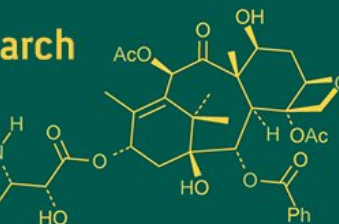
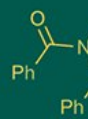


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Studies on the effect of planting date, mulch and fertigation on Tuberose Bulb (*Agave amica* L.)

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Abstract

An experiment entitled “Studies on the effect of planting date, mulch and fertigation on growth and yield of Tuberose (*Agave amica* L.)” was conducted during two consecutive years, 2023-24 and 2024-25, at PFDC, College of Agriculture, Indira Gandhi Krishi Vishwavidyalaya, Krishak Nagar, and Raipur (C.G.). The study was laid out in a split-split plot design with three replications, comprising 24 treatment combinations. Three planting dates (30th May, 30th June, and 30th July) were assigned as factor A, two levels of mulch (silver on black plastic mulch with wastage leaves and silver on black plastic mulch without wastage leaves) were assigned as factor B, and four levels of fertigation (60%, 75%, 90%, and 100% RDF) were assigned as factor C.

The findings of the present investigation revealed that bulb parameters were significantly affected by different treatments involving planting date, mulching and fertigation levels. Among the various combinations, planting on 30th June, application of silver-on-black plastic mulch along with waste leaves, and 90% recommended dose of fertilizers (RDF) through fertigation exhibited a pronounced positive effect on bulb characteristics. This treatment combination resulted in improved values of individual bulb weight (g), bulb diameter (cm), number of bulblets, bulblet weight (g), bulblet diameter (cm), bulb yield per plot (kg), and bulblet yield per plot (kg).

Keywords: Tuberose, Planting date, mulch and fertigation

Introduction

Tuberose (*Agave amica* L.), formerly known as *Polianthes tuberosa*, is recognized as one of the most important ornamental bulbous crops belonging to the family Asparagaceae. It is widely cultivated in tropical and subtropical regions for its highly fragrant and attractive flowers, which are extensively utilized as cut flowers, loose flowers, and for the extraction of essential oil in the perfume and cosmetic industries (Singh *et al.* 2019) ^[16]. Considerable commercial importance has been attributed to this crop due to its long vase life, high economic returns and continuous market demand. The genus *Polianthes* is reported to have originated in Mexico and it has been cultivated since ancient times for ornamental and aromatic purposes (Rao and Reddy, 2017) ^[12]. The presence of aromatic compounds such as geraniol, nerol, benzyl alcohol and eugenol in tuberose flowers has been documented, contributing to its characteristic fragrance and industrial significance (Kumar *et al.* 2020) ^[9]. The productivity and quality of tuberose have been found to be greatly influenced by various agronomic practices, among which planting date, mulching, and fertigation are considered critical factors. The planting date is known to influence sprouting, vegetative growth, flowering behavior, and yield, as it is governed by prevailing environmental conditions such as temperature and photoperiod (Patel *et al.* 2018) ^[10]. It has been reported that optimum planting time ensures better growth and early flowering, thereby improving yield and quality. Mulching has been widely adopted as an important cultural practice for conserving soil moisture, moderating soil temperature, suppressing weed growth and improving soil physical conditions. The beneficial effects of plastic mulch, particularly black polyethylene mulch, on growth and yield parameters of tuberose have been demonstrated in several studies (Sharma *et al.* 2019) ^[15]. Fertigation, defined as the application of fertilizers through irrigation systems, has been increasingly used as an efficient nutrient management practice. Improved

Nutrient use efficiency, reduced nutrient losses and enhanced plant growth and yield have been achieved through fertigation (Yadav *et al.* 2021) ^[20]. It has been suggested that the integration of fertigation with suitable planting dates and mulching practices can significantly improve crop performance. Although the individual effects of planting date, mulch and fertigation have been investigated by several researchers, limited information is available regarding their combined influence under specific agro-climatic conditions. Therefore, the present investigation entitled “Studies on the effect of planting date, mulch and fertigation on tuberose bulb (*Agave amica* L.)” has been undertaken to evaluate the combined effect of these factors on bulb yield to identify the most suitable combination for maximizing productivity under local conditions.

Material and Methods

The field experiment was conducted at the PFDC (Precision Farming Development Centre), Raipur, under the College of Agriculture, IGKV, during the years 2023- 24 and 2024-25. The study followed a split-split plot design with three replications, comprising 24 treatment combinations. These included three planting dates (30th May, 30th June, and 30th July), two mulch treatments (silver-on-black plastic mulch with waste leaves and silver-on-black plastic mulch without waste leaves), and four fertigation levels (60%, 75%, 90% and 100% of the recommended dose of fertilizers). In this design, planting dates were assigned to the main plots, mulch treatments to the sub-plots and fertigation levels to the sub-sub plots. The experimental site at Raipur falls under a dry sub-humid agroclimatic zone and is geographically located at 21.25° N latitude and 81.03° E longitude, with an elevation of 298 meters above mean sea level.

