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Original Article

Effects of bulb types and plant growth regulators on the growth and flowering of tuberose (*Polianthes tuberosa* L.)

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A B S T R A C T

Plant growth regulators have significant role in modifying the growth and flowering of plants. An experiment was conducted at the Landscaping Section of the Department of Horticulture, Bangladesh Agricultural University, Mymensingh during the period from March to October, 2018 to investigate the effects of bulb types and plant growth regulators on growth and flowering of tuberose. The two-factor experiment consisted of two bulb types viz., single (S_1) and double (S_2), and different levels of plant growth regulators viz., = control (T_0), GA_3 @ 200 ppm (T_1), GA_3 @ 400 ppm (T_2), NAA @ 100 ppm (T_3) and NAA @ 300 ppm (T_4). The experiment was laid out in Randomized Complete Block Design with three replications. Bulb types and plant growth regulators had significant effects on almost all the parameters under study. The highest flower yield (25.35 t/ha) of tuberose was recorded from the double bulb while the lowest flower yield (22.53 t/ha) of tuberose was obtained from single bulb. The highest flower yield (26.10 t/ha) of tuberose was obtained from GA_3 @ 400 ppm, whereas, the lowest flower yield (12.20 t/ha) was recorded from control treatment. Combined treatment of double bulb with GA_3 @ 400 ppm gave the highest flower yield (28.91 t/ha) of tuberose while combined treatment of single bulb with control treatment provided the lowest flower yield (14.63 t/ha). Therefore, double bulb along with the application of GA_3 @ 400 ppm was found to be better in respect of growth and flowering of tuberose.

Introduction

Tuberose (*Polianthes tuberosa* L.) is one of the most important commercial ornamental bulbous plants popularly known as `Rajnigandha'. Tuberose is native to Mexico and belongs to the family Amaryllidaceae. The flowers having excellent keeping quality and are widely used as cut flowers. Tuberose is popular among flower loving people because of its sweet and pleasant fragrance and also long keeping quality. 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 a multipurpose flower, which is used for artistic garlands, floral ornaments, bouquets and buttonholes (Sadhu and Bose, 1973). The flower spikes are excellent as cut flower for table decoration. It blooms profusely almost throughout the year and most artistic garlands and floral arrangements are made from its flowers.

Tuberose is commercially propagated by bulbs. The presence of dormancy in the bulb hinders the early sprouting and results in long vegetative phase. The bulb goes through a characteristic cycle of growth beginning with its initiation as a growing point. In the vegetative stage, bulb grows and attains its maximum size, subsequent reproductive stage includes the initiation of flower bud differentiation (generally after 80-90 days from sprouting), elongation of the flowering shoot, and finally flowering results in long-term process of flower production. In order to meet the demand of flowers in the market, efforts are needed to manipulate long vegetative phase and also to enhance the flower production and quality (Bhaskar and Rao, 1999). Since the demand for cut and loose flowers of tuberose is rapidly increasing throughout the year, the standardization of production technology of this crop on commercial basis should be explored.

Tuberose spreads to the different parts of the world during 16th century. Now' a days, it is cultivated on large scale in France, Italy, South Africa, USA and in many tropical and sub-tropical areas, including India and Bangladesh. In

Bangladesh, tuberose has become a popular cut flower for its attractive fragrance and beautiful display in the vase. Now it has high demand in the market and its production is highly profitable (Ara *et al.* 2009). The demand of the flower market depends on certain occasions such as religions, national and social festivals like Eid, Victory day, marriage ceremony, etc. Flower symbolizes beauty and purity but now also a potential revenue earner. In Bangladesh, commercially Tuberose cultivation was introduced in 1980 in Jhikargacha Upazila of Jessore district. Recently, flower cultivation has adopted commercially in 19 districts of our country.

The use of growth regulators has brought about a sort of revolution in the floriculture industry. Synthetic growth regulating chemicals were reported to be very effective in manipulating growth and flowering of tuberose. Growth and development are to be regulated either by a single and double by interaction of several hormones, e.g. gibberellins, auxins or cytokinins. The use of these growth-regulating chemicals in tuberose as dip is expected to enhance the germination of bulbs thereby reducing the long vegetative phase. Furthermore, it may help in increasing number of flower spikes and better quality cut flower by directing the movement of organic metabolites and enhancing vase-life. The role of plant growth regulators in ornamental bulbous plants has received considerable attention. Plant growth substances play a vital role in overall performance including growth and flowering (Biswas *et al*. 1983). Plant hormones enable prolonging the vase life and delaying the onset of senescence. GA_3 and NAA as pre-treatment in tuberose through bulb dipping for improving the growth and flowering (Sarkar *et al.* 2009). Cytokinins and gibberellins tend to retard flower senescence (Halevy and Mayak, 1981). Cytokinins are plant hormones that plants produce naturally and regulate plant growth, including cell division and leaf senescence.

The commercial production of tuberose facing some problem in this country due to lack of mother stock, price of fertilizer and insecticide, lack of scientific knowledge and training, attack by pest and disease, lack of extension work, low market price, etc. Plant growth and economic cultivation of tuberose are affected by many factors such as bulb types and plant growth regulators. Therefore, the present study was therefore been undertaken to see the effects of bulb types and plant growth regulators on the growth and flowering of tuberose.

