Plant Archives Vol. 26, No. 1, 2026 pp. 1887-1896 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org
DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2026.v26.no.1.260

INDUCTION OF VARIABILITY USING CHEMICAL MUTAGENS IN TUBEROSE (*AGAVE AMICA* L.) CV. PRAJWAL

Simran[1]*, Sunil Malik[1], Mukesh Kumar[1], Satendra Kumar[1], L.K. Gangwar[2], Adesh Singh[3] and Mahima Sharma[1]

[1]Department of Floriculture & Landscaping, College of Horticulture, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut, Uttar Pradesh, India – 250110
[2]Department of Genetics and Plant Breeding, College of Agriculture, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut, Uttar Pradesh, India – 250110
[3]Department of Agronomy, College of Agriculture, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut, Uttar Pradesh, India – 250110
Corresponding author E-mail: chaudhary99simran@gmail.com
(Date of Receiving : 16-01-2026; Date of Revision : 08-03-2026; Date of Acceptance : 29-03-2026)

ABSTRACT

Tuberose (*Agave amica* L.) is an important ornamental crop cultivated widely for its fragrant flowers, landscaping, and essential oil extraction. However, its genetic base is narrow due to vegetative propagation. Mutation breeding using chemical mutagens has emerged as a potential strategy to induce variability and develop new cultivars. The present investigation was conducted using bulbs of cv. Prajwal treated with different doses of Ethyl Methane Sulfonate (EMS), Methyl Methane Sulfonate (MMS), and Diethyl Sulfate (DES). The treatments were laid out in Randomized Block Design (RBD) with three replications. Observations were recorded on vegetative, flowering, and bulb yield traits. Results indicated that lower concentrations of mutagens significantly improved parameters such as spike length, number of florets, and bulb yield, whereas higher concentrations caused inhibitory effects. EMS proved to be the most effective mutagen in inducing useful variability. The study demonstrates the potential of chemical mutagenesis in broadening the genetic base of tuberose and suggests its application in breeding programs aimed at developing commercially viable cultivars.
Keywords **:** Tuberose, EMS, DES, MMS, mutation, variability.

Introduction

Tuberose (*Agave amica* L.), popularly known as Rajnigandha (Thiede and Govaerts, 2017), is an economically significant ornamental crop valued for its fragrant flowers used in garlands, bouquets, and perfumes. It holds an important place in both domestic and international markets due to its high demand as a cut flower and loose flower. Despite its commercial importance, tuberose has limited genetic variability because of its propagation through bulbs, which restricts opportunities for conventional breeding. Therefore, alternative breeding approaches are needed. Mutation breeding is a proven method to induce genetic variability by exposing plant material to mutagens such as physical (radiation) or chemical agents (Singh and Kumar, 2022). Among chemical mutagens, EMS, MMS, and DES are widely used to induce point mutations and create novel variability. Several reports in crops like chrysanthemum, gladiolus, and marigold have highlighted the potential of mutagens in improving flower quality and yield traits. However, limited work has been done in tuberose. This study was undertaken to evaluate the effect of different concentrations of EMS, DES, and MMS on growth, flowering, and bulb yield in cv. Prajwal, with an aim to identify promising treatments for generating useful variability.

Materials and Methods

The experiment was carried out at the Horticulture Research Centre, SVPUAT, Meerut, during the Rabi season 2024–25. Uniform and healthy bulbs of tuberose cv. Prajwal were selected for treatment. The bulbs were pre-soaked in distilled water and then treated with different concentrations of EMS (T_1-0.25, T_2-0.50, T_3-0.75, T_4-1.00) %, DES (T_5-0.25, T_6-0.50, T_7-0.75, T_8-1.00, T_9-1.25) %, and MMS (T_{10}-0.01, T_{11}-0.02, T_{12}-0.03, T_{13}-0.04, T_{14}-0.05) % for specified durations. Control bulbs were soaked in distilled water without mutagen treatment (T_{15}). The treated bulbs were planted in plots following Randomized Block Design (RBD) with three replications. Standard cultural practices were adopted throughout the experiment. Data were recorded on vegetative traits (days to sprouting, sprouting percentage, plant height, number of leaves, leaf length, leaf width), flowering traits (days to spike emergence, spike length, rachis length, number of florets per spike, weight of spike, days to opening of first floret, and vase life) at the time of plant growth, and bulb yield traits (number of bulbs and bulblets per clump, bulb diameter, bulb weight, and bulb yield per hectare) at the time of harvesting. Statistical analysis was performed to evaluate the significance of treatments.

Results and Discussion

The application of chemical mutagens significantly influenced the growth, flowering, and bulb yield of tuberose cv. Prajwal. The results obtained are summarized as follows:

Analysis of Variance (ANOVA)

The analysis of variance revealed that the effects of EMS, DES, and MMS were statistically significant for most of the vegetative, flowering, and bulb yield characters under study (Table 1). Significant differences among treatments confirmed the effectiveness of mutagenic treatments in inducing variability in tuberose cv. Prajwal. Traits such as spike length, number of florets per spike, rachis length, bulb number, and bulb weight exhibited highly significant variation. This suggests that chemical mutagenesis was successful in generating variability which can be utilized for selection of superior genotypes. Among the mutagens, EMS at lower concentrations proved to be more effective in improving growth, flowering and yield attributes. The treatment EMS @0.25% exhibited superior performance for traits such as plant height, number of leaves per plant, number of spikes per plant, spike length, number of florets per spike and bulb yield, whereas EMS @0.50% showed better results for rachis length and bulb characters. Similar findings were reported by Kayalvizhi *et al*. (2016), Yadav (2018) and Kaur *et al*. (2018) in tuberose. The control treatment recorded minimum days to bulb sprouting and maximum survival percentage, although lower concentrations of EMS and DES also showed comparatively good performance, which is in accordance with the results of Jyothi *et al*. (2024). Lower concentrations of DES showed better performance for traits like spike weight, width of longest leaf and number of bulblets per plant, as also reported by Kannan *et al*. (2017) and Kapadiya *et al*. (2014). In contrast, MMS exhibited comparatively lesser effectiveness and showed improvement only at the lowest concentration for number of bulblets per plant, which agrees with the findings of Vedwan (2024) and Kumar *et al*. (2021).