Treatment detail

S.No.	Notation used	Treatment details
Main plot- Planting Date		
1.	D ₁	30 th May
2.	D ₂	30 th June
3.	D ₃	30 th July
Sub plot- Types of mulches		
1.	M ₁	Silver on Black plastic mulch with wastage leaves
2.	M ₂	Silver on Black plastic mulch without wastage leaves
Sub - sub plot - Fertigation		
1.	F ₁	Fertigation with 60% RDF
2.	F ₂	Fertigation with 75% RDF
3.	F ₃	Fertigation with 90% RDF
4.	F ₄	Fertigation with 100% RDF

Result and discussion

Individual bulb weight (g)

The significantly maximum bulb weight (44.18, 45.19 and 44.68 g) was observed respectively on 30th June planting (D₂) followed by 30th May planting (D₁) (39.88, 42.34 and 41.11 g). However, minimum bulb weight (35.85, 37.63 and 36.74 g) was observed on 30th July planting (D₃). As regard the effect of mulch treatments, the maximum bulb weight (41.58, 43.38 and 42.48 g) had resulted with the use of Silver on Black plastic mulch with wastage leaves (M₁) than Silver on Black plastic mulch without wastage leaves (38.36, 40.06 and 39.21 g). In case of fertigation, the maximum bulb weight (42.21, 44.03 and 43.12 g) was

recorded with the application of 90% RDF via. Fertigation (F₃) followed by fertigation with 100% RDF (F₄) (41.08, 42.60 and 41.84 g). The minimum bulb weight (36.90, 38.93 and 37.91 g) was found in fertigation with 60% RDF (F₁) during the experiment year 2023-24, 2024-25 and on mean basis, respectively as shown in Table no. 1.

The significantly higher bulb weight observed with 30th June planting may be attributed to the favourable soil temperature and moisture conditions prevailing during this period, which enhance bulb rehydration, enzymatic activity, and mobilization of stored carbohydrates, ultimately promoting greater assimilate accumulation in bulb tissues. The use of silver-on-black plastic mulch combined with waste leaves further improved bulb weight by maintaining a stable rhizosphere microclimate through reduced moisture loss, moderated soil temperature, and enhanced nutrient availability via improved microbial activity. Additionally, the application of 90% RDF through fertigation provided an optimum and balanced nutrient supply, particularly nitrogen and phosphorus, which supported efficient cell division, energy transfer, and carbohydrate translocation to storage organs. Fertigation also ensured better nutrient use efficiency by synchronizing nutrient availability with crop demand. In contrast, both lower and higher fertilizer doses were less effective due to nutrient deficiency or imbalance. Thus, the combined effect of optimal planting time, improved soil environment through mulching and efficient nutrient management through fertigation resulted in enhanced bulb weight in tuberose (Taiz & Zeiger, 2010; Salisbury & Ross, 1992; Arora *et al.* 2002; Deka *et al.* 2017; Patra *et al.* 2018; Carillo *et al.* 2020) ^[2, 4, 5, 11, 13, 18].

Bulb diameter (cm)

It is evident from the data that the effect of planting dates, mulches, fertigation levels was noted the maximum bulb diameter (3.21, 3.51 and 3.36 cm) 30th June planting (D₂) followed by 30th May planting (D₁) (3.01, 3.53 and 3.27 cm). However, minimum bulb weight (2.72, 3.32 and 3.02 cm) was observed on 30th July planting (D₃). Irrespective of mulches, the maximum bulb diameter (3.02, 3.54 and 3.28 cm) had resulted with the use of Silver on Black plastic mulch with wastage leaves (M₁) than Silver on Black plastic mulch without wastage leaves (2.94, 3.37 and 3.15 cm). Among the fertigation, application of 90% RDF through Fertigation (F₃) the maximum bulb diameter (3.13, 3.61 and 3.37 cm) followed by fertigation with 100% RDF (F₄) (3.01, 3.39 and 3.20 cm). The minimum bulb diameter (2.77, 3.40 and 3.08 cm) was found in fertigation with 60% RDF (F₁) during 2023-24 to 2024-25 as shown in Table no. 2.

The results indicated that maximum bulb diameter was obtained with 30th June planting, followed by 30th May, while the minimum was recorded with 30th July planting, highlighting the importance of favorable environmental conditions for bulb development. Bulb diameter reflects sink strength and the capacity of bulbs to accumulate carbohydrates and proteins in storage tissues, which ultimately influences sprouting, spike emergence, and flowering quality in the subsequent season. Delayed planting in July, associated with excessive rainfall and poor soil aeration, likely reduced root efficiency and assimilate accumulation, thereby limiting bulb enlargement. Mulching with silver-on-black polythene combined with organic residues significantly enhanced bulb diameter by improving soil moisture retention, moderating temperature and

promoting microbial activity and nutrient mineralization, which together ensured a continuous supply of water and nutrients and favoured assimilate partitioning towards bulb growth. Similarly, fertigation at 90% RDF resulted in the highest bulb diameter, demonstrating the role of balanced nutrient supply in enhancing sink activity through improved protein synthesis, energy transfer, and carbohydrate deposition, while fertigation also increased nutrient use efficiency by synchronizing supply with crop demand. The comparatively lower performance at 100% RDF suggests that excessive nutrient application may lead to imbalanced growth or luxury consumption, whereas insufficient supply at 60% RDF restricts bulb development. Thus, the combined effect of optimal planting time, improved soil microclimate through mulching, and balanced fertigation significantly contributed to enhanced bulb diameter in tuberose (Kamenetsky & Okubo, 2013; Taiz & Zeiger, 2010; Benschop *et al.* 2010; Deka *et al.* 2017; Patra *et al.* 2018; Carillo *et al.* 2020; Hartmann *et al.* 2011) [3, 4, 5, 6, 7, 11, 18].