Materials and Methods

Experimental site, soil and climate

The experiment was conducted at the Landscape section of the Department of Horticulture, Bangladesh Agricultural University, Mymensingh during the period from March to October, 2018 to investigate the effects of bulb types and plant growth regulators on the growth and flowering of tuberose. The experimental site was situated at 24.6° N latitude and 90.5° E longitude (Edris *et al.*, 1979). The soil of the experimental field was silty clay loam in texture and acidic in nature belonging to the Brahmaputra Flood plain of AEZ 9 (UNDP, 1988) having non- calcareous Dark Grey Flood plain soil (FAO, 1988). The selected plot of the land was medium high land. It was fertile, well drained and slightly acidic with pH varying from 5.5 to 6.8 (BARC, 2005). The experimental site was situated in the subtropical climatic zone and characterized by heavy rainfall during the month of April to September while scanty rainfall during the rest of the year (Anonymous, 1979).

Treatments of the experiment and planting materials

The experiment consisted of two factors, viz., Factor A: Bulb types (S_1= Single, 2 cm diameter, S_2= Double, 3 cm diameter) and Factor B: Different levels of plant growth regulators (T_0 = Control, T_1 = GA_3 @ 200 ppm, T_2 = GA_3 @ 400 ppm, T_3 = NAA @ 100 ppm, T_4= NAA @ 300 ppm). The bulbs of tuberose were collected from a private nursery of Godkhali of Jessore District in Bangladesh. The plant material was characteristic of producing small and large type's inflorescence.

Experimental design and layout

The two-factor experiment was laid out in a Randomized Complete Block Design with three replications. Each block was divided into 10 plots, where treatments were allocated randomly. Thus, there were 30 (2 x 5 x 3) unit plots altogether in the experiment. The size of each plot was l.2 m x l m. The distance between two blocks were l m and 0.5 m wide drains were made between two plots.

Land preparation

The experimental plot was opened in the first week of March 2018 and then it kept open to sun for seven days. Afterwards it was prepared by laddering. The weeds and stubbles were removed after each laddering. Simultaneously the clods were broken and the soil was made into good tilth. The basal dose of manures and fertilizer were mixed into the soil during final land preparation.

Application of manures and fertilizers

Fertilizers were applied at two split installments such as 1st at the time of land preparation and 2nd at the time of spike emergence. The land was applied with well-decomposed cowdung @ 10 t ha^{-1} at the time of final land preparation. Nitrogen (N) in the form of Urea, P in the form of Triple Super Phosphate (TSP) and K in the form of Muriate of Potash (MoP). TSP (250 kg ha^{-1}) and MoP (250 kg ha^{-1}) fertilizers were applied at two split installments such as 1st at the time of land preparation and 2nd at the time of spike emergence. Urea (450 kg ha^{-1}) was applied in three equal installments at 10, 25 and 40 days after bulb planting. After application the fertilizers were incorporated well with the soil during application (Rashid, 2018).

Planting of bulbs

Uniform bulbs of single (2.0 cm diameter) and double (3.0 cm in diameter) were selected for planting. Bulbs were planted in each plot at a depth of 6 cm on March 25, 2018. Every unit plot had 3 rows with 3 plants each. Plant to plant and row-to-row distance was 30 cm and 25 cm, 9 bulbs were planted in each plot. A light irrigation was given just after planting with the hosepipe, so that irrigation water could move from unit plot.

Intercultural operations

Weeding was done as and when required to keep the plots free from weeds and easy aeration of soil, which ultimately ensured better growth and development of plants. The soil was mulched frequently after irrigation by breaking the crust for easy aeration and to conserve soil moisture. The experimental plot was irrigated as and when necessary during the whole period of plant growth and development. Excess water was effectively drained out at the time of heavy rains. For controlling aphid Thiodon @ 2.0 mg/liter was sprayed 2 times at an interval of 15 days starting soon after

the appearance of infestation. No remarkable attack of disease found. The spikes of tuberose were harvested when the first floret in the rachis opened from the lower portion of the spike. Harvesting of flowers was done during 25 May to 30 October 2018.

Parameters measured

Data on various parameters such as plant height (cm), number of leaves per plant, length and breadth of leaf, number of side shoots per plant, days to first flowering, lengths of spike and rachis (cm), diameter of small spike (cm), number of florets per spike, weight of a small spike, number of spikes per plot and per hectare and flower yield (t/ha) were recorded from the sample plants during experimentation. Plant height refers to the length of the plant from ground level up to shoot apex of the plant. It was measured at an interval of 15 days starting from 15 days after planting till 120 days. The number of leaves produced by plant was referred to the number of leaves per plant. All leaves of five selected plants were counted and their mean was calculated at an interval of 15 days starting from 15 DAP till 120 days. Maximum length of leaf was measured from the base to the tip of the longest leaf at an interval of 15 days starting from 15 DAP till 120 days. The breadth of leaf was taken from one margin to another. Data were recorded as the average of five selected plants were counted and their mean was calculated at an interval of 15 days starting from 15 DAP till 120 days. All the green shoots above the soil surface, which developed from mother bulb and adjoined it were counted as side shoot. It was calculated at an interval of 15 days starting from 15 DAP till 120 days. The date when first flower emergence appeared on each tagged plant was noted and days to first flower emergence from the date of planting calculated and average values were worked out. Length of spike (cm) was measured from the base to the tip of the spike. Length of rachis (cm) refers to the length from the axile of first floret up to the tip of the inflorescence. Five spikes from randomly selected plants from each unit plot were cut and the diameter of spikes was taken at 20 cm from the soil surface and their mean was calculated. All the florets of the spike were counted from five randomly selected spikes and their mean was calculated. Five spikes from randomly selected plants from each unit plot were cut and the weights of spikes were recorded to calculate their mean. Number of spikes per plot was computed from number of spikes per plot. Number of spikes per plot was computed from number of spikes per plot and converted to hectare. Yield of flower per hectare was computed from weight of spike per plot and converted to ton per hectare.