Table 1: Analysis of variance for different characters in tuberose cv. Prajwal.

S.No.	Source of Variation	Replication	Treatments	Error	Total
1	df	2	14	28	44
2	DBS	0.88	2.52**	0.33	
3	SP	2.83	188.69**	13.61	
4	PH	14.82	40.7**	4.27	
5	NLP	2.34	18.43**	2.38	
6	LLL	0.19	6.88**	0.23	
7	WLL	0.002	0.061**	0.002	
8	DFF	0.97	13.29**	0.93	
9	NSP	0.001	0.481**	0.002	
10	SL	12.38	24.1**	7.12	
11	RL	0.44	10.4**	2.86	
12	DS	0.03	3.7**	0.22	
13	SW	7.78	36.33**	4.03	
14	NFS	6.02	32.26**	1.97	

15	NBP	0.013	0.255**	0.005	
16	NB/LP	1.02	21.04**	0.48	
17	NBPL	0.2	49.32**	0.85	
18	NB/LPL	28.21	3185.17**	11.9	
19	WBP	0.49	20.71**	0.53	
20	WB/LP	0.04	1.71**	0.07	
21	BD	0.006	0.616**	0.048	
22	YPP	0.001	0.062**	0.001	
23	YPH	13.06	524.32**	11.4	

**Significant at 1%

DBS – days to bulb sprouting
SP – survival%
PH – plant height
NLP – number of leaves per plant
LLL – length of longest leaf
WLL – width of longest leaf
DFF – days required for opening of 1st floret
NSP – number of spikes per plant
SL – spike length
RL – rachis length
DS – diameter of spike
SW – spike weight
NFS – number of florets per spike
NBP – number of bulbs per plant
NB/LP – number of bulblets per plant
NBPL – number of bulbs per plot
NB/LPL – number of bulblets per plot
WBP – weight of bulbs per plant
WB/LP – weight of bulblets per plant
BD – bulb diameter
YPP – yield of bulb kg per plot
YPH – yield of bulb quintal per hectare

Estimation of coefficient of variation

Mean performance indicated that lower doses of EMS (0.25–0.50%) consistently outperformed the control and other mutagens for most vegetative and floral characters in tuberose cv. Prajwal. DES at lower concentrations also improved several growth and flowering traits, whereas MMS showed comparatively moderate effectiveness. In contrast, higher concentrations of all mutagens reduced plant Vigor and yield due to phytotoxic effects. Similar trends have been reported in gladiolus and chrysanthemum, where lower mutagen doses enhanced desirable traits while higher concentrations suppressed growth (Table 2).

Genetic parameters such as genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability and genetic advance were estimated to assess variability among the mutagen-treated populations. High GCV and PCV were observed for number of bulblets per plot, number of bulblets per plant, bulb yield (q/ha), number of bulbs per plot and spike weight, indicating substantial genetic variability, as also reported by Ratna Priyanka *et al*. (2020). High heritability coupled with high genetic advance for bulb yield, number of bulblets per plant and spike weight suggested the predominance of additive gene action and effectiveness of selection Johnson *et al*. (1955). However, traits such as spike length and days to opening of first floret showed moderate heritability with low genetic advance, indicating environmental influence or non-additive gene action. EMS treatments exhibited comparatively higher variability and genetic parameters, indicating its effectiveness in inducing useful variability.

Table 2: Estimation of mean, range, components of variance, heritability and genetic advance for growth, flower and yield parameters in Tuberose cv. Prajwal.

S. No.	Character	Mean	SEM	Range	GCV	PCV	Heritability BS	GA	GA% mean
1	Days to bulb sprouting	28.53	0.33	26.77-30.41	2.99	3.62	68.55	1.46	5.11
2	Survival per cent (%)	88.57	2.13	75.82-99.62	8.63	9.58	81.09	14.17	16.00
3	Plant height (cm)	90.12	1.19	84.02-98.45	3.87	4.50	73.98	6.17	6.85
4	Number of leaves per plant	38.62	0.89	34.52-43.58	5.99	7.20	69.19	3.96	10.26
5	Length of longest leaf	32.86	0.28	30.41-35.14	4.53	4.76	90.45	2.92	8.88
6	Leaf width of longest leaf	1.20	0.02	0.90-1.38	11.63	12.14	91.76	0.28	22.96
7	Days required for opening 1st floret	91.26	0.56	88.37-95.74	2.22	2.46	81.66	3.78	4.14
8	Number of spikes per plant	1.56	0.03	1.20-2.41	25.67	25.84	98.72	0.82	52.54
9	Spike length (cm)	85.52	1.54	81.31-91.95	2.78	4.18	44.26	3.26	3.81
10	Rachis length (cm)	26.46	0.98	23.34-29.35	5.99	8.76	46.76	2.23	8.44
11	Diameter of spike (mm)	9.64	0.27	8.04-11.14	11.18	12.18	84.23	2.04	21.13
12	Spike weight (g)	52.86	1.16	47.90-58.70	6.21	7.28	72.74	5.77	10.91
13	Number of florets per spike	40.66	0.81	35.16-46.73	7.81	8.54	83.67	5.99	14.72

