Asian Plant Research Journal

4(3): 17-30, 2020; Article no.APRJ.57156
ISSN: 2581-9992

Effect of Phosphorus and Gibberellic Acid on Growth and Yield of Tuberose (*Polianthes tuberosa*)

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Authors' contributions

This work was carried out in collaboration among all authors. Authors MHA and MNI planned the experiment and lead the research. Authors LM, MHA and MNI designed and carried out the research. Authors LM and MNI performed the statistical analysis. Authors LM and MHA carried out the research on the field. Author LM collected the data, wrote the manuscript and managed the literature searches. All authors provided critical feedback, helped shape the research, analysis, read and approved the final manuscript.

Article Information

DOI: 10.9734/APRJ/2020/v4i330087
Editor(s):
(1) Dr. Msafiri Yusuph Mkonda, Sokoine University of Agriculture, Tanzania.
Reviewers:
(1) Cassiane Ubessi, Federal University of Santa Maria, Brazil.
(2) Moataz Eliw Mostafa, Al-Azhar University, Egypt.
Complete Peer review History: http://www.sdiarticle4.com/review-history/57156

Original Research Article

Received 20 March 2020
Accepted 27 May 2020
Published 02 June 2020

ABSTRACT

The present study was carried out in the Horticulture farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during October 2017 to March 2018 to study the Effect of phosphorus (P) and gibberellic acid (GA_3) on growth and yield of tuberose (*Polianthes tuberosa*). Four phosphorus levels viz P_0 = 0 kg P_2O_5 ha^{-1}, P_1 = 65 kg P_2O_5 ha^{-1}, P_2 = 85 kg P_2O_5 ha^{-1} and P_3 = 110 kg P_2O_5 ha^{-1} and three GA_3 levels viz. G_0 = 0 ppm GA_3, G_1 = 115 ppm GA_3 and G_2 =145 ppm GA_3. The experiment was laid out in the two factors Randomized Complete Block Design (RCBD) with three replications. Regarding P application, P_3 gave the highest plant height (61.02 cm) and number of leaves $plant^{-1}$ (7. 29.35) compared to control treatment but the highest yield parameters no. of spike ha^{-1} (368.60 thousand), bulb yield (25.88 t ha^{-1}) and bulblet yield (14.21 t ha^{-1}) were found from the treatment P_2 whereas control treatment P0 showed lowest results. In case of GA_3 application, G_2 showed highest growth and yield parameter and the highest no. of spike ha^{-1} (362.30 thousand), bulb yield (25.38 t ha^{-1}) and bulblet yield (14.00 t ha^{-1}) were obtained from G_2 whereas the lowest results were found from the control treatment G_0. Treatment combine of P and GA_3, the highest no. of spike ha^{-1} (405.60 thousand), bulb yield (31.45 t ha^{-1}), and bulblet yield (16.01 t ha^{-1}) were found

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from P_2G_2 combination whereas the lowest no. of spike ha^{-1} (189.60 thousand), bulb yield (14.57 t ha^{-1}) and bulblet yield (9.05 t ha^{-1}) was found from the control treatment combination of P0G0. In terms of economic analysis, the highest gross return (Tk. 471550), net return (Tk. 289337) and BCR (2.59) were also obtained from P_2G_2 whereas the lowest gross return (Tk. 227470), net return (Tk. 57703) and BCR (1.34) was obtained from P_0G_0. From the above results, it can be stated that that the P application @ 85 kg P_2O_5 ha^{-1} and GA_3 application @ 145 ppm can be considered for higher yield and economic return in commercial cultivation of tuberose.

Keywords: Tuberose; phosphorus; gibberellic acid (ga_3); bulb production.

1. INTRODUCTION

Tuberose *(Polianthes tuberosa* L.), the common name derives from the Latin *tuberosa*, meaning swollen or tuberous in reference to its root system, *Polianthes* means “many flowers” in Greek. It is an erect perennial plant with a 75-120 cm stem. It is a member of family Amaryllidacea*,* originated in Mexico and is grown on large scale in Asia [1]. It blooms in summer when planted in spring and its clustered spikes are rich in fragrance. It is an important cut flower crop from aesthetic as well as commercial point of view. There are three types of tuberose; single with one row of corolla segments, double having more than three rows of corolla segments and semi-double bearing flowers with two or three rows of corolla segments [2]. Tuberose is a gross feeder plant receives a large quantity of NPK as organic and inorganic form which have great influence on growth, flower and bulb production [3,4,5]. In determining the yields of flower crops, phosphorus (P) is also one of the major and crucial limiting factors. Thus, it has been called as “the key to life” because it is directly involved in most life processes. Deficiency of phosphorus may adversely affect the plant in maintaining the full supply of N and K and excess application of P may result in various nutritional problems including Ca and Zn deficiency [6]. Also, the potential use of plant growth regulator like GA_3 in flower production has created considerable scientific interest in recent years [7,8]. In Bangladesh, it is necessary to know the real impact of plant growth regulator like GA_3 on tuberose. Keeping in view, the importance of tuberose and unavailability of limited local information regarding its optimum phosphorus requirements and application of GA_3, the present research was undertaken to explore the optimum doses of phosphorus and growth regulator (GA_3) which can produce healthy plants with good quality flowers and give maximum number of spike and spikelets, bulb and bulblets with the following objectives

- To find out the optimum level of phosphorus and GA_3 on growth, flowering and bulb production of tuberose.
- To find out the suitable combination of phosphorus and GA_3 on growth, flowering and bulb production of tuberose.

2. MATERIALS AND METHODS

2.1 Experimental Site and Experimental Framework

The present piece of research work was conducted in the Horticulture Farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during August 2017 to October 2018. The location of the site is 90°33´ E longitude and 23°77´ N latitude with an elevation of 8.2 m from sea level. The soil of the experimental area belongs to the Modhupur Tract [9] under AEZ No. 28 and was dark grey terrace soil. The selected plot was medium high land and the soil series was Tejgaon [10]. The two factors experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The layout of the experiment was prepared for distributing the different combination of phosphorus and GA_3 levels. The different combination of phosphorus and GA_3 are control (P_0), 140 kg TSP ha-^{1} (P_1), 190 kg TSP ha^{-1} (P_2), 240 kg TSP ha^{-1}(P_3) and Control (G_0), 115 ppm GA_3 (G_1), 145 ppm GA_3 (G_2) respectively. The 12 treatment combinations of the experiment were assigned at random into 36 plots. The size of each unit plot 1.5 m × 1 m. The distance between blocks and plots were 1.0 m and 0.5 m respectively. The tuberose variety “Double” was used for the present study.

2.2 Fertilizers and Manure Application

The manure and fertilizer were applied according to BARI recommendation, 2018. N, P and K were applied through urea, TSP and MoP, respectively. Cowdung also used as organic manure. P was applied through TSP as per treatment.