Statistical analysis

The recorded data on various parameters were statistically analyzed using MSTAT-C computer package programme developed by Russel (1986) to find out the significance of variation resulting from the experimental treatments. The mean for the treatments was calculated and analysis of variance for each of the characters was performed by F (variance ratio) test. The significance of the difference among the pairs of treatment means was evaluated by the least significance difference (LSD) test and at 5% level of probability (Gomez and Gomez, 1984).

Results and Discussion

Effect of bulb types

Statistically significant variation was observed between the bulb types of tuberose in terms of all the growth parameters under study (Table 1). Results revealed that during the growth period, plant height, number of leaves per plant, length and breadth of leaf and number of side shoots per plant were increased gradually and reached to peak at 120 days after planting (DAP) (Table 1). The tallest plant (72.99 cm) was obtained from the treatment S_2 (Double bulb) and the shortest plant (69.59 cm) was recorded from the treatment S_1 (Single bulb). This might be due to the variation in genotypic characters. The higher (25.55) number of leaves per plant was recorded from the S_2 (Double bulb) while the lower (21.11) was recorded from the S_1 (Single bulb). The longer leaf length (72.21 cm) was recorded from the S_2 (Double bulb) and the shorter (68.85 cm) was recorded from the S_1 (Single bulb). This might be due to the induction of active cell division and cell elongation, which increased the vegetative growth. These results are in close conformity with the findings of Tak and Nagda (1999) in tuberose. The greater (2.12 cm) breadth of leaves was recorded from the S_2 (Double bulb) and the smaller (2.06 cm) was recorded from S_1 (Single bulb). The higher (11.04) number of side shoot per plant was recorded from the S_2 (Double bulb) while the lower (10.60) number of side shoot per plant was obtained from the S_1 (Single bulb).

Table 1. Main effect of bulb types on growth characteristics of tuberose at days after planting (DAP).

Bulb types	Plant height (cm) at 120 DAP	No. of leaves/ plant at 120 DAP	Length of leaf (cm) at 120 DAP	Breadth of leaf (cm) at 120 DAP	No. of side shoots/plant at 120 DAP
S_1 (Single)	69.59	21.11	68.85	2.06	10.60
S_2 (Double)	72.99	25.55	72.40	2.12	11.04
$LSD_{0.01}$	1.42	1.07	0.42	0.033	1.00
Level of significance	**	**	**	**	**

** = Significant at 1% level of probability, S_1 = Single bulb, S_2 = Double bulb.

The flowering characters of tuberose were also significantly influenced by different bulb types of tuberose (Table 2 & Figure 1). The earlier flowering (83.60 days) was recorded from the S_2 (Double bulb) whereas the most delayed flowering (87.27 days) was recorded from the S_1 (Single bulb) (Table 2). This might be due to early flower primordial development, cell differentiation and early utilization of nutrients (Taha *et al.*, 2012). The longer (84.26 cm) spike was recorded from the S_2 (Double bulb) while the shorter (82.66 cm) was obtained from the S_1 (Single bulb). The increased spike length might be due to rapid internode elongation as a result of increased in cell division and cell elongation in intercalary meristem. The longer (26.47 cm) rachis was recorded from the S_2 (Double bulb) and the shorter (20.23 cm) was obtained from the S_1 (Single bulb). The maximum (0.49 cm) diameter of Small spike was recorded from the S_2 (Double bulb) and the minimum (0.38 cm) was obtained from the S_1 (Single bulb). This might be due to the more food materials like carbohydrates are stored in double bulbs, which gave small spike with greater diameter. The higher (28.37) number of florets per spike was recorded from the S_2 (Double bulb) and the lower (25.23)

was obtained from the S_1 (Single bulb). The higher (30.72 g) weight of small spike was recorded from the S_2 (Double bulb) and the lower (27.02 g) was recorded from the S_1 (Single bulb). Maximum fresh weight (g) of small spike might be due to the fact that these spikes had more number of florets per spike with increased length and diameter. Similar result was obtained by Padaganur *et al.* (2005) in tuberose. The higher (25.07) number of spikes per plot was recorded from the S_2 (Double bulb) and the lower (22.31) number of spikes per plot was obtained from the S_1 (Single bulb). This might be due to the variation in genotypic characters. The greater (208.92) thousand numbers of spikes per ha was recorded from the S_2 (Double bulb) while the less (185.92) thousand numbers of spikes per ha was obtained from the S_1 (Single bulb). The highest (25.35 t/ha) flower yield was recorded from the S_2 (Double bulb) and the lowest (22.53 t/ha) flower yield was recorded from S_1 (Single bulb) (Figure 1). The number of flowers per spike depends on the number of initial flower buds, which varies with genotype (Patil and Jadhav, 2010).

Table 2. Main effect of bulb types on flowering characteristics of tuberose at days after planting (DAP).