14	Number of bulbs per plant	1.79	0.04	1.17-2.19	16.13	16.57	94.84	0.58	32.37
15	Number of bulblets per plant	13.36	0.40	9.83-16.92	19.60	20.27	93.46	5.21	39.03
16	Number of bulbs per plot	21.97	0.53	13.73-28.13	18.30	18.78	94.99	8.07	36.74
17	Number of bulblets per plot	162.26	1.99	116.35-204.64	20.04	20.16	98.89	66.62	41.06
18	Fresh weight of bulb per plant (g)	22.60	0.42	18.30-26.78	11.47	11.92	92.68	5.14	22.75
19	Fresh weight of bulblet per plant (g)	3.75	0.15	2.45-4.99	19.7	20.9	89.2	1.44	38.41
20	Bulb diameter (mm)	2.96	0.13	2.37-3.71	14.71	16.46	79.80	0.80	27.06
21	Yield of bulb (kg/plot)	0.51	0.02	0.25-0.73	28.20	28.97	94.76	0.29	56.55
22	Yield of bulb (q/ha)	47.04	1.95	23.26-68.55	27.80	28.71	93.75	26.08	55.44

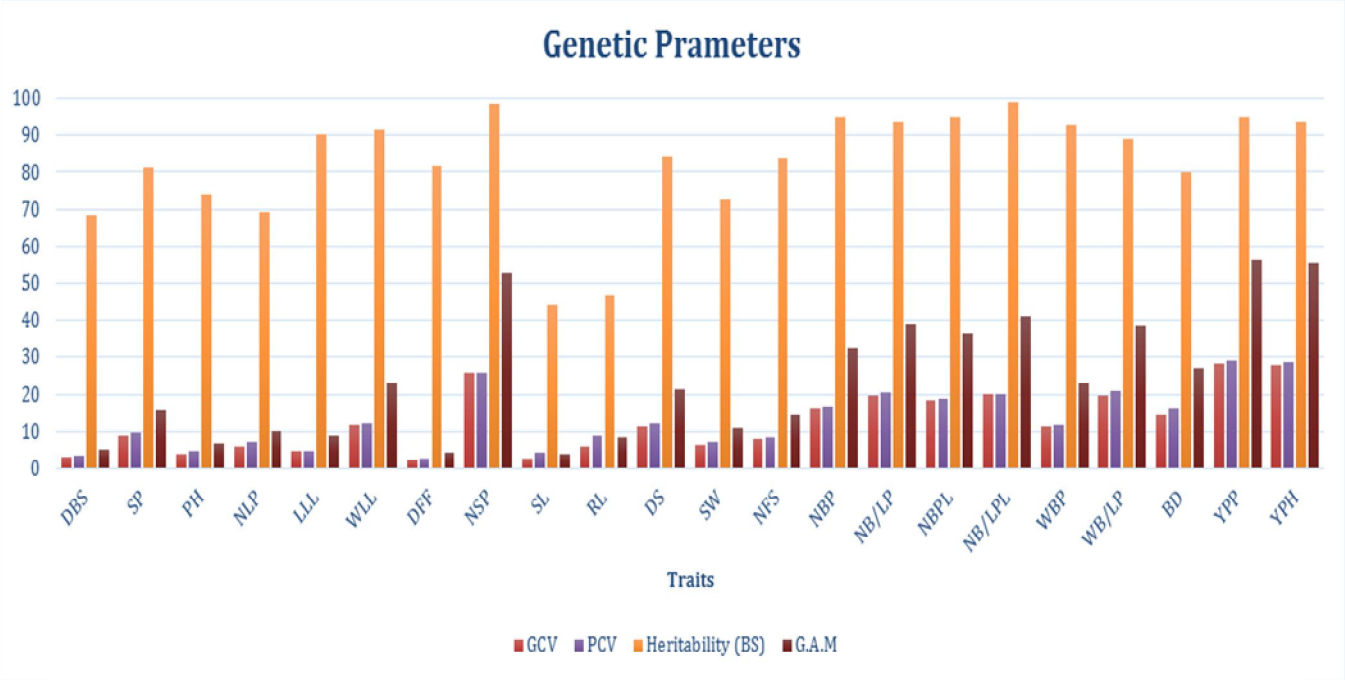

Fig. 1: Genotypic coefficient of variation, Phenotypic coefficient of variation, Heritability and Estimation of Genetic Advance as per cent of mean for different parameters in tuberose cv. Prajwal.

DBS- days to bulb sprouting
SP- survival%
PH- plant height
NLP- number of leaves per plant
LLL- length of longest leaf
YPP- yield of bulb kg per plot
WLL- width of longest leaf
DFF- days required for opening of 1st floret
NSP- number of spikes per plant
SL- spike length
RL- rachis length
YPH- yield of bulb q/ha
DS- diameter of spike
SW- spike weight
NFS- number of florets per spike
NBP- number of bulbs per plant
NB/LP- number of bulblets per plant
NBPL- number of bulbs per plot
NB/LPL- number of bulblets per plot
WBP- weight of bulbs per plant
WB/LP- weight of bulblets per plant
BD- bulb diameter

Correlation Studies

Correlation analysis revealed that spike length, rachis length, number of florets per spike, and spike weight were positively and significantly correlated with bulb yield per hectare. Similarly, bulb diameter and bulb weight showed strong positive associations with total bulb yield. These results suggest that improvement in flowering and bulb traits directly contributes to higher yield. Similar correlations have been reported in tuberose and other ornamental crops, emphasizing the importance of selecting for these traits in breeding programs.

Genotypic Correlation

The genotypic correlation coefficients were generally higher in magnitude compared to phenotypic ones (Table 3), indicating that the observed associations were largely genetic in nature and less influenced by the environment. Spike length maintained a strong positive genotypic correlation with rachis length, number of florets per spike, spike weight, and bulb yield per hectare. This suggests that genetic improvement in spike length would simultaneously lead to improvement in other important yield traits.

