



Plant Archives

Journal homepage: <http://www.plantarchives.org>

DOI Url : <https://doi.org/10.51470/PLANTARCHIVES.2026.v26.no.2.189>

SPACING, DEPTH OF PLANTING OF BULB AND LAND CONFIGURATION AFFECTED TUBEROSE (*Agave amica* SYNONYMOUS *Polianthes tuberosa*) PRODUCTION: A REVIEW

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(Date of Receiving-20-06-2026; Date of Revision-29-08-2026; Date of Acceptance-08-09-2026)

ABSTRACT

Tuberose (*Agave amica* [Medik.] Thiede & Govaerts synonymous *Polianthes tuberosa* Linn.) is one of the most important commercial flower crops in tropical and sub-tropical regions of the world including India. To obtain higher yield of good quality flowers and proper utilization of land and other inputs, the optimum spacing and depth of planting of bulbs along with land configuration are the crucial factors. The high density planting of 50 bulbs/m² following 20×10cm spacing may be followed. Tuberose bulbs may be planted at 20×10, 20×20, 25×25, 30×20 or 30×30cm spacing (row×bulb). After fourth rows about 60cm land may be kept vacant between fourth and fifth rows to facilitate flower harvesting and other necessary operations. The depth of planting depends upon diameter of bulbs and soil texture. Generally, bulbs are planted at 3 to 10cm depth. Planting of bulbs in flat bed observed better than ridge planting method. On the other side, bulbs planted on raised bed land configuration performed better than flatbed method under drip irrigation system.

Key words : *Agave amica*, Flower, Land configuration, Planting depth, Planting spacing, *Polianthes tuberosa*, Tuberose.

Introduction

Tuberose is botanically renamed as *Agave amica* (Medikus) Thiede & Govaerts, earlier it was botanically known as *Polianthes tuberosa* Linn. It is commonly known as Queen of Fragrant Flowers or Mistress of the Night. With the recent phylogenetic studies based on morphological and molecular data *Agave amica* has been included in the family Asparagaceae and sub-family Agavoideae. It belongs to monocot genus group. In India, tuberose is adorning with different vernacular names viz., Rajanigandha (Hindi), Gulcheri or Gulshaboo (Urdu), Rojonigondha (Bangla), Nishigandha (Marathi), Sugandharaja (Kannada) and Sambangi (Tamil). It is primarily cultivated in tropical and sub-tropical regions of the world including India, Bangladesh, China, Iran, Mexico, Nepal, Pakistan, South Africa, etc. According to 2023-24 horticultural statistics, in India tuberose was grown in about 19910 ha area, with a loose flower production of 10790 metric tone and cut flower production of 89.26

lakh number of cut stems. Four main tuberose growing Indian states were: West Bengal, Tamil Nadu, Andhra Pradesh and Karnataka. During 2023-24 in Karnataka state tuberose was cultivated in about 1887 ha area and four major tuberose growing districts (in ha area) were Chitradurga (481), Chikkabalapura (445), Bengaluru Rural (259) and Mysuru (142).

Tuberose is a bulbous, herbaceous, and perennial flower plant, which can be utilized in many sectors viz., floriculture, aromatic, medicinal, food, nutraceutical and cosmetic industries. White waxy florets of tuberose born on straight horizontal spikes impregnate the surroundings with their sweet persistent fragrance. Its flowers are in great demand in various forms of cut flower, loose flower and extraction of essential oils, due to its longer vase life, higher returns, and wider adaptability to varied climates and soils (Singh *et al.*, 2010). Tuberose represents sensuality and is used in aromatherapy for its ability to open the heart and calm the nerves, restoring joy, peace

and harmony. Its essential oils act as sedative, antidepressant, antispasmodic and used to boost blood circulation. Its fragrant flowers are added to the favourite beverage prepared from chocolate and served either cold or hot as desired to the insomnia (Reethu *et al.*, 2022).

