Determining The Effect of Integrated Nutrient Management (INM) on Growth and Yield of Flower of Tuberose (*Polianthes tuberosa* L.) cv. Prajwal

Abstract

Tuberose (*Polyanthes tuberosa* L.) is a highly valued commercial bulbous ornamental plant found in tropical and subtropical climates in the Amaryllidaceae family. It is high demand in both domestic and distant markets due to its long repels, funnel shape, and strong fragrance. The field experiment was carried out to study the effect of integrated nutrient management on growth and flower yield of tuberose cv. Prajwal during the year of 2021 -2022 at Department of Horticulture, Annamalai University, Annamalainagar, Tamil Nadu. The investigation was laid out in Randomized Block Design with 10 treatments and replicated thrice. The treatments comprised of different levels of FYM (25% and 15%), poultry manure (25% and 15%), vermicompost (25 % and 15 %), inoculation of *Azotobacter* (2 kg ha^{-1}) and phosphate solubilizing bacteria (2 kg ha^{-1}) along with RDF (100 % and 75 %). Among the different treatments, T_{10} (75 % RDF + *Azotobacter* @ 2 kg ha^{-1} + PSB @ 2 kg ha^{-1}) was discovered to be more successful in improving all growth, physiological and flowering characters *viz.*, plant height (51.75 cm), number of side shoots plant^{-1} (11.23), leaf area (98.76 cm^{2}), chlorophyll content (0.99 mg g^{-1}), dry matter production (42.37 g plant^{-1}) and flowering and yield parameter *viz.*, number of spike plant^{-1} (3.12), length of spike (105.30 cm), number of florets spike^{-1} (56.11) and flower yield ha^{-1} (15.72 t ha^{-1}).

Keywords: INM, RDF, Tuberose, *Polyanthes tuberosa*, Amaryllidaceae, Flower and Yield