Number of bulblet / plant

The data on Number of bulblet/plant found significantly highest value (11.23, 15.35 and 13.29) recorded on 30th June planting (D2) followed by 30th May planting (10.62, 14.13 and 12.38). However, minimum No. of bulblet /plant (9.39, 13.64 and 11.51) was observed on 30th July planting (D3). Among the mulches, significantly maximum no. of bulblet/plant was observed (10.68, 14.82 and 12.75) had with the use of Silver on Black plastic mulch with wastage leaves (M1) than Silver on Black plastic mulch without wastage leaves (10.14, 13.93 and 12.04) mathbf M2. Likewise within fertigation treatment, significantly maximum No. of bulblet/plant (11.07, 14.82 and 12.95) was recorded with the application of 90% RDF via. Fertigation $\leq$ ft (F3right) followed by fertigation with 75% RDF $\leq$ ft (F2right) (10.56, 14.41 and 12.48). The minimum No. of bulblet/plant (9.66, 14.02 and 11.84) was found in fertigation with 60% RDF (F1) during 2023-24 to 2024-25 as shown in Table no. 3. The superior performance of June planting in terms of bulblet number can be attributed to favourable soil temperature, moisture, and day length during the critical bulblet initiation phase, which enhance photosynthesis, carbohydrate accumulation, and axillary bud differentiation. In contrast, July planting, characterized by excessive rainfall and low solar radiation, reduces photosynthate availability and suppresses bulblet formation. Mulching with silver-on-black plastic combined with organic residues further improved bulblet production by conserving moisture, regulating soil temperature, and enhancing nutrient availability through decomposition, thereby promoting root activity and assimilate translocation to developing bulblets. Among fertigation levels, 90% RDF resulted in the highest bulblet number due to balanced nutrient supply supporting protein synthesis, meristematic activity, and carbohydrate partitioning, whereas lower or excessive fertilizer levels were less effective due to nutrient deficiency or imbalanced vegetative growth (Kamenetsky & Okubo, 2013; Deka *et al.* 2017; Patra *et al.* 2018; Benschop *et al.* 2010; Carillo *et al.* 2020) [3, 4, 5, 7, 11].

Weight of bulblet (g)

The influence of planting date, mulch, fertigation in tuberose was found significantly higher at weight of bulblet. 30th June (D2) recorded maximum weight of bulblet (25.97, 28.71 and 27.34 g) followed by 30th May planting (23.87, 27.00 and 25.44 g). However, minimum weight of bulblet

(21.60, 24.68 and 23.14 g) was observed on 30th July planting (D3). As regard the effect of mulch treatments, the highest weight of bulblet (24.48, 27.65 and 26.06 g) had resulted with the use of Silver on Black plastic mulch with wastage leaves (M1) than Silver on Black plastic mulch without wastage leaves (23.15, 25.94 and 24.54 g). As appraisal of data indicate that there was a significant influence in the fertigation treatment, the maximum weight of bulblet (24.90, 27.88 and 26.39 g) was recorded with the application of 90% RDF via. Fertigation (F3) followed by fertigation with 100% RDF (F4) (24.28, 27.08 and 25.68 g). The minimum weight of bulblet (22.13, 25.38 and 23.76 g) was found in fertigation with 60% RDF (F1) during 2023-24 to 2024-25 as shown in Table no. 4. The results showed that the highest bulblet weight was recorded with 30th June planting, while the lowest was observed with 30th July planting. This may be attributed to favourable soil temperature and moisture during June, which enhance enzymatic activity, carbohydrate mobilization, and assimilate accumulation in bulblets, thereby increasing their weight. In contrast, July planting with excessive rainfall and poor aeration reduces root efficiency and assimilate partitioning, resulting in smaller bulblets. Mulching with silver-on-black polythene combined with waste leaves further improved bulblet weight by conserving moisture, moderating soil temperature, and enhancing nutrient availability and root activity, leading to better assimilate storage. Among fertigation levels, 90% RDF recorded the highest bulblet weight due to balanced nutrient supply, improved nutrient use efficiency, and enhanced carbohydrate partitioning, whereas lower or higher levels were less effective due to nutrient deficiency or excessive vegetative growth (Taiz & Zeiger, 2010; Benschop *et al.* 2010; Deka *et al.* 2017; Patra *et al.* 2018; Carillo *et al.* 2020; Vaid *et al.* 2019; Sharma *et al.* 2022; Soujanya *et al.* 2025) [3, 4, 5, 11, 14, 17, 18, 19].

Diameter of bulblet (cm)

It is clear from the data on diameter of bulblet that 30th June planting (D1) recorded maximum Diameter of bulblet (1.42, 1.75 and 1.59 cm) followed by treatment D2 (1.32, 1.64 and 1.48 cm) 30th May planting, while, minimum diameter of bulblet (1.23, 1.59 and 1.41 cm) 30th July planting (D3). Due to the effect of mulches, significantly maximum diameter of bulblet was observed (1.37, 1.69 and 1.53 cm) with the use of Silver on Black plastic mulch with wastage leaves (M1) than Silver on Black plastic mulch without wastage leaves (1.28, 1.63 and 1.45 cm) mathbf M2 . Likewise within fertigation treatment, significantly maximum Diameter of bulblet (1.41, 1.70 and 1.55 cm) was recorded with the application of 90% RDF via. Fertigation $\leq$ ft (F3right) followed by fertigation with 100% RDF (F4) (1.34, 1.68 and 1.51 cm). The minimum diameter of bulb (1.26, 1.61 and 1.43 cm) was found in fertigation with 60% RDF (F1) during 2023-24 to 2024-25 as shown in Table no. 5. The maximum bulblet diameter was recorded with 30th June planting, while the minimum was observed with 30th July planting, likely due to favourable soil temperature and moisture in June that enhance cell division, enzymatic activity, and carbohydrate translocation to developing bulblets. Mulching with silver-onblack polythene combined with waste leaves significantly improved bulblet diameter by conserving moisture, regulating soil temperature, and enhancing nutrient availability and root activity. Among fertigation levels, 90% RDF produced the largest bulblets due to balanced nutrient supply supporting sink strength and assimilate accumulation, whereas lower or higher levels

were less effective due to nutrient deficiency or excessive vegetative growth (Kamenetsky & Okubo, 2013; Deka *et al.* 2017; Patra *et al.* 2018; Benschop *et al.* 2010; Carillo *et al.* 2020) [3, 4, 5, 7, 11].

