INFLUENCE OF SPACING AND GIBBERELLIC ACID ON GROWTH AND FLOWERING OF TUBEROSE

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INFLUENCE OF SPACING AND GIBBERELLIC ACID ON GROWTH AND FLOWERING OF TUBEROSE

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This is to certify that thesis entitled, **"INFLUENCE OF SPACING AND GIBBERELLIC ACID ON GROWTH AND FLOWERING OF TUBEROSE''** submitted to the Department of Horticulture, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE in HORTICULTURE**, embodies the result of a piece of ***bona fide*** research work carried out by **MD. BASIRUL ALAM**, Registration No. **10-04207** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: June, 2012
Place: Dhaka, Bangladesh

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Dedicated to

My Beloved Parents

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ABSTRACT

An experiment was conducted at the Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka during the period from May to December 2011 to find the influence of spacing and gibberellic acid on growth and flowering of tuberose . The experiment consisted of two factors. Three levels of spacing viz., (i) S_1: 20 × 10 cm ; (ii) S_2: 20 × 15 cm and (iii) S_3: 20 × 20 cm and four levels of GA_3 viz., (i) G_0: 0 ppm (ii) G_1: 200 ppm (iii) G_2: 250 ppm and (iv) G_3: 300 ppm GA_3 respectively . The experiment was conducted in a Randomized Complete Block Design with three replications. The maximum number of spike (695000/ha) and bulb (846500/ha) was recorded from S_2 and maximum number of spike (780700/ha) and bulb (948300/ha) was obtained from G_2 . In respect of combined effect, S_3G_2 produced the maximum number of spike (801700/ha) and bulb (958300/ha) and lowest from S_2G_3. The maximum benefit cost ratio (2.07) was obtained from S_3G_2 and the minimum (1.03) from S_1G_0.. Considering above findings the 20 cm × 20 cm spacing with 250 ppm GA_3 was suitable for tuberose cultivation.

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LIST OF ACRONYMS

ABBREVIATIONS	ELABORATIONS
AEZ	Agro-Ecological Zone
Anon	Anonymous
ANOVA	Analysis of Variance
BARI	Bangladesh Agricultural Research Institute
BAU	Bangladesh Agricultural University
BBS	Bangladesh Bureau of Statistics
BCR	Benefit Cost Ratio
CV	Coefficient of Variation
DAS	Days after sowing
df	Degrees of Freedom
DMRT	Duncan`s Multiple Range Test
e.g.	example
et al.	and others
etc.	etcetera
FAO	Food and Agricultural Organization
GA_3	Gibberellic acid
Hort.	Horticulture
J.	Journal
LSD	Least Significant Difference
MoP	Muriate of Potash
NFPS	Number of florets per spike
NLPP	Number of leaves per plant
NS	Non Significant
PGR	Plant Growth Regulator
p^H	Hydrogen ion concentration
Res.	Research
RH	Relative Humidity
SAU	Sher-e-Bangla Agricultural University
Sci.	Science
Vol.	Volume
UNDP	United Nations Development Programme

CHAPTER I

INTRODUCTION

Tuberose (*Polianthes tuberosa* cv. Double) belongs to the family Amaryllidaceae, produces attractive, elegant and fragrant white flowers. The flowers having excellent keeping quality are used as cut flowers. It occupies a very selective and special position to flower loving people because of its prettiness, elegance and sweet pleasant fragrance. It has a great economic potential for cut flower trade and essential oil industry. The flowers remain fresh for quite a long time and stand distance transportation and fill a useful place in the flower market .

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

Tuberose is a native of Mexico from where it spread to the different parts of the world during 16th century. How and when the tuberose found its entrance to India, Ceylon and elsewhere in the Orient is probably an unanswerable question. Now a day, it is cultivated on large scale in France, Italy, South Africa, and USA and in many tropical and sub-tropical areas, including India and Bangladesh.

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

There are many factors which can affect the plant growth and economic cultivation of tuberose. Spacing is of prime importance among the cultural factors which greatly influences the growth, flowering and bulb production. For economic production and good yield, proper spacing is to be determined. In case of low density, there is actually loss of land, labour and energy. When plants are grown high density, competition occurs among plants for space, water, nutrient, light, carbondioxide and oxygen. Developmental process also depends on plant spacing. At closer spacing, flowering may early before the completion of full vegetative growth, often senescence starts earlier and develops faster at wider plant spacing (Vandor Valk & Timmer, 1974). In case of tuberose, number of flower spikes/plant and bulb production increases with spacing (Mukhopdahyay *et al.*1986). However, there are reports that the highest production of bulbs can be achieved from higher plant spacing (Cirrito and Zizzo, 1980).

Application of certain growth substances has been found to influence the growth and flowering of tuberose (Bose and Yadav, 1998). Mukhopdahyay and Banker (1983) sprayed the plants of cv. Single with GA_3 and observed that GA_3 increased spike length and number of flower/spike. Duration of flower in the field was improved with $GA_{3.}$ According to Dhua *et al*. (1987), treatment with GA_3 caused earliest flowering and gave the highest yield of spikes and flowers.

In Bangladesh, a little work has been done in respect of plant spacing and use of plant growth regulator for tuberose cultivation. So, research work is so lack about the production technique of tuberose. Considering the facts, such research is very important for the greater interest of the scientist as well as the growers of our country.

The present study was undertaken with the following objectives:

1. To find out the suitable plant spacing for tuberose in order to achieve a highest growth, flowering and bulb yield.
2. To determine the appropriate concentration of GA_3 on growth , flowering and bulb production of tuberose
3. To investigate the suitable combination of spacing and concentration of GA_3 for ensuring the growth, flowering and bulb production of tuberose.

CHAPTER II

REVIEW OF LITERATURE

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

2.1 Effect of plant spacing on the growth, flowering and bulb production of Tuberose

An experiment was carried out by Mane *et al*.(2006) in Parbhani, India in 1999 with tuberose *(P. tuberosa*) cv. Single, involving 3 spacings (20x15, 20x20 and 20x25 cm), 2 bulb sizes (2.5 and 3.0 cm diameter) and 3 planting depths (3, 5 and 7 cm). There were 18 treatment combinations. Though the wider-spaced plants were shorter in vegetative growth, there was less competition between plants for nutrients and produced higher number of bulbs having greater weight and size (i.e. length and diameter). The bigger-sized bulbs used for planting showed better results, producing vigorous plants and increasing significantly the bulb quality. Though the plant height decreased, the number of bulbs increased in deeper planting. In the case of weight and size of bulbs, the depth of planting did not play any significant role. By planting bigger-sized bulbs at wider spacing and medium depth of planting (5 cm), there was an appreciable improvement in growth and bulb production of single tuberose under Parbhani conditions.

A field trial was conducted by Kadam *et al* (2005) in Maharashtra, India during, 2001-02 to obtain a better quality of flowers and improve the cultivation practices of tuberose (*Polianthes tuberosa*). Treatments comprised: 2 cultivars (Local Single and Shringar), 3 spacings (30x20 cm, 30x30 cm and 30x40 cm) and 2 bulb sizes (1.5- to 2.5-cm and 2.6- to 3.5-cm). Shringar had earlier sprouting and flowering, higher number of leaves per plant and longer vase life than Local Single. Local

Single recorded longer spikes, rachis length, higher number of flowers per spike, flower stalk diameter, number of spikes per plant and per m^2 than Shringar. Among the spacing, the 40x30 cm spacing recorded the highest length of spikes, rachis length and flower stalk diameter, followed by the 30x30 cm spacing. Spacing had no significant effect on sprouting, flowering and vase life of the spikes in plain water. Although its yield was comparatively less than that of Local Single, Shringar was better for commercial cut flower production since most of its floral characters were superior to those of Local Single, which is preferred in the market.

Singh (2003) was studied the effects of spacing (30 × 20, 30 ×10, 20 × 20, 20 × 12.5, 20 × 10 and 20 × 8.5 cm) on flower and bulb production by *P. tuberosa* cv. Shringar in India during 1997/98. The highest yields of cut flowers (142.75) and loose flowers (5.34 kg/plot (2.4 m^2) were recorded for a spacing of 20 ×10 cm. A spacing of 30 × 20 cm resulted in the greatest weight of individual bulb (12.39 g) and number of bulbs/clump (5.6). The highest number of bulbs (559.5) and bulblets/plot (1848.0) were recorded for a spacing of 20 × 10 and 20 × 8.5 cm, respectively. The length of rachis and flower spikes, number of florets/spike, fresh weight of individual floret, diameter of individual bulb, and number of bulblets/clump were not significantly affected by the spacing. The results suggested that high-density planting (50 plants/m^2) using a spacing of 20 ×10 cm was optimum for Shringar under Bangalore conditions.

Ramesh *et al.* (2003) shown that the effects of bulb size (<1.5, 1.5-2.5 or 2.5-3.5 cm), spacing (20 × 20, 25 × 25 or 30 × 30 cm) and planting depth (3, 6 or 9 cm) on the growth and development of tuberose (*Polianthes tuberosa* cv. Single) were studied in Meghalaya, India during 1998 and 1999. Sprouting was delayed with the increase in bulb size and planting depth, and reduction in spacing. Large bulbs resulted in the earliest spike emergence (93.89 days). Spike emergence was delayed with the increase in the planting depth. Spike length (88.78 and 89.37 cm) and rachis length (19.76 and 20.06 cm) were greatest with medium and large bulbs. The depth of planting was inversely related to flower quality in terms of spike and rachis length. Thus, the longest spike (89.52 cm) and rachis (19.48 cm) were obtained with a planting depth of 9 cm. The number of flower spikes decreased with the deep planting of small bulbs at closer spacing. The number of florets/spike increased with the increase in spacing; thus, the highest number of florets/spike (33.70) was recorded for a spacing of 30×30 cm. This parameter, however, was independent of bulb size and planting depth. Increasing bulb size up to 2.5 cm and planting depth up to 9 cm increased bulb production. Small bulbs in combination with the widest spacing resulted in the earliest bulb sprouting (8.28 days). Medium bulbs with moderate planting depth (6 cm) and spacing (25x25 cm) gave higher yields of flowers and bulbs.

Singh and Sangama (2000) noted the effect of seven plant spacing, viz. 30 × 30, 30 × 20, 30 × 10, 20 × 20, 20 × 12.5, 20 × 10 and 20 × 8.5 cm, on vegetative growth, flowering and postharvest quality of cut spikes in tuberose cv. Single was investigated at Bangalore, Karnataka, India, during 1997-98. Wider spacing resulted in longer rachis and heavier individual florets. Closer spacing produced higher yield of cut flower and loose flower per plot basis. Wider and closer spacing have vice versa effect on above floral parameters. Rest of the studied parameters namely, plant height, number of leaves per clump, spike length, diameter of second floret, flowering duration under field condition and number of florets per spike and their corresponding weight and post harvest quality of cut flower were not influenced significantly by the plant densities.

Singh and Manoj (1999) reported that the effect of spacing, depth and time of planting on growth, flowering and bulb production of tuberose cv. Double. The tuberose [*Polianthes tuberosa*] was planted on 3 dates (2nd week of October, March or June) at 3 spacings (15 x 20, 20 x 20 or 25 x 20 cm) and at 2 planting depths (5 or 8 cm). Data are presented on days to sprouting, sprouts/bulb, leaves/plant, days to flowering, spike length, number of spikes/clump, number of florets/spike, diameter and weight of the largest bulb/plant, and number of bulbs/plant. The longest flower spikes and the highest numbers of spikes/clump resulted from June planting and the lowest plant density. Shallow planting gave more spikes/clump. The number of bulbs/plant was highest for June planting, and this planting date also gave the largest bulbs. As plant density increased, the number of bulbs/plant decreased. Deep planting also gave more bulbs/plant than shallow planting.

Patel *et al.* (1997) conducted with three spacing (45 × 45 cm, 45 × 30 cm or 45 × 15 cm) and 4 fertilizer rates (5 kg organic manure/m^2 or NPK at 100+50+0, 200+100+50 or 300+ 200+100 kg/ha) were compared in trials in Navsari, Gujrat, India, in 1992-95 with (*Polianthes tuberosa* cv. Double) grown for cut flower. Neither plant height nor leaf width was affected by the different spacing or fertilizer treatments. Leaf number was highest with the widest spacing and highest NPK fertilizer rate. The field of flower spikes/plant was similar in all treatments but the yield/ha was highest at the closest spacing (1047530 spikes/ha). Flower spike length and the number of florets/spike were highest and the closest spacing with the highest NPK rate. The highest cost benefit ratios were obtained with the closest spacing (45 cm × 15cm) and the highest NPK rate or organic manure.

A field experiment was conducted by Balak *et al*. (1999) during 1994-96 at Bantha Research Station, Lucknow, India, to determine the N and plant spacing requirements of (*P. tuberosa*), grown in sodic soil. Application of 180kg N/ha with a plant spacing of 45 X 30 cm significantly influenced growth (plant height, leaf area, number of spikes and spike length), and was the best treatment for promoting flower yield.