Introduction

Tuberose (*Polianthes tuberosa* L.), popularly known as Rajnigandha and member of the Amaryllidaceae family. Among other flower crops, tuberose is a significant commercial bulbous flower crop in India and is well-liked for its highly fragrant and long-lasting spikes (Hemanta *et al.*, 2017). Because of its pleasant scent, longer spike vase life, greater returns, and wide soil and climate tolerance, tuberose is a valuable commercial cut flower crop. It offers significant economic possibilities for the trade in cut flowers and the essential oil industry. Spikes can be used as cut flowers in bouquets and vases, while individual flowers can be used to make crowns, veni, garlands, buttonholes, or garland. Tuberose oil comes from it, and it smells delicious. The pricey raw material for perfume is the natural floral oil of the tuberose. There is a significant economic potential for the trade in loose and cut flowers as well as essential oils. (Alan *et al.*, 2007 and Pathil *et al.*, 1999). It is a perennial herbaceous bulbous plant that is half-hardy. The leaves are long, thin, and thick, with a pale green color. The base leaves are 1.2 to 1.5 cm wide, 30 to 40 cm long, and occasionally reddish close to the base. The blooming stems are tall, typically reaching a height of 60 to 75 cm, but they can grow as high as 100 cm (Bahadoran and Salehi, 2015). The pure white, waxy-textured raceme of flowers is found in the upper part of the stalk. The flowers are 3 to 6 cm long and are borne in pairs on a loose spike. The segments are funnel-shaped, slender, tube-shaped, and 1 to 2 cm long. They bend slightly at the base. The upper section of the corolla has filaments linked to it. Ovary: three-celled, stigmatized, ovate falcate. Fruit with flat seeds and a prolonged perianth at its peak (Farooqi *et al.*, 2004). Commercial tuberose is grown in many places across the world, including Hawaii, South Africa, Taiwan, USA, Egypt, China, India, Kenya, Mexico, Morocco, France, Italy, and many more tropical and subtropical regions. Within India, West Bengal, Tamil Nadu, Maharashtra, Andhra Pradesh, Karnataka, Assam, Rajasthan, Gujarat, Uttar Pradesh, Punjab, and Chhattisgarh are the states where tuberose cultivation for commercial purposes is most preferred. Districts of Coimbatore, Madurai, and Dindigul in Tamil Nadu are the primary locations for tuberose cultivation. Vegetative development and higher floral quality yields are dependent on plant nutrition. Since tuberose uses a lot of nitrogen, phosphate, and potassium, it reacts favorably to both inorganic and organic fertilizers, especially those that are high in nitrogen. The types of soil and climates have an impact on the need for fertilizers. The problems with the ecology throughout the world have gained more attention recently. In addition to the soil's varied physical, chemical, and biological qualities being disrupted, the soil's fertility is declining as a result of increased and ongoing applications of chemical fertilizers. Following the green revolution, crop production increased its usage of chemical pesticides and fertilizers, endangering the environment and ecosystem. Consequently, it appears that organic farming is the only way to solve this issue (Rawat, 2002). Experience from the past has made it abundantly evident that no one source of input can achieve the dual challenges of maintaining increasing output and protecting the environment. Consequently, it supports the idea of spreading awareness of the "Integrated Nutrient Supply System" (IPNS), which entails utilizing many nutrient sources simultaneously, including chemical fertilizers, organic manures, and biofertilizers. Utilizing organic wastes, farm yard manures, compost, vermicompost, and poultry manures is emphasized by the world's elite society as the most effective way to partially protect the environment. The safest sources of plant nutrients are organic materials, which don't harm soil or crops. Green manure, vermicompost, chicken manure, and farm yard manure are all great sources of organic matter and basic plant nutrients (Pieters, 2005). It has been demonstrated that vermicompost contains high concentrations of micronutrients, growth regulators, phosphorus, potassium, total and accessible nitrogen, as well as microbial and enzymatic activity (Chaoui *et al*., 2003). According to Kumaresan *et al.* (2023), vermicompost is a highly effective plant growth medium that accelerates the growth of a wide range of plant species. Spike output and floret quality are significantly impacted by nitrogen, phosphate, and potassium (Singh and Singh, 2005). Due to its high concentration of nitrogen, phosphorous, potassium, and other vital nutrients, poultry dung is a superior organic manure (Garg *et al.*, 2008). The most often utilized organic manure is farm yard manure, which enhances the soil's structure and ability to retain water by pulverizing the soil. In addition to improving soil structure by providing food and energy for beneficial soil bacteria to create polysaccharides, increasing microbial activity in the organically supplemented soil facilitates N fixing and P solubilization. Chemical fertilizers alone are insufficient for the crop because major nutrients, particularly nitrogen, can be lost through evaporation or leaching, and P can be fixed in the soil in complex forms. As a result, the crop receives less N and P availability, which may not be enough for the plant to reach its full potential and yield more. Biofertilizers are becoming more and more popular as an additive to mineral fertilizers, and they have the potential to increase agricultural yield and quality. As they don't require non-renewable energy sources during manufacture, biofertilizers are more affordable, environmentally benign, and sustainable. Live or dormant microbe cells are the usual component of biofertilizers, which can be used to fix nitrogen biologically, solubilize P, mineralize nitrogen, and convert various elements into forms that are useful. According to Zaredost *et al.* (2014), biofertilizers typically used in horticulture crops include phosphate-solubilizing bacteria, Azotobacter, VAM fungi, and Azospirillum. Therefore, to preserve the fertility condition and health of the soil while also boosting tuberose yield, biofertilizers can be employed as an alternative to the overuse of inorganic fertilizers.

Materials and Methods

The field investigation was carried out to study the effect of integrated nutrient management on growth and flower yield of tuberose cv. Prajwal at Department of Horticulture, Annamalai University, Annamalainagar, Tamil Nadu. The experimental site is located in the southern region of India at latitude 11°24' N and longitude 74°44' E, at an elevation of + 5.79 m above mean sea level. During the experiment, the temperature and relative humidity ranged from 28.5 to 38.5ºC and 78.0 to 96.0%, respectively. “The experimental farm's soil is categorized as Typic Haplusterts (clay), with characteristics such as neutral reaction (pH 7.4,7.5), organic carbon content 4.6 and 5.8 g kg^{-1}, CEC of 20.7 and 21.4 c mol (P+) kg $^{-1}$, low available N (227 and 230 kg ha^{-1}), medium available P (1.9 and 21.3 kg ha^{-1}), and high available K (281 and 276 kg ha^{-1})”. [38]