Bulb yield per plot (kg)

It is crystal clear from the data on bulb yield per plot was recorded maximum (1350.13, 1381.44 and 1365.78 g) 30th June planting (D2) followed by 30th May planting (1261.19, 1323.12 and 1292.15 g), whereas minimum Bulb yield per plot (1172.61, 1184.11 and 1178.36 g) was observed on 30th July planting (D3). In respect with mulch, significantly maximum bulb yield per plot (1292.90, 1320.15 and 1306.53 g) had resulted with the use of Silver on Black plastic mulch with wastage leaves (M1) than Silver on Black plastic mulch without wastage leaves (1229.72, 1272.29 and 1251.01g). Considering the fertigation, the maximum Bulb yield per plot (1307.40, 1335.13 and 1321.26 g) was recorded with the application of 90% RDF via. Fertigation (F3) followed by fertigation with 100% RDF (F4) (1285.44, 1348.61 and 1317.03 g). The minimum bulb yield per plot (1201.74, 1227.02 and 1214.38 g) was found in fertigation with 60% RDF (F1) during 2023- 24 to 2024-25 as shown in Table no. 6.

The highest bulb yield per plot was recorded with 30th June planting, while the lowest was observed with 30th July planting, which may be attributed to favorable soil temperature, moisture and light conditions during June that enhance photosynthesis, carbohydrate assimilation and partitioning to storage tissues. Mulching with silver-on-black polythene combined with waste leaves further increased yield by improving soil moisture retention, moderating temperature and enhancing nutrient availability and root activity, thereby promoting better assimilate allocation to bulbs. Among fertigation levels, 90% RDF produced the highest yield due to balanced nutrient supply supporting protein synthesis, energy metabolism, and carbohydrate translocation, whereas lower or excessive levels were less effective due to nutrient deficiency or diversion towards vegetative growth. Overall, the combined effect of optimum planting time, improved soil microclimate through mulching and efficient nutrient management through fertigation resulted in enhanced bulb yield (Ahmad *et al.* 2019; Kandalkar *et al.* 2021; Patel *et al.* 2018; Benschop *et al.* 2010) [1, 3, 8, 10].

Bulblet yield per plot (kg)

Bulblet yield per plant significantly influenced by planting aDate. The significantly maximum bulblet yield (254.86, 266.34 and 260.60 g) 30th June planting (D2) followed by 30th May planting (221.91, 234.34 and 228.12 g), whereas

minimum bulblet yield per plot (205.07, 209.02 and 207.04 g) was observed on 30th July planting (D3). In respect with mulch, significantly maximum bulblet yield per plot (234.84, 242.07 and 238.46 g) had resulted with the use of Silver on Black plastic mulch with wastage leaves (M1) than Silver on Black plastic mulch without wastage leaves (219.71, 231.06 and 225.39 g). Considering the fertigation, the maximum bulblet yield per plot (239.51, 248.42 and 243.96 g) was recorded with the application of 90% RDF via. Fertigation (F3) followed by fertigation with 100% RDF (F4) (232.58, 243.56 and 238.07 g). The minimum Bulblet yield per plot (213.49, 223.17 and 218.33 g) was found in fertigation with 60% RDF (F1) during 2023-24 to 2024-25 as shown in Table no. 7.

The highest bulblet yield per plant was recorded with 30th June planting, while the lowest was observed with 30th July planting, which may be attributed to favorable temperature, moisture, and light conditions that enhance photosynthesis, carbohydrate accumulation, and assimilate translocation to developing bulblets. Mulching with silver-on-black polythene combined with organic residues further increased bulblet yield by conserving soil moisture, moderating temperature, and improving nutrient availability and root activity. Among fertigation levels, 90% RDF produced the highest bulblet yield due to balanced and efficient nutrient supply supporting protein synthesis, energy metabolism, and carbohydrate accumulation, whereas lower levels were less effective. Overall, improved source-sink relationships under optimum planting, mulching, and fertigation contributed to enhanced bulblet yield and better crop performance (Ahmad *et al.* 2019; Kandalkar *et al.* 2021; Patel *et al.* 2018) [1, 8]. Comparable findings have been reported in onion (*Allium cepa*), where balanced fertigation improved bulb yield and quality by optimizing nutrient use efficiency (Patel *et al.* 2018) [10].

Overall, higher bulblet yield per plant reflects better source-sink relationships, ensuring sufficient assimilate storage in bulbs for vigorous sprouting, longer spikes and higher flower and bulb yield. These findings highlight the importance of optimal planting date, organic mulching and balanced fertigation in enhancing both bulb and bulblet development and subsequent flowering quality in bulbous crops.

The interaction effects between, planting date and mulch, planting date and fertigation, mulch and fertigation and combined effect of all three factors (planting date, mulch and fertigation) on individual bulb weight (g), bulb diameter (cm), number of bulblets, bulblet weight (g), bulblet diameter (cm), bulb yield per plot (kg), and bulblet yield per plot (kg) per plot was found non-significant during both the years and on mean basis.