The N, P and K uptake by *Polianthes tuberosa* cv. Single was studied in an experiment conducted by Mohanty *et al.*, (1999) in Bapatla, Andhra Pradesh, India. Treatments consisted of 3 intrarow spacing 10 (S_I), 20 (S_2) and 30 (S_3) cm, keeping a constant interrow spacing of 30 cm; and /or 4 NPK application rates (100kg N +50kg P_20_5 +50 kg K_20/ha (F_1), 175 kg N+ 75kg P_20_5 + 75 g K_20/ha (F_2), 250 kg N + 100 kg P_20_5 + 100 kg K_20/ha (F_3), and 325 kg N +125 kg P_20_5 + 125 kg K_20/ha (F_4). F_4,S_3 and its combination resulted in the highest N, P and K uptake, both at 50% flowering stage and harvesting stage.

Field experiments were conducted by Misra *et al.*(2000) to determine the effect of bulb size spacing on plant growth and flowering of two tuberose (*Polianthes tuberose* L.) cultivars (Single and Double) in Faizabad, Uttar Pradesh, India, during 1997 – 1998. Bulb size significantly influenced the initiation of spikes in both cultivars. The highest days for spike initiation by smaller bulb size was 170.8 and 222.7 days for single and double cultivars, respectively. The larger bulb size produced the highest number of spikes/plant for both cultivars. With closer spacing, the plants took a longer time to produce spikes than wider spaced-plants. The number of spikes/plant was higher in wider spaced-plants. The spike length and number of florets decreased in closer spaced-plants. However, a bulb size of 2.60 – 3.00 cm at 30 × 30 cm spacing was the best for both the cultivars.

Patil *et al.* (1987), conducted an experiment, they used bulbs having 1.5 -2.5, 2.6 – 3.0 cm diameter 15 × 20, 20 × 20 and 25 × 20 cm spacing and the plants are grown for three years for cut flowers. The highest yield of top quality flowers were obtained from the large bulbs planted at 15 × 20 cm.

Kumar *et al.* (2003) studied the effect of bulb size (<1.5, 1.5 – 2.5 or 2.5 – 3.5 cm in diameter), spacing (20 ×20, 25 × 25, 30 × 30 cm) and planting depth (3, 6 or 9 cm) on growth and development of tuberose (*P. tuberosa* cv. Single) in Unium, Meghalaya, India, during 1998 and 1999. Sprouting was delayed with the increase in bulb size, planting depth and reduction in spacing. Large bulb resulted in the earliest spike emergence (93.89). Spike emergence was delayed with the increase of the planting depth. Spike length 88.78 and 89.37 cm and rachis lengths 19.76 and 20.06 cm were greatest with the medium and large size bulbs. The depth of planting was inversely related to flower quality in terms of spike and rachis length. Thus, the longest length of spike 89.52 cm and rachis length 19.48 cm were obtained with a planting depth with of 9 cm. The number of flower spike decreased with deep planting of small size of bulb at closer spacing. The number of floret per spike increased with the increase of spacing. Thus the highest number of florets per spike (33.70) was recorded from the spacing of 30 × 30 cm. This parameter, however, was independent of bulb size and planting depth. Increasing bulb size 2.5 cm and planting depth up to 9 cm increased bulb production.. Small bulb in combination with the widest spacing resulted in the earliest bulb sprouting 8.28 days, medium bulbs with moderate planting depth 6 cm and spacing 25 x 25 cm gave higher yield of flower and bulb.

2.2 Effect of growth regulators (GA_3) on the growth, flowering and bulb production of tuberose

Asil *et al.(*2011) shown that the effect of different chemical treatments on quantitative characteristics of *Polianthes tuberosa* L. (cv. Goldorosht Mahallat) was investigated. This research was conducted in a factorial experiment based on Randomized Block design with 3 replications. 40 and 54 days after planting, the flowers were sprayed with various concentrations of Gibberellic acid (GA_3) and Benzyladenine (BA) (0, 50, and 100 ppm). The results showed that , flowering stem length and leaves length were greatest with GA_3 at 100 ppm while BA no increase these traits compared to the control. GA_3 resulted in earlier flowering compared to the control. BA and GA_3 decreased number of floret. Greatest diameter of floret and vase life of cut flower was BA at 50 and 100 ppm, respectively.

A study was conducted by Nejad and Etemadi (2010) to evaluate the effects of gibberellic acid (GA_3) on flower quality and flowering date of tuberose (*Polianthes tuberosa*). Double cultivar tuberose bulbs, ranging from 6 to 7 cm in diameter were used. GA_3 solutions used were 100, 200, 250 and 300 ppm. The bulbs were soaked before cultivation or soaked and bud sprouts were sprayed with GA_3 solutions at two stages of plant development. GA_3 application methods did not show significant differences on the evaluated characters, while significant variations were observed among various GA_3 concentrations. Comparing the date of flower harvest indicated that the highest number of flowers were picked 3 to 4 weeks after flowering for both GA_3 application method. The application of GA_3 (300 ppm) by soaking the bulbs before cultivation significantly increased the number of flowering shoots and the flowering time.

A Field experiment was conducted by Bharti and Ranjan (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 ad 300 ppm) and SADH (100, 200 and 300 ppm) on the flowering of two cultivars of tuberose viz., Shringar and Kalyani Double. Cultivar Shringar was superior in inducing early spike emergence, first floret opening and also produced maximum number of spikes/m^2. However, cv. Kalyani Double showed maximum number of florets and spike length and flowering duration. Among various treatments, GA_3 (150 ppm) was observed best in inducing early spike emergence, opening of first floret, 50 per cent floret opening and maximum spike yield per sq. meter. The spikes characters, such as length of rachis and spike, number of florets per spike, increased significantly with the application of GA_3 (100 ppm). Maximum days to withering of first opened floret and flowering duration were observed with Kinetin (150 ppm). However, Ethrel (300 ppm) exhibited delayed flowering, minimum flowering duration and reduced length of spike characters.

Jitendra *et al.* (2009) to study the effect of vitalizer (GA_3) and nitrogenous fertilizer (urea) on growth and floral parameters in tuberose cv. Pearl Double. The experiment was conducted at Horticultural Research Farm, Department of Horticulture, C.C.S. University Campus, Meerut, consisting two levels of GA_3 (100 ppm and 200 ppm) and two levels of urea (55 and 110 g/m^2). There were 9 treatment combinations, replicated three times and laid out in factorial randomized block design. The results revealed that combined application of gibberellic acid and nitrogeneous 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. Earliest 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).

An experiment was conducted by Devadanam *et al.* (2007) to study the effect of foliar applied plant growth regulators on the flowering and vase life of tuberose. The treatments comprised: 50, 100 and 150 ppm GA< sub>3</ sub>; 100, 150 and 200 ppm NAA; 1000, 1500 and 2000 mg thiourea/litre. Foliar application was conducted at 30, 60 and 90 days after planting. GA< sub>3</ sub> at 150 ppm gave the earliest number of days required for spike emergence (43.48) and longest vase life (11.35 days). Further, GA< sub>3</ sub> gave maximum spike length (87.20 cm), spike girth (2.84 cm), rachis length (21.37 cm), floret length (6.56 cm) and floret diameter (3.88 cm).

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

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

Sanap *et al.* (2004) conducted a field experiment during 1996/97 at Pune, Maharashtra, India to evaluate the effects of GA< sub>3</ sub> (100, 150 and 200 ppm) and CCC [chlormequat] (100, 200 and 300 ppm) on tuberose cv. Single. Foliar spraying of the growth regulators was performed at 40, 55 and 70 days after planting. Data were recorded for various growth (number of leaves, leaf length and leaf breadth) and flowering characters (days to flower spike emergence, days to flowering and days from spike emergence to flower harvest). All growth regulator treatments were significantly superior to the control (water spray), with GA< sub>3</ sub> at 150 ppm and CCC at 200 ppm sprays giving optimum growth and earliest flowering.

Manisha and Shyamal (2002) studied tuberose (*P. tuberose* L.) cv. Single in Varanasi, Uttar Pradesh, India, during 1999-2000. Treatments comprised of a control of foliar spray of gibberellic acid (GA_3) at 100, 150 and 200 ppm at 40, 60 and 80 days after planting. Treatment with GA_3 at all concentrations promoted the height of the plants and increased the number of leaves/plant, being highest (55.50 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 observed with this treatment. GA_3 at all concentrations significantly increased the number of spikes/plant, number of flowers/spike and yield/ha. All these characters were the highest in plants applied with GA_3 at 150 ppm. Applications of GA_3 at all concentrations significantly increased the length of leaf, flower spike and rachis. Among the 3 concentrations of GA_3 used, 150 ppm was found the most superior.

Nagar and Saraf (2002) conducted an experiment of identify the effects of gibberellic acid (GA_3: 0, 100, 200, and 300 mg/litre) and nitrogen fertilizer (0, 15, 30, and 50 kg/feddan as ammonium nitrate), singly or in combination, on tuberose (*P. tuberosa* cv. Double) in Alexandria, Egypt during the summer seasons of 2000 and 2001. The roots were soaked in GA_3 for 24 month after planting and twice within the following 42 days. The application of 200 mg GA_3/litre+30 kg N/faddan resulted in the earliest flowering (109.30 days), and the greatest average plant height (99.34 cm), number of leaves/plant (51.85), leaf dry weight (14.88 g), number of spike/plant (4.94), number of florets/spike (29.91), flower duration (18.28 days), number of corms and cormels/clump (28.74), fresh and dry weights of corms and cormels/clump (121.72 and 8.67 g respectively), and total cholorophyll content (229.87 mg/100 g leaf fresh weight). The highest average floret dry weight (4.47 g) was obtained with 100 mg GA_3/litre + 30 kg N/feddan, whereas the highest nitrogen content (3.92%) was obtained with 300 mg GA_3/litre + 50 kg N/Feddan. The contribution ratio of N fertilizer on growth and yield increased with increasing N rate. The contribution ratio of soil N decreased with increasing N fertilizer rate but increased with increasing GA_3 rate.

Tiwari and Singh (2002), observed an experiment to identify the effects of bulb size, i.e. large (> 1.5 cm diameter), medium (1.0-1.5 cm), and small (<1.00 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 raised from large bulbs had the greatest plant height, number of leaves/clump, leaf length, leaf width, foliage weight, clump weight, bulb and bulblets/clump, inflorescence length, spike length, flower length, spike diameter, flowers/spike, spikes/plant, and showed the earliest flowering. Similar results were recorded for plants from bulbs treated with 200 ppm GA_3, except for leaf width which was highest with 150 ppm GA_3. Large bulbs soaked in 200 ppm GA_3 showed significant increase in growth flowering and bulb production.

A field experiment was conducted by Wankhede *et al*. (2002) during 2000-2001 at the College of Agriculture, Nagpur, Maharashtra, India, to study the effect of GA_3(gibberellic acid) treatments (soaking of bulbs in 0,50,100, and 150 ppm as main treatments, and foliar spraying of 0,100,150, and 200 ppm as sub-treatments) on P, tuberose (*P.tuberosa*). Higher concentrations of bulb soaking treatment at 150 ppm, foliar spraying of GA_3 at 200 ppm, and the interaction of these two treatments showed significant increase in diameter and length of fully opened floret, length of rachis, diameter of spike, weight of floret/spike, number of spikes, and fresh weight of bulbs.

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

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

Singh and Manoj (1999) conducted an experiment in Meerut, Uttar Pradesh, India during 1997-98 on tuberose (*P. tuberose*) cv. Double. The treatments comprised of water dipping (control); dipping in GA_3, IAA, and NAA at 50 and 100 ppm each;

spraying GA_3 and 100 ppm each ; spraying GA_3, IAA., and NAA; and dipping + spraying GA_3, IAA, and NAA. The number of flowers, flower length, and longevity of the whole spike were highest for bulbs dipped in 100 ppm GA_3 for 24 hour before planting + spraying with 100 ppm GA_3 at 30 days after planting. Spike length and rachis length were also highest in bulbs dipped and sprayed with 100 ppm GA_3 at 100 ppm (dipping + spraying) increased the number (28.4), weight (90.52g), diameter (4.20cm), and yield (305.25 g/ha) of tuberose) .

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

Deotale *et al*. (1995) observed that Chrysanthemum (cv. Raja) was sprayed with GA_3 at 0, 50, 100 or 150 ppm, as 2 applications 15 days after planting and again 1 month later. Planting on 24 June and spraying with 105 ppm GA_3 produced the heaviest (2.15g) and largest (6.42 cm diameter) flowers.

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

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

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

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

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

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

CHAPTER III

MATERIALS AND METHODS

3.1 Site of the experiment

The experiment was conducted at the Horticulture farm, Sher-e-Bangla Agricultural University Campus, Sher-e-Bangla Nagar, Dhaka to study the effects of plant spacing and different levels of gibberellic acid on the growth, flowering and bulb production in Tuberose during the period from the month of May, 2011 to September, 2011. The location of the site is $23^{0}74^{'}$ N latitude and $90^{0}35'$ E longitude with an elevation of 8.2 m from the sea level (Anon, 1989).

3.2 Climatic condition

The experimental area was 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 highest and lowest temperature, rainfall and relative humidity, soil temperature as recorded by the Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka, during the period of study have been presented in Appendix I.

3.3 Characteristics of 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 Laboratory, Khamarbari, Dhaka and details of the soil characteristics have been presented in Appendix II.

3.4 Design of the experiment

The experiment was laid out two factors Randomized Complete Block Design with three replications.