The experimental site's geographic coordinates are $11^{0}24^{I}$ North latitude and $79^{0}44^{I}$ East longitude, with an elevation of +5.79 m above mean sea level. The summers are hot and the weather is often warm. 35^{0}C is the mean maximum temperature, and 23.5^{0}C is the mean lowest temperature. The average annual rainfall is 1500 mm, of which 1000 mm occur between October and December during the North East monsoon, 400 mm between June and September during the South West monsoon, and 100 mm during summer showers (March - May). There is a 72% relative humidity on average. The treatments comprised of different levels of FYM (25% and 15%), poultry manure (25% and 15%), vermicompost (25 % and 15 %), inoculation of *Azotobacter* (2 kg ha^{-1}) and phosphate solubilizing bacteria (2 kg ha^{-1}) along with RDF (100 % and 75 %). According to the treatments, the recommended fertilizer dosage has been applied to the chosen plots. When plants were planted, a basal application of two thirds of nitrogen, complete dosages of P and K, were given. Six weeks after planting, one-third of the nitrogen was top-dressed. N, P, and K were supplied, respectively, by urea, super phosphate, and muriate of potash. The observations were recorded at various stages of crop growth. The growth and physiological parameters *viz*., plant height, number of side shoots plant^{-1}, number of leaves plant^{-1}, leaf area, chlorophyll content, dry matter production and flowering and yield parameter *viz*., Days to fifty per cent flowering, number of spike plant^{-1}, length of spike, length of rachis, number of florets spike^{-1}, floret length, floret diameter, hundred floret weight, flower yield plant^{-1}, flower yield plot^{-1} and flower yield ha^{-1}. The statistical analysis of data was carried out for the experiment as suggested by Panse and Sukhatme (1985).

Results and discussion

Plant height (cm)

The plant height at different stages of growth differed significantly. Among all the nutrient management levels, the maximum plant height (58.45cm) was observed in T_{10} (75 % RDF + *Azotobacter* @ 2 kg ha^{-1} + PSB @ 2 kg ha^{-1}) and minimum (49.72 cm) was found to be in T_9 (75 % RDF + PSB @ 2 kg ha^{-1}). The beneficial activity of biofertilizers (Azotobacter) may have contributed to the rise in plant height by increasing the availability of nitrogen and certain growth factors such auxins, gibberellins, vitamins, and organic acids released by bioinoculants. The studies conducted by Ajimuddin (2002) and Yadav *et al.* (2005) also supported the influence of Azotobacter on plant height in tuberose. Because nitrogen is a component of protein and is necessary for the formation of protoplasm, which improves cell division and enlargement and ultimately increases plant height, the increase in plant height may have resulted from the increased availability of nitrogen and phosphorus due to the use of biofertilizers (Halil *et al*., 2023).

Number of side shoots plant^{-1}

The number of side shoots plant^{-1} differed significantly by the effect of various nutrient management treatments. The maximum (11.23) number of side shoots plant^{-1} was observed in T_{10} (75 % RDF + *Azotobacter* @ 2 kg ha^{-1} + PSB @ 2 kg ha^{-1}). The minimum number of side shoots (7.27) was recorded in T_9 (75 % RDF + PSB @ 2 kg ha^{-1}). The production of cytokinins by Azotobacter and PSB, as well as growth regulators like NAA, may be the cause of the significant rise in branches plant-1. These factors have hastened the formation of more branches and broken apical dominance. It is also possible that the process of cell division and differentiation was sped up by the increased nitrogen feeding, which Azotobacter corrected. The findings of African marigold and Patil *et al.* (2013), as well as those of Sunitha *et al.* (2007) and Thumar et al. (2013), support the prior results. When Azotobacter and PSB were combined with 75% nitrogen in marigold plants, Gupta et al. (1999) observed the highest number of branches per plant as well as yield.

The increased metabolic transport, photosynthesis, and cell multiplication in marigold may be the cause of the N and P's stimulating influence on plant growth. Yadav et al. (2005) made a similar observation on tuberose cv. Double. It's possible that the PSB, Azotobacter, or Azospirillium produced more leaves because they alone or in combination produced growth-promoting compounds like IAA or GA, such as vitamin B12, thiamine, riboflavin (B2), etc. All of these elements support the growth, division, and multiplication of cells, which may have improved photosynthesis and, ultimately, vegetative growth. As a result, compared to the control, the treatment's leaf count greatly rose. Gladiolus cv. American Beauty had more leaves after applying biofertilizers, specifically Azotobacter and PSB (Srivastava and Govil's 2007).