Table 1: Effect of planting date, mulch and fertigation on Individual bulb Weight (g) of Tuberose

Treatments		2023-24					2024-25					Pooled mean				
		F ₁	F ₂	F ₃	F ₄	Mean	F ₁	F ₂	F ₃	F ₄	Mean	F ₁	F ₂	F ₃	F ₄	Mean
D ₁	M ₁	37.63	38.87	44.17	43.20	40.97	40.93	41.80	46.70	45.10	43.63	39.28	40.33	45.43	44.15	42.30
	M ₂	35.40	38.27	41.50	40.00	38.79	37.90	40.47	43.47	42.37	41.05	36.65	39.37	42.48	41.18	39.92
	Mean	36.52	38.57	42.83	41.60	39.88	39.42	41.13	45.08	43.73	42.34	37.97	39.85	43.96	42.67	41.11
D ₂	M ₁	42.60	49.03	47.90	46.63	46.54	44.50	47.43	49.27	47.57	47.19	43.55	48.23	48.58	47.10	46.87
	M ₂	39.83	41.23	43.63	42.53	41.81	41.20	43.90	45.07	42.60	43.19	40.52	42.57	44.35	42.57	42.50
	Mean	41.22	45.13	45.77	44.58	44.18	42.85	45.67	47.17	45.08	45.19	42.03	45.40	46.47	44.83	44.68
D ₃	M ₁	34.23	36.60	39.53	38.50	37.22	36.43	38.57	41.60	40.70	39.33	35.33	37.58	40.57	39.60	38.27
	M ₂	31.70	34.10	36.50	35.60	34.48	32.60	35.77	38.07	37.27	35.93	32.15	34.93	37.28	36.43	35.20
	Mean	32.97	35.35	38.02	37.05	35.85	34.52	37.17	39.83	38.98	37.63	33.74	36.26	38.93	38.02	36.74
MXF	M ₁	38.16	41.50	43.87	42.78	41.58	40.62	42.60	45.86	44.46	43.38	39.39	42.05	44.86	43.62	42.48
	M ₂	35.64	37.87	40.54	39.38	38.36	37.23	40.04	42.20	40.74	40.06	36.44	38.96	41.37	40.06	39.21
	Mean	36.90	39.68	42.21	41.08	39.97	38.93	41.32	44.03	42.60	41.72	37.91	40.50	43.12	41.84	40.84

Factor	SEm			CD (P=0.05)		
	2023-24	2024-25	Pooled mean	2023-24	2024-25	Pooled mean
D	0.50	0.55	0.08	1.98	2.17	0.32
M	0.35	0.42	0.34	1.21	1.47	1.17
F	0.69	0.54	0.43	1.99	1.54	1.23
DXM	0.60	0.74	0.59	NS	NS	NS
DXF	1.20	0.93	0.74	NS	NS	NS
MXF	0.98	0.76	0.61	NS	NS	NS
DXMXF	1.70	1.32	1.05	NS	NS	NS

Table 2: Effect of planting date, mulch and fertigation on Bulb Diameter (cm) of Tuberose

Treatments		2023-24					2024-25					Pooled mean				
		F ₁	F ₂	F ₃	F ₄	Mean	F ₁	F ₂	F ₃	F ₄	Mean	F ₁	F ₂	F ₃	F ₄	Mean
D ₁	M ₁	2.67	3.02	3.13	3.10	2.98	3.35	3.48	3.59	3.54	3.49	3.01	3.25	3.36	3.32	3.23
	M ₂	2.85	2.97	3.23	3.10	3.04	3.22	3.39	3.91	3.80	3.58	3.04	3.18	3.57	3.45	3.31
	Mean	2.76	2.99	3.18	3.10	3.01	3.28	3.43	3.75	3.67	3.53	3.02	3.21	3.47	3.39	3.27
D ₂	M ₁	3.12	3.22	3.33	3.30	3.24	3.59	3.72	3.76	3.54	3.65	3.35	3.47	3.54	3.42	3.45
	M ₂	2.98	3.40	3.16	3.15	3.17	3.44	3.50	3.64	2.87	3.36	3.21	3.45	3.40	3.01	3.27
	Mean	3.05	3.31	3.24	3.23	3.21	3.51	3.61	3.70	3.20	3.51	3.28	3.46	3.47	3.21	3.36
D ₃	M ₁	2.46	2.76	3.18	2.96	2.84	3.59	3.24	3.63	3.45	3.48	3.03	3.00	3.41	3.20	3.16
	M ₂	2.53	2.73	2.75	2.43	2.61	3.20	3.19	3.10	3.14	3.16	2.87	2.96	2.93	2.79	2.88
	Mean	2.49	2.74	2.97	2.70	2.72	3.40	3.21	3.37	3.29	3.32	2.95	2.98	3.17	2.99	3.02
MXF	M ₁	2.75	3.00	3.21	3.12	3.02	3.51	3.48	3.66	3.51	3.54	3.13	3.24	3.44	3.31	3.28
	M ₂	2.79	3.03	3.05	2.89	2.94	3.29	3.36	3.55	3.27	3.37	3.04	3.20	3.30	3.08	3.15
	Mean	2.77	3.01	3.13	3.01	2.98	3.40	3.42	3.61	3.39	3.45	3.08	3.22	3.37	3.20	3.22