2.3 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 115 ppm and 145 ppm solution of GA_3, 115 ml and 145 25 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.

2.4 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 LSD Test [11].

2.5 Economic Analysis

Economic analysis was done to find out the cost effectiveness of different treatments like different levels of phosphorus and GA_3 in cost and return were done in details according to the procedure of Alam et al. (1989).

2.6 Benefit Cost Ratio (Bcr)

The economic indicator BCR was calculated by the following formula for each treatment combination.

$$\text{Benefit cost ratio (BCR)} = \frac{\text{Gross income per hectare}}{\text{Total cost of production per hectare}}$$

3. RESULTS AND DISCUSSION

3.1 Growth Parameters

3.1.1 Plant height

Significant influence was observed in plant height of tuberose at different growth stages (Fig. 1). Results indicated that the highest plant heights (22.54, 45.37, 52.30 and 61.02 cm at 30, 55, 80 and 105 DAP, respectively) were found from the treatment P_3 which was significantly different from all other treatments whereas the shortest plant was recorded in control at all growth stages (17.53, 37.35, 44.87 and 52.41 cm at 30, 55, 80 and 105 DAP, respectively). This result indicates that phosphorous has tremendous effect on growth and development in tuberose and was found that plant height was increased with increasing P levels. This result is supported by Sultana et al. [4] in tuberose whom reported that phosphorus had much more influence on plant growth and development in tuberose.

Variation on plant height among the treatments was significant at different growth stages of tuberose (Fig. 2). Results showed that the highest plant height (21.67, 4.91, 51.05 and 59.46 cm at 30, 55, 80 and 105 DAP, respectively) was found from the treatment G_2 whereas the lowest plant height (18.90, 40.03, 46.51 and 54.33 cm at 30, 55, 80 and 105 DAP, respectively) was found from the control treatment G_0. This result indicated that the plant height increased linearly with the increasing level of GA_3. The observed results were in agreement with the findings of Nagaraja et al. [12] and Wankhade et al. [13] and they found that plant height was increased with the increasing level of GA_3 to a certain level.

Significant variation was recorded due to combined effect of P and GA_3 in terms of plant height of tuberose at 30, 55, 60, 80 and 105 days after planting (DAP) (Table 1). Results showed that the highest plant height (21.67, 4.91, 51.05 and 59.46 cm at 30, 55, 80 and 105 DAP, respectively) was found from the treatment G_2 whereas the lowest plant height (18.90, 40.03, 46.51 and 54.33 cm at 30, 55, 80 and 105 DAP, respectively) was found from the control treatment G_0. This result indicated that the plant height increased linearly with the increasing level of GA_3. The observed results were in agreement with the findings of Nagaraja et al. [12] and Wankhade et al. [13] and they found that plant height was increased with the increasing level of GA_3 to a certain level.

3.1.2 Number of leaves plant^{-1}

Significant differences were recorded on number of leaves plant^{-1} at different growth stages except at 30 DAP by applying different levels of P plant^{-1} (Fig. 3). The highest number of leaves plant^{-1} (7.02, 13.92, 24.14 and 29.35 at 30, 55, 80 and 105 DAP, respectively) was found from the treatment P_3 whereas the lowest number of leaves plant^{-1} (6.00, 9.53, 15.89 and 19.34 at 30, 55, 80 and 105 DAP, respectively) was found from the control treatment P_0.

Significant variation was found in case of number of leaves plant^{-1} due to application of different levels of GA_3 at different days after planting except 30 DAP. (Fig. 4). The highest number of leaves $plant^{-1}$ (6.80, 13.24, 22.73 and 27.17 at 30, 55, 80 and 105 DAP, respectively) was found from the treatment G_2 whereas the lowest number of leaves $plant^{-1}$ (6.24, 10.83, 18.13 and 22.10 at 30, 55, 80 and 105 DAP, respectively) was found from the control treatment G_0. The number of leaves increased with the advancement of time with increasing of GA_3. The higher number of leaves per plant achieved on account of higher level of plant growth 35 regulators. The present findings also support to the results of Wankhede et al. [13].

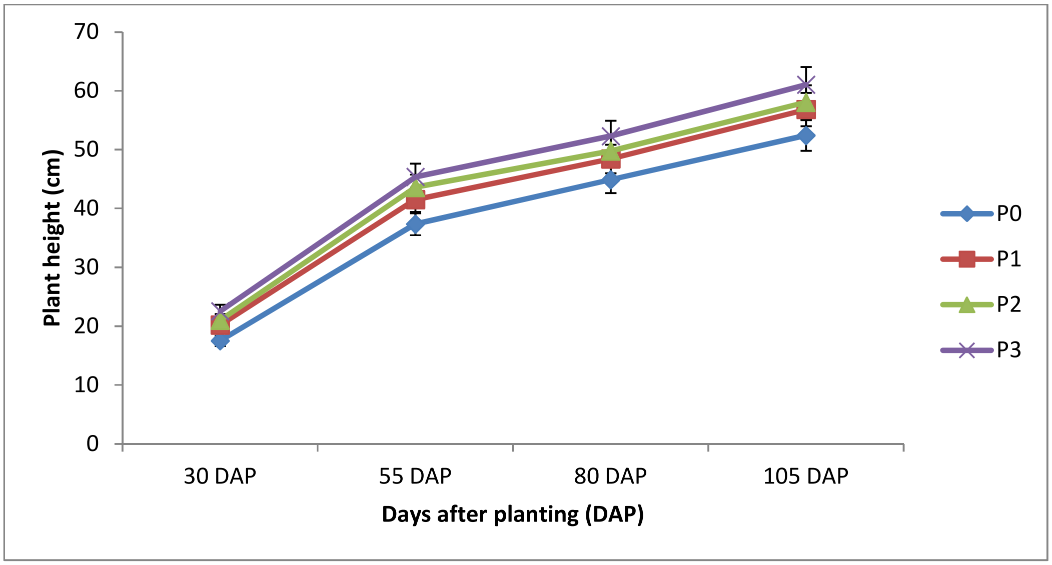

Fig. 1. Plant height of tuberose at different days after planting as influenced by phosphorus
P_0 = Control (0 kg $P_2O_5 ha^{-1}$), P_1 = 140 kg TSP ha^{-1} = 65 kg P_2O_5 ha^{-1}, P_2 = 190 kg TSP ha^{-1} =85 kg P_2O_5 ha^{-1}, P_3 = 240 kg TSP ha^{-1} = 110 kg P_2O_5 ha^{-1}