Similarly, bulb diameter and bulb weight were positively and strongly correlated at the genotypic level, both contributing significantly towards higher bulb yield. Negative genotypic correlations were observed between days to flowering and bulb yield, reinforcing the need to select for early flowering genotypes to maximize yield.

These results align with reports of Kannan *et al*. (1998), Ranchana *et al*. (2015), and Gogoi *et al*. (2019), who also highlighted the stronger nature of genotypic correlations in tuberose compared to phenotypic ones. The consistency of these findings suggests that genetic selection based on correlated traits such as spike length, florets per spike, and bulb diameter would be highly effective in tuberose improvement programs.

Phenotypic Correlation

The phenotypic correlation coefficients revealed that most of the flowering and yield traits were positively associated with each other (Table 4). Spike length exhibited a significant positive correlation with rachis length, number of florets per spike, and spike weight, indicating that longer spikes not only accommodated more florets but also contributed to higher spike weight. Similarly, bulb diameter and bulb weight showed a strong positive correlation with total bulb yield per hectare, suggesting that improvement in bulb size directly enhances yield potential.

However, days to flowering showed a negative phenotypic correlation with bulb yield, indicating that delayed flowering reduces the productive potential of plants. Such associations emphasize the importance of selecting for earliness in flowering along with superior floral traits. These findings agree with earlier studies in tuberose by Kannan *et al*. (1998) and Ranchana *et al*. (2015), who also reported strong positive correlations between spike length, florets per spike, and bulb yield.

Path Coefficient Analysis

Path coefficient analysis partitioned the correlation into direct and indirect effects, thereby providing a clearer understanding of trait interrelationships. Spike length and number of florets exhibited high positive direct effects on bulb yield, suggesting that these traits should be given priority in selection. Rachis length also contributed positively, both directly and indirectly, while days to flowering showed a negative direct effect on yield. This implies that early flowering genotypes may not always be high yielding unless supported by superior spike and bulb traits. These findings align with earlier reports in gladiolus and marigold where spike characters contributed significantly towards yield.

Genotypic Path Analysis

At the genotypic level, spike length, florets per spike, bulb diameter, and bulb weight showed strong positive direct effects on yield. Rachis length also contributed positively, mainly through its association with spike length. Days to flowering again exerted a negative direct effect (Table 5). These results agree with Kannan *et al*. (1998) and Ratna Priyanka *et al*. (2020).

Phenotypic Path Analysis

Phenotypic path analysis indicated that spike length had the highest positive direct effect on bulb yield, followed by florets per spike and spike weight. Rachis length contributed indirectly through spike length, while days to flowering had a negative direct effect (Table 6). Similar trends were noted by Ranchana *et al*. (2015) and Singh *et al*. (2019).

Conclusion

The present study demonstrated that chemical mutagens, particularly EMS at lower concentrations (0.25%, 0.50%), can effectively induce variability in tuberose cv. Prajwal. Enhanced vegetative growth, improved flowering traits, and increased bulb yield were observed under optimum doses. In contrast, higher concentrations of mutagens proved detrimental. EMS proved superior among the mutagens tested, highlighting its potential use in tuberose breeding programs. The variability induced can contribute to the development of improved cultivars with higher ornamental and commercial value.

Table 3: Genotypic correlation analysis for growth, flower and yield parameters in cv. Prajwal of tuberose.

	DBS	SP	PH	NLP	LLL	WLL	DFF	NSP	SL	RL	DS	SW	NFS	NBP	NB/LP	NBPL	NB/LPL	WBP	WB/LP	BD	YPP	YPH
DBS	1.00	-0.95**	-0.63*	-0.79**	0.51	-0.47	0.87**	-0.51	-0.76**	-0.93**	-0.82**	-0.87**	-0.37	-0.63*	-0.79**	-0.68**	-0.83**	-0.54*	-0.68**	-0.64*	-0.65**	-0.63*
SP		1.00	0.72**	0.92**	-0.31	0.47	-0.95**	0.67**	0.93**	0.95**	0.91**	0.99**	0.69**	0.88**	0.97**	0.90**	0.95**	0.77**	0.89	0.62	0.86	0.85
PH			1.00	0.98**	-0.17	0.72**	-0.73**	0.94**	0.98**	0.92**	0.90**	0.98**	0.77**	0.65**	0.78**	0.72**	0.78**	0.81**	0.75**	0.78**	0.78**	0.79**
NLP				1.00	-0.09	0.52*	-0.84**	0.96**	0.97**	0.96**	0.94**	0.95**	0.79**	0.88**	0.96**	0.92**	0.92**	0.90**	0.96**	0.78**	0.94**	0.93**
LLL					1.00	-0.54*	0.55*	0.18	-0.11	-0.29	-0.28	-0.34	0.10	-0.06	-0.28	-0.08	-0.36	-0.21	-0.11	-0.45	-0.14	-0.12
WLL						1.00	-0.67**	0.46	0.84**	0.49	0.72**	0.76**	0.39	0.21	0.54*	0.25	0.56*	0.37	0.27	0.57*	0.32	0.30
DFF							1.00	-0.53*	-0.79**	-0.93**	-0.86**	-0.95**	-0.49	-0.75**	-0.87**	-0.77**	-0.90**	-0.70**	-0.76**	-0.67**	-0.75**	-0.74**
NSP								1.00	0.96**	0.86**	0.75**	0.82**	0.84**	0.63**	0.76**	0.72**	0.72**	0.76**	0.76**	0.68**	0.78**	0.78**
SL									1.00	0.95**	0.96**	0.94**	0.92**	0.75**	0.98**	0.90**	0.98**	0.96**	0.98**	0.98**	0.98**	0.97**
RL										1.00	0.85**	0.93**	0.75**	0.86**	0.87**	0.93**	0.87**	0.84**	0.92**	0.79**	0.91**	0.91**
DS											1.00	0.93**	0.79**	0.81**	0.94**	0.85**	0.95**	0.78**	0.83**	0.78**	0.84**	0.84**
SW												1.00	0.85**	0.81**	0.93**	0.87**	0.97**	0.88**	0.89**	0.91**	0.90**	0.90**
NFS													1.00	0.70**	0.76**	0.78**	0.75**	0.79**	0.82**	0.64**	0.82**	0.84**
NBP														1.00	0.87**	0.98**	0.87**	0.85**	0.96**	0.65**	0.95**	0.95**
NB/LP															1.00	0.90**	0.99**	0.86**	0.92**	0.79**	0.91**	0.90**
NBPL																1.00	0.90**	0.90**	0.99**	0.74**	0.98**	0.98**
NB/LPL																	1.00	0.89**	0.92**	0.83**	0.92**	0.92**
WBP																		1.00	0.94**	0.86**	0.97**	0.97**
WB/LP																			1.00	0.76**	0.98**	0.98**
BD																				1.00	0.83**	0.83**
YPP																					1.00	0.98**
YPH																						1.00