Leaf area (cm^2)

The treatments significantly influenced the leaf area. Larger leaves (98.76 cm^2) were observed in the treatment T_{10} (75 % RDF + *Azotobacter* @ 2 kg ha^{-1} + PSB @ 2 kg ha^{-1}) whereas the smaller leaf area (52.86 cm^2) was observed T_9 (75 % RDF + PSB @ 2 kg ha^{-1}). The application of biofertilizers (Azotobacter and PSB) may have increased leaf area because they released growth regulators such as cytokinins. These growth-promoting substances may have increased cell division and elongation, which in turn led to enhanced leaf expansion, which in turn increased leaf length and leaf width. These results closely correspond with the marigold research conducted by Kumar et al. (2009).

Chlorophyll content (mg g^{-1})

The chlorophyll content was found to be significantly influenced by all the treatments. The highest value (0.992 mg g^{-1}) was recorded in treatment T_{10} (75 % RDF + *Azotobacter* @ 2 kg ha^{-1} + PSB @ 2 kg ha^{-1}) followed by T_1 (100 % RDF (200:200:200 kg NPK ha^{-1}) which recorded 0.908 mg g^{-1}. The lowest value (0.740 mg g^{-1}) was recorded in T_9 (75 % RDF + PSB @ 2 kg ha^{-1}).

An increase in nitrogen, the main component of protein and protoplasm, causes a rise in chlorophyll content, which in turn increases photosynthetic activity. The production of cytokinin by microbial inoculants may have increased as a sink to draw in nutrients such as magnesium, iron, and potassium, leading to an increase in the synthesis of chlorophyll in tuberose (Sumitha *et al*., 2017).

Dry matter production (g $plant^{-1}$)

The effect of treatments on dry matter production was found to be highly significant. Among the different treatments, the highest dry matter production (42.37 g $plant^{-1}$) was recorded in T_{10} (75 % RDF + *Azotobacter* @ 2 kg ha^{-1} + PSB @ 2 kg ha^{-1}). It was followed by T_4 (39.57). The least dry matter (28.78 g plant^{-1}) was recorded in T_9 (75 % RDF + PSB @ 2 kg ha^{-1}). The results of the study are in close conformity with the findings of Sumitha *et al.* (2017) who had recorded significant improvement in dry matter content in marigold due to the application of *Azotobacter* with different levels of chemical fertilizers. The promotive effect of bio and chemical fertilizers on vegetative attributes had also been observed by Kumar *et al.* (2003) in China aster.

Number of spikes plant^{-1}

The maximum number of spikes plant^{-1} (3.12) was recorded in T_{10} (75 % RDF + *Azotobacter* @ 2 kg ha^{-1} + PSB @ 2 kg ha^{-1}), followed by T_4 (75 % RDF + Poultry manure 25 %) recorded 3.09 spikes and the minimum number of spikes (2.92) was observed in T_9 (75 % RDF + PSB @ 2 kg ha^{-1}). The increased number of spikes could be attributed to various factors such as atmospheric nitrogen fixation, improved root proliferation, increased water and nutrient uptake, increased photosynthesis, enhanced food accumulation, and increased capacity for cell division, all of which could have contributed to better plant growth and a subsequent increase in the number of spikes and florets. These results were consistent with gladiolus research by Kathiresan and Venkatesha (2002), Godse *et al.* (2006) and Anu *et al.*, 2020 in marigold cv. Pusa Narangi Gainda

Number of florets spike^{-1}

Among the various treatments, T_{10} (75 % RDF + *Azotobacter* @ 2 kg ha^{-1} + PSB @ 2 kg ha^{-1}) recorded a greater number of florets spike^{-1} (56.11) and this was followed by T_4 (54.39). The least number of florets (48.37) was recorded in T_9 (75 % RDF + PSB @ 2 kg ha^{-1}). Higher levels of NPK in the soil may have encouraged the synthesis of more amino acids, the formation of chlorophyll, and better carbohydrate transformation, which in turn led to better growth and longer rachis, which in turn produced more florets per spike, explaining the notable increase in floret count in T_{10}. These conclusions were supported by the findings of Achal *et al.*, 1984, Gowda *et al.*, 1991 and Gopitha *et al.*, 2021.