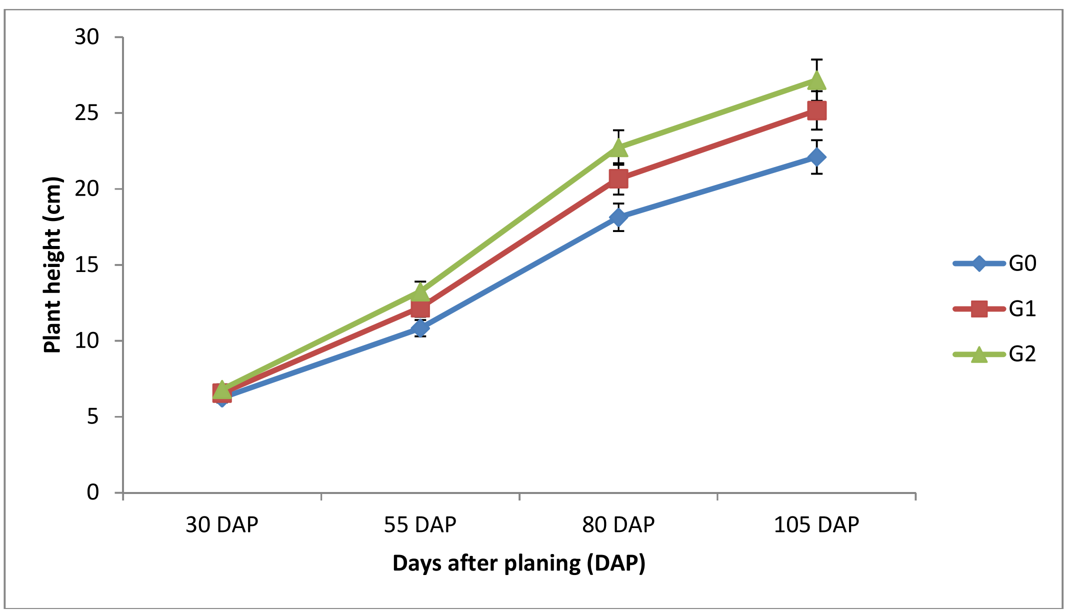

Fig. 2. Plant height of tuberose at different days after planting as influenced by GA_3
G_0 = Control, G_1 = 115 ppm GA_3, G_2 = 145 ppm GA_3

Table 1. Plant height of tuberose at different days after planting as influenced by phosphorus and GA_3

Treatments	Plant height (cm)			
	30 DAP	**55 DAP**	**80 DAP**	**105 DAP**
P_0G_0	16.85 i	36.35 i	44.24 i	50.82 h
P_0G_1	17.55 h	37.50 hi	44.83 hi	52.74 g
P_0G_2	18.19 g	38.20 gh	45.53 gh	53.68 fg
P_1G_0	18.78 fg	39.38 g	46.51 fg	54.33 f
P_1G_1	19.84 e	41.04 f	47.43 ef	56.47 de
P_1G_2	22.03 c	44.12 cd	51.30 c	59.69 c
P_2G_0	19.28 ef	42.49 ef	47.25 ef	55.00 ef
P_2G_1	21.27 d	42.77 de	49.91 d	58.81 c
P_2G_2	22.54 bc	45.49 bc	52.17 c	60.31 bc
P_3G_0	20.68 d	41.92 ef	48.07 e	57.16 d
P_3G_1	23.00 b	46.37 ab	53.63 b	61.75 b
P_3G_2	23.92 a	47.83 a	55.20 a	64.15 a
$LSD_{0.05}$	0.6245	1.557	1.078	1.559
CV(%)	6.56	8.36	10.30	9.61

In a column, figure (s) bearing same letter do not differ significantly at P ≤ 0.05 by LSD, P_0 = Control (0 kg $P_2O_5ha^{-1}$), P_1 = 140 kg TSP ha^{-1} = 65 kg P_2O_5 ha^{-1}, P_2 = 190 kg TSP ha^{-1} =85 kg P_2O_5 ha^{-1}, P_3 = 240 kg TSP ha^{-1} = 110 kg P_2O_5 ha^{-1}, G_0 = Control, G_1 = 115 ppm GA_3, G_2 = 145 ppm GA_3

Significant variation was recorded on number of leaves plant^{-1} of tuberose due to combined effect of P and GA_3 in terms of except 30 DAP (Table 2). It was observed that the highest number of leaves plant^{-1} (7.33, 15.11, 26.13 and 31.95 at 30, 55, 80 and 105 DAP, respectively) was found from the treatment combination of P_3G_2. At 105 DAP, the highest number of leaves plant^{-1} (29.35) was statistically similar with the treatment combination of P_3G_1. The lowest number of leaves plant^{-1} (5.91, 8.16, 14.97 and 18.39 at 30, 55, 80 and 105 DAP, respectively) was found from the control treatment combination of P_0G_0. At 105 DAP, the lowest number of leaves plant^{-1} (18.39) was statistically similar with the treatment combination of P_0G_1 and P_0G_2.

3.1.3 Number of side shoots plant^{-1}

Significant variation was observed in terms of number of side shoot plant^{-1} affected by different levels of P at different growth stages (Table 3). The maximum number of side shoot plant^{-1} (2.04, 4.47 and 6.69 at 30, 55 and 80 DAP, respectively) was found from the treatment P_2 which was statistically identical with P_3 at all growth stages whereas the minimum number of side shoot plant^{-1} (0.92, 2.17 and 4.07 at 30, 55 and 80 DAP, respectively) was found from the control treatment P_0. Different levels of P showed a gradual increasing trend in terms of number of side shoot per plant of tuberose with the increasing of P application to a certain level.

Different concentrations of GA_3 showed significant difference on number of side shoot plant^{-1} at different growth stages (Table 3). The highest number of side shoot plant^{-1} (2.00, 4.43 and 6.64 at 30, 55 and 80 DAP, respectively) was found from the treatment G_2 whereas the lowest number of side shoot plant^{-1} (1.13, 2.59 and 4.57 at 30, 55 and 80 DAP, respectively) was found from the control treatment G_0. Pathak et al. [14] found similar trend of results in their trail which is support to the present finding by using GA_3 they found that side shoot was increased with increasing GA_3 rate and it was highest with 200 ppm.

Combined effect of P and GA_3 showed the significant variation in terms of number of side shoot per plant of tuberose at different growth stages (Table 3). The highest number of side shoot plant^{-1} (2.66, 5.49 and 7.79 at 30, 55 and 80 DAP, respectively) was recorded from the treatment combination of P_2G_2 whereas the lowest number of side shoot plant^{-1} (0.3, 1.70 and 3.17 at 30, 55 and 80 DAP, respectively) was found from the control treatment combination of P_0G_0.

3.2 Yield Contributing Parameters and Yield

3.2.1 Spike length (cm)

Different levels of phosphorus significantly influenced the spike length (Table 4). The highest spike length (79.13 cm) was found from the treatment P_2 which was statistically identical with P_3 whereas the lowest spike length (64.06 cm) was found from the control treatment P_0. This result is in agreement with the findings of Dahiya et al. [15] who reported that the number of side shoots $plant^{-1}$ increased with increasing phosphorous levels from 30 to 150 kg P_2O_5 ha^{-1} in tuberose.