Bulb types	Days to first flowering	Length of spike	Length of rachis	Diameter of single spike	No. of florets per spike	Wt. of single spike (g)	No. of spikes/plot	No of spike/ha (thousand)
S_1 (Single)	87.27	82.66	20.23	0.38	25.23	27.02	22.31	185.92
S_2 (Double)	83.60	84.26	26.47	0.49	28.37	30.72	25.07	208.92
$LSD_{0.01}$	0.58	0.38	0.30	0.05	0.70	0.45	0.61	5.57
Level of significance	**	**	**	**	**	**	**	**

** = Significant at 1% level of probability, S_1 = Single bulb, S_2 = Double bulb.

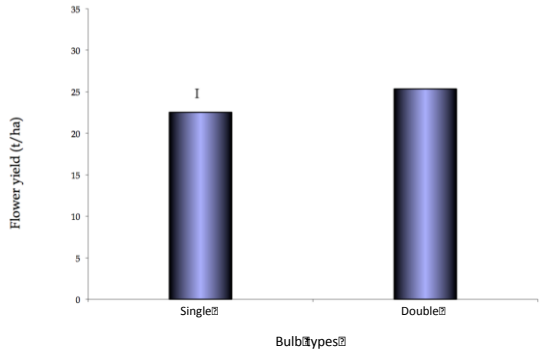

Figure 1. Main effect of bulb types on flower yield of tuberose. Vertical bar represents LSD at 5% level of probability.

Effect of plant growth regulators

Statistically significant variation was observed between the plant growth regulators in terms of all the growth parameters under study (Table 3). Results revealed that during the growth period, plant height, number of leaves per plant, length and breadth of leaf and number of side shoots per plant were increased gradually and reached to peak at 120 days after planting (DAP) (Table 3). The tallest tuberose plant (76.57 cm) was recorded from T_2 (GA_3 @ 400 ppm) and the shortest plant (63.70 cm) was found from the treatment T_0 (Control). It is suggested that these growth-promoting compounds imparted significant effect on vegetative growth, plant biomass along with increment in chlorophyll level that led to better plant efficiency (Sarkar *et al*., 2009). GA_3 increased the plant height, number of leaves, number of shoots and leaf area. This might be due the increase in cell elongation, cell division or both induced by gibberellin (Singh *et al.*, 1991). The highest (26.35) number of leaves per plant was recorded from T_2 (GA_3 @ 400 ppm) and the lowest (18.80) was found from the treatment T_0 (Control). Plant growth regulators activate several enzymes and involve themselves in chlorophyll synthesis and various physiological activities resulting in an increased plant growth and development through overall promotion of parameters like number of leaves per plant. These observations and findings in the present investigation are in conformity with those reported earlier by Sarkar *et al*. (2009) in tuberose. The longest leaf length (76.66 cm) was recorded from T_2 (GA_3 @ 400 ppm) and the shortest (62.68 cm) was found from the treatment T_0 (Control). Earlier, Singh (1999) reported that 400 ppm GA_3 increased the leaf length in tuberose. The maximum (2.31 cm) breadth of leaves was recorded from T_2 (GA_3 @ 400 ppm) and the minimum (1.80 cm) was recorded from the treatment T_0 (Control). Similarly, GA_3 might have led to elongated breadth of leaves due to both cell division and elongation by Sarkar *et al.* (2009). The maximum (11.72) number of side shoot per plant was recorded from T_2 (GA_3 @ 400 ppm) and the minimum (9.90) number of side shoot per plant was found from the treatment T_0 (Control). Increase in plant growth parameters might be due to the fact that gibberellin (GA_3) is a constituent of protein, which is essential for formation of protoplasm and thus, affecting cell division and cell elongation. All these contributed in enhancing shoot length and number of shoots per plant of tuberose. The present findings are in conformed to the report of Kumar *et al.* (2014).

Table 3. Main effect of plant growth regulators on growth characteristics of tuberose at days after planting (DAP).

Plant growth regulators	Plant height (cm) at 120 DAP	No. of leaves/ plant at 120 DAP	Length of leaf (cm) at 120 DAP	Breadth of leaf (cm) at 120 DAP	No. of side shoots /plant at 120 DAP
T_0 = 0 ppm	63.70	18.80	62.68	1.80	9.90
T_1 = GA_3 @ 200 ppm	70.21	24.01	70.55	2.12	10.83
T_2 = GA_3 @ 400 ppm	76.56	26.35	76.65	2.31	11.72
T_3 = NAA @ 100 ppm	70.26	22.65	69.55	2.05	10.52
T_4 = NAA @ 300 ppm	74.70	24.83	73.70	2.20	11.15
$LSD_{0.01}$	2.25	1.70	0.67	0.053	0.158
Level of significance	**	**	**	**	**

** = Significant at 1% level of probability, T_0 = 0 ppm, T_1 = GA_3 @ 200 ppm, T_2 = GA_3 @ 400 ppm, T_3 = NAA @ 100 ppm, T_1, T_4 = NAA @ 300 ppm.

