum number of florets (43.00) was found in K_2 (150 kg K_2O/ha) and the minimum number of florets (35.55) was found in K_0. The results are in agreement with the findings of Bankar *et al. (*1985).

Due to the effect of different concentrations of GA_3 on number of florets per spike was showed significance (Table 7). The highest number of florets per spike (38.93) was found in G_1 (120 ppm) and the lowest (37.58) was found in G_0 (control). Ramaswamy *et al.* (1979) reported that GA_3 has been found to influence the growth and flowering of tuberose.

Combined effect of potassium and GA_3 on number of florets per spike showed significance variation (Table 7). However, the highest number of florets per spike (44.00) was found in treatment combination of K_2G_1 and the lowest number of florets per spike (34.00) was obtained from control treatment combination (K_0G_0). The present results are in agreement the findings of Singh and Sangama (2000).

4.10 Diameter of single bulb

Diameter of single bulb of tuberose showed significant due to the effect of different levels of potassium (Table 7). The highest diameter of single bulb (2.35 cm) was found in K_2 (150 kg K_2O/ha) and the lowest diameter of single bulb (1.77 cm) was found in K_0. Bankar *et al.* (1985) reported that P and K improved vegetative growth, flowering and bulb production.

Diameter of single bulb showed significant due to the effect of different concentrations of GA_3 (Table 7). The highest diameter of bulb (2.10 cm) was found in G_1 (120 ppm) and the lowest diameter of bulb (1.95 cm) was found in G_0 (control).

Combined effect of potassium and GA_3 on diameter of single bulb showed significance variation (Table 7). However, the highest diameter of single bulb (2.72 cm) was found in treatment combination of K_2G_1 and the lowest diameter of single bulb (1.86) was obtained from control treatment combination (K_0G_0). The present results are in agreement the findings of Singh and Sangama (2000).

Table 7: Effect of Potassium and GA_3 on diameter of spike, weight of single spike, length of rachis, number of florets per spike and diameter of single bulb

Treatment(s)	Diameter of spike (cm)	Weight of single spike (g)	Length of rachis (cm)	No. of florets per spike	Diameter of single bulb (cm)
Effect of Potassium					
K_0	1.47d	32.78d	25.67d	35.55d	1.77d
K_1	1.62c	36.10c	26.34b	35.65c	1.94c
K_2	1.85a	42.94a	27.22a	43.00a	2.35a
K_3	1.69b	40.42b	26.31c	36.77b	2.02b
LSD (0.05)	0.416	1.653	0.0231	0.0431	0.247
Effect of GA_3					
G_0	1.50c	36.73c	26.24c	37.58c	1.95c
G_1	1.68a	39.08a	26.46a	38.93a	2.10a
G_2	1.55b	37.23b	26.30b	37.82b	2.01b
LSD (0.05)	0.0231	3.045	0.202	0.0534	0.444
Combined effect of Potassium and GA_3					
K_0G_0	1.48e	31.21k	25.25k	34.00f	1.86j
K_0G_1	1.51de	32.13j	25.98i	35.66e	1.96i
K_0G_2	1.46f	34.99i	25.79j	37.00d	2.08g
K_1G_0	1.57d	35.24h	26.25g	40.00c	2.06hi
K_1G_1	1.60d	36.25g	26.36f	39.00c	2.22f
K_1G_2	1.64c	36.99f	26.43e	36.66de	2.30e
K_2G_0	1.71b	41.24c	27.26b	42.66b	2.52c
K_2G_1	1.77a	44.27a	27.36a	44.00a	2.72a
K_2G_2	1.69b	43.32b	27.04c	42.33b	2.61b
K_3G_0	1.58de	39.23e	26.22gh	39.00c	2.32e
K_3G_1	1.65bc	40.99d	26.17h	37.00d	2.11gh
K_3G_2	1.67bc	41.04d	26.54d	34.33f	2.42d
LSD (0.05)	0.540	0.0210	0.05463	1.118	0.0551
Level of significance	*	*	*	*	*
CV (%)	3.96	4.66	3.30	4.75	5.52