Factor A Spacing : Three levels

S_1 : 20 x 10 cm
S_2 : 20 x 15 cm
S_3 : 20 x 20 cm

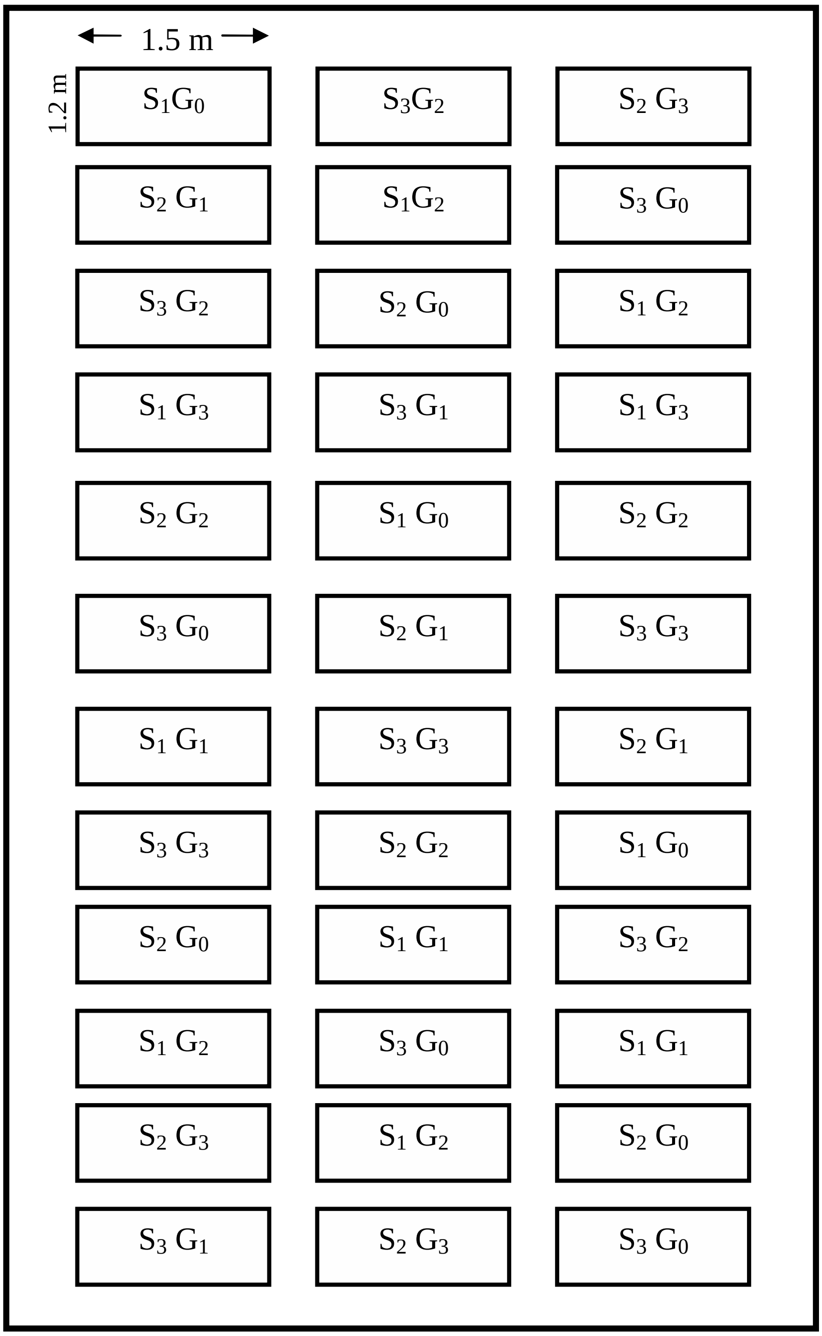
Factor B Gibberellic acid (GA_3) : Four concentration

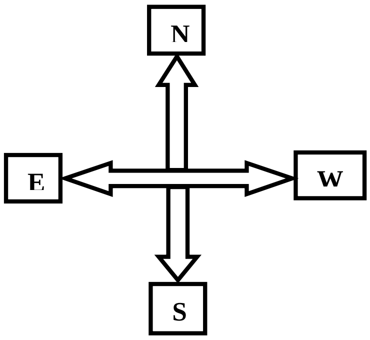
G_0 : 0 ppm GA_3
G_1 : 200 ppm GA_3
G_2 : 250 ppm GA_3
G_3 : 300 ppm GA_3

There were altogether 12 treatment combinations, which were S_1G_0, S_1G_1, S_1G_2, S_1G_3, S_2G_0, S_2G_1, S_2G_2, S_2G_3, S_3G_0, S_3G_1, S_3G_2 and S_3G_3.

3.5 Design and layout of the experiment

The two-factor experiment was laid out following Randomized Complete Block Design (RCBD) with three replications. The total area (20.4 m×7.5 m) of the experimental land was divided into three equal blocks. Each block was then divided into 12 plots where 12 treatments were allotted at random. Thus, there were 36 (12 × 3) unit plots altogether in the experiment. The size of each plot was 1.5 m × 1.2 m. The block to block and plot to plot distances were 1 m and 0.5 m, respectively. The layout of the experiment is shown in Fig. 1.





Plot size: 1.5 m × 1.2 m
Plot to plot distance: 0.5 m
Block to block distance: 1.0 m

Factor A : Spacing
S_1 = 20 × 10 cm
S_2 = 20 × 15 cm
S_3 = 20 × 20 cm

Factor B : Gibberellic Acid
G_0 = 0 ppm GA_3
G_1 = 200 ppm GA_3
G_2 = 250 ppm GA_3
G_3 = 300 ppm GA_3

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

3.6 Land preparation

The land which was selected to conduct the experiment was opened on 10 May, 2011 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 made until good tilth.

3.7 Manures and fertilizer application

The following doses of manures and fertilizers were used in this experiment:

Manures/Fertilizer	**Doses/ha**	**Doses/plot**
Cowdung	15 ton	2.7 kg
Urea	260 kg	46.8 g
Triple Super Phosphate (TSP)	200 kg	36.0 g
Muriate of Potash (MoP)	250 kg	45.0 g

The entire amount of cowdung, TSP and half of MoP and urea were applied during final land preparation. The applied manures and chemical fertilizers were mixed properly with the soil in the plot using a spade. The rest amount of urea and MoP were applied as equal three top dressings. The first top dressing was done at 30 days after emergence of tuberose bulbs, second one after 30 days of first top dressing and the last top dressing during first blooming of 25% plants in each plot.

3.8 Application and preparation of GA_3

The stock solution of 1000 ppm of GA_3 was made by mixing of 1 g of GA_3 with small amount of ethanol to dilute and then mixed in 1 litre of water. Then as per requirement of 200 ppm , 250 ppm and 300 ppm solution of GA_3, 200 ml , 250 ml and 300 ml of stock solution were mixed with 1 litre of water respectively. Application of GA_3 was done at 40 days and 60 days after planting of bulb .

3.9 Collection and planting of bulbs

The bulbs of tuberose were used as planting materials in this experiment. The bulbs were collected from Barisal Nursery, Savar, Dhaka. The collected bulbs were planted in the experimental field on 28 May 2011. The bulbs were transplanted following raised bed system with 5 cm depth in row as per to the treatment specifications. After transplanting, the bulbs were covered with loose soil.

3.10 Intercultural operations

3.10.1 Weeding

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

3.10.2 Irrigation and drainage

Irrigation was applied for three times, where the first irrigation at 25 DAP, second at 45 DAP and the last irrigation at 65 DAP. The drainage was not needed because no water logging condition was observed during the experimental period.

3.10.3 Pest management

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

3.10.4 Disease management

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

3.11 Harvesting

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

3.12 Collection of data

Data on the following parameters were recorded from the sample plants during the course of experiment. In this regard, ten sample plants were selected randomly from each unit plot to collect data on different plant characteristics of tuberose in terms of 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 GA_3.

3.12.1 Plant height

Plant height was measured in centimeter (cm) by a meter scale at 30, 55, 80 and 105 DAP from the point of attachment of the leaves to the bulb (ground level) up to the tip of the longest leaf.

3.12.2 Number of leaves per plant (mother bulb)

Numbers of leaves/plant of ten random selected plants were counted at 30, 55, 80 and 105 DAP. All the leaves of each plant were counted separately. Only the smallest young leaves at the growing point of the plant were excluded from the counting and the average number was recorded.

3.12.3 Length of leaves per plant

For the determination of leaf length, at first, leaves of ten random selected plants were made detached by a sharp knife and their lengths were measured at 30, 55, 80 and 105 DAP with a meter scale.

3.12.4 Days to spike emergence

Days to spike emergence was recorded from transplanting to spike emergence of tuberose plants.

3.12.5 Length of spike (mother bulb)

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

3.12.6 Length of spike (side shoot)

The average length of spike (side shoot) which produced from side shoot was measured from ten random selected plants in centimeter with the help of a meter scale from the basal (cutting) end of the spike to the last point of the tip floret of the spike in each treatment.

3.12.7 Diameter of spike (mother bulb)

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

3.12.8 Length of rachis (mother bulb)

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

3.12.9 Length of rachis (side shoot)

After harvest, the length of rachis which produced from side shoots were measured with the help of a meter scale from ten random selected plants and mean was expressed in centimeter which raised from mother bulb.

3.12.10 Number of florets per spike (mother bulb)

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

3.12.11 Number of spike per hectare (‘000’)

Total number of spike was counted from ten selected plants at each unit area of plot and was converted to the total number of spikes/ha.

3.12.12 Number of bulb per hectare (‘000’)

Total number of bulb was counted from ten selected plants at each unit area of plot and was converted to the total number of bulb/ha.

3.13 Statistical analysis

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

3.14 Economic analysis

The cost of production was analyzed in order to find out the most economic combination of plant spacing and GA_3. All input cost including the cost for lease of land and interests on running capital was computed for the cost of production. The interests were calculated @ 13% in simple rate. The market price of spike and bulb were considered for estimating the cost and return. Analysis were done according to the procedure of Alam *et al.* (1989). The benefit cost ratio was calculated as follows:

$$\text{BCR} = \frac{\text{Gross return per hectare (TK.)}}{\text{Total cost of production (TK.)}}$$

CHAPTER IV
RESULTS AND DISCUSSION

The results of the present study have been presented and discussed and possible interpretations have been given under the following headings. However, the analysis of variances for different characters has been presented in appendices I to VIII . Data on different parameters were analyzed statistically and the results have been presented in respective tables and figures in this chapter.

4.1 Plant height

The plant height varied significantly at 30, 55, 80 and 105 days after planting (DAP) due to different plant spacing (Appendix III). At 30 DAP, the tallest plant (20.6 cm) was found from the widest spacing of 20 cm ×20 cm (S_3) and the shortest plant (18.3 cm) was observed in the closest spacing of 20 cm x10 cm (S_1) (Fig 2). The highest plant height (40.4 cm) was found in the widest spacing of 20 cm ×20 cm (S_3) and the lowest plant was observed in (36.5 cm) the closest spacing of 20 cm x10 cm (S_1) at 55 DAP (Appendix III &Fig 2). At 80 DAP the longest plant height (48.2 cm) was found in the widest spacing of 20 cm ×20 cm (S_3) and the shortest plant was observed in (45.0 cm) the closest spacing of 20 cm x10 cm (S_1) (Appendix III &Fig 2). The maximum plant height (57.2 cm) was observed in the widest spacing of 20 cm ×20 cm (S_3) the minimum plant height was recorded from (53.3 cm) the closest spacing of 20 cm x10 cm (S_1) at 105 DAP (Appendix III &Fig 2) . It was observed that the plant height gradually increased over time in all observations. Balak *et al.* (1999) also reported that wider spacing gave the longest plant height.

The plant height also varied significantly due to application of different concentration of GA_3. The plant height increased linearly with the increasing level of GA_3 (Appendix III & Fig. 3). Application of GA_3 significantly varied on plant height at 30, 55, 80 and 105 days after planting (DAP). At 30 DAP, the longest plant height (20.1 cm) was obtained from the higher level of GA_3 (G_2; 250 ppm of GA_3) and the shortest plant height (18.5 cm) was found from the control level of GA_3 (G_0: 0 ppm of GA_3) . The highest plant height (39.6 cm) was observed from the higher level of GA_3 (G_2; 250 ppm of GA_3) and the lowest plant height (37.4 cm) was found from the control level of GA_3 (G_0: 0 ppm of GA_3) at 55 DAP . At 80 DAP, the longest plant height (48.0 cm) was obtained from the higher level of GA_3 (G_2; 250 ppm of GA_3) and the shortest plant height (45.3 cm) was found from the control level of GA_3 (G_0: 0 ppm of GA_3) . The maximum plant height (57.2 cm) was recorded from the higher level of GA_3 (2_3; 250 ppm of GA_3) and the minimum plant height (54.2 cm) was found from the control level of GA_3 (0_1: 0 ppm of GA_3) at 105 DAP (Appendix III & Fig 3) The findings of the study also supported to the results of Mukhopadyay and Banker (1983) .