Ramachander (1990) observed that among commercial flower crops, tuberose considered as priority crop in India. According to survey (Ramachander, 1990), the major researchable issues faced in tuberose where efforts may be intensified are- breeding of essential oils rich varieties and standardization of agro-techniques for higher yield and quality production of flowers. Spacing/ density and depth of planting of bulbs alongwith land configuration are essential package of practices in regulating growth, quantity and quality of tuberose yield. Therefore, keeping above facts in consideration the author felt that there is a necessity to collect and critically review globally available literature pertaining to above said agro techniques on tuberose. This review aims to bridge the knowledge gap by consolidating old and current research findings on tuberose pertaining to different spacings (distance or density) and depths for bulbs planting and land configuration for crop production. It evaluates application techniques, physiological and biochemical response and agronomic outcomes. The overreaching goal is to promote science based sustainable planting spacing, depth and land configuration for bulbs planting management technologies in tuberose cultivation to enhance higher productivity, flower quality and returns to growers.

Planting spacing or density

The planting distance/spacing/density of bulbs planting in tuberose cultivation influences plant growth, yield and quality of flowers, bulbs, bulblets production and recovery of essential oils per unit area. The bulb to bulb and row to row spacing may be varied with the cultivar to be selected, diameter of bulbs, agro-climatic condition of growing area and purpose for which crop is to be grown (Singh, 1995).

Desai (1957) reported that tuberose bulbs are planted in flat beds in rows about nine to twelve inch apart. Jindal (1958) observed that for planting in ground, tuberose bulbs may be planted in about six inch apart. Sadhu and Das (1973) suggested a planting spacing of 15-20cm between the bulbs and 25cm between the rows under Nadia, West Bengal condition. Rameshwar (1976) suggested a spacing of 30-38cm between the rows and 15-20cm between the bulbs, accommodating 40,000 to 50,000 bulbs per acre. Percy Lancaster (1977) advocated that tuberose bulbs may be planted in intra-rows between 10-15cm, while

the inter rows to be spaced 25cm apart. Singh (1972) suggested the best spacing for tuberose in high alkaline-saline soils of CSIR- National Botanical Research Institute, Sub-Research Station at Banthara, Lucknow, Uttar Pradesh to be 30×30cm. However, under very poor soil condition this spacing may be increased to 45×45cm. Haralennayavar (1975) observed that tuberose bulbs are planted at 22-30cm apart in rows. Sadhu and Das (1978) evaluated three planting spacings viz., 25×20, 20×20 and 15×20cm accommodating 27, 33 and 42 bulbs per square meter, respectively in tuberose cultivar Single (Calcutta Singh) under Kolkata, West Bengal condition. They observed that there is no commercial advantage from close planting left in the ground for two years. However, Bhattacharjee *et al.* (1979) tested three planting spacings viz., 15, 20 and 25cm (either way) in tuberose cultivar Single (Calcutta Single) under Hawrah, West Bengal condition. They found that planting of bulbs at wider spacing (25cm) resulted in better vegetative growth, larger number of bulbs and bulblets and also exhibited a trend of improved flowering.

Singh and Chatterjee (1981) reported that planting of tuberose bulbs is done at 30 × 30cm apart. After four rows, 60cm space is kept vacant between fourth and fifth rows, to facilitate plucking of flowers and other necessary operations. Nambisan and Krishnan (1983) recommended a planting spacing of 20×20cm with a population of 2,50,000 plants per hectare under Madurai, Tamil Nadu condition. Mukhopadhyay and Bankar (1981) tested three planting spacings in tuberose cultivar Double (Pearl Double) under Bengaluru, Karnataka State, condition. They observed that number of florets per spike and number of leaves and spikes per clump were significantly increased with increasing planting spacings. Plant height, spike and rachis length and flowering duration did not significantly influence by different spacings. Randhawa and Mukhopadhyay (1986) noted that in high rainfall areas with rich soil or in places with assured irrigation facilities, tuberose bulbs are planted at least 30cm apart from plant to plant and row to row, especially when bulbs are to be left undisturbed for two to three years. In dry areas, comparatively closer spacing may be followed.