The increased number could be attributed to a variety of factors, including increased photosynthesis, improved food accumulation, improved root proliferation, improved water and nutrient uptake, increased ability to divide cells, and atmospheric nitrogen fixation. All of these factors could have contributed to improved plant growth and a subsequent increase in the number of spikes and florets. These results were consistent with those of the following studies: Barman et al. (2003), Yadav et al. (2005) in tuberose, Gayathri et al. (2004) in statice, Kathiresan and Venkatesha (2002), Madinatul-Nisa *et al*., (2016) and Godse et al. (2006) in gladiolus.

Floret length (cm)

There was a significant difference between the treatments. Among all the treatments, T_{10} (75 % RDF + *Azotobacter* @ 2 kg ha^{-1} + PSB @ 2 kg ha^{-1}), registered the maximum floret length (6.73 cm) and this was followed by T_4 (75 % RDF + Poultry manure 25 %) which recorded 6.08 cm. The minimum floret length (4.66 cm) was observed in T_9 (75 % RDF + PSB @ 2 kg ha^{-1}).

The increase in flowering parameters may be the result of adequate phosphorus availability during vegetative growth, which has a positive impact on the development of flowering parameters. Similar results were also seen in crossandra by Narasimharaju and Haripriya (2001) and in tuberose by Barman *et al.* (2003). Azotobacter fixes nitrogen and PSB makes insoluble phosphorus available by secreting organic acids, primarily Pseudomonas, the improved floral characteristics may be the result of increased availability of N and P, which are necessary for flower growth (Dave and Patel, 2003).

Flower yield ha^{-1} (t ha^{-1})

Among the treatments, T_{10} (75 % RDF + *Azotobacter* @ 2 kg ha^{-1} + PSB @ 2 kg ha^{-1}) recorded the highest flower yield (15.72t ha^{-1}). It was followed by T_4 (14.73 t ha $^{-1}$) and the lowest yield was observed in T_9 (11.54 t ha^{-1}). The increase in yields per hectare-1 may have resulted from the beneficial actions of Azotobacter and PSB in combination with inorganic fertilizers, which aided in the plant's general development and improved yield production. These outcomes agree with those of Yadav et al. (2005) and Swaminathan et al. (1999) in relation to tuberose. Similar results were also observed in the studies of Mogal et al. (2006) in China aster, Gayithri et al. (2004) in statice, Abhishek *et al*., 2022 and Gupta et al. (1999) in marigold. The impact of integrated nutrient management on the garland chrysanthemum's yield and relative economics was assessed by Angadi (2014). According to the reports, Azospirillum + PSB + 50% vermicompost equivalent to RDN + 50% prescribed NPK resulted in considerably increased yield features, such as number of flowers/plant, flower yield/plant, and flower yield/ha.

Economic analysis

Effect of different sources of nutrient significantly imparted the effect on B:C ratio (Table 3). The maximum B: C ratio (2.93) was recorded in the treatment T_{10} (75 % RDF + Azotobacter @ 2 kg ha $^{-1}$ + PSB @ 2 kg ha $^{-1}$), the minimum (1.88) was recorded in treatment T 9 (75 % RDF + PSB @ 2 kg ha $^{-1}$).

Conclusion

The experiment is concluded that the application of 75 % RDF + *Azotobacter* @ 2 kg ha^{-1} + PSB @ 2 kg ha^{-1} was found to be more effective for better performance of all the growth, physiological and flowering characters of tuberose.