The plant height was significantly influenced by the combined effect of different plant spacing and different levels of GA_3 (Appendix III & Table I). At 30 DAP, the tallest plant (22.6 cm) was obtained from S_3G_2 (widest spacing along with 250 ppm GA_3) while the shortest plant height (17.0 cm) was found in S_1G_0 . The longest plant (44.0 cm) was found from S_3G_2 (widest spacing along with 250 ppm GA_3) while the lowest plant height (34.6 cm) was observed in S_1G_0 at 55 days . At 80 DAP, the tallest plant (53.0 cm) was obtained from S_3G_2 (widest spacing along with 250 ppm GA_3) while the shortest plant (44.3 cm) was found in S_1G_0 .

The highest plant height (61.0 cm) was recorded from the treatment combination of S_3G_2 and the lowest plant height was obtained S_1G_0 treatment combination at 105 DAP (Appendix III & Table I)

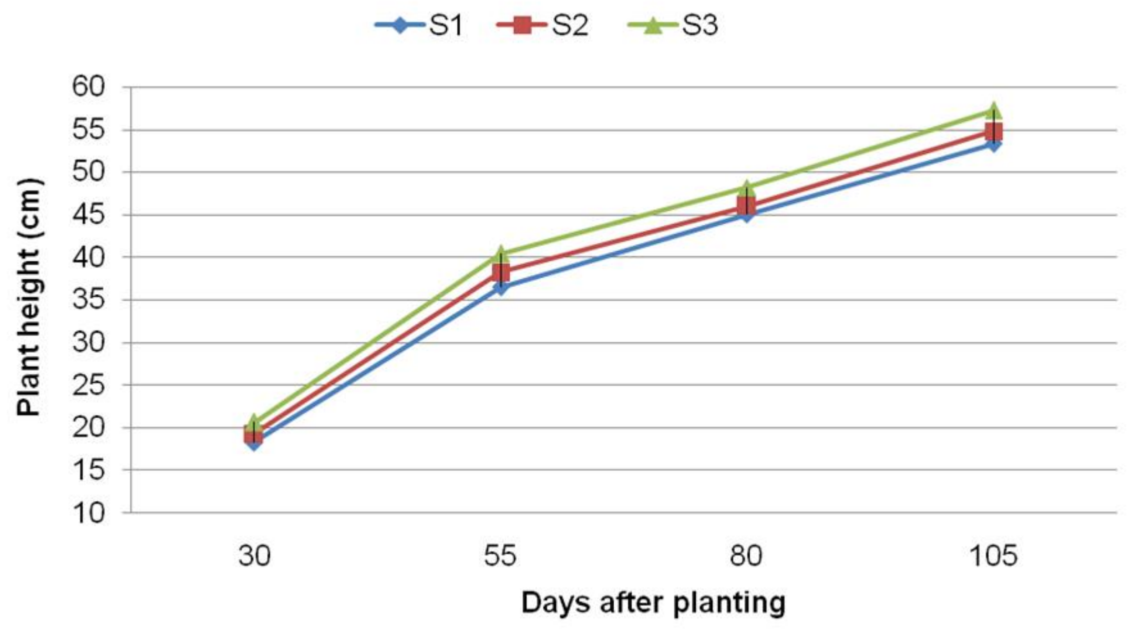


Fig. 2 Effect of spacing on the plant height of tuberose

Note: S_1 =20 cm × 10 cm, S_2 = 20 cm × 15 cm and S_3 = 20 cm × 20 cm

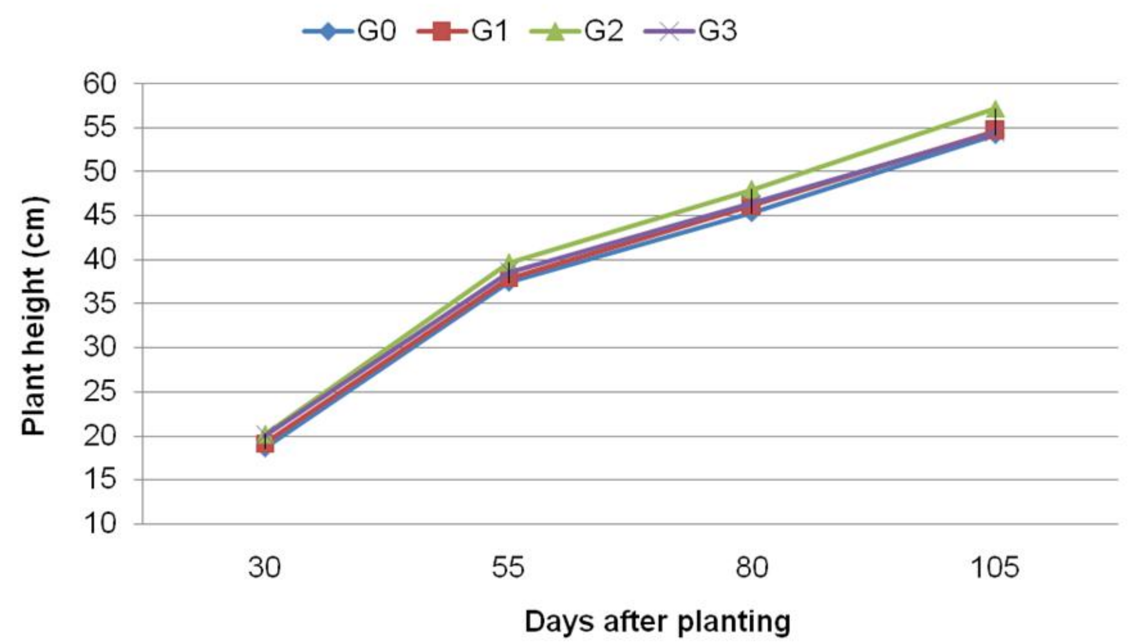


Fig. 3 Effect of GA_3 on the plant height of tuberose

Note: G_0 = 0 ppm GA_3 , G_1 = 200 ppm GA_3 , G_2 = 250 ppm GA_3 and G_3 = 300 ppm GA_3

Table 1 Combined effect of spacing and GA_3 Concentration on plant height of tuberose at different days after planting

Treatment (s)	Plant height (cm)			
	30 DAP	55 DAP	80 DAP	105 DAP
S_1G_0	17.0f	34.6g	44.3c	51.3d
S_1G_1	18.0ef	36.0fg	45.6bc	55.0b-d
S_1G_2	18.6de	38.6b-e	46.0bc	55.0b-d
S_1G_3	19.6b-d	36.6d-g	44.3c	52.0cd
S_2G_0	18.6de	38.6b-e	46.3bc	55.0b-d
S_2G_1	19.0c-e	37.6c-f	45.0bc	52.3cd
S_2G_2	19.0 c-e	36.3e-g	45.0bc	55.6bc
S_2G_3	20.6b	40.3b	48.0b	56.3b
S_3G_0	20.0bc	39.0b-d	45.3bc	56.3b
S_3G_1	20.3b	40.0bc	47.6bc	56.6b
S_3G_2	22.6a	44.0a	53.0a	61.0a
S_3G_3	19.6b-d	38.6b-e	47.0bc	55.0b-d
Level of significance	**	**	**	*
CV (%)	3.4	3.3	3.9	3.7
LSD (0.05)	1.1	2.1	3.0	3.4

Note: S_1 = 20 cm × 10 cm , S_2 = 20 cm × 15 cm , S_3 = 20 cm × 20 cm
G_0 = 0 ppm GA_3 , G_1 = 200 ppm GA_3 , G_2 = 250 ppm, GA_3 , and G_3 = 300 ppm GA_3

4.2 Number of leaves per plant (mother bulb)

Different plant spacing significantly influenced on number of leaves per plant at different days after planting i.e, 55, 80 and 105 DAP except 30 DAP (Fig. 4). At 30 DAP, the highest number of leaves per plant (5.9) was obtained from the widest plant spacing (20 cm × 20 cm) and the lowest number of leaves (4.5) was found from the closest plant spacing (20 cm × 10 cm) . At 55 DAP, the highest number of leaves per plant (7.5) was obtained from the widest plant spacing (20 cm × 20 cm) and the lowest number of leaves (6.0) was found from the closest plant spacing (20 cm × 10 cm). The highest number of leaves per plant (12.0) was found from the widest plant spacing (20 cm × 20 cm) and the lowest number of leaves per plant (10.0) was obtained from the closest plant spacing at 80 DAP. The maximum number of leaves per plant (17.0) was observed in the widest spacing of 20 cm ×20 cm (S_3) and the minimum number of leaves per plant was recorded from (15.0) the closest spacing of 20 cm x10 cm (S_1) at 105 DAP (Appendix III &Fig 4) .

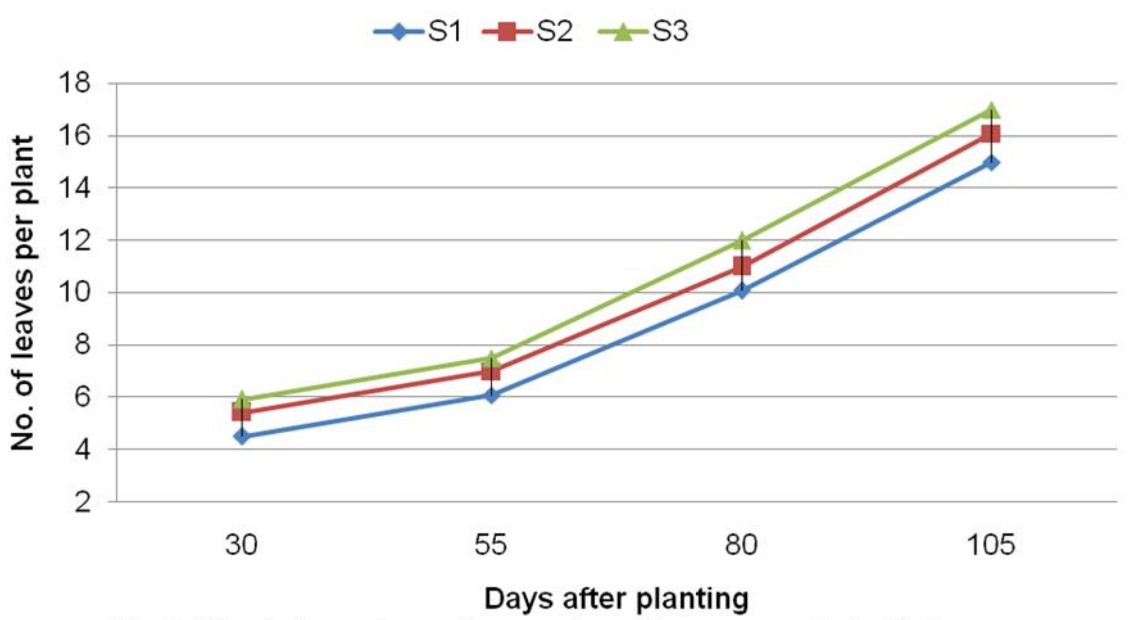


Fig. 4 Effect of spacing on the number of leaves per plant of tuberose

Note: S_1 =20 cm × 10 cm, S_2 = 20 cm × 15 cm and S_3 = 20 cm ×20 cm

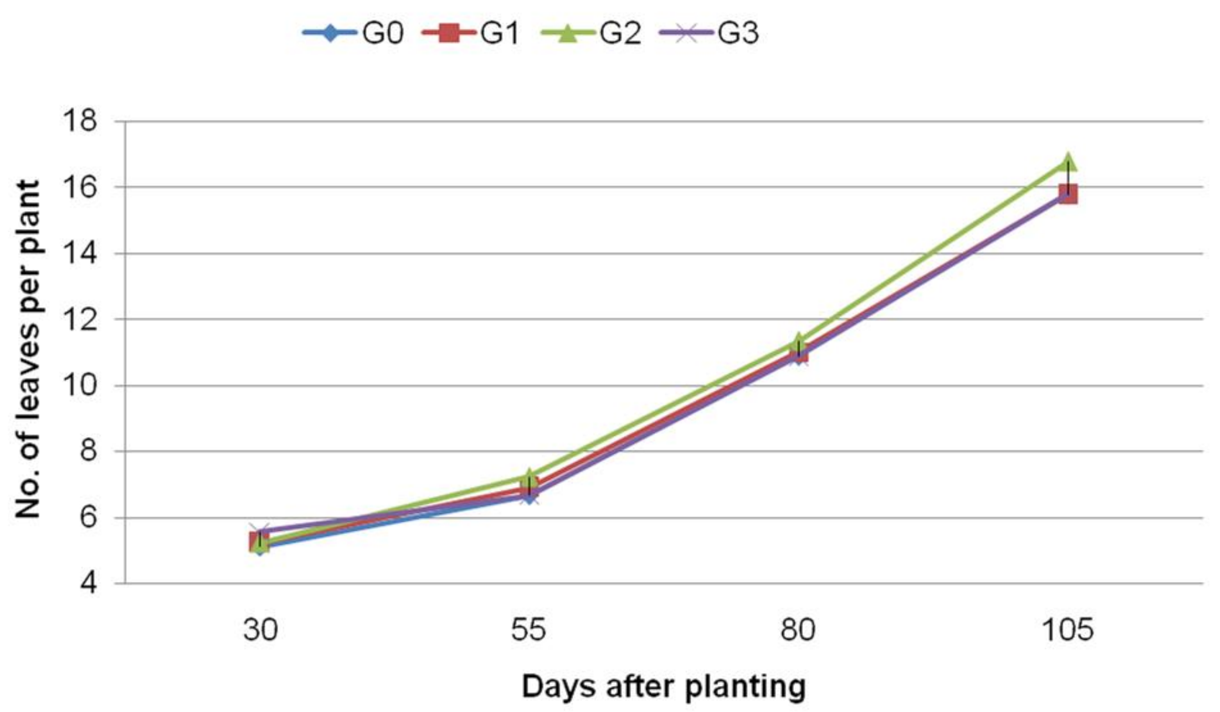


Fig. 5 Effect of GA_3 on the number of leaves per plant of tuberose

Note: G_0 = 0 ppm GA_3, G_1 = 200 ppm GA_3, G_2 = 250 ppm GA_3 and G_3 = 300 ppm GA_3