Bhaskaraia *et al.* (1991) at S.V. Agricultural College, Tirupati, Andhra Pradesh, carried out an experiment in tuberose cultivar Single (Mexican Single) with four intra-row spacings viz., 10, 15, 20 and 25cm, keeping a constant inter-row spacing of 30cm. Number of leaves and tillers per clump were significantly increased with increase in intra-row spacings from 10cm to 25cm. The plant height did not significantly influence due to varying intra-row

spacings. Significant increase was also noted in spike length and number of spikes and bulbs per clump under wide spacings. Increase in intra-row spacing from 10 to 25cm resulted in significant increase in the number and weight of flowers per clump. However, the yield per plot decreased with increase in intra-row spacing. Closer spacing (30×10cm) recorded the highest loose flowers yield per hectare (9.37t/ha) while the wider spacing (30×25cm) recorded the lowest loose flowers yield per hectare (6.43t/ha).

Sharma *et al.* (1995) investigated the response of four planting spacings namely, 5×10, 10×15, 15×20 and 20×25cm in tuberose cultivar Single (Mexican Single) under Tirupura (North Eastern Hill) condition. Plants at two closer spacings (5×10 and 10×15cm) were taller than those at wider spacings. But three closest spacings (5×10, 10×15 and 15×20cm) were detrimental to bulb production, flower stalk length and number of florets per spike. Two widest spacings gave the most flower spike length and number of florets per spike. It is suggested that two closet spacings may be planted for loose flowers production and two widest spacings may be planted for cut flowers and bulbs production.

Singh (1996) and Singh (1997) at ICAR- Indian Institute of Horticultural Research, Bengaluru, planted tuberose cultivars Arka Shringar and Mexican Single bulbs at seven spacings (cm×cm) viz., 25×25, 25×20, 25×15, 20×20, 20×15, 25×10 and 20×10 (row × bulb). He accommodated 36, 48, 60, 64, 80, 90 and 120 bulbs per plot (1.5×1.5m), respectively. The results indicated that significantly the highest length of spike and rachis, number of florets per spike and flowering duration were recorded by planting of bulbs at 25×20cm apart and the spacings of 25×25cm, 25×20cm, 25×15cm and 20×20cm were recorded to be *at par* with each other. On the other hand, significantly the highest number of days taken for first flowering and total yield of flowers per plot were recorded under close spacing (20×10cm). However, the spacings of 25×10cm and 20×10cm reported to be *at par* with each other. The diameter, length and weight of individual open florets and per spike and per plot basis did not differ significantly due to different spacings. Thus, a bulb density of 50 plants/m² (20×10cm) could be followed for tuberose cultivars Arka Shringar and Mexican Single in and around Bengaluru condition. Kumar and Singh (1998) planted tuberose cultivar Single (Mexican Single) bulbs at three planting distances viz., 20×20cm, 30×20cm and 30×30cm under Kanpur, Uttar Pradesh condition. They recorded significantly the highest characteristics of vegetative growth (plant height, number of leaves per clump), flowers yield and quality (flowering duration, spike and rachis

length, number of florets per spike, vase life of cut spikes), bulb production (number, weight and diameter of individual bulb and bulblet) and dry matter per cent in bulbs and bulblets at 30×30cm spacing (wider) compared to 20×20cm and 30×20cm spacings.