Application of different concentration of GA_3 showed significant variation on length of spike (Table 4). The highest spike length (78.66 cm) was found from G_2 and the lowest spike length (67.24 cm) was found from the control treatment G_0. Results also showed that spike length was increased with increasing rate of GA_3. The results also agreed with the findings of Singh [16] in tuberose plant who reported that the higher spike length was due to 150 ppm compared to 50 and 100 ppm GA_3.

Application of different combination of P and GA_3 showed significant variation on spike length (Table 4). The highest spike length (85.96 cm) was found from the treatment combination of P_2G_2 which was significantly 40 different from all other treatment combinations. The lowest spike length (60.64 cm) was found from the control treatment combination of P_0G_0.

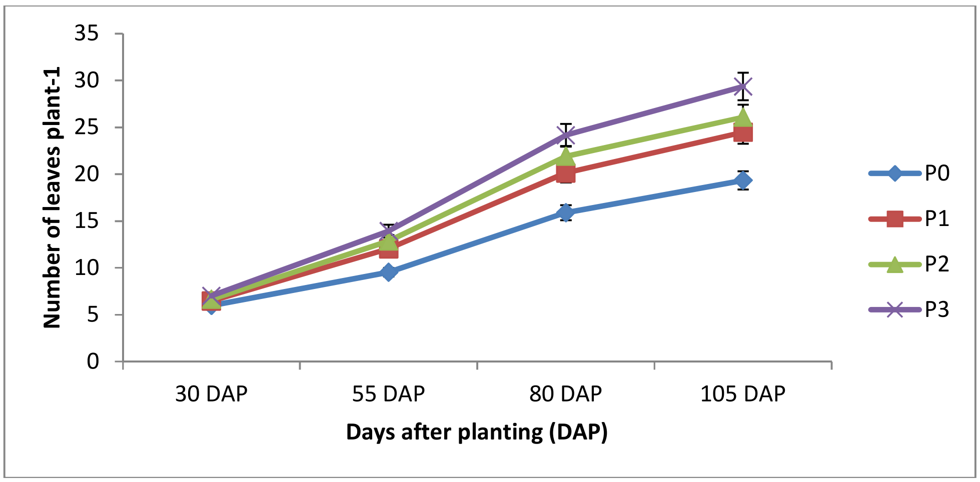

Fig. 3. Number of leaves plant of tuberose at different days after planting as influenced by phosphorus
P_0 = Control (0 kg $P_2O_5ha^{-1}$), P_1 = 140 kg TSP ha^{-1} = 65 kg P_2O_5 ha^{-1}, P_2 = 190 kg TSP ha^{-1} =85 kg P_2O_5 ha^{-1}, P_3 = 240 kg TSP ha^{-1} = 110 kg P_2O_5 ha^{-1}

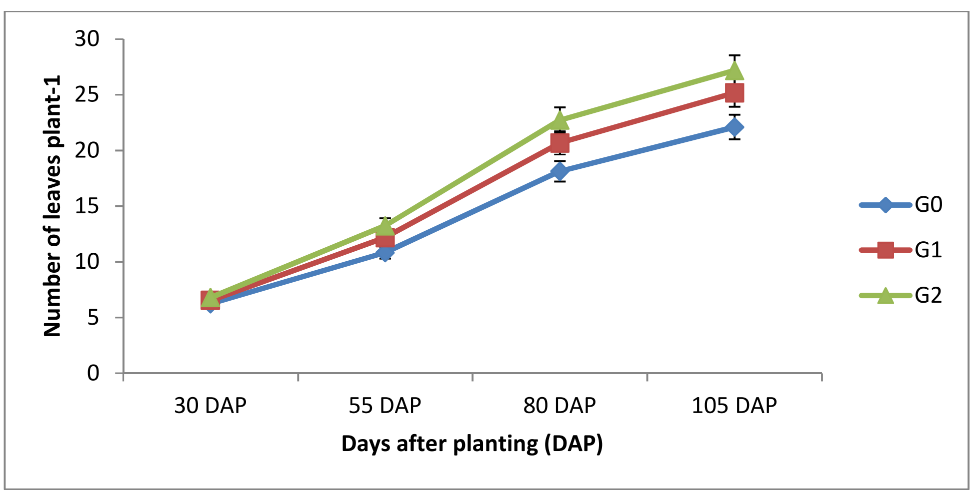

Fig. 4. Number of leaves plant of tuberose at different days after planting as influenced by GA_3
G_0 = Control, G_1 = 115 ppm GA_3, G_2 = 145 ppm GA_3

Table 2. Number of leaves plant of tuberose at different days after planting as influenced by phosphorus and GA_3

Treatments	Number of leaves plant^{-1}			
	30 DAP	55 DAP	80 DAP	105 DAP
P_0G_0	5.91	8.16 i	14.97 g	18.39 h
P_0G_1	6.01	9.75 h	16.03 fg	19.07 h
P_0G_2	6.08	10.69 g	16.67 fg	20.57 gh
P_1G_0	6.10	11.19 fg	17.72 ef	21.57 g
P_1G_1	6.44	11.77 ef	19.20 e	24.14 ef
P_1G_2	6.85	13.17 cd	23.42 bc	27.71 cd
P_2G_0	6.28	11.67 ef	18.60 e	22.64 fg
P_2G_1	6.75	12.90 d	22.40 cd	27.16 cd
P_2G_2	6.95	14.01 bc	24.72 ab	28.46 bc
P_3G_0	6.67	12.29 de	21.23 d	25.78 de
P_3G_1	7.05	14.35 ab	25.07 ab	30.30 ab
P_3G_2	7.33	15.11 a	26.13 a	31.95 a
$LSD_{0.05}$	NS	0.8992	1.777	2.233
CV(%)	5.96	6.39	6.03	8.31

In a column, figure (s) bearing same letter do not differ significantly at $P \leq 0.05$ by LSD, P_0 = Control (0 kg $P_2O_5ha^{-1}$), P_1 = 140 kg TSP ha^{-1} = 65 kg P_2O_5 ha^{-1}, P_2 = 190 kg TSP ha^{-1} =85 kg P_2O_5 ha^{-1}, P_3 = 240 kg TSP ha^{-1} = 110 kg P_2O_5 ha^{-1}, G_0 = Control, G_1 = 115 ppm GA_3, G_2 = 145 ppm GA_3

3.2.2 Spike diameter (cm)

Different levels of phosphorus did not show significant influence on spike diameter (Table 4). However, the highest spike diameter (1.93 cm) was found from the treatment P_2 and the lowest spike diameter (1.65 cm) was found from the control treatment P_0.

Application of different concentration of GA_3 showed non-significant variation among the treatment on spike diameter (Table 4). However, the highest spike diameter (1.95 cm) was found from the treatment G_2 whereas the lowest spike diameter (1.78 cm) was found from the control treatment G_0.