* Significant at 5% level of probability, CV= Coefficient of variation, (K_0 = control 0 kg K_2O/ha, K_1 = 130kg K_2O/ha, K_2 = 150 kg K_2O/ha, K_3 = 170 kg K_2O/ha, G_0 = control, G_1 = 120 ppm, G_2 = 150 ppm)

4.11 Yield of bulb

Yield of bulb of tuberose was significant due to the effect of different levels of potassium (Figure 11 and Appendix VII). The maximum yield of bulb (18.86 t/ha) value was found in K_2 (150 kg K_2O/ha) and the minimum yield of bulb (15.38 t/ha) was found in K_0. K_3 gave the yield 17.57 t/ha and K_1 gave the yield 16.44 t/ha. The results are in agreement the findings of Cirrito (1975). Singh *et al.* (1976) reported that flower yield and bulb of tuberose depends upon the dose of potassium.

Due to the effect of different concentrations of GA_3 on yield of bulb was significance (Figure 12 and Appendix VII). The maximum yield of bulb (17.21 t/ha) was found from G_1 (120 ppm) and the minimum yield of bulb (16.74 t/ha) was found from G_0 (control).

Combined effect of Potassium and GA_3 on yield of bulb showed significance variation (Table 8, Appendix VII). However, the highest yield of bulb (19.36 t/ha) was found in treatment combination of K_2G_1 and the lowest yield of bulb (15.21 t/ha) was obtained from control treatment combination (K_0G_0). The present results are in agreement the findings of Banker *et al.* (1985).

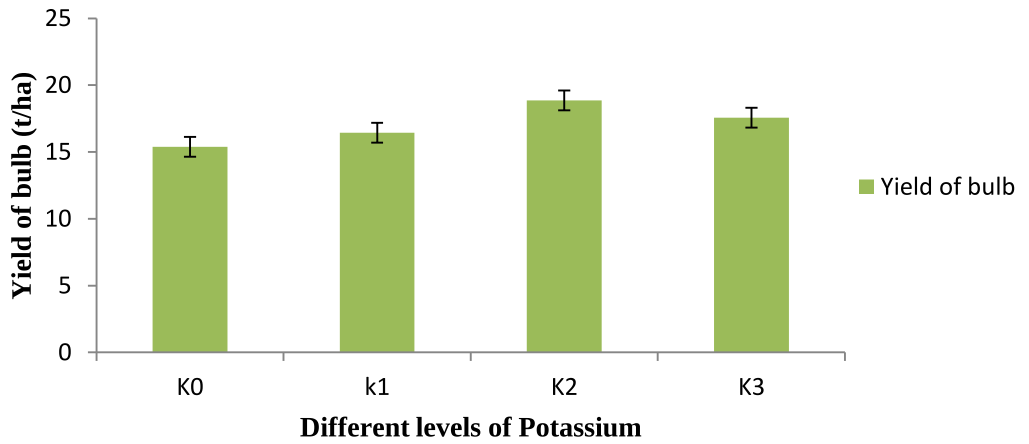


Figure 11: Effect of Potassium on yield of bulb of tuberose at 5% levels of probability and vertical bar represents standard error,
K_0 = control 0 kg K_2O/ha, K_1 = 130 kg K_2O/ha, K_2 = 150 kg K_2O/ha, K_3 = 170 kg K_2O/ha.