Mohanty *et al.* (1999) at Agricultural College, Bapatla, Andhra Pradesh, planted tuberose cultivar Single (Mexican Single) bulbs at three intra-row spacings viz., 10, 20 and 30cm and keeping a constant inter-row spacing of 30cm. Recently matured leaves at 50% flowering stage and harvesting stage were sampled for N, P and K content of leaves on dry weight basis. They noted the maximum content of nitrogen, phosphorus and potash of plant tissues viz., 3.40%, 0.14% and 0.20% g/plant, respectively at 50% flowering stage and 2.94, 0.47% and 3.30% g/plant, respectively at harvesting stage, were recorded by plants spaced at greater intra-row spacing (30×30cm). Ram *et al.* (1999) at CSIR- National Botanical Research Institute, Research Sub-Station, Banthara, Lucknow, planted tuberose cultivar Single (Mexican Single) bulbs at three spacings i.e.; 30×15, 30×30 and 45×30cm. The crop under same spacings was retained as ratoon in second year. The results revealed that there was non-significant difference with respect to spike diameter, length of spike and rachis and number of florets per spike in main crop as well as in ratoon crop in different planting spacings. However, significantly higher plant height, leaf area and number of spikes and bulbs per clump were recorded under 45×30cm spacing (wider).

Singh and Sangama (2000) and Singh (2003) at ICAR- Indian Institute of Horticultural Research, Bengaluru, planted tuberose cultivars Arka Shringar and Mexican Single bulbs, respectively at six spacings viz., 30×20, 30×10, 20×20, 20×12.5, 20×10 and 20×8.5cm (row×plant) accommodating 36, 72, 60, 96, 120 and 126 plants per plot (2.0m×1.2m), respectively. Planting densities have significant effect on rachis length, number of spikes per plot (cut flowers) and weight of florets (loose flowers) per plot basis. There was non-significant difference with respect to spike length, number of florets per spike, weight of individual floret, bulb diameter and number of bulblets per plot basis. There was an increasing trend in both cut flowers and loose flowers production with increase in planting densities. The highest yield of cut and loose flowers per plot was recorded with a planting density of 20×10cm (50 plants/m²). However, significant difference was not noticed among the treatments with the spacings of 20×12.5cm, 20×10cm and 20×8.5 with respect to flower production per plot basis. The postharvest quality parameters of cut flowers were not influenced significantly due to different plant densities in

cultivar Mexican Single.

Malam *et al.* (2010) at Junagadh Agricultural University, Janagadh, Gujarat State, studied the response of five spacings i.e. 45×45, 45×30, 45×15, 30×30 and 30×15cm and crop duration i.e., main crop (first year), first ratoon crop and second ratoon crop on tuberose cultivar Double (Pearl Double) production. The widest spacing (45×45cm) registered the highest values for plant height, number of leaves per clump, length of spike and rachis, spike diameter, open floret diameter, number of florets per spike and number of spikes, bulbs and bulblets per clump. A planting distance of 30×30cm realized the highest cut flower yield and that of 30×15cm recorded the highest bulb production over the first year crop. The earlier spike emergence and flowering was noticed in ratoon crops compared to the first year crop. However, spike and flower quality was inferior to that of first year crop with regard to length of spike and rachis, diameter and number of florets per spike and diameter of open florets.

Lopes (1971) at Universidade Fedral Vicosa, Brazil, planted tuberose transplants weighing 70,200 or 340g at population levels of 30, 40 or 50 thousands plants per hectare. The planting density had non-significant effect on flower production, length of flower stalks and plant weight increase. Khalaj and Edrisi (2012) and Khalaj *et al.* (2012) felt that spacing of plants is one of the most important factors affecting the quality and quantity of tuberose crop. They experimented four plant densities (inter row spacing) viz., 10×10, 15×15, 20×20 and 25×25 (cm×cm). They observed that plant spacing significantly affected some qualitative and quantitative characteristics. An increase in plant spacing had increased flower stalk height, spike length, number and diameter of florets, bulb weight, vase life and flower quality. From these results it can be concluded that tuberose bulbs should be planted at row spacing of 25×25cm to obtain the maximum flower qualitative and quantitative characteristics under agro-climatic condition of Iran.