Factor	SEm			CD (P=0.05)		
	2023-24	2024-25	Pooled mean	2023-24	2024-25	Pooled mean
D	0.05	0.08	0.05	0.18	0.32	0.19
M	0.04	0.10	0.06	0.13	0.35	0.22
F	0.12	0.11	0.08	0.35	0.30	0.24
DXM	0.07	0.18	0.11	NS	NS	NS
DXF	0.21	0.18	0.14	NS	NS	NS
MXF	0.17	0.15	0.12	NS	NS	NS
DXMXF	0.30	0.26	0.20	NS	NS	NS

Table 3: Effect of planting date, mulch and fertigation on no. of bulblet per plant of Tuberose

Treatments		2023-24					2024-25					Pooled mean				
		F ₁	F ₂	F ₃	F ₄	Mean	F ₁	F ₂	F ₃	F ₄	Mean	F ₁	F ₂	F ₃	F ₄	Mean
D ₁	M ₁	9.63	10.50	11.57	10.60	10.58	13.67	14.50	15.43	14.77	14.59	11.65	12.50	13.50	12.68	12.58
	M ₂	9.33	10.73	11.67	10.90	10.66	14.00	13.30	13.77	13.63	13.68	11.67	12.02	12.72	12.27	12.17
	Mean	9.48	10.62	11.62	10.75	10.62	13.83	13.90	14.60	14.20	14.13	11.66	12.26	13.11	12.48	12.38
D ₂	M ₁	10.57	11.93	12.43	12.10	11.76	15.60	15.87	16.40	16.07	15.98	13.08	13.90	14.42	14.08	13.87
	M ₂	10.43	10.60	11.03	10.70	10.69	14.63	14.47	15.00	14.77	14.72	12.53	12.53	13.02	12.73	12.70
	Mean	10.50	11.27	11.73	11.40	11.23	15.12	15.17	15.70	15.42	15.35	12.81	13.22	13.72	13.41	13.29
D ₃	M ₁	9.23	9.40	10.13	10.03	9.70	13.53	13.67	14.53	13.77	13.88	11.38	11.53	12.33	11.90	11.79
	M ₂	8.77	8.97	9.60	9.00	9.08	12.70	13.63	13.80	13.47	13.40	10.73	11.30	11.70	11.23	11.24
	Mean	9.00	9.18	9.87	9.52	9.39	13.12	13.65	14.17	13.62	13.64	11.06	11.42	12.02	11.57	11.51
MXF	M ₁	9.81	10.61	11.38	10.91	10.68	14.27	14.68	15.46	14.87	14.82	12.04	12.64	13.42	12.89	12.75
	M ₂	9.51	10.10	10.77	10.20	10.14	13.78	13.80	14.19	13.96	13.93	11.64	11.95	12.48	12.08	12.04
	Mean	9.66	10.36	11.07	10.56	10.41	14.02	14.24	14.82	14.41	14.37	11.84	12.30	12.95	12.48	12.39

Factor	SEm			CD (P=0.05)		
	2023-24	2024-25	Pooled mean	2023-24	2024-25	Pooled mean
D	0.12	0.31	0.11	0.47	1.22	0.44
M	0.14	0.33	0.22	0.48	1.15	0.76
F	0.21	0.34	0.20	0.60	0.98	0.58
DXM	0.24	0.57	0.38	NS	NS	NS
DXF	0.36	0.59	0.35	NS	NS	NS
MXF	0.30	0.48	0.29	NS	NS	NS
DXMXF	0.52	0.84	0.50	NS	NS	NS

Table 4: Effect of planting date, mulch and fertigation on Weight (g) of bulblet of Tuberose

Treatments		2023-24					2024-25					Pooled mean				
		F ₁	F ₂	F ₃	F ₄	Mean	F ₁	F ₂	F ₃	F ₄	Mean	F ₁	F ₂	F ₃	F ₄	Mean
D ₁	M ₁	22.43	24.17	25.87	25.23	24.43	26.57	27.40	29.67	27.33	27.74	24.50	25.78	27.77	26.28	26.08
	M ₂	20.87	23.43	24.77	24.17	23.31	24.27	26.23	27.20	27.37	26.27	22.57	24.83	25.98	25.77	24.79
	Mean	21.65	23.80	25.32	24.70	23.87	25.42	26.82	28.43	27.35	27.00	23.53	25.31	26.88	26.03	25.44
D ₂	M ₁	25.27	26.97	28.10	27.40	26.93	28.33	29.57	31.40	30.13	29.86	26.80	28.27	29.75	28.77	28.40
	M ₂	23.80	26.23	25.00	25.00	25.01	27.30	28.27	27.33	27.33	27.56	25.55	27.25	26.17	26.17	26.28
	Mean	24.53	26.60	26.55	26.20	25.97	27.82	28.92	29.37	28.73	28.71	26.18	27.76	27.96	27.47	27.34
D ₃	M ₁	20.27	21.97	23.37	22.67	22.07	23.50	25.47	26.20	26.27	25.36	21.88	23.72	24.78	24.47	23.71
	M ₂	20.17	20.83	22.30	21.20	21.13	22.33	24.13	25.47	24.03	23.99	21.25	22.48	23.88	22.62	22.56
	Mean	20.22	21.40	22.83	21.93	21.60	22.92	24.80	25.83	25.15	24.68	21.57	23.10	24.33	23.54	23.14
MXF	M ₁	22.66	24.37	25.78	25.10	24.48	26.13	27.48	29.09	27.91	27.65	24.39	25.92	27.43	26.51	26.06
	M ₂	21.61	23.50	24.02	23.46	23.15	24.63	26.21	26.67	26.24	25.94	23.12	24.86	25.34	24.85	24.54
	Mean	22.13	23.93	24.90	24.28	23.81	25.38	26.84	27.88	27.08	26.80	23.76	25.39	26.39	25.68	25.30