**Significant at 1% &*Significant at 5%

DBS- days to bulb sprouting
SP- survival%
PH- plant height
NLP- number of leaves per plant
LLL- length of longest leaf
YPP- yield of bulb kg per plot
WLL- width of longest leaf
DFF- days required for opening of 1st floret
NSP- number of spikes per plant
SL- spike length
RL- rachis length
YPH- yield of bulb q/ha
DS- diameter of spike
SW- spike weight
NFS- number of florets per spike
NBP- number of bulbs per plant
NB/LP- number of bulblets per plant
NBPL- number of bulbs per plot
NB/LPL- number of bulblets per plot
WBP- weight of bulbs per plant
WB/LP- weight of bulblets per plant
BD- bulb diameter

Table 4: Phenotypic correlation analysis for growth, flower and yield parameters in cv. Prajwal of tuberose.

	DBS	SP	PH	NLP	LLL	WLL	DFF	NSP	SL	RL	DS	SW	NFS	NBP	NB/LP	NBPL	NB/LPL	WBP	WB/LP	BD	YPP	YPH
DBS	1	-0.73**	-0.46**	-0.52**	0.4**	-0.4**	0.72**	-0.43**	-0.38**	-0.46**	-0.66**	-0.57**	-0.35*	-0.55**	-0.68**	-0.56**	-0.68**	-0.48**	-0.51**	-0.53**	-0.55**	-0.53**
SP		1	0.57**	0.75**	-0.29	0.38**	-0.8**	0.61**	0.47**	0.55**	0.77**	0.67**	0.59**	0.81**	0.81**	0.8**	0.88**	0.7**	0.78**	0.56**	0.77**	0.77**
PH			1	0.75**	-0.1	0.59**	-0.44**	0.8**	0.6**	0.59**	0.71**	0.68**	0.67**	0.53**	0.63**	0.63**	0.69**	0.66**	0.64**	0.62**	0.67**	0.65**
NLP				1	-0.11	0.39**	-0.6**	0.81**	0.71**	0.46**	0.62**	0.72**	0.65**	0.7**	0.77**	0.76**	0.79**	0.73**	0.77**	0.55**	0.78**	0.78**
LLL					1	-0.49**	0.51**	0.15	-0.16	-0.18	-0.24	-0.32*	0.11	-0.08	-0.25*	-0.05	-0.35*	-0.22	-0.1	-0.39**	-0.12	-0.11
WLL						1	-0.56**	0.43**	0.52**	0.39**	0.63**	0.61**	0.33*	0.2	0.51**	0.24	0.53**	0.34*	0.22	0.47**	0.3*	0.29
DFF							1	-0.48**	-0.53**	-0.51**	-0.73**	-0.72**	-0.42**	-0.7**	-0.76**	-0.64**	-0.79**	-0.63**	-0.67**	-0.57**	-0.65**	-0.63**
NSP								1	0.73**	0.57**	0.69**	0.71**	0.77**	0.62**	0.73**	0.69**	0.71**	0.74**	0.71**	0.61**	0.75**	0.75**
SL									1	0.39**	0.6**	0.76**	0.63**	0.49**	0.66**	0.52**	0.65**	0.59**	0.54**	0.49**	0.58**	0.59**
RL										1	0.55**	0.62**	0.45**	0.6**	0.54**	0.6**	0.59**	0.54**	0.51**	0.53**	0.59**	0.57**
DS											1	0.79**	0.63**	0.73**	0.81**	0.75**	0.87**	0.69**	0.72**	0.68**	0.75**	0.74**
SW												1	0.64**	0.65**	0.79**	0.73**	0.81**	0.7**	0.66**	0.64**	0.75**	0.74**
NFS													1	0.63**	0.67**	0.7**	0.69**	0.7**	0.74**	0.56**	0.74**	0.75**
NBP														1	0.82**	0.94**	0.85**	0.8**	0.88**	0.57**	0.89**	0.89**
NB/LP															1	0.85**	0.95**	0.81**	0.83**	0.65**	0.86**	0.86**
NBPL																1	0.88**	0.86**	0.91**	0.68**	0.97**	0.97**
NB/LPL																	1	0.86**	0.87**	0.75**	0.9**	0.89**
WBP																		1	0.86**	0.82**	0.95**	0.95**
WB/LP																			1	0.66**	0.92**	0.92**
BD																				1	0.79**	0.77**
YPP																					1	0.99**
YPH																						1

**Significant at 1% &*Significant at 5%

DBS- days to bulb sprouting
SP- survival%
PH- plant height
NLP- number of leaves per plant
LLL- length of longest leaf
YPP- yield of bulb kg per plot
WLL- width of longest leaf
DFF- days required for opening of 1st floret
NSP- number of spikes per plant
SL- spike length
RL- rachis length
YPH- yield of bulb q/ha
DS- diameter of spike
SW- spike weight
NFS- number of florets per spike
NBP- number of bulbs per plant
NB/LP- number of bulblets per plant
NBPL- number of bulbs per plot
NB/LPL- number of bulblets per plot
WBP- weight of bulbs per plant
WB/LP- weight of bulblets per plant
BD- bulb diameter

Table 5: Genotypic path coefficient analysis for yield of bulb q/ha in cv. Prajwal of tuberose.