Significant variation was not found in terms of spike diameter influenced by different levels of P and GA_3 combination (Table 4). The highest spike diameter (2.22 cm) was found from the treatment combination of P_2G_2 whereas the lowest spike diameter (1.62 cm) was found from the control treatment combination of P_0G_0.

3.2.3 Rachis length (cm)

Different levels of phosphorus significantly influenced the rachis length (Table 4). The highest rachis length (31.21 cm) was found from the treatment P_2 which was statistically identical with P_3 whereas the lowest rachis length (24.91 cm) was found from the control treatment P_0.

Application of different concentration of GA_3 showed significant variation on rachis length (Table 4). The highest rachis length (31.01 cm) was found from the treatment G_2 which was significantly different from all other treatments. The lowest rachis length (26.33 cm) was found from the control treatment G_0.

Combined effect of P and GA_3 showed significant variation in terms of rachis length of tuberose (Table 4). The highest rachis length (34.20 cm) was found from the treatment combination of P_2G_2 which was significantly different from all other treatment combinations followed by P_3G_2. The lowest rachis length (23.07 cm) was found from the control treatment combination of P_0G_0.

3.2.4 Number of florets spike^{-1}

Different levels of phosphorus showed significant influenced on number of florates spike^{-1} (Table 4). Results indicated that the highest no. of florates spike^{-1} (21.95) was found from the treatment P_2 which was statistically identical with P_3. The lowest no. of florates spike^{-1} (14.96) was found from the control treatment P_0.

Different concentrations of GA_3 showed significant difference on no. of florates spike^{-1} (Table 4). It was observed that the highest no. of florates spike^{-1} (21.75) was found from the treatment G_2 whereas the lowest no. of florates spike^{-1} (16.72) was found from the control treatment G_0.

Table 3. Number of side shoot plant^{-1} of tuberose at different days after planting as influenced by phosphorus and GA_3

Treatments	Number of side shoot plant^{-1}		
	30 DAP	55 DAP	80 DAP
Effect of phosphorus (P)			
P_0	0.92 c	2.17 c	4.07 c
P_1	1.52 b	3.36 b	5.57 b
P_2	2.04 a	4.47 a	6.69 a
P_3	1.94 a	4.35 a	6.55 a
$LSD_{0.05}$	0.201	0.205	0.221
CV (%)	4.22	7.64	9.74
Effect of GA_3			
G_0	1.13 c	2.59 c	4.57 c
G_1	1.69 b	3.75 b	5.96 b
G_2	2.00 a	4.43 a	6.64 a
$LSD_{0.05}$	0.142	0.17	0.187
CV (%)	4.22	7.64	9.74
Combined effect of P and GA_3			
P_0G_0	0.73 i	1.70 h	3.17 i
P_0G_1	0.87 hi	1.95 gh	4.10 h
P_0G_2	1.17 gh	2.85 f	4.95 g
P_1G_0	1.02 ghi	2.16 g	4.44 h
P_1G_1	1.66 de	3.77 d	5.86 e
P_1G_2	1.87 cd	4.16 c	6.42 d
P_2G_0	1.29 fg	3.09 ef	5.20 fg
P_2G_1	2.18 b	4.85 b	7.07 bc
P_2G_2	2.66 a	5.49 a	7.79 a
P_3G_0	1.48 ef	3.42 e	5.47 f
P_3G_1	2.03 bc	4.43 c	6.78 cd
P_3G_2	2.32 b	5.21 a	7.40 b
$LSD_{0.05}$	0.301	0.343	0.386
CV (%)	4.22	7.64	9.74

In a column, figure (s) bearing same letter do not differ significantly at $P \leq 0.05$ by LSD, P_0 = Control (0 kg $P_2O_5ha^{-1}$), P_1 = 140 kg TSP ha^{-1} = 65 kg P_2O_5 ha^{-1}, P_2 = 190 kg TSP ha^{-1} =85 kg P_2O_5 ha^{-1}, P_3 = 240 kg TSP ha^{-1} = 110 kg P_2O_5 ha^{-1}, G_0 = Control, G_1 = 115 ppm GA_3, G_2 = 145 ppm GA_3

Combined effect of P and GA_3 demonstrated the significant variation regarding no. of florates spike^{-1} of tuberose (Table 4). It was noted that the highest no. of florates spike^{-1} (24.57) was found from the treatment combination of P_2G_2 which was statistically similar with P_3 whereas the lowest no. of florates spike^{-1} (12.37) was found from the control treatment combination of P_0G_0.

3.2.5 Single spike weight (g)

Different levels of phosphorus significantly influenced the single spike weight (Table 4). The highest single spike weight (69.22 g) was found from the treatment P_2 which was statistically identical with P_3 whereas the lowest single spike weight (58.67 g) was found from the control treatment P_0.

Application of different concentration of GA_3 showed significant variation on single spike weight (Table 4). The highest single spike weight (68.71 g) was found from the treatment G_2 which was significantly different from all other treatments. The lowest single spike weight (60.85 g) was found from the control treatment G_0.

Different concentrations of P and GA_3 combinations showed statistically significant variation on single spike weight (Table 4). The highest single spike weight (74.50 g) was found from the treatment combination of P_2G_2 which was significantly different from all other treatment combinations followed by P_3G_2. The lowest single spike weight (56.13 g) was found from the control treatment combination of P_0G_0 which was also significantly different from all other treatment combinations.

Table 4. Yield contributing parameters and yield of tuberose spike as influenced by phosphorus and GA_3