Factor	SEm			CD (P=0.05)		
	2023-24	2024-25	Pooled mean	2023-24	2024-25	Pooled mean
D	0.58	0.50	0.53	2.27	1.96	2.09
M	0.42	0.35	0.35	1.47	1.21	1.20
F	0.54	0.53	0.26	1.56	1.52	0.76
DXM	0.74	0.60	0.60	NS	NS	NS
DXF	0.94	0.92	0.46	NS	NS	NS
MXF	0.77	0.75	0.37	NS	NS	NS
DXMXF	1.33	1.30	0.65	NS	NS	NS

Table 5: Effect of planting date, mulch and fertigation on Diameter of bulblet (cm) of Tuberose

Treatments		2023-24					2024-25					Pooled mean				
		F ₁	F ₂	F ₃	F ₄	Mean	F ₁	F ₂	F ₃	F ₄	Mean	F ₁	F ₂	F ₃	F ₄	Mean
D ₁	M ₁	1.25	1.33	1.38	1.41	1.34	1.64	1.63	1.71	1.68	1.67	1.44	1.48	1.55	1.55	1.50
	M ₂	1.23	1.29	1.35	1.32	1.30	1.56	1.60	1.63	1.68	1.62	1.40	1.45	1.49	1.50	1.46
	Mean	1.24	1.31	1.37	1.37	1.32	1.60	1.62	1.67	1.68	1.64	1.42	1.46	1.52	1.52	1.48
D ₂	M ₁	1.38	1.41	1.76	1.41	1.49	1.74	1.78	1.81	1.78	1.78	1.56	1.60	1.78	1.60	1.63
	M ₂	1.32	1.37	1.36	1.37	1.36	1.61	1.68	1.80	1.79	1.72	1.47	1.53	1.58	1.58	1.54
	Mean	1.35	1.39	1.56	1.39	1.42	1.68	1.73	1.80	1.79	1.75	1.51	1.56	1.68	1.59	1.59
D ₃	M ₁	1.21	1.25	1.33	1.28	1.27	1.60	1.63	1.69	1.60	1.63	1.41	1.44	1.51	1.44	1.45
	M ₂	1.16	1.09	1.25	1.24	1.19	1.51	1.53	1.59	1.55	1.55	1.34	1.31	1.42	1.40	1.37
	Mean	1.19	1.17	1.29	1.26	1.23	1.56	1.58	1.64	1.58	1.59	1.37	1.37	1.46	1.42	1.41
MXF	M ₁	1.28	1.33	1.49	1.37	1.37	1.66	1.68	1.74	1.69	1.69	1.47	1.50	1.61	1.53	1.53
	M ₂	1.24	1.25	1.32	1.31	1.28	1.56	1.60	1.67	1.67	1.63	1.40	1.43	1.50	1.49	1.45
	Mean	1.26	1.29	1.41	1.34	1.32	1.61	1.64	1.70	1.68	1.66	1.43	1.47	1.55	1.51	1.49

Factor	SEm			CD (P=0.05)		
	2023-24	2024-25	Pooled mean	2023-24	2024-25	Pooled mean
D	0.03	0.01	0.01	0.11	0.03	0.04
M	0.02	0.02	0.02	0.09	0.07	0.07
F	0.03	0.02	0.02	0.10	0.07	0.06
DXM	0.04	0.03	0.03	NS	NS	NS
DXF	0.06	0.04	0.04	NS	NS	NS
MXF	0.05	0.03	0.03	NS	NS	NS
DXMXF	0.08	0.06	0.05	NS	NS	NS

Table 6: Effect of planting date, mulch and fertigation on bulb yield per plot (kg) of Tuberose

Treatments		2023-24					2024-25					Pooled mean				
		F ₁	F ₂	F ₃	F ₄	Mean	F ₁	F ₂	F ₃	F ₄	Mean	F ₁	F ₂	F ₃	F ₄	Mean
D ₁	M ₁	1216.63	1279.13	1341.80	1315.27	1288.21	1320.37	1337.37	1373.33	1350.83	1345.48	1268.50	1308.25	1357.57	1333.05	1316.84
	M ₂	1173.47	1218.50	1283.63	1261.10	1234.18	1178.37	1343.40	1333.23	1348.03	1300.76	1175.92	1280.95	1308.43	1304.57	1267.47
	Mean	1195.05	1248.82	1312.72	1288.18	1261.19	1249.37	1340.38	1353.28	1349.43	1323.12	1222.21	1294.60	1333.00	1318.81	1292.15
D ₂	M ₁	1325.33	1394.60	1453.23	1425.60	1399.69	1308.33	1338.10	1442.37	1498.27	1396.77	1316.83	1366.35	1447.80	1461.93	1398.23
	M ₂	1238.07	1293.37	1349.20	1321.60	1300.56	1277.87	1285.17	1415.23	1486.20	1366.12	1257.97	1289.27	1382.22	1403.90	1333.34
	Mean	1281.70	1343.98	1401.22	1373.60	1350.13	1293.10	1311.63	1428.80	1492.23	1381.44	1287.40	1327.81	1415.01	1432.92	1365.78
D ₃	M ₁	1141.77	1170.53	1236.47	1214.40	1190.79	1151.40	1183.50	1284.43	1253.53	1218.22	1146.58	1177.02	1260.45	1233.97	1204.50
	M ₂	1115.20	1147.77	1180.07	1174.70	1154.43	1125.77	1157.30	1162.17	1154.80	1150.01	1120.48	1152.53	1171.12	1164.75	1152.22
	Mean	1128.48	1159.15	1208.27	1194.55	1172.61	1138.58	1170.40	1223.30	1204.17	1184.11	1133.53	1164.78	1215.78	1199.36	1178.36
MXF	M ₁	1227.91	1281.42	1343.83	1318.42	1292.90	1260.03	1286.32	1366.71	1367.54	1320.15	1243.97	1283.87	1355.27	1342.98	1306.53
	M ₂	1175.58	1219.88	1270.97	1252.47	1229.72	1194.00	1261.96	1303.54	1329.68	1272.29	1184.79	1240.92	1287.26	1291.07	1251.01
	Mean	1201.74	1250.65	1307.40	1285.44	1261.31	1227.02	1274.14	1335.13	1348.61	1296.22	1214.38	1262.39	1321.26	1317.03	1278.77