	DBS	SP	PH	NLP	LLL	WLL	DFF	NSP	SL	RL	DS	SW	NFS	NBP	NB/LP	NBPL	NB/LPL	WBP	WB/LP	BD	YPP
DBS	**0.023**	-0.295	0.058	-0.073	0.038	-0.049	0.229	0.195	-0.108	-0.098	-0.104	0.045	0.013	0.1	-0.369	-0.028	0.65	-0.137	0.003	-0.046	-0.674
SP	-0.022	**0.312**	-0.066	0.085	-0.023	0.05	-0.249	-0.254	0.132	0.107	0.115	-0.051	-0.024	-0.139	0.457	0.037	-0.748	0.194	-0.004	0.044	0.895
PH	-0.015	0.223	**-0.092**	0.091	-0.013	0.076	-0.191	-0.358	0.174	0.097	0.113	-0.051	-0.027	-0.103	0.366	0.029	-0.61	0.205	-0.003	0.056	0.817
NLP	-0.018	0.286	-0.091	**0.093**	-0.007	0.055	-0.221	-0.365	0.146	0.125	0.119	-0.049	-0.028	-0.14	0.45	0.038	-0.724	0.228	-0.004	0.055	0.98
LLL	0.012	-0.096	0.016	-0.008	**0.075**	-0.057	0.143	-0.066	-0.016	-0.03	-0.035	0.017	-0.003	0.01	-0.129	-0.003	0.282	-0.052	0.0005	-0.032	-0.148
WLL	-0.011	0.146	-0.067	0.048	-0.04	**0.106**	-0.176	-0.175	0.119	0.052	0.091	-0.039	-0.014	-0.033	0.252	0.01	-0.435	0.094	-0.001	0.04	0.33
DFF	0.02	-0.296	0.067	-0.078	0.041	-0.071	**0.262**	0.199	-0.113	-0.099	-0.109	0.049	0.017	0.119	-0.409	-0.031	0.702	-0.176	0.003	-0.048	-0.785
NSP	-0.012	0.208	-0.087	0.089	0.013	0.049	-0.138	**-0.38**	0.151	0.091	0.094	-0.043	-0.03	-0.1	0.356	0.03	-0.562	0.192	-0.003	0.049	0.808
SL	-0.018	0.289	-0.113	0.095	-0.008	0.089	-0.208	-0.403	**0.143**	0.111	0.14	-0.054	-0.037	-0.119	0.471	0.037	-0.771	0.243	-0.004	0.072	0.918
RL	-0.021	0.315	-0.085	0.11	-0.021	0.052	-0.245	-0.326	0.15	**0.106**	0.108	-0.053	-0.027	-0.136	0.408	0.038	-0.683	0.213	-0.004	0.056	0.952
DS	-0.019	0.283	-0.083	0.088	-0.021	0.076	-0.227	-0.284	0.158	0.09	**0.126**	-0.053	-0.028	-0.129	0.442	0.035	-0.742	0.196	-0.003	0.055	0.879
SW	-0.02	0.309	-0.091	0.088	-0.025	0.08	-0.249	-0.313	0.149	0.107	0.13	**-0.052**	-0.03	-0.128	0.435	0.036	-0.757	0.222	-0.004	0.065	0.941
NFS	-0.008	0.214	-0.071	0.074	0.007	0.041	-0.128	-0.32	0.149	0.08	0.099	-0.044	**-0.035**	-0.111	0.358	0.032	-0.591	0.2	-0.003	0.045	0.853
NBP	-0.015	0.273	-0.06	0.082	-0.005	0.022	-0.196	-0.239	0.107	0.091	0.103	-0.042	-0.025	**-0.159**	0.409	0.041	-0.686	0.214	-0.004	0.047	0.991
NB/LP	-0.018	0.303	-0.072	0.089	-0.021	0.057	-0.228	-0.288	0.143	0.092	0.119	-0.048	-0.027	-0.138	**0.47**	0.037	-0.784	0.217	-0.004	0.057	0.948
NBPL	-0.016	0.279	-0.066	0.085	-0.006	0.026	-0.201	-0.275	0.128	0.098	0.108	-0.045	-0.027	-0.159	0.421	**0.041**	-0.709	0.226	-0.004	0.053	0.919
NB/LPL	-0.019	0.297	-0.072	0.086	-0.027	0.059	-0.235	-0.273	0.14	0.092	0.119	-0.05	-0.027	-0.139	0.47	0.037	**-0.784**	0.224	-0.004	0.059	0.962
WBP	-0.013	0.24	-0.075	0.084	-0.015	0.039	-0.183	-0.29	0.138	0.089	0.098	-0.046	-0.028	-0.135	0.404	0.037	-0.697	**0.252**	-0.004	0.061	0.908
WB/LP	-0.016	0.276	-0.069	0.089	-0.008	0.028	-0.199	-0.29	0.139	0.097	0.105	-0.046	-0.029	-0.153	0.432	0.041	-0.721	0.237	**-0.004**	0.054	0.937
BD	-0.015	0.193	-0.072	0.072	-0.034	0.06	-0.177	-0.259	0.144	0.083	0.098	-0.047	-0.022	-0.104	0.373	0.031	-0.647	0.216	-0.003	**0.071**	0.867
YPP	-0.015	0.267	-0.072	0.087	-0.011	0.033	-0.198	-0.294	0.139	0.097	0.106	-0.047	-0.029	-0.151	0.427	0.04	-0.723	0.244	-0.004	0.059	**0.943**

R square = 0.99, Residual effect = 0.0008

Bold values shows direct and normal values shows indirect effect.