Treatments	Yield contributing parameters and yield of tuberose spike					
	Spike length (cm)	Spike diameter (cm)	Rachis length (cm)	No. of florates Spike^{-1}	Single spike weight (g)	Spike yield (No. of spike ha^{-1}) ('000')
Effect of phosphorus (P)						
P_0	64.06 c	1.65	24.91 c	14.96 c	58.67 c	241.30 c
P_1	72.93 b	1.70	28.47 b	19.14 b	64.45 b	323.60 b
P_2	79.13 a	1.93	31.21 a	21.95 a	69.22 a	368.60 a
P_3	78.23 a	1.80	31.04 a	21.79 a	68.07 a	365.30 a
$LSD_{0.05}$	2.142	0.412 ^{NS}	0.9956	0.9708	1.294	9.082
CV(%)	8.98	8.55	6.76	5.10	7.33	8.12
Effect of GA_3						
G_0	67.24 c	1.78	26.33 c	16.72 c	60.85 c	277.80 c
G_1	74.85 b	1.86	29.39 b	19.92 b	65.75 b	334.00 b
G_2	78.66 a	1.95	31.01 a	21.75 a	68.71 a	362.30 a
$LSD_{0.05}$	1.796	0.491 ^{NS}	1.375	1.193	1.404	8.001
CV(%)	8.98	8.55	6.76	5.10	7.33	8.12
Combined effect of P and GA_3						
P_0G_0	60.64 i	1.62	23.07 i	12.37 h	56.13 i	189.60 j
P_0G_1	63.53 h	1.63	24.98 h	14.69 g	58.43 h	241.80 i
P_0G_2	68.01 fg	1.71	26.69 fg	17.83 f	61.45 g	292.40 g
P_1G_0	65.99 g	1.69	25.80 gh	16.10 g	60.19 g	267.50 h
P_1G_1	75.58 d	1.92	29.46 de	20.20 de	65.54 e	345.80 de
P_1G_2	77.23 cd	1.97	30.15 d	21.11 cd	67.61 d	357.70 cd
P_2G_0	70.07 ef	1.84	27.64 f	18.60 ef	63.03 f	321.50 f
P_2G_1	81.36 b	2.03	31.78 c	22.67 bc	70.14 bc	378.70 b
P_2G_2	85.96 a	2.22	34.20 a	24.57 a	74.50 a	405.60 a
P_3G_0	72.29 e	1.89	28.79 e	19.79 de	64.06 f	332.50 ef
P_3G_1	78.95 c	2.00	31.32 c	22.11 bc	68.87 cd	369.80 bc
P_3G_2	83.46 b	2.09	33.01 b	23.49 ab	71.28 b	393.60 a
$LSD_{0.05}$	NS	0.675	1.119	1.681	1.467	14.10
CV(%)	8.98	8.55	6.76	5.10	7.33	8.12

In a column, figure (s) bearing same letter do not differ significantly at $P \le 0.05$ by LSD, P_0 = Control (0 kg $P_2O_5 ha^{-1}$), P_1 = 140 kg TSP ha^{-1} = 65 kg P_2O_5 ha^{-1}, P_2 = 190 kg TSP ha^{-1} =85 kg P_2O_5 ha^{-1}, P_3 = 240 kg TSP ha^{-1} = 110 kg P_2O_5 ha^{-1} , G_0 = Control, G_1 = 115 ppm GA_3, G_2 = 145 ppm GA_3

3.2.6 Number of spike ha^{-1} ("000")

Different levels of phosphorus significantly influence the no. of spike ha^{-1} (Table 4). The highest no. of spike ha^{-1} (368.60 thousand) was found from the treatment P_2 which was statistically identical with P_3. The lowest number of spike ha^{-1} (241.30 thousand) was found from the control treatment P_0.

Application of different concentration of GA_3 showed significant variation on no. of spike ha^{-1} (Table 4). The highest no. of spike ha^{-1} (362.30 thousand) was found from the treatment G_2 which was significantly different from G_1 and control treatment. The lowest no. of spike ha^{-1} (277.80 thousand) was found from the control treatment G_0. The result obtained from the present study was similar with the findings of Bharti and Ranjon [17] [2] who concluded that GA3 (150 ppm) was observed best in inducing early spike emergence and maximum spike yield per sq. meter.

Different concentrations of P and GA_3 combinations showed significant variation on number of spike ha^{-1} (Table 4). The highest no. of spike ha^{-1} (405.60 thousand) was found from the treatment combination of P_2G_2 which was statistically identical with the treatment combination of P_3G_2 followed by P_2G_1. The lowest no. of spike ha^{-1} (189.60 thousand) was found from the control treatment combination of P_0G_0.

3.2.7 Bulb length (cm)

Different levels of phosphorus significantly influenced the bulb length (Table 5). However, the highest bulb length (7.69 cm) was found from the treatment P_2 whereas the lowest bulb length (6.71 cm) was found from the control treatment P_0.

Application of different concentration of GA_3 showed significant variation on bulb length (Table 5). The highest bulb length (7.68 cm) was found from the treatment G_2 whereas the lowest bulb length (6.89 cm) was found from the control treatment G_0.

Different concentrations of P and GA_3 combinations showed statistically significant variation on bulb length (Table 5). The highest bulb length (8.19 cm) was found from the treatment combination of P_2G_2 which was statistically similar with P_3 whereas the lowest bulb length (6.51 cm) was found from the control treatment combination of P_0G_0.

3.2.8 Bulb diameter (cm)

Different levels of phosphorus significantly influenced the bulb diameter (Table 5). The highest bulb diameter (4.11 cm) was found from the treatment P_2 which was statistically identical with P_3 whereas the lowest bulb diameter (3.17 cm) was found from the control treatment P_0.

Due to application of different concentrations of GA3 showed significant variation on bulb diameter (Table 5). The highest bulb diameter (4.09 cm) was found from the treatment G_2 which was significantly different from all other treatments. The lowest bulb diameter (3.42 cm) was found from the control treatment G_0.

Different concentrations of P and GA_3 combinations showed significant variation on bulb diameter (Table 5). The highest bulb diameter (4.52 cm) was found from the treatment combination of P_2G_2 which was statistically similar with P_3G_2 followed by P_2G_1. The lowest bulb diameter (2.90 cm) was found from the control treatment combination of P_0G_0.

3.2.9 Number of bulb plant^{-1}

Different levels of phosphorus significantly influenced the number of bulb plant^{-1} (Table 5). The highest no. of bulb plant-1 (5.02) was found from the treatment P_2 which was statistically identical with P_3 whereas the lowest no. of bulb plant^{-1} (3.32) was found from the control treatment P_0.

Application of different concentration of GA_3 showed significant variation on no. of bulb plant^{-1} (Table 5). The highest no. of bulb plant^{-1} (4.95) was found from the treatment G_2 whereas the lowest no. of bulb plant^{-1} (3.67) was found from the control treatment G_0.

Different concentrations of P and GA_3 combinations showed significant variation on no. of bulb plant^{-1} (Table 5). The highest no. of bulb plant^{-1} (5.77) was found from the treatment combination of P_2G_2 which was statistically identical with P_3G_2 followed by P_2G_1. The lowest no. of bulb plant^{-1} (2.81) was found from the control treatment combination of P_0G_0.

3.2.10 Fresh weight of bulb plant^{-1} (g)

Different levels of phosphorus significantly influenced the fresh weight of bulb plant^{-1} (Table 5). The highest fresh weight of bulb plant^{-1} (129.4 g) was found from the treatment P_2 which was significantly different from all other treatments. The lowest fresh weight of bulb plant^{-1} (82.87 g) was found from the control treatment P_0.

Application of different concentration of GA_3 showed significant variation on fresh weight of bulb plant^{-1} (Table 5). The highest fresh weight of bulb plant^{-1} (126.9 g) was found from the treatment G_2 whereas the lowest fresh weight of bulb plant^{-1} (90.99 g) was found from the control treatment G_0.