Factor	SEm			CD (P=0.05)		
	2023-24	2024-25	Pooled mean	2023-24	2024-25	Pooled mean
D	29.38	22.31	33.82	115.36	87.61	132.81
M	12.77	7.16	13.52	44.18	24.79	46.79
F	23.85	22.91	20.37	68.40	65.70	58.43
DXM	22.11	12.41	23.42	NS	NS	NS
DXF	41.31	39.67	35.28	NS	NS	NS
MXF	33.73	32.39	28.81	NS	NS	NS
DXMXF	58.42	56.11	49.90	NS	NS	NS

Table 7: Effect of planting date, mulch and fertigation on bulblet yield per plot (kg) of Tuberose

Treatments		2023-24					2024-25					Pooled mean				
		F ₁	F ₂	F ₃	F ₄	Mean	F ₁	F ₂	F ₃	F ₄	Mean	F ₁	F ₂	F ₃	F ₄	Mean
D₁	M₁	215.23	218.73	238.10	223.67	223.93	225.57	221.00	256.77	255.40	239.68	220.40	219.87	247.43	239.53	231.81
	M₂	204.67	215.67	230.47	228.73	219.88	213.60	218.93	244.70	238.73	228.99	209.13	217.30	237.58	233.73	224.44
	Mean	209.95	217.20	234.28	226.20	221.91	219.58	219.97	250.73	247.07	234.34	214.77	218.58	242.51	236.63	228.12
D₂	M₁	259.37	263.30	280.67	279.80	270.78	260.43	270.33	283.07	276.90	272.68	259.90	266.82	281.87	278.35	271.73
	M₂	223.13	236.83	253.03	242.77	238.94	254.70	259.07	263.40	262.83	260.00	238.92	247.95	258.22	252.80	249.47
	Mean	241.25	250.07	266.85	261.28	254.86	257.57	264.70	273.23	269.87	266.34	249.41	257.38	270.04	265.58	260.60
D₃	M₁	195.17	208.37	221.40	214.33	209.82	198.80	212.43	225.47	218.67	213.84	196.98	210.40	223.43	216.50	211.83
	M₂	183.40	198.30	213.40	206.17	200.32	185.93	204.93	217.10	208.80	204.19	184.67	201.62	215.25	207.48	202.25
	Mean	189.28	203.33	217.40	210.25	205.07	192.37	208.68	221.28	213.73	209.02	190.83	206.01	219.34	211.99	207.04
MXF	M₁	223.26	230.13	246.72	239.27	234.84	228.27	234.59	255.10	250.32	242.07	225.76	232.36	250.91	244.79	238.46
	M₂	203.73	216.93	232.30	225.89	219.71	218.08	227.64	241.73	236.79	231.06	210.91	222.29	237.02	231.34	225.39
	Mean	213.49	223.53	239.51	232.58	227.28	223.17	231.12	248.42	243.56	236.57	218.33	227.33	243.96	238.07	231.92

Factor	SEm			CD (P=0.05)		
	2023-24	2024-25	Pooled mean	2023-24	2024-25	Pooled mean
D	3.17	2.41	2.73	12.47	9.45	10.72
M	4.27	2.10	1.15	14.79	7.25	3.97
F	4.97	2.79	2.67	14.26	8.01	7.65
DXM	7.40	3.63	1.99	NS	NS	NS
DXF	8.61	4.84	4.62	NS	NS	NS
MXF	7.03	3.95	3.77	NS	NS	NS
DXMXF	12.18	6.84	6.53	NS	NS	NS

Conclusion

The present investigation clearly demonstrates that bulb growth, yield and quality of tuberose were significantly influenced by planting date, mulching, and fertigation levels. Among the treatments, 30th June planting proved most effective, as favourable environmental conditions during this period enhanced photosynthesis, carbohydrate accumulation, and their efficient partitioning to bulb tissues, resulting in improved bulb size, weight and yield. Mulching with silver-onblack polythene combined with organic residues created a favourable rhizospheric microclimate by conserving soil moisture, regulating temperature, and enhancing nutrient availability, which further supported bulb development. Fertigation at 90% RDF was found optimal, ensuring balanced nutrient supply and higher nutrient use efficiency, thereby strengthening sink activity and promoting greater assimilate storage in bulbs. Overall, the combined effect of optimum planting time, improved soil environment through mulching, and efficient nutrient management through fertigation significantly enhanced bulb parameters, indicating that this integrated approach is most suitable for maximizing bulb production and quality in tuberose.

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