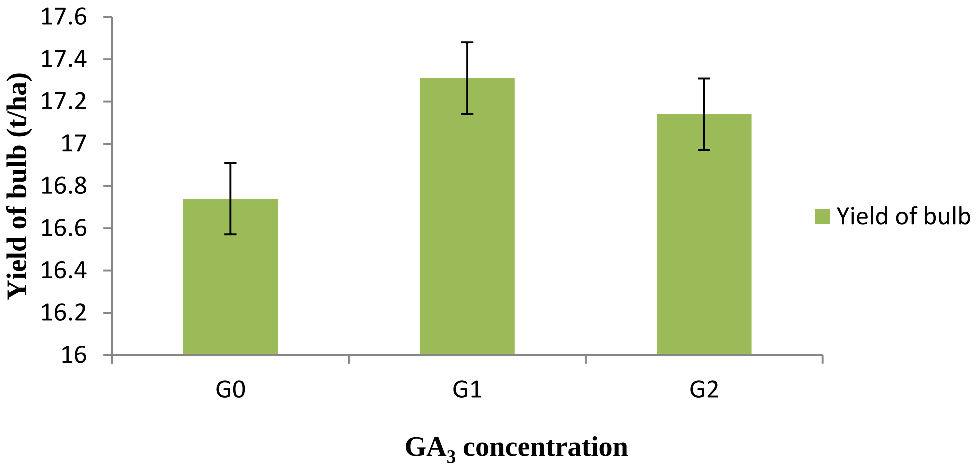


Figure 12: Effect of GA_3 on yield of bulb of tuberose at 5% levels of probability and vertical bar represents standard error,

G_0 = control, G_1 = 120 ppm, G_2 = 150 ppm

Table 8: Combined effects of Potassium and GA_3 on yield of bulb of tuberose

Treatments × GA_3	Yield of bulb
K_0G_0	15.21l
K_0G_1	15.32k
K_0G_2	15.62j
K_1G_0	16.30h
K_1G_1	16.99g
K_1G_2	16.03i
K_2G_0	18.23c
K_2G_1	19.36a
K_2G_2	18.99b
K_3G_0	17.21f
K_3G_1	17.59e
K_3G_2	17.91d
CV (%)	0.03
Level of significance	*
LSD at 5%	0.05474

* Significant at 5% level of probability, CV= Coefficient of variation, (K_0 = control 0 kg K_2O/ha, K_1 = 130 kg K_2O/ha, K_2 = 150 kg K_2O/ha, K_3 = 170 kg K_2O/ha, G_0 = control, G_1 = 120 ppm, G_2 = 150 ppm)

4.12 Yield of bulblet

Yield of bulblet of tuberose was significance due to the effect of different levels of potassium (Figure 13 and Appendix VII). The highest bulblet yield (20.70 t/ha) was found in K_2 (150 kg K_2O/ha) and the lowest bulblet yield (15.23 t/ha) was found in K_0. 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 bulblet of tuberose showed significance due to the effect of different concentrations of GA_3 (Figure 14 and Appendix VII). The maximum yield of bulblet (17.86 t/ha) was found in G_1 (120 ppm) and the minimum yield of bulblet (17.11 t/ha) was found in G_0 (control). Preeti *et al*. (1997) reported that bulblets production was higher in GA_3 applied plants than control plants that supported the present experimental result.

Combined effect of Potassium and GA_3 on yield of bulblet showed significance variation (Table 9, Appendix VII). However, the highest yield of bulblet (21.99 t/ha) was found in treatment combination of K_2G_1 and the lowest yield of bulb (15.11 t/ha) was obtained from control treatment combination (K_0G_0). The present results are in agreement the findings of Banker and Mukhopadhay (1985).