The flowering characters of tuberose were also significantly influenced by various plant growth regulators (Table 4 & Figure 2). The earlier flowering (82.00 days) was recorded from T_2 (GA_3 @ 400 ppm) and the most delayed flowering (88.50 days) was recorded from the treatment T_0 (Control). GA_3 at higher concentration might have reduced the vegetative period, resulting in induction of early flower development. Likewise, GA_3 treatments at the highest concentration significantly shortened the time taken from planting to flowering in *Iris sp*. Taha *et al.,* (2012). The highest spike length (86.39 cm) was recorded from T_2 (GA_3 @ 400 ppm) and the lowest (79.96 cm) was found from the treatment T_0 (Control). Tiwari (1992) reported significant increase in spike length with GA_3 and NAA in tuberose. Similar results were also reported by Mukhopadhyay and Banker (1983) and Kumar and Gautam (2011) in tuberose. The maximum (26.05 cm) rachis length was recorded from T_2 (GA_3 @ 400 ppm) and the minimum was (20.15 cm) was recorded from the treatment T_0 (Control). The increase in length of rachis may be due to the role of these plant growth regulators in activation of enzymes important in cell elongation process. Devadanam *et al.* (2005) found that GA_3 gave maximum rachis length. The highest (0.49 cm) diameter of spikes was recorded from T_2 (GA_3 @ 400 ppm) and the lowest was (0.36 cm) recorded from the treatment T_0 (Control). Favourable effect of application of gibberellins on diameter of spike might be due to improved physiological, efficiency selective ion uptake and sufficient water uptake causing high rate of accumulate deposition. Rani and Singh (2013) showed significant increase in diameter of spike in tuberose. The highest (31.12) number of florets per spike was recorded from T_2 (GA_3 @ 400 ppm) and the lowest (17.72) was recorded from the treatment T_0 (Control). The number of flowers per spike depends on the number of initial flower buds which varies with genotype. The favorable effect of GA_3 might be attributed to the greater amount of carbohydrate accumulation and increase in metabolic activities by Mukhopadhyay and Banker (1983). The highest (31.15 g) weight of small spike was recorded from T_2 (GA_3 @ 400 ppm), whereas, the lowest was (25.67 g) recorded from the treatment T_0 (Control). The highest (27.53) number of spikes per plot was recorded from T_2 (GA_3 @ 400 ppm) and the lowest (19.38) number of spikes per plot was recorded from the treatment T_0 (Control). Increase in number of spikes per plot may be due to increase in cell division and cell elongation with GA_3 and at lower concentration of NAA application by Kumar and Gautam (2011). Similar result was obtained by Narayan and Shyamal (2002) in tuberose. The highest (229.38) thousand number of spikes per ha was recorded from T_2 (GA_3 @ 400 ppm) and the lowest was (161.46) thousand number of spikes per ha was recorded from the treatment T_0 (Control). The higher (26.10 t/ha) flower yield was recorded from T_2 (GA_3 @ 400 ppm) and the lower (12.20 t/ha) flower yield was recorded from the treatment T_0 (Control) (Figure 2). The number of flowers per spike depends on the number of initial flower buds which varies with genotype. Similar findings have also been obtained by Patil and Jadhav (2010).

Table 4. Main effect of plant growth regulators on flowering characteristics of tuberose.

Plant growth regulators	Days to first flowering	Length of spike	Length of rachis	Diameter of single spike	No. of florets per spike	Wt. of single spike (g)	No. of spikes/ plot	No of spike/ha (thousand)
T_0 = 0 ppm	88.50	79.96	20.15	0.36	17.72	25.67	19.38	161.46
T_1 = GA_3 @ 200 ppm	85.67	83.54	23.64	0.44	28.35	29.41	23.10	192.50
T_2 = GA_3 @ 400 ppm	82.00	86.39	26.05	0.49	31.12	31.15	27.53	229.38
T_3 = NAA @ 100 ppm	87.00	82.40	22.48	0.40	27.18	28.30	22.30	185.84
T_4 = NAA @ 300 ppm	84.00	85.02	24.45	0.48	29.64	29.84	26.15	217.92
$LSD_{0.01}$	0.92	0.60	0.47	0.07	1.11	0.71	0.97	8.81
Level of significance	**	**	**	**	**	**	**	**

** = Significant at 1% level of probability, T_0 = 0 ppm, T_1 = GA_3 @ 200 ppm, T_2 = GA_3 @ 400 ppm, T_3 = NAA @ 100 ppm, T_1, T_4 = NAA @ 300 ppm

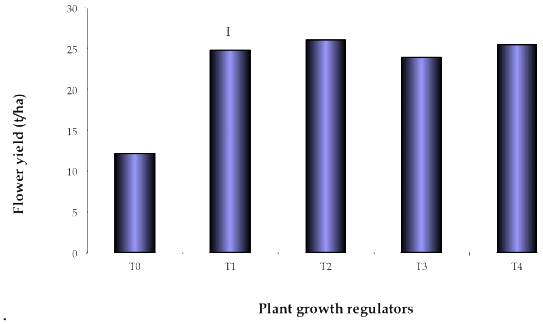

Figure 2. Main effect of plant growth regulators on flower yield of tuberose. Vertical bar represents LSD at 5% level of significance. (T_0 = 0 ppm, T_1 = GA_3 @ 200 ppm, T_2 = GA_3 @ 400 ppm, T_3 = NAA @ 100 ppm, T_4 = NAA @ 300 ppm).