Table 2 Combined effect of spacing and GA_3 Concentration on number of leaves/plant of tuberose at different days after planting

Treatment (s)	Number of leaves per plant			
	30 DAP	55 DAP	80 DAP	105 DAP
S_1G_0	4.3	6.3ef	10.0fg	14.6ef
S_1G_1	4.6	6.6de	10.6d-f	15.6d-f
S_1G_2	4.3	5.3g	9.3g	14.3f
S_1G_3	4.6	6.0f	10.3ef	15.3d-f
S_2G_0	5.3	6.3ef	10.3ef	15.3d-f
S_2G_1	5.3	7.0cd	11.0c-e	15.6d-f
S_2G_2	5.3	7.6b	11.6bc	17.0bc
S_2G_3	5.6	7.0cd	11.0c-e	16.3b-d
S_3G_0	5.6	7.3bc	12.3ab	17.3b
S_3G_1	5.6	7.0cd	11.3cd	16.0c-e
S_3G_2	6.0	8.6a	13.0a	19.0a
S_3G_3	6.3	7.0cd	11.3cd	15.6c-f
Level of significance	NS	**	**	**
CV (%)	4.4	4.11	4.4	4.4
LSD (0.05)	2.9	0.363	0.8	1.2

Note: S_1 = 20 cm × 10 cm , S_2 = 20 cm × 15 cm , S_3 = 20 cm × 20 cm
G_0 = 0 ppm GA_3 , G_1 = 200 ppm GA_3 , G_2 = 250 ppm , GA_3 and G_3 = 300 ppm GA_3

Significant variation was found in case of number of leaves per plant due to application of different levels of GA_3 at different days after planting except 30 DAP. The number of leaves increased with the advancement of time.

At 30 DAP, there was no significant differences among the treatments, however, the highest number of leaves per plant (5.2) was recorded from G_2 (250 ppm GA_3) and the lowest number of leaves per plant (5.1) was recorded from control treatment G_0 (0 ppm GA_3) . The highest number of leaves per plant (7.2) was recorded from G_2 (250 ppm GA_3) and the lowest number of leaves per plant (6.6) was recorded from control treatment G_0 (0 ppm GA_3) at 55 DAP . At 80 DAP, G_2 (250 ppm GA_3) produced the highest number of leaves (11.3) while the lowest number of leaves per plant (10.8) produced the control treatment G_0 (0 ppm GA_3).

The maximum number of leaves per plant (16.7) was recorded from G_2 (250 ppm GA_3) and the minimum (15.7) was recorded from control treatment G_0 (0 ppm GA_3) at 105 DAP (Appendix III & Fig 5). The higher number of leaves per plant achieved on account of higher level of plant growth regulator. The present findings also support to the results of Wankhede *et al.* (2002).

The number of leaves per plant was significantly influenced by the combined effect of different levels of plant spacing and plant growth regulator with the advancement of time except 30 DAP (Appendix III). At 30 DAP, the highest number of leaves per plant (6.3) was recorded from treatment combination S_3G_3 (widest plant spacing with 300 ppm GA_3) and the lowest number of leaves/plant (4.3) was recorded from treatment combination S_1G_0 (closest plant spacing with 0 ppm GA_3) . The highest number of leaves per plant (8.6) was recorded from the treatment combination of S_3G_2 and the lowest number of leaves per plant (5.1) was recorded from the treatment combination S_1G_0(closest plant spacing with 0 ppm GA_3) which was statistically similar to S_1G_3 and S_2G_0 at 55 DAP. The highest number of leaves per plant (13.0) was recorded from treatment combination S_3G_2 which was similar to S_3G_0 and the lowest number of leaves per plant (10.0) was recorded from treatment combination S_1G_0 (closest plant spacing with 0 ppm GA_3) at 80 DAP. The maximum number of leaves per plant (19.0) was recorded from treatment combination S_3G_2 (widest plant spacing with 250 ppm GA_3) and the lowest number of leaves per plant (14.6) was recorded from treatment combination S_1G_0 (closest plant spacing with 0 ppm GA_3) (Appendix III & Table 2) at 105 DAP.

4.3 Length of leaves

A significant variation was found due to plant spacing at 30, 55, 80 and 105 days after planting (Appendix IV). The longest leaf (20.2 cm) was obtained from the widest spacing S_3 (20 ×20 cm) while the lowest (14.5 cm) was found from the closest spacing S_1(20×10 cm) at 30 DAP .

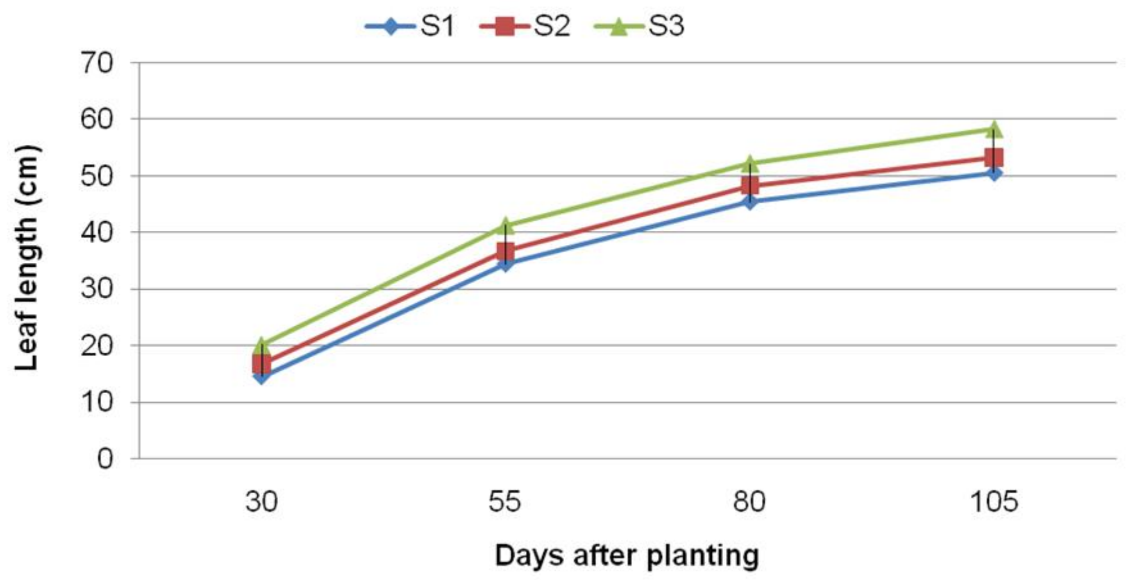


Fig. 6 Effect of spacing on the length of tuberose leaf

Note: S_1 =20 cm × 10 cm, S_2 = 20 cm × 15 cm and S_3 = 20 cm ×20 cm

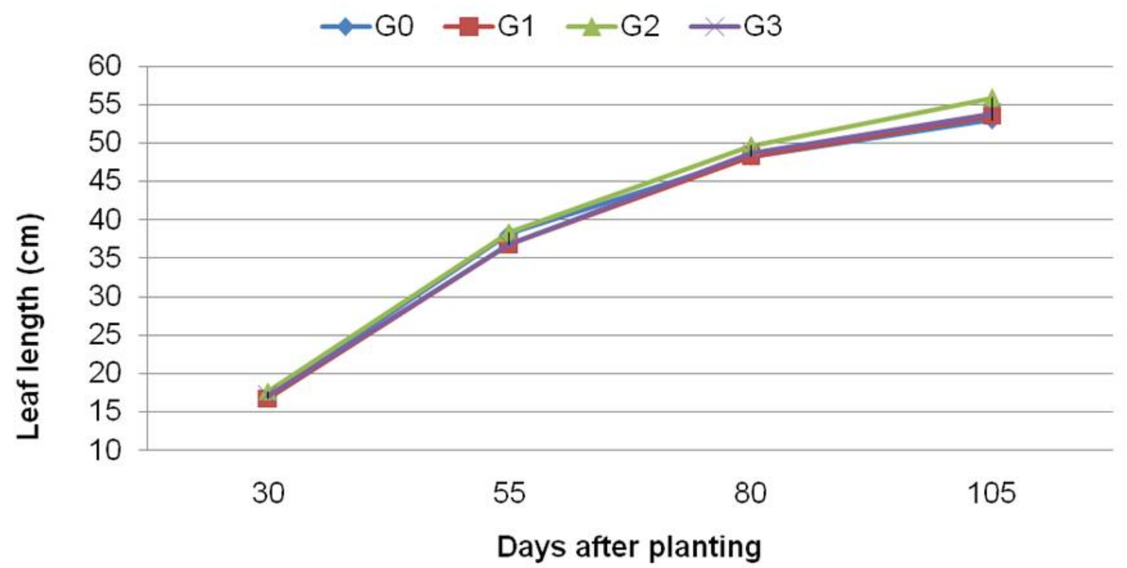


Fig. 7 Effect of GA_3 on the length of tuberose leaf

Note: G_0 = 0 ppm GA_3, G_1 = 200 ppm GA_3, G_2 = 250 ppm GA_3 and G_3 = 300 ppm GA_3

At 55 DAP, the widest spacing (20 ×20 cm) gave the longest (41.3 cm) length of leaf while the closest spacing (20 × 10 cm) produced the shortest (34.5) length of leaf . At 80 DAP, the longest leaf length (52.2 cm) was produced by S_3 and the shortest (45.5 cm) was found from S_1. At 105 DAP, the maximum leaf length (58.3

cm) was obtained from the widest plant spacing S_3 (20 × 20 cm) and the shortest (50.5cm) was noted from closest spacing S_1 (20 × 10 cm) (Appendix IV & Fig. 6).

Table 3 Combined effect of spacing and GA_3 Concentration on leaf length of tuberose at different days after planting

Treatment (s)	Length of leaves (cm)			
	30 DAP	55 DAP	80 DAP	105 DAP
S_1G_0	14.0f	35.3d-f	44.0e	49.3e
S_1G_1	14.3f	34.0f	46.0de	51.0de
S_1G_2	15.0ef	34.6ef	46.0de	51.0de
S_1G_3	15.0ef	34.0f	46.0de	51.0de
S_2G_0	17.0d	36.6de	48.0cd	53.0b-e
S_2G_1	16.6d	36.6c-e	48.0cd	53.0b-e
S_2G_2	16.0de	36.3d-f	47.6cd	52.6c-e
S_2G_3	17.3d	37.3cd	49.6c	54.6b-d
S_3G_0	20.6ab	42.6a	52.6ab	56.6b
S_3G_1	19.3bc	39.7b	50.6bc	56.6b
S_3G_2	22.0a	44.0a	55.3a	64.0a
S_3G_3	19.0c	39.0bc	50.3bc	56.0bc
Level of significance	**	**	**	**
CV%	5.0	4.4	4.2	3.8
LSD (0.05)	1.4	2.1	2.7	3.5

Note: S_1 = 20 cm × 10 cm , S_2 = 20 cm × 15 cm , S_3 = 20 cm × 20 cm
G_0 = 0 ppm GA_3 , G_1 = 200 ppm GA_3 , G_2 = 250 ppm, GA_3 and G_3 = 300 ppm GA_3

The different concentration of GA_3 had significant influenced on leaf length at 55, 80 and 105 DAP except 30 DAP (Appendix IV). The longest leaf (17.6 cm) was obtained from the higher level of GA_3 (250 ppm) while the lowest (17.22 cm) was found from the control treatment of GA_3 (0 ppm) at 30 DAP . At 55 DAP, the longest leaf (38.3 cm) was obtained from the higher level of GA_3 (250 ppm) while the lowest (38.2 cm) was found from the control treatment (0 ppm) . The longest leaf (49.6 cm) was obtained from the higher level of GA_3 (250 ppm) while the lowest (48.2 cm) was found from the control treatment of GA_3 (0 ppm) at 80 DAP.

The maximum length of leaf (55.8 cm) was obtained from the higher level of GA_3 (250 ppm) while the minimum length (53.0 cm) was found from the control treatment (0 ppm) at 105 DAP (Appendix IV & Fig. 7) . Monisha *et al.* (2002) showed the highest length of leaf in all concentration of GA_3 compared to control treatment which agreed to the present study.