Different concentrations of P and GA_3 combinations showed significant variation on fresh weight of bulb plant^{-1} (Table 5). The highest fresh weight of bulb plant^{-1} (157.3 g) was found from the treatment combination of P_2G_2 which was significantly different from all other treatment combinations followed by P_3G_2. The lowest fresh weight of bulb plant^{-1} (72.85 g) was found from the control treatment combination of P_0G_0.

3.2.11 Bulb yield (t ha^{-1})

Different levels of phosphorus significantly influenced the bulb yield (Table 5). The highest bulb yield (25.88 t ha^{-1}) was found from the treatment P_2 which was significantly different from all others. The lowest bulb yield (16.57 t ha^{-1}) was found from the control treatment P_0. Similar result was also observed by Sharma et al. [18] and they found that 70 kg P_2O_5 per hectare treatment improved the bulb production.

Application of different concentration of GA_3 showed significant variation on bulb yield (Table 5). The highest bulb yield (25.38 t ha^{-1}) was found from the treatment G_2 but the lowest bulb yield (18.20 t ha^{-1}) was found from the control treatment G_0 Tiwari and Singh [19] also found similar result on bulb production and concluded that 200 ppm GA_3 showed significant increase in bulb production.

Different concentrations of P and GA_3 combinations showed significant variation on bulb yield (Table 5). The highest bulb yield (31.45 t ha^{-1}) was found from the treatment combination of P_2G_2 which was significantly different from all other treatment combinations followed by P_3G_2. The lowest bulb yield (14.57 t ha^{-1}) was found from the control treatment combination of P_0G_0.

3.2.12 Number of bulblets plant^{-1}

Different levels of phosphorus significantly influenced the single spike weight (Table 6). The highest no. of bulblets plant^{-1} (12.75) was found from the treatment P_2 which was statistically identical with P_3 whereas the lowest no. of bulblets plant^{-1} (8.86) was found from the control treatment P_0.

Application of different concentration of GA3 showed significant variation on number of bulblets plant^{-1} (Table 6). The highest no. of bulblets plant^{-1} (12.66) was found from the treatment G_2 which was significantly different from others whereas the lowest number of bulblets plant^{-1} (9.60) was found from the control treatment G_0.

Table 5. Yield and yield contributing parameters as influenced by phosphorus and GA_3

Treatments	**Yield contributing parameters and yield of tuberose bulb**				
	Bulb length (cm)	**Bulb diameter (cm)**	**No. of bulb plant^{-1}**	**Fresh weight of bulb plant^{-1} (g)**	**Bulb yield (t ha^{-1})**
Effect of phosphorus (P)					
P_0	6.71	3.17 c	3.32 c	82.87 d	16.57 d
P_1	7.28	3.74 b	4.23 b	102.8 c	20.56 c
P_2	7.69	4.11 a	5.02 a	129.4 a	25.88 a
P_3	7.67	4.08 a	4.91 a	123.1 b	24.63 b
$LSD_{0.05}$	0.996^{NS}	0.320	0.1749	4.198	1.027
CV(%)	5.68	5.96	5.72	10.37	7.37
Effect of GA_3					
G_0	6.89	3.42 c	3.67 c	90.99 c	18.20 c
G_1	7.45	3.82 b	4.48 b	110.8 b	22.15 b
G_2	7.68	4.09 a	4.95 a	126.9 a	25.38 a
$LSD_{0.05}$	0.863^{NS}	1.340	0.126	3.809	0.8968
CV(%)	5.68	5.96	5.72	10.37	7.37
Combined effect of P and GA_3					
P_0G_0	6.51 i	2.90 j	2.81 i	72.85 j	14.57 j
P_0G_1	6.71 hi	3.15 i	3.30 h	82.23 i	16.44 i
P_0G_2	6.91 gh	3.59 gh	3.85 g	93.53 gh	18.70 gh
P_1G_0	6.82 gh	3.40 h	3.53 h	87.68 hi	17.54 hi
P_1G_1	7.44 e	3.92 def	4.48 de	109.5 e	21.89 e
P_1G_2	7.57 de	4.01 cde	4.67 cd	111.3 e	22.25 e
P_2G_0	7.01 fg	3.70 fg	4.05 fg	99.13 fg	19.82 fg
P_2G_1	7.87 c	4.22 bc	5.23 b	131.9 c	26.38 c
P_2G_2	8.19 a	4.52 a	5.77 a	157.3 a	31.45 a
P_3G_0	7.20 f	3.83 ef	4.30 ef	104.3 ef	20.86 ef
P_3G_1	7.77 cd	4.14 cd	4.92 c	119.5 d	23.90 d
P_3G_2	8.05 ab	4.39ab	5.51 a	145.6 b	29.11 b
$LSD_{0.05}$	0.233	0.226	0.273	8.110	1.622
CV(%)	5.68	5.96	5.72	10.37	7.37

In a column, figure (s) bearing same letter do not differ significantly at $P \leq 0.05$ by LSD, P_0 = Control (0 kg $P_2O_5ha^{-1}$), P_1 = 140 kg TSP ha^{-1} = 65 kg P_2O_5 ha^{-1}, P_2 = 190 kg TSP ha^{-1} =85 kg P_2O_5 ha^{-1}, P_3 = 240 kg TSP ha^{-1} = 110 kg P_2O_5 ha^{-1}, G_0 = Control, G_1 = 115 ppm GA_3, G_2 = 145 ppm GA_3

Table 6. Yield contributing parameters and yield of tuberose bulblets as influenced by phosphorus and GA_3

Treatments	Yield contributing parameters of tuberose		
	No. of bulblets plant^{-1}	Fresh weight of bulblet plant^{-1} (g)	Bulblet yield (t ha^{-1})
Effect of phosphorus (P)			
P_0	8.86 c	50.10 c	10.02 c
P_1	11.12 b	61.55 b	12.31 b
P_2	12.75 a	71.03 a	14.21 a
P_3	12.47 a	69.55 a	13.91 a
$LSD_{0.05}$	1.147	2.333	0.466
CV(%)	6.93	8.78	7.48
Effect of GA_3			
G_0	9.60 c	54.07 c	10.81 c
G_1	11.64 b	65.10 b	13.02 b
G_2	12.66 a	70.01 a	14.00 a
$LSD_{0.05}$	0.662	1.911	0.492
CV(%)	6.93	8.78	7.48
Combined effect of P and GA_3			
P_0G_0	7.66 i	45.25 i	9.05 i
P_0G_1	8.77 h	50.33 h	10.07 h
P_0G_2	10.14 g	54.71 g	10.94 g
P_1G_0	9.18 h	52.72 gh	10.54 gh
P_1G_1	11.88 e	64.09 e	12.82 e
P_1G_2	12.29 de	67.85 d	13.57 d
P_2G_0	10.60 fg	58.24 f	11.65 f
P_2G_1	13.25 bc	74.82 b	14.97 b
P_2G_2	14.41 a	80.04 a	16.01 a
P_3G_0	10.97 f	60.07 f	12.01 f
P_3G_1	12.66 cd	71.16 c	14.23 c
P_3G_2	13.78 ab	77.42 ab	15.48 ab
$LSD_{0.05}$	0.783	2.780	0.603
CV(%)	6.93	8.78	7.48