Combined effects of bulb types and plant growth regulators

Combined effects of bulb types and plant growth regulators had significant influence on almost all the growth parameters studied except breadth of leaf (Table 5). Results revealed that during the growth period, plant height, number of leaves per plant, length and breadth of leaf and number of side shoots per plant were increased gradually and reached to peak at 120 days after planting (DAP) (Table 5). The tallest plant height (79.13 cm) of tuberose was found from the treatment combination of double bulb with GA_3 @ 400 ppm (S_2T_2) followed by double bulb with NAA @ 300 ppm (S_2T_4) (76.20 cm) whereas, the shortest plant height (63.17 cm) was recorded from the treatment combination of single bulb with control (S_1T_0) followed by S_2T_0 (64.23 cm). The maximum (29.33) number of leaves per plant was obtained from the treatment combination of double bulb with GA_3 @ 400 ppm (S_2T_2) followed by double bulb with NAA @ 300 ppm (S_2T_4) (27.40 cm) whereas, the minimum (18.27) was recorded from the treatment combination of single bulb with control (S_1T_0) followed by S_2T_0 (19.33 cm). The highest leaf length (78.23 cm) of tuberose was obtained from the treatment combination of double bulb with GA_3 @ 400 ppm (S_2T_2) followed by double bulb with NAA @ 300 ppm (S_2T_4) (75.26 cm) at 120 DAP. Whereas, the lowest (62.08 cm) was recorded from the treatment combination of single bulb with control (S_1T_0) followed by S_2T_0 (63.28 cm). The

highest leaf breadth (2.35 cm) of tuberose was obtained from the treatment combination of double bulb with GA_3 @ 400 ppm (S_2T_2) followed by double bulb with NAA @ 300 ppm (S_2T_4) (2.25 cm) whereas, the lowest (1.78 cm) was recorded from the treatment combination of single bulb with control (S_1T_0) followed by S_2T_0 (1.81 cm). The maximum number of side shoot per plant (11.80) of tuberose was obtained from the treatment combination of double bulb with GA_3 @ 400 ppm (S_2T_2) followed by double bulb with NAA @ 300 ppm (S_2T_4) (11.33 cm) whereas, the minimum (9.59) number of side shoot per plant was recorded from the treatment combination of single bulb with control (S_1T_0) followed by S_2T_0 (10.20 cm).

Table 5. Combined effects of bulb types and plant growth regulators on growth characteristics of tuberose at days after planting (DAP).

Treatment combination	Plant height (cm) at 120 DAP	No. of leaves/plant at 120 DAP	Length of leaf (cm) at 120 DAP	Breadth of leaf (cm) at 120 DAP	No. of side shoots/plant at 120 DAP
S_1T_0	63.16	18.27	62.08	1.78	9.59
S_1T_1	67.16	21.42	68.06	2.10	10.55
S_1T_2	74.00	23.37	75.08	2.26	11.64
S_1T_3	68.40	20.22	66.90	2.02	10.27
S_1T_4	73.20	22.26	72.13	2.15	10.97
S_2T_0	64.23	19.33	63.28	1.81	10.20
S_2T_1	73.26	26.60	73.05	2.13	11.10
S_2T_2	79.13	29.33	78.23	2.35	11.80
S_2T_3	72.13	25.07	72.20	2.07	10.77
S_2T_4	76.20	27.40	75.26	2.25	11.33
$LSD_{0.05}$	2.33	1.75	0.69	0.054	0.163
$LSD_{0.01}$	3.18	2.40	0.95	0.074	0.223
Level of significance	*	**	**	NS	**

**, * = Significant at 1 and 5% levels of probability, NS = Not significant, S_1= Single bulb, $S_{2=}$ Double bulb, T_0 = 0 ppm, T_1 = GA_3 @ 200 ppm, T_2 = GA_3 @ 400 ppm, T_3 = NAA @ 100 ppm, T_4 = NAA @ 300 ppm.

Almost all the flowering characters of tuberose were also significantly influenced by the combined effects of bulb types and various plant growth regulators except days to first flowering and diameter of single spike (Table 6 & Figure 3). The shortest day (80.00) was recorded from the treatment combination of double bulb with GA_3 @ 400 ppm (S_2T_2) followed by double bulb with NAA @ 300 ppm (S_2T_4) (82.33 days), whereas, the most delayed (90.00 days) was recorded from the treatment combination of single bulb with control (S_1T_0) followed by S_2T_0 (87.00 days) (Table 6). The maximum (87.67 cm) spike length was found from the treatment combination of double bulb with GA_3 @ 400 ppm (S_2T_2) followed by double bulb with NAA @ 300 ppm (S_2T_4) (86.00 cm) whereas, the minimum (79.57 cm) was recorded from the treatment combination of single bulb with control (S_1T_0) followed by S_2T_0 (80.35 cm). The highest (29.30 cm) rachis length was found from the treatment combination of double bulb with GA_3 @ 400 ppm (S_2T_2) followed by double bulb with NAA @ 300 ppm (S_2T_4) (27.67 cm) and the lowest (17.12 cm) was recorded from the treatment combination of single bulb with control (S_1T_0) followed by S_2T_0 (23.18 cm). The maximum (0.55 cm) diameter of spikes was found from the treatment combination of double bulb with GA_3 @ 400 ppm (S_2T_2) followed by double bulb with NAA @ 300 ppm (S_2T_4) (0.53 cm) whereas, minimum (0.31 cm) was recorded from the treatment combination of single bulb with control (S_1T_0) followed by S_2T_0 (0.40 cm). The maximum (32.95) number of florets per spike was found from the treatment combination of double bulb with GA_3 @ 400 ppm (S_2T_2) followed by double bulb with NAA @ 300 ppm (S_2T_4) (31.07 cm) whereas, the minimum (15.15) was recorded from the treatment combination of single bulb with control (S_1T_0) followed by S_2T_0 (20.28 cm). The maximum (33.55 g) weight of single was found from the treatment combination of double bulb with GA_3 @ 400 ppm (S_2T_2) followed by double bulb with NAA @ 300 ppm (S_2T_4) (32.10 g) and the minimum (25.20 g) was recorded from the treatment combination of single bulb with control (S_1T_0) followed by S_2T_0 (26.14 g). The maximum (29.47) number of spikes per plot was found from the treatment combination of double bulb with GA_3 @ 400 ppm (S_2T_2) followed by double bulb with NAA @ 300 ppm (S_2T_4) (28.13) and the minimum (18.40) number of spikes per plot found from the treatment combination of single bulb with control (S_1T_0) followed by S_2T_0 (20.35 cm). The maximum (245.56) thousand number of spikes per ha was found from the treatment combination of double bulb with GA_3 @ 400 ppm (S_2T_2) followed by double bulb with NAA @ 300 ppm (S_2T_4) (234.44) and the minimum (153.33) thousand was recorded from the treatment combination of single bulb with control (S_1T_0) followed by S_2T_0 (169.58). The highest (28.91 t/ha) flower yield was found from the treatment combination of double bulb with GA_3 @ 400 ppm (S_2T_2) followed by double bulb with NAA @ 300 ppm (S_2T_4) (26.79 t/ha) whereas, the lowest (14.63 t/ha) flower yield was recorded from the treatment combination of single bulb with control (S_1T_0) followed by S_2T_0 (15.77 t/ha) (Figure 3).