The combined effect of different plant spacing and different concentration of GA_3 produced significant influence on leaf length (Appendix IV & Table 3). At 30 DAP, the highest length of leaves per plant (22.0 cm) was recorded from the treatment combination of S_3G_2 which was similar to S_3G_0 and the lowest length of leaves per plant (14.0 cm) was recorded from treatment combination S_1G_0 (closest plant spacing with 0 ppm GA_3). At 55 DAP, the highest length of leaves per plant (44.0 cm) was recorded from the treatment combination of S_3G_2 which was similar to S_3G_0 (widest plant spacing with 250 ppm GA_3) and the lowest length of leaves per plant (34.0 cm) was recorded from treatment combination S_1G_1 (closest plant spacing with 200 ppm GA_3) . The highest length of leaves per plant (55.3 cm) was recorded from the treatment combination of S_3G_2 and the lowest length of leaves per plant (44.0 cm) was recorded from the treatment combination of S_1G_0 (closest plant spacing with 0 ppm GA_3) at 80 DAP. At 105 DAP, the longest length of leave per /plant (64.0 cm) was recorded from the treatment combination of S_3G_2 (widest plant spacing with 250 ppm GA_3) and the shortest length of leaves per plant (49.3cm) was recorded from the treatment combination of S_1G_0 (closest plant spacing with 0 ppm GA_3) .

4.4 Days to spike emergence

Days to spike emergence showed significant differences due to different plant spacing (Appendix IV). The longest days (82.3 days) were required to spike emergence from S_1 while the shortest days (77.8 days) were required for S_3 (table 4).

Different concentration of GA_3 also showed significant variation on days to spike emergence (Table 5). The highest period (81.6 days) was required for G_1 and the shortest period (77.8 days) was for G_4. Rama Swamy (1997); Mohanthy *et al.* (1999) and Monisha *et al.* (2002) also stated that tuberose plants treated with GA_3 required lowest days to spike emergence.

The combined effect of plant spacing and GA_3 showed significant differences on days to spike emergence . However, the highest days (84.6 days) were counted for spike emergence from the treatment combination of S_1G_0 and the lowest (75.3 days) from S_3G_3 (Table 6).

4.5 Length of spike (mother bulb)

The length of spike showed significant differences due to different plant spacing (Appendix IV & Table 4). The longest length of spike (82.6 cm) was obtained from the widest spacing S_3 (20 ×20 cm) while the shortest (71.5 cm) was recorded from closest spacing S_1 (20 × 10 cm).

Application of different concentration of GA_3 showed non significant variation on length of spike (Appendix IV & Table 5). However, the longest length of spike (76.7 cm) was recorded from the moderate level of GA_3 (G_1: 200 ppm) and the shortest length of spike (76.0 cm) was recorded from the highest level of GA_3 (G_3: 300ppm).

The combined effect of spacing and GA_3 did not show significant variation on length of spike of mother bulb.(Appendix IV & Table 6) . However, the longest length of spike (84.0 cm) was recorded from S_3G_2 (widest plant spacing along with 250 ppm GA_3) whereas, the treatment combination of S_1G_0 produced the lowest length of spike (71.0 cm).

4.6 Length of spike (side shoot)

The spike length of side shoot varied significantly due to different plant spacing (Table 4). Treatment S_3 produced the longest length of spike (66.5 cm) while S_1 (closest spacing: 20×10 cm) showed the shortest (58.3 cm) length of spike. Kumer *et al.* (2003) also found similar trends of result.

Application of different concentration of GA_3 showed non significant variation on length of spike (Table 5). However, the higher level of GA_3 (G_2:250 ppm) produced the longest length of spike (63.0 cm) and the shortest length of spike (61.6 cm) was recorded from G_1 (200ppm. The present investigation agreed to the findings of Misra *et al*. (2000) and Mukhapadayay and Banker (1983).

There were no significant variations among different plant spacing and GA_3 on length of spike of side shoot due to combined effect (Table 6). However, the longest length of spike (70.0 cm) was obtained from S_3G_2 (20 x 20 cm spacing and 250 ppm GA_3) while the treatment combination of S_1G_2 gave the shortest length of spike (57.6 cm) of side shoot.

Table 4 Main effect of spacing on different plant characters of tuberose

Spacing	Length of spike (side shoot) cm	Days to spike emergence	Length of spike (mother bulb) cm	Diameter of spike (mother bulb) cm
S_1 (20×10 cm)	58.3c	82.3a	71.5c	0.7b
S_2 (20×15 cm)	62.0b	79.6b	75.0b	0.7b
S_3 (20×20 cm)	66.5a	77.8c	82.6 a	0.8a
Level of significance	**	**	**	**
CV (%)	4.2	4.1	5.2	5.9
LSD (0.05)	1.7	-	3.3	0.03

Note: S_1 = 20 cm × 10 cm, S_2 = 20 cm × 15 cm, S_3 = 20 cm × 20 cm

Table 5 Main effect of GA_3 Concentration on different plant characters of tuberose

GA_3	Length of spike (side shoot) cm	Days to spike emergence	Length of spike (mother bulb) cm	Diameter of spike (mother bulb) cm
G_0 (0 ppm GA_3)	61.7	81.6a	76.3	0.8
G_1 (200 ppm GA_3)	61.6	79.8b	76.7	0.8
G_2 (250 ppm GA_3)	63.0	80.3b	76.6	0.8
G_3 (300 ppm GA_3)	62.6	77.8c	76.0	0.8
Level of significance	NS	**	NS	NS
CV%	4.2	4.1	5.2	5.9
LSD (0.05)	-	-	-	-

Note: G_0 = 0 ppm GA_3, G_1 = 200 ppm GA_3, G_2 = 250 ppm GA_3 and G_3 = 300 ppm GA_3

Table 6 Combined effect of spacing and GA_3 Concentration on different plant characters of tuberose

Treatment (s)	Spike length (side shoot) cm	Days to spike emergence	Spike length (mother bulb) cm	Spike diameter (mother bulb) cm
S_1G_0	58.3d	84.6a	71.0	0.7
S_1G_1	58.3d	81.6b	72.6	0.7
S_1G_2	57.6d	81.6b	71.0	0.7
S_1G_3	59.0d	81.3b	71.6	0.7
S_2G_0	61.3cd	79.6bc	75.3	0.8
S_2G_1	61.0cd	81.0b	75.3	0.8
S_2G_2	61.3cd	81.0b	75.0	0.7
S_2G_3	64.3bc	77.0de	74.6	0.7
S_3G_0	65.6b	80.6b	82.6	0.8
S_3G_1	65.6b	77.0de	82.3	0.8
S_3G_2	70.0a	78.3cd	84.0	0.8
S_3G_3	64.6bc	75.3e	81.6	0.8
Level of significance	*	**	NS	NS
CV%	4.2	4.1	5.2	5.9
LSD (0.05)	3.4	-	-	-

Note: S_1 = 20 cm × 10 cm , S_2 = 20 cm × 15 cm , S_3 = 20 cm × 20 cm
G_0 = 0 ppm GA_3 , G_1 = 200 ppm GA_3 , G_2 = 250 ppm, GA_3 and G_3 = 300 ppm GA_3

4.7 Spike diameter (mother bulb)

Diameter of spike showed the significant differences due to use of different plant spacing (Appendix IV & Table 4). The highest diameter of spike (0.8 cm) was obtained from the widest spacing S_3 (20 × 20 cm) while the lowest (0.7 cm) was recorded from the closest spacing S_1 (20 × 10 cm) .

There was no significant variation on diameter of spike due to application of different levels of GA_3 (Appendix IV & Table 5). The highest diameter of spike (0.8 cm) were recorded from control treatment G_0 (0 ppm) and the shortest length of spike (0.7 cm) were recorded from rest of all treatments .

Combined effect of different levels of plant spacing and GA_3 did not perform the significant variation on diameter of spike. (Appendix IV & Table 6). The highest diameter of spike (0.8 cm) was recorded from S_3G_2 (widest plant spacing and higher level of 250 ppm GA_3) whereas, the lowest (0.7 cm) was recorded from the treatment combination of S_1G_1.

4.8 Rachis length (mother bulb)

A significant variation was found on length of rachis of mother bulb due to different plant spacing ((Appendix V & Table7). The widest plant spacing (S_3: 20 × 20 cm) produced the longest length of rachis (31.7 cm) from mother bulb and the shortest (22.4 cm) was recorded from the closest spacing (S_1: 20 × 10 cm). The present study supported the findings of Singh and Sangama (2000).

Different concentration of GA_3 showed non significant variation on length of rachis ((Appendix IV & Table 8). The higher level of GA_3 (G_2: 250 ppm) produced the highest length of rachis (27.2 cm) and the shortest length of rachis (26.2 cm) was recorded from G_1 (200 ppm).

There was no significant variation on length of rachis of mother bulb due to combined effect of different plant spacing and different levels of GA_3 (Appendix V & Table 9). The longest rachis (32.6 cm) was recorded in S_3G_0 whereas, the shortest (21.9 cm) from the treatment combination of S_1G_0.

4.9 Rachis length (side shoot)

Length of rachis showed significant differences due to use of different plant spacing in the present study ((Appendix V & Table 7). The highest length of rachis (23.3 cm) was obtained from the widest spacing (S_3: 20×20 cm) while the shortest (15.2 cm) was recorded from closest spacing (S_1:20×10 cm).Kumer *et al.* (2003) noted that wider plant spacing produced the highest length of rachis.

Application of different concentration of GA_3 showed non significant variation on length of rachis ((Appendix V & Table 8). However, the higher concentration of

GA_3 (G_2:250 ppm GA_3) produced the longest rachis (19.2 cm) and the shortest length of spike (18.6 cm) was recorded from control treatment where the plots did not receive GA_3 (control condition) .

Combined effect of plant spacing and GA_3 concentration did not found the significant variation on length of rachis produced from side shoot. (Appendix V & Table 9). The highest length of rachis from side shoot (24.0 cm) was recorded from S_3G_2 (widest spacing and 250 ppm GA_3) whereas, the lowest (14.6 cm) was recorded from the treatment combination of S_1G_3.

4.10 Florets / spike (mother bulb)

Significant variation was found on number of florets/spike (mother bulb) due to use of different plant spacing ((Appendix V & Table 7). The widest spacing (S_3; 20 x 20 cm) produced the highest number of florets/spike (33.5) and the shortest (23.0) was recorded from S_1.

A non significant variation was found on number of florets per spike due to application of different concentration of GA_3 ((Appendix V & Table 8). The highest level of GA_3 (G_3:300 ppm GA_3) produced the highest number of florets per spike (27.7) and the lowest number of florets per spike (27.3) was recorded from control condition. Nagar *et al.* (2002) found the highest number of florets per spike from higher level of GA_3 which supported to the present trial.

No significant variation was observed on number of florets per spike produced from mother bulb due to combined effect of different levels of plant spacing and plant growth regulator ((Appendix V &Table 9) .The highest number of florets per spike (35.3) was counted from the treatment combination of S_3G_2 while the lowest (22.0) was recorded from S_1G_1

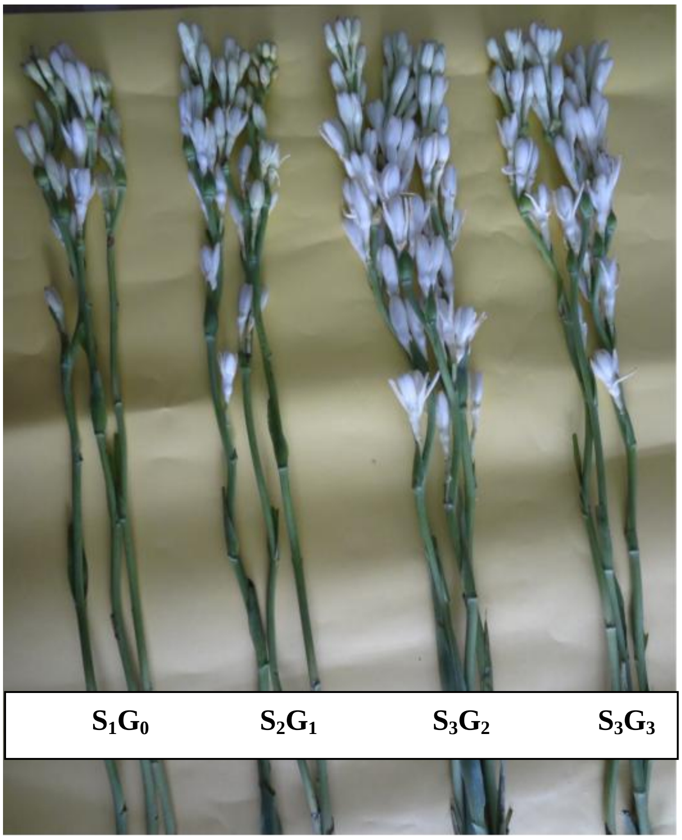


Fig 8 Combined effect of spacing and GA_3 concentration on number of florets/spike of tuberose

4.11 Spike number / ha ('000')

Number of spike per hectare showed non significant differences due to use of different plant spacing (Appendix V & Table 7). The highest number of spike per hectare (695.0) in thousand was recorded from S_2 while the lowest (685.0) in thousand was counted from the widest spacing S_3.

Application of different concentration of GA_3 showed significant variation on number of spike per hectare ('000') (Appendix V & Table 8). The maximum number of spike per hectare (780.7) in thousand was recorded from G_2 (250 ppm GA_3). and the minimum number of spike per hectare (630.0) in thousand was counted from control treatment G_0 (0 ppm GA_3). Similar trends of result were also obtained by Dhua *et al.* (1987).

Combined effect of different plant spacing and different concentration of GA_3 showed significant variation on number of spike per hectare (Appendix V & Table 9). The maximum number of spike per hectare (801.7) in thousand was recorded from S_3G_2 (20×20 cm spacing along with 250 ppm GA_3) whereas, the minimum number of spike per hectare (610.0) in thousand was counted from the treatment combination of S_2G_3.