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Table 1. Effect of Integrated Nutrient Management on Growth and physiological characters of Tuberose

Treatments		Plant height (cm)	Number of side shoots plant^{-1}	Leaf area (cm^2)	Chlorophyll content (mg g^{-1})	Dry matter production (g plant^{-1})
T_1	100 % RDF (200:200:200 kg NPK ha^{-1})	53.35	10.53	87.03	0.908	37.57
T_2	75 % RDF + Vermicompost 25 %	51.75	10.08	80.26	0.825	35.77
T_3	75 % RDF + Vermicompost 15 %	51.22	9.50	74.26	0.793	33.71
T_4	100 % RDF + Poultry manure 25 %	55.48	11.14	92.88	0.856	39.57
T_5	75 % RDF + Poultry manure 15 %	51.93	8.00	83.91	0.781	36.77
T_6	75 % RDF + FYM 25 %	51.45	9.00	71.02	0.820	34.31
T_7	75 % RDF + FYM 15 %	50.41	8.25	61.76	0.753	30.75
T_8	75 % RDF + *Azotobacter* @ 2 kg ha^{-1}	51.11	8.85	67.76	0.773	32.75
T_9	75 % RDF + PSB @ 2 kg ha^{-1}	49.72	7.27	52.86	0.740	28.78
T_{10}	75 % RDF + *Azotobacter* @ 2 kg ha^{-1} + PSB @ 2 kg ha^{-1}	58.45	11.23	98.76	0.992	42.37
S.Ed		**0.16**	**0.23**	**2.33**	**0.006**	**0.69**
CD (P=0.05)		**0.30**	**0.44**	**4.59**	**0.012**	**1.36**

Table 2. Effect of Integrated Nutrient Management on flower and yield characters of Tuberose

Treatments		Spike length (cm)	Number of spikes plant^{-1}	Number of florets spike^{-1}	Floret length (cm)	Flower yield hectare^{-1} (t ha^{-1})
T_1	100 % RDF (200:200:200 kg NPK ha^{-1})	99.58	3.07	53.19	5.74	14.02
T_2	75 % RDF + Vermicompost 25 %	96.23	3.06	52.15	5.50	13.35
T_3	75 % RDF + Vermicompost 15 %	89.06	3.03	50.32	5.11	12.47
T_4	100 % RDF + Poultry manure 25 %	102.40	3.09	54.39	6.08	14.73
T_5	75 % RDF + Poultry manure 15 %	96.85	3.06	52.18	5.54	13.49
T_6	75 % RDF + FYM 25 %	93.31	3.04	51.21	5.34	12.90
T_7	75 % RDF + FYM 15 %	90.16	3.02	49.33	4.87	12.06
T_8	75 % RDF + *Azotobacter* @ 2 kg ha^{-1}	90.32	3.03	50.25	5.08	12.43
T_9	75 % RDF + PSB @ 2 kg ha^{-1}	77.04	2.92	48.37	4.66	11.54
T_{10}	75 % RDF + *Azotobacter* @ 2 kg ha^{-1} + PSB @ 2 kg ha^{-1}	105.30	3.12	56.11	6.73	15.72
S.Ed		**2.42**	**0.15**	**0.45**	**0.090**	**0.24**
CD (P=0.05)		**2.66**	**0.26**	**0.86**	**0.19**	**0.51**

Table 3: Economics of crop production of tuberose as influenced by different sources of nutrient

Treatments		**Cost of cultivation (Rs. ha^{-1})**	**Gross income (Rs. ha^{-1})**	**Net income (Rs. ha^{-1})**	**B:C Ratio**
T_1	100 % RDF (200:200:200 kg NPK ha^{-1})	324252	1121600	797348	2.45
T_2	75 % RDF + Vermicompost 25 %	329436	1068000	738564	2.24
T_3	75 % RDF + Vermicompost 15 %	325197	997600	672403	2.06
T_4	100 % RDF + Poultry manure 25 %	321912	1178400	856488	2.66
T_5	75 % RDF + Poultry manure 15 %	728278	1079200	758278	2.36
T_6	75 % RDF + FYM 25 %	326437	1032000	705563	2.16
T_7	75 % RDF + FYM 15 %	323637	964800	641163	1.98
T_8	75 % RDF + *Azotobacter* @ 2 kg ha^{-1}	319517	994400	674883	2.11
T_9	75 % RDF + PSB @ 2 kg ha^{-1}	319517	923200	603683	1.88
T_{10}	75 % RDF + *Azotobacter* @ 2 kg ha^{-1} + PSB @ 2 kg ha^{-1}	319597	1257600	938003	2.93