Table 6. Combined effects of bulb types and plant growth regulators on flowering characteristics of tuberose.

Treatment combination	Days to first flowering	Length of spike	Length of rachis	Diameter of single spike	No. of florets per spike	Wt. of single spike (g)	No. of spikes/ plot	No of spike/ ha (thousand)
S_1T_0	90.00	79.57	17.12	0.31	15.15	25.20	18.40	153.33
S_1T_1	87.33	82.87	20.30	0.39	27.46	27.36	22.07	183.89
S_1T_2	84.00	85.10	22.80	0.43	29.28	28.74	25.58	213.19
S_1T_3	89.33	81.73	19.73	0.34	26.05	26.23	21.33	177.78
S_1T_4	85.67	84.03	21.22	0.42	28.20	27.57	24.17	201.39
S_2T_0	87.00	80.35	23.18	0.40	20.28	26.14	20.35	169.58
S_2T_1	84.00	84.20	26.97	0.49	29.23	31.45	24.13	201.11
S_2T_2	80.00	87.67	29.30	0.55	32.95	33.55	29.47	245.56
S_2T_3	84.67	83.07	25.23	0.46	28.30	30.36	23.27	193.89
S_2T_4	82.33	86.00	27.67	0.53	31.07	32.10	28.13	234.44
$LSD_{0.05}$	0.95	0.62	0.49	0.08	1.14	0.73	1.00	9.10
$LSD_{0.01}$	1.30	0.85	0.66	0.11	1.57	1.00	1.37	12.46
Level of significance	NS	**	**	NS	**	**	**	**

** = Significant at 1% level of probability, NS = Not significant, S_1= Single bulb, $S_{2=}$ Double bulb, T_0 = 0 ppm, T_1 = GA_3 @ 200 ppm, T_2 = GA_3 @ 400 ppm, T_3 = NAA @ 100 ppm, T_4 = NAA @ 300 ppm.

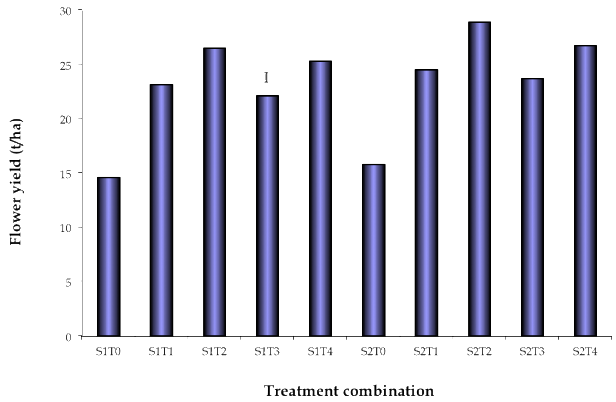

Figure 3. Combined effect of bulb types and plant growth regulators on flower yield of tuberose. Vertical bar represents LSD at 5% level of probability. (S_1= Single bulb, $S_{2=}$ Double bulb, T_0 = 0 ppm, T_1 = GA_3 @ 200 ppm, T_2 = GA_3 @ 400 ppm, T_3 = NAA @ 100 ppm, T_4 = NAA @ 300 ppm).

Conclusion

The result revealed that the application of GA_3 on double bulb had better performance for higher yield of tuberose. The highest flower yield (29.67 t/ha) of tuberose was produced due to the application of 400 ppm GA_3 on double bulb. On the other hand, the lowest yield (27.27 t/ha) was found from the application of plant growth regulators at control dose on single bulb. Therefore, it can be calculated that the use of GA_3 @ 400 ppm along with double bulb (3 cm in diameter) followed by NAA @ 300 ppm along with double bulb found to be better for the growth and flowering of tuberose.

References

Anonymous (1979). Detailed soil survey of Bangladesh Agricultural University Campus, Mymensingh. Department of Soil survey, Government of the People's Republic of Bangladesh.