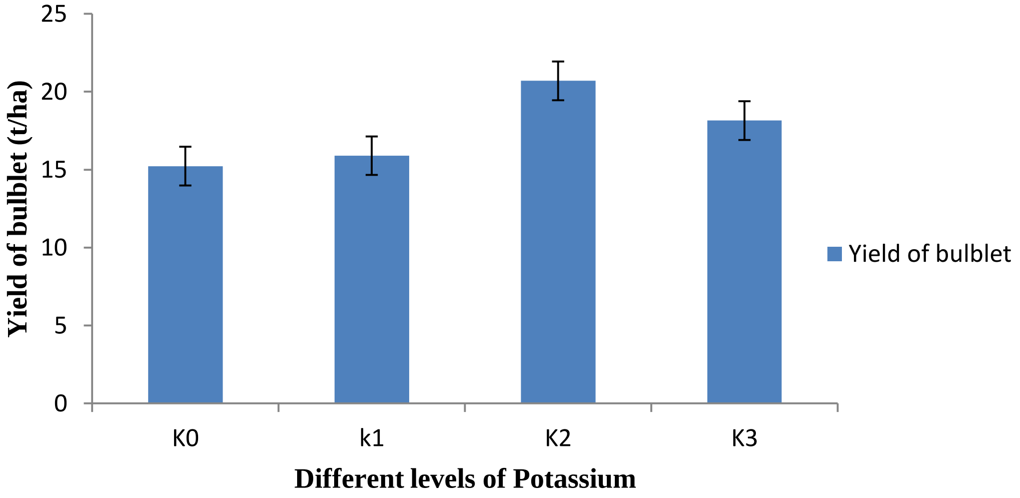


Figure 13: Effect of Potassium on yield of bulblet of tuberose at 5% levels of probability and vertical bar represents standard error, K_0= control 0 kg K_2O/ha, K_1 = 130 kg K_2O/ha, K_2 = 150 kg K_2O/ha, K_3 = 170 kg K_2O/ha.

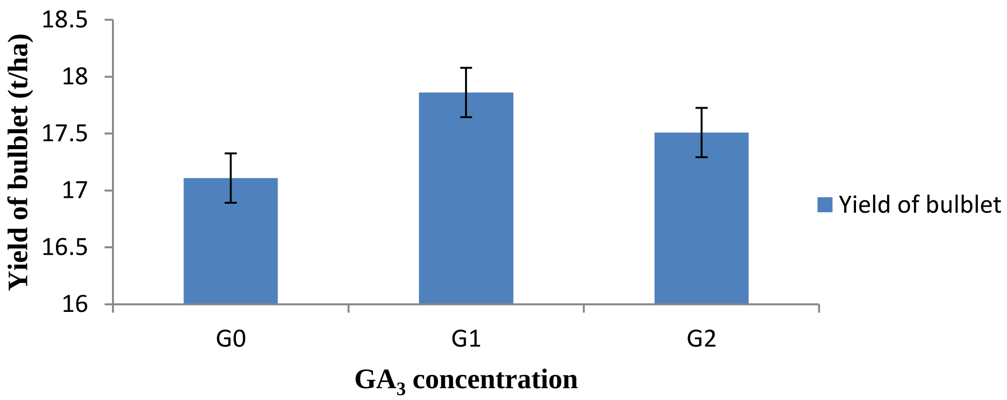


Figure 14: Effect of GA_3 on yield of bulblet of tuberose at 5% levels of probability and vertical bar represents standard error, G_0 = control, G_1 = 120 ppm, G_2 = 150 ppm

Table 9: Combined effects of Potassium and GA_3 on yield of bulblet of tuberose

Treatments × GA_3	Yield of bulblet
K_0G_0	15.11l
K_0G_1	15.24k
K_0G_2	15.33j
K_1G_0	15.98g
K_1G_1	15.91h
K_1G_2	15.83i
K_2G_0	20.13b
K_2G_1	21.99a
K_2G_2	19.98c
K_3G_0	17.24f
K_3G_1	18.30e
K_3G_2	18.91d
CV (%)	0.04
Level of significance	*
LSD at 5%	0.05474

* Significant at 5% level of probability, CV= Coefficient of variation, (K_0= control 0 kg K_2O/ha, K_1 = 130 kg K_2O/ha, K_2 = 150 kg K_2O/ha, K_3 = 170 kg K_2O/ha, G_0 = control, G_1 = 120 ppm, G_2 = 150 ppm)

CHAPTER V

SUMMARY AND CONCLUSIONS

The present research work was conducted at the Horticulture Farm, Department of Horticulture, Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla Nagar, Dhaka-1207 during the period from August, 2017 to October, 2018 to find out the effect of Gibberellic Acid ($GA_{3)}$ and potassium on growth, flowering and yield of bulb of tuberose. The experiment consisted of two factors namely. Factor A: levels of Potassium (K_0 = control 0 kg K_2O/ha, K_1 = 130 kg K_2O/ha, K_2 = 150 kg K_2O/ha, K_3 = 170 kg K_2O/ha) and Factor B: concentration of Gibberellic Acid (G_0 = control, G_1 = 120 ppm, G_2 = 150 ppm) with three replications. The experiment was laid out in Randomized Complete Block Design (RCBD).