4.12 Bulb number / ha ('000')

A non significant variation was found on number of bulb per hectare ('000') due to the effect of different plant spacing (Appendix V & Fig 8). The maximum number of bulb per hectare (846.5) in thousand was recorded from plant spacing (S_2: 20 × 15 cm) and the minimum number of bulb per hectare (841.5) in thousand was recorded from the widest spacing (S_3:20 ×20 cm).

A significant variation was found on number of bulb per hectare ('000') due to application of different concentration of GA_3 (Appendix V & Fig 9). The maximum number of bulb per hectare (948.3) in thousand was recorded from the higher level of GA_3 (G_2:250 ppm GA_3) and the control treatment performed the minimum number (772.7) in thousand of bulb per hectare.

A significant variation was observed on number of bulb per hectare ('000') due to combined effect of different plant spacing and different levels of GA_3 (Appendix V & table 9). The maximum number of bulb per hectare (958.3) was noted from the treatment combination of S_3G_2 (widest plant spacing and 250 ppm GA_3) and the minimum number of bulb per hectare (762.7) was noted from the treatment combination of S_2G_3. Singh and Sangma (2000) recorded the highest yield of bulb from the treatment combination of 30 × 30 cm spacing.

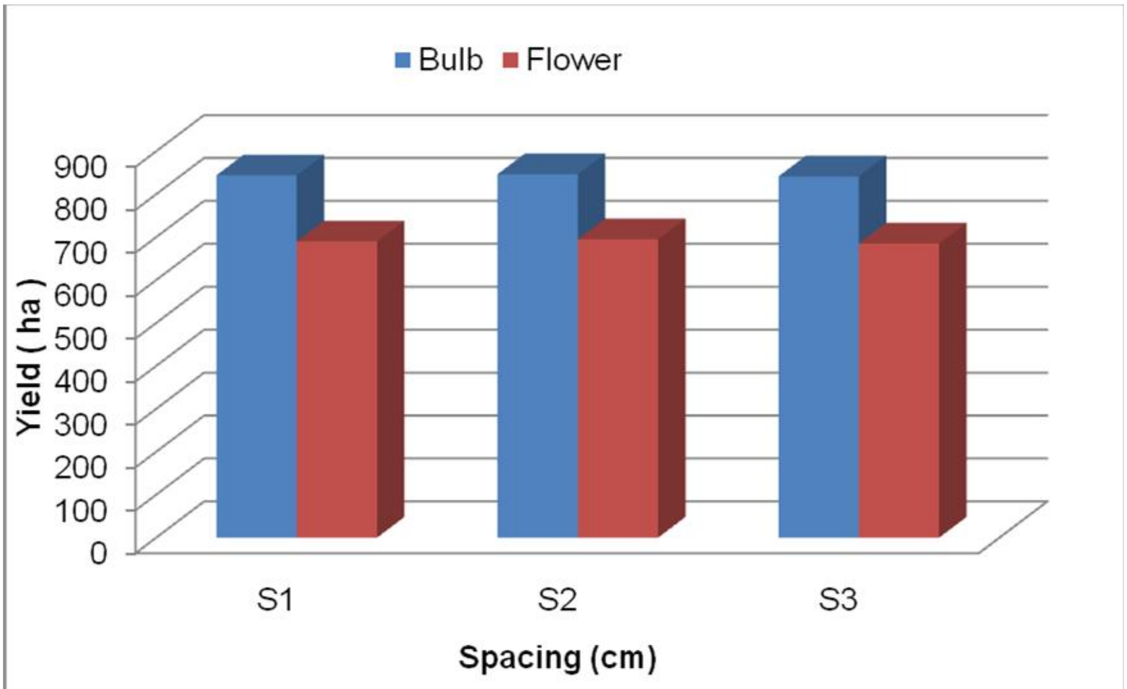


Fig. 9 Effect of spacing on the yield of tuberose

Note: S_1 = 20 cm × 10 cm, S_2 = 20 cm × 15 cm, S_3 = 20 cm × 20 cm

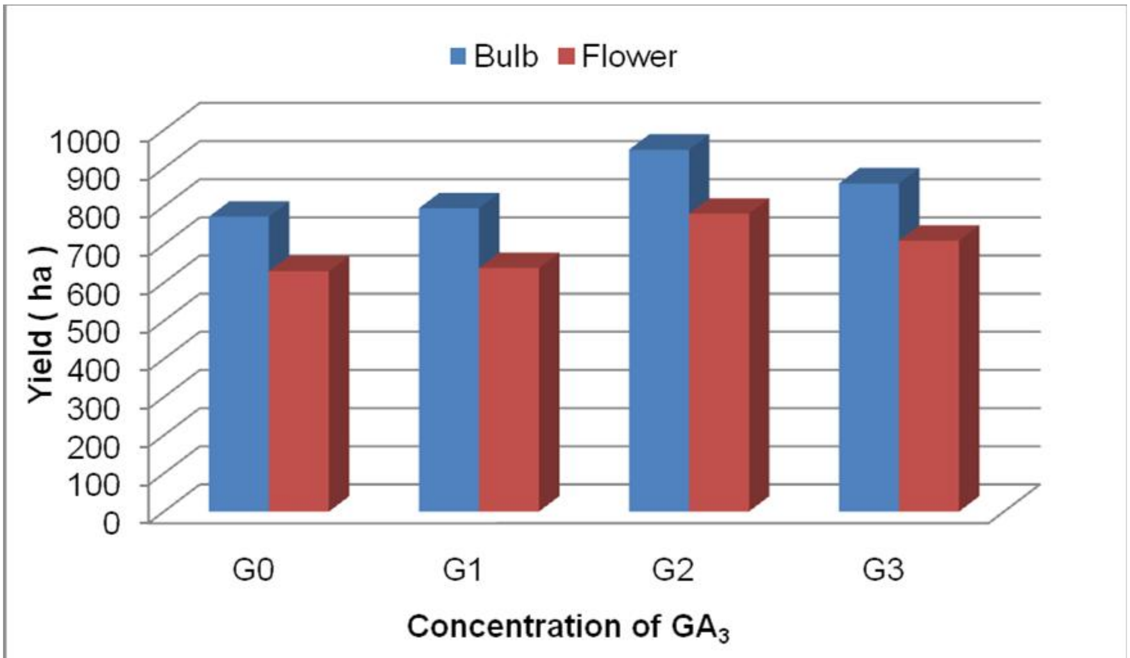


Fig. 10 Effect of GA_3 on the yield of tuberose

Note: G_0 = 0 ppm GA_3, G_1 = 200 ppm GA_3, G_2 = 250 ppm GA_3 and G_3 = 300 ppm GA_3

Table 7 Main effect of plant spacing on yield contributing characters of tuberose

Spacing	Number of florets /spike	Rachis length (mother bulb) cm	Rachis length (side shoot) cm	Spike number/ha ('000')	Bulb number /ha ('000')
S_1(20×10)	23.0c	22.4c	15.2c	690.0a	844.0a
S_2 (20×15)	26.0b	25.9b	18.0b	695.0a	846.5a
S_3(20×20)	33.5a	31.7a	23.3a	685.0a	841.5a
Level of significance	**	**	**	NS	NS
CV%	7.7	5.0	5.0	9.98	8.93
LSD (0.05)	-	-	-	116.60	127.60

Note: S_1 = 20 cm × 10 cm, S_2 = 20 cm × 15 cm, S_3 = 20 cm × 20 cm

Table 8 Main effect of GA_3 concentration on yield contributing characters of tuberose

GA_3	Number of florets/spike	Rachis length (mother bulb) cm	Rachis length (side shoot) cm	Spike number/ha ('000')	Bulb number /ha ('000')
G_0	27.3	26.7	18.6	630.0b	772.7b
G_1	27.3	26.2	18.8	638.3b	795.0b
G_2	27.5	27.2	19.2	780.7a	948.3a
G_3	27.7	26.6	18.7	710.0ab	860.0ab
Level of significance.	NS	NS	NS	**	**
CV%	7.78	5.07	5.06	9.98	8.93
LSD (0.05)	-	-	-	116.60	127.60

Note: G_0 = 0 ppm GA_3, G_1 = 200 ppm GA_3, G_2 = 250 ppm GA_3 and G_3 = 300 ppm GA_3

Table 9 Combined effect of plant spacing and GA_3 on yield contributing characters of tuberose

Treatment (s)	Number of florets/spike	Rachis length (mother bulb) cm	Rachis length (side shoot) cm	Spike number/ha ('000'	Bulb number/ha (‘000’)
S_1G_0	24.0	21.9f	15.3de	710.0abcd	860.0abc
S_1G_1	22.0	23.3ef	15.3de	730.0abcd	870.0abc
S_1G_2	22.0	22.0f	15.6de	690.0abcd	850.0abc
S_1G_3	24.0	22.6f	14.6e	618.3d	785.0 c
S_2G_0	26.6	25.6cd	16.6cd	638.3cd	795.0c
S_2G_1	26.0	24.6de	18.3bc	658.3bcd	805.0bc
S_2G_2	25.3	27.0c	18.0bc	650.0bcd	782.7c
S_2G_3	26.0	26.3cd	19.3b	610.0d	762.7c
S_3G_0	31.3	32.6a	24.0a	630.0cd	772.7c
S_3G_1	34.0	30.6b	23.0a	781.7ab	948.3a
S_3G_2	35.3	32.6 a	24.0a	801.7a	958.3a
S_3G_3	33.3	31.0ab	22.3a	761.7 abc	938.3ab
Level of significance	NS	*	**	**	**
CV%	7.7	5.0	5.0	9.9	8.9
LSD(0.05)	-	1.8	1.6	116.6	127.6

Note: S_1 = 20 cm × 10 cm , S_2 = 20 cm × 15 cm , S_3 = 20 cm × 20 cm
G_0 = 0 ppm $GA_{3,}$ G_1 = 200 ppm $GA_{3,}$ G_2 = 250 ppm , GA_3 and G_3 = 300 ppm GA_3

4.13 Economic analysis

Input costs for land preparation, bulb, fertilizer, gibberellic acid (GA_3), pesticide, irrigation and manpower required for all the operations including harvesting of flowers and bulb were recorded for unit plot and converted into cost per hectare. Prices of the spikes and bulb were considered in the market rate basis. The economic analysis was done to find out the gross and the net return and the benefit cost ratio in the present experiment and the presented under the following headings.

4.14 Gross return

In the combination of different plant spacing and different levels of GA_3 showed different gross return. The highest gross return (TK.1175000.0) was obtained from the treatment combination of S_3G_2 (widest spacing ; 20 cm×20 cm with 250 ppm GA_3) (AppendixVI & Table10) and The second highest gross return (TK.962500.0) was obtained from the treatment combination of S_3G_3 . (Appendix VI & Table 10). The lowest gross return (TK.737500.0) was obtained from the treatment combination of S_3G_0. (Appendix VI & Table 10)

4.15 Net return

In case net return different treatment combination showed various net return. The highest net return (TK.607568.9) was obtained from the treatment combination S_3G_2 .(Appendix VI & Table 10) and the second highest net return (TK.389493.9) was obtained from the treatment combination S_3G_3 . (Appendix VI & Table 10) The lowest net return (TK.27293.9) was obtained from the treatment combination S_1G_0 . (Appendix VI & Table 10).

4.16 Benefit cost ratio

The combination of different plant spacing and different levels of GA_3 for benefit cost ratio was different for treatment combination (Appendix VI & Table 10). The highest (2.0) benefit cost ratio was recorded from S_3G_2 and the lowest benefit cost ratio (1.0) was recorded from S_1G_0. From economic point of view, it was apparent from the above results treatment combination of S_3G_2 was more profitable compare to others.

Table 10 Cost and return of tuberose cultivation as influenced by spacing and GA_3 Concentration

Treatment Combination	Flower spike yield ('000')	Flower spike return (Tk.)	Bulb yield ('000')	Bulb return (Tk.)	Gross return (Tk.)	Total Cost of Production (Tk.)	Net return (Tk.)	BCR
S_1G_0	700.0	700000	850.0	212500.0	912500.0	885206.0	27293.9	1.0
S_1G_1	710.0	710000	860.0	215000.0	925000.0	896356.0	28643.9	1.0
S_1G_2	720.0	720000	870.0	217500.0	937500.0	901931.0	35568.9	1.0
S_1G_3	730.0	730000	880.0	220000.0	950000.0	907506.0	42493.9	1.0
S_2G_0	580.0	580000	750.0	187500.0	767500.0	662206.0	105293.9	1.1
S_2G_1	605.0	605000	755.0	188750.0	793750.0	673356.0	120393.9	1.1
S_2G_2	655.0	655000	805.0	201250.0	856250.0	678931.0	177318.9	1.2
S_2G_3	680.0	680000	830.0	207500.0	887500.0	684506.0	202993.9	1.3
S_3G_0	560.0	560000	710.0	177500.0	737500.0	550706.0	186793.9	1.3
S_3G_1	705.0	705000	855.0	213750.0	918750.0	561856.0	356893.9	1.6
S_3G_2	900.0	900000	1100.0	275000.0	1175000.0	567431.0	607568.9	2.0
S_3G_3	740.0	740000	890.0	222500.0	962500.0	573006.0	389493.9	1.6

Market price of bulb @ Tk. 0.25 /bulb
Market price of spike @ Tk. 1.0 /spike

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted at the Horticulture Farm of Sher-e-Bangla Agricultural University, Sher-e- Bangla nagar, Dhaka, Bangladesh to evaluate the effect of plant spacing and different levels of GA_3 on the growth, flowering and bulb production of tuberose (*Polianthes tuberose* L.) cv. Double during the period from May 2011 to December 2011. The experiment consisted of three plant spacing viz., S_1 (20×10 cm), S_2 (20 ×15 cm), S_3 (20 × 20 cm) and different levels of GA_3 viz., G_0 (no GA_3; control), G_1 (200 ppm GA_3), G_2 (250 ppm GA_3) and G_3 (300 ppm GA_3). The two-factor experiment was laid out in Randomized Complete Block Design with three replications. Data on different yield contributing characters and yield were recorded to find out the optimum plant spacing and optimum level of GA_3 on tuberose. Economic analysis was done to find out the profitability of the treatments.