Ara KA, Sharifuzzaman SM, Ahmed S (2009). Floriculture in Bangladesh. A paper presented on Expert Consultation Meeting of Floriculture. Kunming, China. pp. 9-20.

BARC (2005). Fertilizer Recommendation Guide. Bangladesh Agricultural Research Council, Dhaka. 45 119-120.

Bhaskar G, Rao JM (1999). The control of floral evocation and morphogenesis in tuberose (*Polianthes tuberosa* L.). *Scientia Horticulture 29*: 175-179.

Biswas J, Bose JK, Maiti RG 1983: Effect of growth substances on growth and flowering of tuberose (*Polinathes tuberosa* L.). *South Indian Horticulture* 3: 129-132.

Devadanam A, Shinde BN, Sable PB, Vedpathak SG (2005). Effect of foliar spray of plant growth regulators on flowering and vase life of tuberose (*Polianthes tuberose* L.). *Journal of Soils and Crops* 17(1): 86-88.

Edris KM, Islam AMAT, Chowdhury MS, Haque AKMM (1979). Detailed soil survey, BAU Farm, Mymensingh. Depertment of soil survey. Government of the People's Republic of Bangladesh. p. 118.

FAO (1988). A report of Food and Agricultural Organization of the United Nations, Rome, Italy. pp. 59-60.

Gomez KA, Gomez AA (1984). Statistical Procedures for Agricultural Research (2nd Edition). John Wiley & Sons, New York, United States of America. pp. 28-192.

Halevy AH, Mayak S (1981). Senescence and postharvest physiology of cut flowers. Part 2. *Horticultural Reviews* 3: 59-143.

Kumar A, Gautam DK (2011a). Effect of plant growth regulators on spike yield and bulb production of tuberose (*Polianthes tuberosa* Linn.) cv. "Hyderabad Large". *Progressive Horticulture* 43(2): 234-236.

Kumar A, Gautam DK (2011b). Effect of plant growth regulators on vegetative growth and flowering behaviour of tuberose (*Polianthes tuberosa* Linn.) cv. ''Hyderabad Large''. *Plant Archives* 11(2): 919-921.

Kumar S, Yadav AL, Vishwakarma G, Yadav DK (2014). Effect of foliar feeding of nutrients and plant growth regulators on vegetative growth and yield of phalsa (*Grewia Subinaequalis* D.C.). *Research in Environment and Life Sciences* 7(4): 293- 294.

Mukhopadhyay A, Banker GL (1983). Regulation of growth and flowering in tuberose. *Journal of Ornamental Horticulture* 6: 80-81.

Narayan M, Syamal MM (2000). Effect of gibbrellic acid on tuberose (*Polianthes tuberosa* L.) cv. Small. Floriculture research trend in India. Proc. of Symposium Indian Floriculture in New Millennium 25-27 Feb.

Padaganur VG, Mokashi AN, Patil VS (2005). Effect of growth regulators on growth and yield of tuberose cv. Small. Karnataka. *Journal of Agricultural Science* 18(2): 469-473.

Patel MM, Parmer PB, Parmer BR *(*2006). Effect of nitrogen, phosphor and spacing on growth and flowering in tuberose cv. Small. *Journal of Ornamental Horticulture* 9: 260-263.

Patil ND, Jadhav PB (2010). Effect of growth regulators and bulb size on flower yield of tuberose cv. Large. *Indian Journal of Horticulture* 67 (Special Issue) 372-377.

Rani P, Singh P (2013). Impact of gibberellic acid pretreatment on growth and flowering of tuberose (*Polianthes tuberosa* L.) cv. Prajwal. *Journal of Tropical Plant Physiology* 5: 33-41.

Rashid MHA (2018). Effect of corm size and plant growth regulators on growth, flowering and quality of gladiolus (*Gladiolus grandiflorus* L.). *Fundamental and Applied Agriculture*, 3 (3): 596-601.

Russel DF (1986). MSTAT-C packsge programme. Crop and Soil Science Department Michigan State University, USA.

Sadhu MK, Bose TK (1973). Tuberose for most artistic garlands. *Indian journal of Horticulture* 18(3): 17-20.

Sarkar J, Mishra RL, Singh SK, Prasad KV, Arora A (2009). Effect of growth regulators on growth and flowering in tuberose under north India conditions. *Indian Journal of Horticulture* 66(4): 502- 507.

Singh AK (1999). Response of tuberose growth, flowering and bulb production to plant bioregulators spraying. *Programme of Horticulture* 31(4): 181-183.

Singh MP, Singh RP, Singh GN (1991). Effect of GA3 and ethrel on growth and flowering of African marigold *(Tagetes erecta* L.). *Progressive Horticulture* 24: 92-95.

Taha RA (2012). Effect of some growth regulators on growth, flowering, bulb productivity and chemical composition of iris plants. *Journal of Horticultural Science & Ornamental Plants* 4 (2): 215-220.

Tak D, Nagda CL (1999). Effect of growth regulators on growth and flower yield of tuberose (*Polianthes tuberosa* L.) cv. Small. *Scientia Horticulturae* 6: 147-150.

Tiwari JK (1992). Effect of pre-planting treatment of different size of bulb with GA_3 on growth flowering and bulb production of tuberose (*Polianthes tuberosa* L.). M.Sc. Ag., Thesis CSAUA & T Kanpur.

UNDP (1988). Land Resource Appraisal of Bangladesh for Agricultural Development Report 2. Agro-ccological Region of Bangladesh. FAO. Rome, Italy. p. 577.