The data were recorded on plant height, number of leaves, number of spike per plant, side shoot per plant, emergence spike, diameter of spike, weight of single spike, length of rachies, number of floret per spike, diameter of single bulb, yield of bulb and yield of bulblet. At 30 days the highest plant height, number of leaves per plant, number of spike per plant and side shoot per plant 32.16 cm, 6.11, 6.33 and 1.12 was found from K_2 (150 kg K_2O/ha) whereas, the lowest plant height, number of leaves per plant, number of spike per plant and side shoot per plant 28.06 cm, 4.00, 4.60 and 0.62 was found from K_0 (control 0 kg K_2O/ha). At 75 days the highest plant height, number of leaves per plant, number of spike per plant and side shoot per plant 63.50 cm, 10.22, 16.09 and 1.90 was found from K_2 (150 kg K_2O/ha) whereas, the lowest plant height, number of leaves per plant, number of spike per plant and side shoot per plant 59.22 cm, 8.00, 9.19 and 0.89 was found from K_0 (control, 0 kg K_2O/ha).

The highest value of emergence spike 72.66 days was found from K_0 (control 0 kg K_2O/ha) and the lowest value of emergence spike 65.33 days was found from K_2 (150 kg K_2O/ha). For diameter of spike, weight of single spike, length of rachies, number of floret per spike, diameter of single bulb, yield of bulb and yield of bulblet the highest value 1.85 cm, 42.94 g, 27.22 cm, 43.00, 2.35 cm, 18.86 t/ha and 20.70 t/ha was found from K_2 (150 kg K_2O/ha) whereas lowest value 1.47 cm, 32.78 g, 25.67 cm, 35.55, 1.77 cm, 15.38 t/ha and 15.23 t/ha was found from K_0 (control 0 kg K_2O/ha). At 30 days the highest plant height, number of leaves per plant, number of spike per plant and side shoot per plant 31.87 cm, 5.08, 5.42 and 0.89 was found from G_1 (120 ppm) whereas, the lowest plant height, number of leaves per plant, number of spike per plant and side shoot per plant 29.89 cm, 5.00, 5.45 and 0.82 was found from G_0 (control). At 75 days the highest plant height, number of leaves per plant, number of spike per plant and side shoot per plant 62.55 cm, 9.16, 12.67 and 1.45 was found from G_1 (120 ppm) whereas, the lowest plant height, number of leaves per plant, number of spike per plant and side shoot per plant 59.30 cm, 8.50, 11.22 and 1.18 was found from G_0 (control). The highest value of emergence spike 69.66 days was found in G_0 (control) and the lowest value of emergence spike 68.70 days was found in G_1 (120 ppm). For diameter of spike, weight of single spike, length of rachies, number of floret per spike, diameter of single bulb, yield of bulb and yield of bulblet the highest value 1.68 cm, 39.08 g, 26.46 cm, 38.93, 2.10 cm, 17.21 t/ha and 17.86 t/ha was found in G_1 (120 ppm) where lowest value 1.50 cm, 36.73 g, 26.24 cm, 37.58, 1.95 cm, 16.74 t/ha and 17.11 t/ha was found from G_0 (control). The best interaction was found in K_2G_1 that produced the maximum yield of bulb (19.36 t/ha) and bulblet (21.99 t/ha).

Conclusion: Treatment K_2 (150 kg k_2o/ha) and G_1 (120 ppm) was the best for tuberose bulb production. In considering the physical characteristics growth, flowering and yield of bulb combined application of potassium dose 150 kg/ha and Gibberellic Acid concentration 120 ppm showed highest performance. Further study may be conducted in different agro ecological zones of Bangladesh for more confirmation in order to get the higher yield.

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APPENDICES

Appendix I: Monthly record of temperature, relative humidity and rainfall, of the experimental site during the period from August, 2017 to April, 2018.