Plant spacing significantly influenced all the parameters. The widest spacing (S_3; 20 × 20 cm) gave the highest plant height (57.2 cm), number of leaves (17.0/plant), length of leaf (58.33 cm) at 105 days after planting (DAP). The length of spike which produced from mother bulb (82.6 cm), length of spike which produced from side shoot (66.5 cm), diameter of spike (0.8 cm), length of rachis which produced from mother bulb (31.7 cm), length of rachis which produced from side shoot (23.3 cm), number of florets/spike which produced from mother bulb (33.5) was recorded from the widest plant spacing (S_3; 20 ×20 cm) treatment which was significantly superior to all other treatments and the lowest result was performed by the closest plant spacing. But the highest number of spike/ha (695000) and number of bulb/ha (846500) was recorded from wider plant spacing (S_2; 20 x15 cm) and the lowest result was performed by the widest plant spacing .The highest time was required for days to spike emergence (82.3 days) due to the effect of closest spacing (S_1).

Application of different concentration of GA_3 treatments showed a significant effect on plant height, number of leaves, length of leaf, (at all dates of observation), days to spike emergence, length of spike which produced from mother bulb, length of spike which produced from side shoot, diameter of spike, length of rachis which produced from mother bulb, length of rachis which produced from side shoot, number of florets/spike which produced from mother bulb was recorded from the higher level GA_3 (G_2:250 ppm GA_3) and the lowest result was noted from control condition. But the lowest days were required to spike emergence.

The highest vegetative growth was recorded at 105 days after planting (DAP). The tallest plant (57.2 cm) was recorded from G_2 (250 ppm GA_3). The maximum number of leaves (16.7/plant) was recorded from G_2 (250 ppm GA_3). The highest length of leaf/plant (55.8 cm) was recorded from G_2 treatment (G_3: 250 ppm). The highest length of spike which produced from mother bulb (76.7 cm) was recorded from G_1 treatment (200 ppm GA_3), length of spike which produced from side shoot (63.0 cm) was recorded from G_2 (250 ppm GA_3). Days to spike emergence (81.67) was obtained from control treatment G_0 (0 ppm) diameter of spike (0.80 cm), length of rachis which produced from mother bulb (27.22 cm), length of rachis which produced from side shoot (19.2 cm) was recorded from G_2 treatment (G_2: 250 ppm). Number of florets/spike which produced from mother bulb (27.7) was recorded from G_3 treatment (G_3: 300 ppm). Weight of single spike (41.9 g) was recorded from G_2 treatment (G_2: 250 ppm).The maximum number of spike/ha (780700) and bulb/ha (948300) from G_2 treatment (G_2: 250 ppm). The minimum result was performed by control treatment G_0 (0 ppm GA_3) in the most of all above parameters.

Combined effects of spacing and concentration of GA_3 had significant influenced on plant growth, flowering and bulb yield contributing characters of tuberose (*polianthes tuberosa* L.) cv. double. However, the widest spacing with higher level of GA_3 (treatment combination of S_3G_2) performed the tallest plant (61.0 cm) while the shortest plant (51.3 cm) was observed from the treatment combination of S_1G_0(closest spacing and no GA_3) at 105 days after planting (DAP). The combined effect of different plant spacing and different levels of GA_3 showed significant variation on number of leaves per plant at different days after planting. The maximum number of leaves per plant (19.0) was observed from the treatment combination S_3G_2 (widest spacing S_3; 20 x 20 cm with higher level of GA_3 250 ppm GA_3) and the minimum number of leaves/plant (14.6) was recorded from S_1G_0 at 105 days after planting (DAP). The tallest length of leaf (64.0 cm) was obtained from S_3G_2 while the shortest length of leaf (49.3 cm) was noted from S_1G_0 at 105 DAP. Treatment combination of S_3G_2 took the lowest (80.6) days to spike emergence whereas, the highest (84.6 days) was required for $S_1G_{0.}$ The tallest length of spike which produced from mother bulb (84.0 cm) was recorded from S_3G_2 and the shortest (71.0 cm) was found from $S_1G_{0.}$ The tallest length of spike which produced from side shoot (70.0 cm) was obtained from the treatment combination of the widest spacing (20 x20 cm) with higher level of GA_3 (250 ppm GA_3) while S_1G_0 treatment gave the shortest (57.6 cm) length of spike. Treatment combination of S_3G_2 produced the highest diameter of spike (0.86 cm) while the lowest (0.74 cm) was noted from $S_1G_{1.}$ The tallest length of rachis which produced from mother bulb (32.6 cm) was obtained from the treatment combination of widest plant spacing (20 × 20 cm) with higher level of GA_3 (250 ppm GA_3) while S_1G_0 treatment gave the shortest (21.9 cm). The tallest length of rachis which produced from side shoot (24.0 cm) was obtained from the treatment combination of S_3G_2 while the S_1G_3 treatment gave the shortest (14.6 cm). The maximum number of florets per spike which produced from mother bulb (35.3) was recorded from the treatment combination of S_3G_2 whereas; the minimum (22.0) was counted from $S_1G_{1.}$ The maximum number of spike/ha (801700) was counted from S_3G_2 while the treatment combination of

S_2G_3 gave the minimum number of spike/ ha (610000). The maximum number of bulb/ha (958300) was obtained from the treatment combination of S_3G_2 and the minimum number of bulb/ ha (762700) was found from S_2G_3.

Conclusion and suggestions

From the investigation, it may be concluded that wider plant spacing (S_3: 20 × 20 cm) along with 250 ppm GA_3 was suitable combination for highest growth of flower and bulb production of tuberose (*Polianthes tuberosa* L.) cv. Double .

However, the same study may be conducted further with different plant spacing and different levels of GA_3 in various soils and climatic situation for more confirmation of results before final recommendation to the tuberose growers.

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APPENDICES

Appendix I Characteristics of soils analyzed by SRDI, Khamarbari, Farmgate, Dhaka

A. Morphological characteristics of the experimental field.

Morphological factors	Characters
Location	Horticultural farm, SAU, Dhaka
AEZ	Madhupur Tract(28)
General soil type	Non calcareous soil
Soil series	Tejgaon
Topography	Fairy level
Drainage	Well drained
Cropping pattern	Fellow Mukhi kachu

B. Physical and chemical properties of initial soil.

Characters	Value
Particle size analysis	
% Sand	27
% Silt	43
% Clay	35
Textural class	Silty loam
pH	6.3
% Organic Carbon	0.78
% Organic matter	0.03
% Total nitrogen	20.00
Available P(ppm)	35
Exchangeable K (me/100 gm soil)	0.10

Source: Soil Resources and Development Institute, Dhaka.

Appendix II Monthly minimum and maximum temperatures, average temperature, average rainfall and relative humidity during the period of January, 2011 to December, 2011

Name of month	Average lowest temperatures (°C)	Average highest temperature (°C)	Average temperature (°C)	Average rainfall/ precipitation (mm)	Relative humidity (%)
January, 2011	16	28	22	8	54

February, 2011	15	28	21	32	49
March, 2011	20	32	26	61	45
April, 2011	23	34	28	137	55
May, 2011	24	33	29	245	72
June, 2011	26	32	29	315	79
July, 2011	26	31	29	329	79
August, 2011	26	31	29	337	78
September, 2011	26	31	29	248	78
October, 2011	24	31	27	134	72
November, 2011	19	29	24	24	66
December, 2011	14	26	20	5	63

Source: Bangladesh Meteorological Department (Climate Division) Agargaon, Dhaka- 1207.

Appendix III Analysis of variance of different characters of tuberose

Source of variation	df	Plant height (cm)				Number of leaves/plant			
		30 DAP	55 DAP	80 DAP	105 DAP	30 DAP	55 DAP	80 DAP	105 DAP
Replication	2	0.361	1.25	1.34	1.44	0.009	0.027	0.438	1.444
Factor A(spacing)	2	16.444**	46.19**	31.44**	46.86**	6.198NS	6.202**	10.998**	12.028**
Factor B(GA_3)	3	4.963**	8.40**	11.28*	17.65**	0.337NS	0.627**	0.403**	2.250**
A x B	6	3.407**	13.26**	15.03**	11.60*	0.083NS	1.574**	1.743**	3.694**
Error	22	0.452	1.61	3.35	4.23	0.055	0.046	0.241	0.505

** = Significant at 1% level of probability
 * = Significant at 5% level of probability
NS = Not significant

Appendix IV Analysis of variance of different characters of tuberose

Source of variation	df	Length of leaves (cm)				Days to spike emergence	Length of spike (side Shoot) cm	Length of spike (mother bulb)cm	Diameter of spike (mother bulb) cm
		30 DAP	55 DAP	80 DAP	105 DAP				
Replication	2	0.528	0.16	0.14	0.583	0.682	3.626	12.11	0.006
Factor A	2	98.111**	146.22**	137.86**	185.250**	192.04**	200.952**	385.19**	0.017**
Factor B	3	1.213NS	6.68**	4.17NS	14.250*	21.420**	3.892NS	1.11NS	0.001NS
A x B	6	3.074**	6.01**	8.56**	16.694**	32.802**	10.648*	1.97NS	0.001NS
Error	22	0.740	1.68	2.56	4.300	5.112	4.152	16.05	0.002

** = Significant at 1% level of probability
* = Significant at 5% level of probability
NS = Not significant

Appendix V. Analysis of variance of different characters of tuberose

Source of variation	df	Number of florets/spike	Length of rachis (mother bulb) cm	Length of rachis (side shoot) cm	Number of spike/ha ('000')	Number of bulb/ha (‘000’)
Replication	2	0.333	0.875	1.571	11606.25	15662.250
Factor A	2	351.000**	263.093**	201.825**	45216.667NS	55892.667NS
Factor B	3	0.407NS	1.516NS	0.522NS	300.00*	75.00**
A x B	6	6.407NS	3.059*	2.815**	1500.00**	375.00**
Error	22	4.576	1.185	0.913	4744.886	5675.159

** = Significant at 1% level of probability
* = Significant at 5% level of probability
NS = Not significant

Appendix VI Production cost of tuberose per hectare.

A. Input cost

Treatment Combination	Labour cost	Ploughing cost	Bulb Cost	Irrigation cost	Manure and fertilizers				G
					Cowdung	Urea	TSP	MoP	
S_1G_0	15000	10000	700000	5000	6000	3120	4400	3750	0
S_1G_1	15000	10000	700000	5000	6000	3120	4400	3750	100

S_1G_2	15000	10000	700000	5000	6000	3120	4400	3750	150
S_1G_3	15000	10000	700000	5000	6000	3120	4400	3750	200
S_2G_0	15000	10000	500000	5000	6000	3120	4400	3750	0
S_2G_1	15000	10000	500000	5000	6000	3120	4400	3750	100
S_2G_2	15000	10000	500000	5000	6000	3120	4400	3750	150
S_2G_3	15000	10000	500000	5000	6000	3120	4400	3750	200
S_3G_0	15000	10000	400000	5000	6000	3120	4400	3750	0
S_3G_1	15000	10000	400000	5000	6000	3120	4400	3750	100
S_3G_2	15000	10000	400000	5000	6000	3120	4400	3750	150
S_3G_3	15000	10000	400000	5000	6000	3120	4400	3750	200

B . Overhead cost

(13% of value of land Tk. 8,00000/year)	Miscellaneous cost (Tk. 5% of the input cost)	Interest on running capital for 6 months (Tk. 13% of cost/year)	Sub total (Tk) (B)	Total cost of production (Tk./ha) [Input cost(A)+ overhead cost (B)]
52000	37363.5	48572.55	137936.05	885206.05
52000	37863.5	49222.55	139086.05	896356.05
52000	38113.5	49547.55	139661.05	901931.05
52000	38363.5	49872.55	140236.05	907506.05
52000	27363.5	35572.55	114936.05	662206.05
52000	27863.5	36222.55	116086.05	673356.05
52000	28113.5	36547.55	116661.05	678931.05
52000	28363.5	36872.55	117236.05	684506.05
52000	22363.5	29072.55	103436.05	550706.05
52000	22863.5	29722.55	104586.05	561856.05
52000	23113.5	30047.55	105161.05	567431.05
52000	23363.5	30372.55	105736.05	573006.05