Depth of planting

The depth of planting of bulb is one of the most effective techniques affecting growth and flowering traits in tuberose plants. The depth of planting in tuberose depends upon the diameter of bulbs. The bigger is the bulb, the more is the depth of planting. Similarly, the smaller is the bulb size (diameter), the shallow is the depth of planting, which ranges from 2-10cm. Also, the depth of planting varies due to soil texture. In light soils, depth of planting is kept deeper compared to heavy soils (Singh, 1995). Tuberose bulbs are carefully placed upright by

hand and covered with soil. Usually bulbs planting is done at seven centimeter depth (Sharga, 1977). Desai (1957) reported that tuberose bulbs are planted about 5cm (2 inch) deep in soil.

Sadhu and Das (1978) observed that in tuberose cultivar Single (Calcutta Single), deep planting (6cm) significantly increased number of days taken for bulb sprouting, number of leaves and bulbs per clump and length of spike and rachis over shallow planting (4cm). It was noticed that number of spikes per clump, number of florets per spike and length of florets did not differ significantly due to by shallow or deep planting of bulbs. Bhattacharjee *et al.* (1979) planted tuberose cultivar Single (Calcutta Single) bulbs at three depths viz., 2, 4 and 6cm and observed significantly earlier flower bud appearance and first flowering of spikes by shallow planting (2cm). On the other hand, deep planting (6cm) produced significantly higher plant height, number of spikes, bulbs and bulblets per clump, number of florets per spike, spike length and flowering duration, when compared with other depths of planting.

Mukhopadhyay *et al.* (1986) and Mukhopadhyay and Bankar (1981) planted tuberose cultivars Single (Mexican Single) and Double (Pearl Double) bulbs, respectively at three depths of planting viz., 3, 5 and 7cm and noticed that depths of planting had very little influence on vegetative growth and flower production characteristics. Yadav *et al.* (1984) planted tuberose cultivar Single (Calcutta Single) bulbs at four depths viz., 2, 4, 6 and 8cm. They observed that planting of bulbs at greater depth delayed sprouting of bulbs. The plant height and number of leaves per clump were maximum at shallow depth of planting (2cm). The first flowering was delayed under deeper planting. Although, shallow planting promoted vegetative growth but larger number of spikes and weight of loose flowers (florets) per hectare were obtained by planting of bulbs upto a depth of 6cm. Rao *et al.* (1991) and Rao *et al.* (1992) observed that shallow planting (2cm) gave significantly better vegetative growth, bulb production and yield and quality of flowers when compared with deeper plantings (4 or 6cm) in tuberose cultivar Single (Mexican Single). Furthermore, Mukhopadhyay and Nagaraju (1988) observed that shallow (3cm) and deep (7cm) plantings did not have significant effect on total percentage of nitrogen content, reducing, non-reducing and total sugars of bulbs, bulblets and leaves in tuberose cultivar Single (Mexican Single).

Mane *et al.* (2007) experimented three depths of bulbs planting i.e., 3, 5 and 7cm in tuberose cultivar Single (Mexican Single). They reported that planting of bulbs at

shallow depth (3cm) resulted in the earliest spike emergence, but had no identical difference with medium depth (5cm) of planting. The length of spikes, number of spikes per clump and flowering duration increased significantly at 7cm depth of planting, while at 5cm depth recorded significantly superior results in case of spike diameter, number of florets per spike and rachis length.