Months	Temperature (^0C)		Relative humidity	Rainfall
	Maximum	Minimum	(%)	mm
August	33.7	23.6	85	356.3
September	32.9	24.5	82	339.4
October	32.1	26.1	76	172.4
November	31.4	24.2	74	33.1
December	28.6	18.5	73	12.5
January	26.5	16.5	72	123.4
February	31.6	23.8	78	172.3
March	32.6	22.2	84	183.4
April	36.4	24.1	85	256.8

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

Appendix II: Characteristics of Sher-e-Bangla Agricultural University (SAU) Farm soil analyzed by Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka

a) Morphological characteristics of experimental field

Morphological feature	Characteristics
Location	SAU Farm, 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

b) Physical and chemical properties of the soil

Characteristics	Value
Partical size analysis % Sand	27
% Silt	43
% Clay	30
Texture class	Silty Clay Loam (ISSS)
pH	5.6
Organic carbon (%)	Fairly leveled
Organic matter (%)	Above flood level
Total N (%)	Well drained
Available P (ppm)	20
Exchangeable K (me/100g soil)	0.1
Available S (ppm)	45

Appendix III: Analysis of variance (mean square) of the data on plant height of tuberose influenced by Potassium and GA_3

Sources of Variation	Degrees of freedom	Mean square value of plant height at different DAP			
		30 days	45days	60 days	75 days
Replication	2	0.005	0.004	0.005	0.280
Factor A (Potassium)	3	53.450 *	53.181*	52.096*	49.382NS
Factor B (GA_3)	2	11.735 *	11.574 *	11.781*	15.863*
AB	6	4.478*	4.610 *	4.659*	10.689*
Error	16	0.001	0.001	0.001	4.399

* Significant at 5% level, NS = not significance

Appendix IV: Analysis of variance (mean square) of the data on number of leaves per plant of tuberose influenced by Potassium and GA_3

Sources of Variation	Degrees of freedom	Mean square value of number of leaves at different DAP			
		30 days	45days	60 days	75 days
Replication	2	0.028	0.028	0.028	0.111
Factor A (Potassium)	3	6.694*	0.028*	11.80*	7.444NS
Factor B (GA_3)	2	0.028*	0.028*	1.194*	0.111*
AB	6	0.028*	0.028*	0.972*	0.111*
Error	16	0.028	0.001	0.001	0.111

* Significant at 5% level , NS = not significance

Appendix V: Analysis of variance (mean square) of the data on number of spike per plant of tuberose influenced by Potassium and GA_3

Sources of Variation	Degrees of freedom	Mean square value of number of spike per plant at different DAP			
		30 days	45days	60 days	75 days
Replication	2	0.006	0.003	0.002	0.002
Factor A (Potassium)	3	13.47*	22.567*	41.788*	106.016*
Factor B (GA_3)	2	0.037*	0.229*	0.145*	0.724*
AB	6	3.603*	0.648*	0.784*	0.836*
Error	16	0.028	0.001	0.001	0.111

* Significant at 5% level

Appendix VI: Analysis of variance (mean square) of the data on number of side shoots per plant of tuberose influenced by Potassium and GA_3

Sources of Variation	Degrees of freedom	Mean square value of number of side shoots per plant at different DAP			
		30 days	45days	60 days	75 days
Replication	2	0.002	0.002	0.028	0.002
Factor A (Potassium)	3	0.380*	0.491*	1.146*	1.677*
Factor B (GA_3)	2	0.013*	0.011*	0.117*	0.229*
AB	6	0.021*	0.223*	0.533*	0.648*
Error	16	0.008	0.001	0.023	0.011

* Significant at 5% level

Appendix VII: Analysis of variance (mean square) of the data on yield and yield contributing characters of tuberose as influenced by Potassium and GA_3

Sources of Variation	Mean square value			
	Degrees of freedom	Emergence of spike	Yield of bulb	Yield of bulblet
Replication	2	7.194	0.002	0.002
Factor A (Potassium)	3	87.259*	139.055*	0.821*
Factor B (GA_3)	2	1.343*	1.989*	0.036*
AB	6	13.926*	3.635*	0.012*
Error	16	0.389	0.003	0.011

* Significant at 5% level