DBS- days to bulb sprouting
SP- survival%
PH- plant height
NLP- number of leaves per plant
LLL- length of longest leaf
YPP- yield of bulb kg per plot
WLL- width of longest leaf
DFF- days required for opening of 1st floret
NSP- number of spikes per plant
SL- spike length
RL- rachis length
DS- diameter of spike
SW- spike weight
NFS- number of florets per spike
NBP- number of bulbs per plant
NB/LP- number of bulblets per plant
NBPL- number of bulbs per plot
NB/LPL- number of bulblets per plot
WBP- weight of bulbs per plant
WB/LP- weight of bulblets per plant
BD- bulb diameter

Table 6: Phenotypic path coefficient analysis for yield of bulb q/ha in cv. Prajwal of tuberose.

	DBS	SP	PH	NLP	LLL	WLL	DFF	NSP	SL	RL	DS	SW	NFS	NBP	NB/LP	NBPL	NB/LPL	WBP	WB/LP	BD	YPP
DBS	**0.02**	-0.045	0.027	0.022	-0.038	-0.008	0.063	-0.048	-0.022	0.018	0.015	0.021	-0.013	0.059	-0.038	-0.546	0.106	-0.206	-0.021	-0.022	0.133
SP	-0.014	**0.061**	-0.034	-0.032	0.027	0.008	-0.069	0.068	0.027	-0.021	-0.017	-0.024	0.021	-0.087	0.045	0.774	-0.136	0.303	0.033	0.024	-0.189
PH	-0.009	0.035	**-0.059**	-0.032	0.009	0.012	-0.038	0.089	0.035	-0.023	-0.016	-0.025	0.024	-0.057	0.036	0.605	-0.106	0.283	0.027	0.026	-0.163
NLP	-0.01	0.046	-0.044	**-0.042**	0.011	0.008	-0.052	0.091	0.041	-0.018	-0.014	-0.026	0.024	-0.076	0.043	0.736	-0.122	0.316	0.032	0.024	-0.189
LLL	0.008	-0.017	0.006	0.005	**-0.095**	-0.01	0.045	0.016	-0.009	0.007	0.005	0.012	0.004	0.008	-0.014	-0.046	0.054	-0.094	-0.004	-0.016	0.03
WLL	-0.008	0.023	-0.035	-0.016	0.047	**0.021**	-0.049	0.048	0.03	-0.015	-0.014	-0.022	0.012	-0.02	0.029	0.228	-0.082	0.149	0.01	0.02	-0.068
DFF	0.014	-0.048	0.026	0.025	-0.049	-0.012	**0.087**	-0.054	-0.031	0.02	0.016	0.026	-0.015	0.075	-0.043	-0.62	0.123	-0.271	-0.028	-0.024	0.157
NSP	-0.009	0.037	-0.047	-0.034	-0.014	0.009	-0.042	**0.112**	0.043	-0.022	-0.015	-0.026	0.028	-0.067	0.041	0.672	-0.11	0.32	0.03	0.026	-0.183
SL	-0.008	0.029	-0.035	-0.03	0.015	0.011	-0.046	0.082	**0.058**	-0.015	-0.014	-0.028	0.023	-0.053	0.037	0.507	-0.101	0.256	0.023	0.021	-0.142
RL	-0.009	0.033	-0.035	-0.019	0.017	0.008	-0.044	0.064	0.023	**-0.038**	-0.012	-0.023	0.016	-0.065	0.03	0.584	-0.091	0.234	0.022	0.023	-0.145
DS	-0.013	0.047	-0.042	-0.026	0.023	0.013	-0.064	0.077	0.035	-0.021	**-0.022**	-0.029	0.023	-0.079	0.045	0.729	-0.135	0.298	0.03	0.029	-0.182
SW	-0.011	0.041	-0.04	-0.03	0.03	0.013	-0.062	0.08	0.044	-0.024	-0.018	**-0.036**	0.023	-0.07	0.044	0.704	-0.126	0.303	0.028	0.027	-0.182
NFS	-0.007	0.036	-0.039	-0.027	-0.01	0.007	-0.037	0.086	0.037	-0.017	-0.014	-0.023	**0.036**	-0.068	0.037	0.68	-0.106	0.304	0.031	0.024	-0.18
NBP	-0.011	0.049	-0.031	-0.03	0.007	0.004	-0.061	0.07	0.029	-0.023	-0.016	-0.024	0.023	**-0.108**	0.046	0.905	-0.132	0.348	0.037	0.024	-0.219
NB/LP	-0.013	0.049	-0.038	-0.033	0.024	0.01	-0.066	0.082	0.038	-0.021	-0.018	-0.029	0.024	-0.088	**0.056**	0.824	-0.147	0.349	0.035	0.028	-0.21
NBPL	-0.011	0.049	-0.037	-0.032	0.005	0.005	-0.056	0.078	0.03	-0.023	-0.017	-0.027	0.026	-0.101	0.048	**0.967**	-0.137	0.371	0.038	0.029	-0.237
NB/LPL	-0.013	0.053	-0.041	-0.033	0.033	0.011	-0.069	0.08	0.038	-0.022	-0.02	-0.03	0.025	-0.092	0.053	0.852	**-0.155**	0.371	0.036	0.032	-0.219
WBP	-0.009	0.043	-0.039	-0.031	0.021	0.007	-0.055	0.083	0.034	-0.021	-0.016	-0.026	0.026	-0.087	0.045	0.831	-0.133	**0.432**	0.036	0.035	-0.232
WB/LP	-0.01	0.047	-0.038	-0.032	0.009	0.005	-0.058	0.079	0.031	-0.02	-0.016	-0.024	0.027	-0.095	0.046	0.883	-0.134	0.371	**0.042**	0.028	-0.224
BD	-0.01	0.034	-0.037	-0.023	0.037	0.01	-0.05	0.069	0.029	-0.02	-0.015	-0.023	0.021	-0.061	0.037	0.656	-0.117	0.355	0.028	**0.042**	-0.192
YPP	-0.011	0.047	-0.04	-0.033	0.012	0.006	-0.056	0.084	0.034	-0.023	-0.017	-0.027	0.027	-0.097	0.048	0.94	-0.14	0.411	0.039	0.033	**-0.24**

R SQUARE = 0.9997, RESIDUAL EFFECT = 0.0053,
Bold values shows direct and normal values shows indirect effect.