In a column, figure (s) bearing same letter do not differ significantly at $P \leq 0.05$ by LSD, P_0 = Control (0 kg $P_2O_5 ha^{-1}$), P_1 = 140 kg TSP ha^{-1} = 65 kg P_2O_5 ha^{-1}, P_2 = 190 kg TSP ha^{-1} =85 kg P_2O_5 ha^{-1}, P_3 = 240 kg TSP ha^{-1} = 110 kg P_2O_5 ha^{-1}, G_0 = Control, G_1 = 115 ppm GA_3, G_2 = 145 ppm GA_3

Different concentrations of P and GA_3 combinations showed statistically significant variation on bulblet yield (Table 6). The highest bulblet yield (16.01 t ha^{-1}) was found from the treatment combination of P_2G_2 which was statistically identical with the treatment combination of P_3G_2. The lowest bulblet yield (9.05 t ha^{-1}) was found from the control treatment combination of P_0G_0.

3.2.13 Fresh weight of bulblet plant^{-1} (g)

Due to application of different levels of phosphorus significantly influenced on the fresh weight of bulblet plant^{-1} (Table 6). The highest fresh weight of bulblet plant^{-1} of tuberose (71.03 g) was found from the treatment P_2 which was statistically identical with P_3 whereas the lowest fresh weight of bulblet plant^{-1} (50.10 g) was found from the control treatment P_0.

Application of different concentration of GA_3 showed significant variation on fresh weight of bulblet plant^{-1} (Table 6). The highest fresh weight of bulblet plant^{-1} (70.01 g) was found from the treatment G_2 which was significantly different from others whereas the lowest fresh weight of bulblet plant^{-1} (54.07 g) was found from the control treatment G_0.

Different concentrations of P and GA_3 combinations showed significant variation on fresh weight of bulblet plant^{-1} (Table 6). The highest fresh weight of bulblet plant-1 (80.04 g) was found from the treatment combination of P_2G_2 which was statistically identical with the treatment combination of P_3G_2. The lowest fresh weight of bulblet plant^{-1} (45.25 g) was found from the control treatment combination of P_0G_0.

3.2.14 Bulblet yield (t ha^{-1})

Different levels of phosphorus significantly influenced the bulblet yield (Table 6). The highest bulblet yield (14.21 t ha^{-1}) was found from the treatment P_2 which was statistically identical with P_3 whereas the lowest bulblet yield (10.02 t ha^{-1}) was found from the control treatment P_0.

Application of different concentration of GA_3 showed significant variation on bulblet yield (Table 6). The highest bulblet yield (14.00 t ha^{-1}) was found from the treatment G_2 which was significantly different from others whereas the lowest bulblet yield (10.81 t ha^{-1}) was found from the control treatment G_0.

Different concentrations of P and GA_3 combinations showed statistically significant variation on bulblet yield (Table 6). The highest bulblet yield (16.01 t ha^{-1}) was found from the treatment combination of P_2G_2 which was statistically identical with the treatment combination of P_3G_2. The lowest bulblet yield (9.05 t ha^{-1}) was found from the control treatment combination of P_0G_0.

3.3 Economic Analysis

The economic analysis is presented under the following headlines:

3.3.1 Gross income

The highest gross return (Tk. 471550) obtained from P_2G_2 treatment combination and lowest gross return (Tk. 227470) obtained from the treatment combination of P_0G_0.

3.3.2 Net return

The highest net return (Tk. 289337/ha) obtained from the treatment combination of P_2G_2 and lowest net return (Tk. 57703/ha) obtained from the treatment combination of P_0G_0.

3.3.3 Benefit cost ratio (BCR)

The highest BCR (2.59) was obtained from the treatment combination of P_2G_2 and lowest BCR (1.34) was obtained from P_0G_0 treatment combination. From economic point of view, it was noticeable from the above results, the treatment combination of P_2G_2 was more profitable than rest of the treatment combinations.

4. CONCLUSION

In terms of growth parameters, results showed that the highest plant height (64.15 cm) and number of leaves plant^{-1} (31.95) were found from the treatment combination of P_3G_2 but the 57 highest number of side shoot plant^{-1} (7.79) was found from the treatment combination of P_2G_2 whereas the lowest plant height (50.82 cm), number of leaves plant^{-1} (18.39 a) and number of side shoot plant^{-1} (3.17) were found from the control treatment combination of P_0G_0. In case of yield and yield contributing parameters of tuberose, the highest spike length (85.96 cm), spike diameter (2.22 cm), rachis length (34.20 cm), no. of florates spike^{-1} (24.57), single spike weight (74.50 g) no. of spike ha^{-1} (405.60 thousand), bulb length (8.19 cm), bulb diameter (4.52 cm), no. of bulb plant^{-1} (5.77), fresh weight of bulb plant^{-1} (157.3 g), bulb yield (31.45 t ha^{-1}), no. of bulblets plant^{-1} (14.41), fresh weight of bulblet plant-1 (80.04 g) and bulblet yield (16.01 t ha-1) were found from the treatment combination of P_2G_2 whereas the lowest spike length (60.64 cm), spike diameter (1.62 cm), rachis length (23.07 cm), no. of florates spike-1 (12.37), single spike weight (56.13 g), no. of spike ha^{-1} (189.60 thousand), bulb length (6.51 cm), bulb diameter (2.90 cm), no. of bulb plant^{-1} (2.81), fresh weight of bulb plant^{-1} (72.85 g), bulb yield (14.57 t ha^{-1}), no. of bulblets plant^{-1} (7.66), fresh weight of bulblet plant^{-1} (45.25 g) and bulblet yield (9.05 t ha^{-1}) was found from the control treatment combination of P_0G_0. In terms of economic analysis, the highest gross return (Tk. 471550/ha), net return (Tk. 289337/ha) and BCR (2.59) were obtained from the treatment combination of P_2G_2 (85 kg P_2O_5 ha^{-1} with 145 ppm GA_3) whereas the lowest gross return (Tk. 227470/ha), net return (Tk. 57703/ha) and BCR (1.34) was obtained from P_0G_0 (no P and GA_3). From the above results, it can be concluded that the treatment combination of P_2G_2 (85 kg P_2O_5 ha^{-1} with 145 ppm GA_3) showed highest yield advantage regarding economic return. Therefore, the results suggest that the combination of P and GA_3 i.e. P_2G_2 (85 kg P_2O_5 ha^{-1} with 145 ppm GA_3) is suitable for the higher spike, bulb and bulblet yield production of tuberose. So, this treatment combination can recommend as the best treatment combination considering yield and economic return.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/57156