Planting depth usually maintained approximately three times the diameter of tuberose bulbs (Armitage and Laushman, 1990). Tehranifar and Akbari (2012) for study of response of planting depths on yield and flowering quality parameters in tuberose cultivar Double, response of three planting depths *i.e.*, 4, 6 and 10cm on vegetative and flowering parameters was evaluated under greenhouse condition. The results revealed that for increasing of yield and producing desirable flowers with more value economically, the planting depth of 6cm for cultivation of tuberose flowers is ideal under Iran condition. Hussain *et al.* (2016) carried out an experiment to find out the response of three planting depths *i.e.*, 5, 10 and 15cm of bulbs planting in tuberose. They concluded that planting of tuberose bulbs at the depth of 15cm gave excellent results in agro-ecological condition of Peshwar, Pakistan. A pot experiment was conducted by Mahros (1999) to evaluate the effect of two planting depths of bulbs planting *i.e.*, 3 and 6cm on tuberose production. Bulbs planted at 3cm depth sprouted earlier than those planted deeper (6cm). While the time taken to flowering was not affected significantly. Length of spike and rachis, number of leaves per clump and bulb production were observed higher at 3cm planting depth.

Land configuration

At Istituto Sperimentale per la Floricoltura, Sanremo, Palermo in Italy, Carrito and Zizzo (1980) planted tuberose cultivar Pearl at planting rates of 24, 36 and 48 bulbs/m² on high ridges, medium ridges and flat soil and observed the performance. The production of daughter bulbs was maximum at the highest planting rate (48 bulbs/m²). The planting systems did not significantly affect production. Singh and Sujatha (1990) at ICAR-Indian Institute of Horticultural Research, Bengaluru, Karnataka state, studied the effect of different methods of bulbs planting in tuberose cultivar Single (Mexican Single). The planting methods were- planting on flat bed, medium ridge (12cm) and high ridge (18cm). The length of spike and rachis were significantly higher when bulbs were planted on flat bed compared to planting on medium or high ridge. Non-significant differences observed with regard to other floral and bulb traits *viz.*, number of days taken to first flowering, flowering duration, number of florets per spike,

number of spikes per unit area, number of bulbs and bulblets per clump and diameter and weight of bulbs. Although flatbed planting method was observed better than ridge planting.

Soujanya *et al.* (2026) at ICAR-Indian Agricultural Research Institute, New Delhi (under semi-arid and sub-tropical climate) compared two land configurations: raised beds and flatbed on tuberose cultivar Arka Prajwal. The raised beds configuration involved forming beds 120 cm wide and 15 cm high with 40 cm channels between beds to facilitate drainage and aeration. The flat bed treatment maintained conventional level planting. Raised bed planting consistently outperformed flatbed configuration across all measured parameters namely, improved plant height, leaf length and width, number of leaves per clump and advancing earlier first flowering by 12.2d. Raised beds should be adopted as the standard land configuration for commercial drip-irrigated tuberose cultivation. Furthermore, Soujanya *et al.* (2025) observed that the raised bed configuration significantly produced higher loose flower yield of 16.89t/ha in contrast, the flat bed configuration yielded 14.81t/ha.

Chawla *et al.* (2018) conducted experiments on evaluation of land configuration for tuberose cultivar Arka Prajwal. Four methods of land configuration were tried *viz.*, (1) In flat bed or plot method (farmers practices)- Bulbs were planted at 40×30cm distance, (2) Ridge and furrow method- Ridges of 50cm were prepared after leaving 30cm space between two ridges and two lines of bulbs at 30×30cm distance were planted on a ridge leaving 10cm space from both sides of ridge. (3) Raised beds of 90cm with three rows- Raised beds of 15cm height were prepared and bulbs were planted at 30×30cm distance. Raised beds (90cm wide) with three lines of bulbs planting and 30cm space between two beds and (4) Raised beds of 120cm with four rows of bulbs planting- Raised beds of 120cm wide accommodating three lines of bulbs having 40cm space between two beds. The results revealed that planting of bulbs in three rows on raised bed (90cm width) recorded significantly early sprouting of bulbs with maximum sprouting percentage, plant height, number of leaves per clump, leaf area, number of florets per spike, length of spike and rachis, flowering duration, vase life of spikes, number of spikes per clump as well as well per hectare and bulb and bulblet parameter.

Disclaimer (artificial intelligence)

Author hereby declares that NO generative artificial intelligence technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during writing or editing of this manuscript.

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