DBS- days to bulb sprouting
SP- survival%
PH- plant height
NLP- number of leaves per plant
LLL- length of longest leaf
YPP- yield of bulb kg per plot
WLL- width of longest leaf
DFF- days required for opening of 1st floret
NSP- number of spikes per plant
SL- spike length
RL- rachis length
DS- diameter of spike
SW- spike weight
NFS- number of florets per spike
NBP- number of bulbs per plant
NB/LP- number of bulblets per plant
NBPL- number of bulbs per plot
NB/LPL- number of bulblets per plot
WBP- weight of bulbs per plant
WB/LP- weight of bulblets per plant
BD- bulb diameter

Acknowledgement

The authors are grateful to the Department of Floriculture and Landscaping, College of Horticulture, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut, Uttar Pradesh, India, for providing the necessary facilities and support to carry out the present investigation.

References

Gogoi, B. J., Saikia, A. and Borah, S. (2019). Genetic variability, heritability and correlation in tuberose (*Polianthes tuberosa* L.). *Journal of Crop and Weed*, **15**(3), 48–53.

Johnson, H. W., Robinson, H. F. and Comstock, R.E. (1955). Estimates of genetic and environmental variability in soybeans. *Agronomy Journal*, **47**, 314–318.

Jyothi R., Singh, K. P., Kiran K. N. and Pooran Chand. (2024). Induced mutation breeding in tuberose *(Polianthes tuberosa)* – a review. *Current Horticulture*, **12**(2), 12–21.

Kannan, M., Ganga, M. and Kayalvizhi, K. (2017). Effect of Physical and Chemical Mutagens on Morphological Characters in M1V2 Generation of Tuberose (*Polianthes tuberosa* L.). *International Journal of Current Microbiology and Applied Sciences*, **6**(4), 2492–2499.

Kannan, M., Jawaharlal, M. and Vijayakumar, M. (1998). Correlation and path analysis in tuberose (*Polianthes tuberosa* L.). *South Indian Horticulture*, **46**(3-6), 280–284.

Kapadiya, D. B., Mehta, D. R. and Pansuriya, A. G. (2014). Induction of variability through mutagens in chrysanthemum (*Chrysanthemum morifolium* Ramat.). *The Bioscan*, **9**(1), 347–352.

Kaur, M. and Kumar, S. (2018). Effect of mutagen ethyl methane sulfonate on growth characters of tuberose (*Polianthes tuberosa* L.) cv. Prajwal. *IJCS*, **6**(4), 412-416.

Kayalvizhi, K., Kannan, M. and Ganga, M. (2016). Mutagenic effects of chemical mutagens on tuberose (*Polianthes tuberosa* L.) Var. Prajwal. *Journal of Innovative Agriculture*, **3**(2), 11-13.

Kumar, M., Chaudhary, V., Kumar, M., Sirohi, U. and Yadav, M. K. (2021). Application of conventional and mutation approaches in genetic improvement of tuberose (*Polianthes tuberosa* L.): A review on recent development and future perspectives. *International Journal of Agriculture, Environment and Biotechnology*, **14**(3), 277–297.

Ranchana, R., Arumugam, T., Jawaharlal, M. and Vadivel, E. (2015). Correlation and path analysis in tuberose (*Polianthes tuberosa* L.). *The Asian Journal of Horticulture*, **10**(1), 163–166.

Ranchana, R., Misra, R. L. and Singh, K. P. (2015). Studies on variability, heritability and genetic advance in tuberose (*Polianthes tuberosa* L.). *Indian Journal of Horticulture*, **72**(1), 99–103.

Ratna Priyanka, G., Rani, W. U. and Rao, T. M. (2020). Assessment of Genetic Variability, Heritability and Genetic Advance in Mutagenised Population of Tuberose (*Polianthes tuberosa* L.) cv. Prajwal. *Journal of Pharmacognosy and Phytochemistry*, **9**(4), 1633-1637.

Singh, A., Prasad, K. V., Singh, R. and Shukla, S. (2019). Mutation breeding in tuberose (*Polianthes tuberosa* L.) for flower and plant type improvement. *Indian Journal of Horticulture*, **76**(1), 101–105.

Thiede, J. and Govaerts, R. (2017). *The transfer of Polianthes to Agave (Asparagaceae: Agavoideae)*. Phytotaxa, **297**(2), 115–136.

Singh, A. K. and Kumar, S. (2022). Mutation breeding in floriculture: Opportunities and challenges. *Indian Journal of Genetics and Plant Breeding*, **82**(**3**), 537–543.

Vedwan, A. (2024). Morphological characterization induced by physical and chemical mutagens on tuberose cv. Swarna Rekha. (Master's dissertation, Sardar Vallabhbhai Patel University of Agriculture and Technology).

Yadav, G., Beniwal, B. S., Sheoran, V., Kumar, S., Vijay, Sourabh, Kaur, M. and Kumar, S. (2018). Effect of mutagen ethyl methane sulfonate on growth characters of tuberose (*Polianthes tuberosa* L.) cv. Prajwal. *International Journal of Chemical Studies*, **6**(4), 412–416.