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RESEARCH ARTICLE

Intercomparison of drone and conventional spraying of macro and micro nutrients on growth yield and quality of Tuberose (*Agave amica* Medik.) *cv*. Arka Prajwal

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Abstract

Improper nutrient management is one of the major challenges for sustainable production of tuberose cultivation. The present study has utilized drones to deliver agricultural inputs, particularly nutrients, in tuberose cultivation over 2 seasons (2022-2024) in Sathiyamangalam, Tamil Nadu. Present study has conducted with 10 treatments replicated thrice in a randomized block design, the treatments included NPK 19:19:19, micronutrients, humic acid and GA_3 at various concentrations. Nutrients were applied via foliar spray using drones and knapsack sprayers. Results demonstrated a significant positive impact of drone-facilitated foliar nutrient application on tuberose growth and yield. Drone spray of micro nutrient mixture + 0.5 % poly feed + 0.6 % humic acid + 150 ppm GA_3 with spray fluid of 50 L ha^{-1} recorded the maximum plant growth and yield attributes over other treatments. The study showed enhanced flowering attributes in tuberose, including a reduced time to first spike emergence (77.18 days), increased spike length (99.22 cm) and number of florets per spike (43.39). Additionally, higher yield and quality parameters were observed, such as hundred floret weight (221.57 g), floret diameter (4.36 cm), floret length (6.88 cm), spike weight (126.89 g) and yield per plant (390.51 g). Physiological parameters were also higher in plots treated with a drone spray of MN mixture + 0.5 % poly feed + 0.6 % humic acid + GA_3 at 150 ppm, followed by those treated with a knapsack spray of the same mixture. The findings revealed that foliar application of nutrients and growth regulators using drones significantly improved the growth, yield and quality of tuberose.

Keywords

Tuberose; Unmanned Aerial Vehicle; Nutrient spraying; Plant growth regulators; Growth and yield

Introduction

Floriculture is a crucial sector in India, significantly boosting the economy. The country's diverse agroclimatic conditions allow the cultivation of a wide variety of flower crops across 2.82 lakh ha, producing 22.98 million tonnes annually, including 614.6 lakh loose and cut flowers. India's floriculture exports, valued at USD 88.38 million, are primarily concentrated in the southern states (1). Tuberose, cultivated on 21.71 thousand ha in India, is a tropical flower valued for its long-lasting spikes used as cut and loose flowers. Its adaptability to various climates and its use in the perfume industry, where its volatile oil contains compounds like geraniol and methyl benzoate, make it a profitable crop.

Soil applied nutrients often suffer from losses due to leaching, volatilization and runoff, reducing nutrient use efficiency. Foliar nutrition addresses deficiencies and significantly impacts tuberose yield by delivering macro and micronutrients directly to the plant. Manual application with knapsack sprayers is common, but labour shortages and rising costs are challenges for cultivation (2). Drone-based nutrient application offers a time- and cost-saving alternative, reducing labour and improving yields and crop quality. Unmanned Ariel Vehicle is called as a drone used for both crop protection and fertilizer application with NPK fertilizers enhancing productivity and nutritional value. Foliar spraying during critical growth stages is essential for optimal nutrient utilization and improved crop production (3). This study evaluated the impact of drone and knapsack sprayer used to spraying of plant nutrients and growth regulators on the growth, yield and quality of tuberose.

Materials and Methods

The experiment was conducted over 2 consecutive seasons (June 2022 - May 2023 and June 2023 - May 2024) in farmer field at Sathiyamangalam, Erode, Tamil Nadu during 2022-2024. The soil texture is sandy clay loam and slightly alkaline in nature. The experiment was laid in a randomized block design (RBD) with 10 treatments and replicated thrice. Treatment details are shown in Table 1. The composition of nutrient solution contains poly feed and micro nutrient mixture is 19:19:19 NPK/kg and 0.25 % $FeSO_4$, 0.25 % $ZnSO_4$ and 0.3 % H_3BO_3. Tuberose cv. Arka Prajwal was used in the study for both seasons. Bulbs were planted with spacing of 45 cm × 30 cm. Sprinkler irrigation with Irrigation Water/Cumulative Pan Evaporation ratio of 1.0 was adopted and fertilizer dose of 200:200:200 kg/ha was supplied through drip fertigation for all the treatments.

Foliar spray of nutrient solution was done at 60 days interval from 45 days after planting using drone and knapsack sprayer with spray fluid of 50 and 500 L ha^{-1} respectively. Technical parameters of the drone and knapsack sprayer was given in Table 2.

Drones were equipped with battery capacity of 16000 mAh and discharge rate of 1.5 L min^{-1}. The effectiveness of different treatments was evaluated by measuring growth, flower, yield and quality parameters including physiological and leaf nutrient contents. Plant height, number of leaves and leaf area index were recorded at first spike emergence stage of the crop. Different parameters were determined using specific method details given in Table 3.

Plant samples collected at 180 days after planting were oven-dried at 65 °C until reaching a constant weight for nutrient analysis. To check the significant difference between various treatments and phenological stages for leaf area index, the values of 2 seasons were averaged and Two-way ANOVA was performed. Two-way ANOVA was performed to check significant differences in crop yields for various treatments between different seasons. All statistical tests were performed in SPSS statistical software (IBM SPSS Statistics 23).

Table 1. Treatment details of the experiment.

Treatments	Treatment Combinations
T_1	Drone spray of MN mixture + 0.5 % Poly feed + 0.4 % Humic acid + 100 ppm GA_3
T_2	Drone spray of MN mixture + 0.5 % Poly feed + 0.4 % Humic acid + 150 ppm GA_3
T_3	Drone spray of MN mixture + 0.5 % Poly feed + 0.6 % Humic acid + 100 ppm GA_3
T_4	Drone spray of MN mixture + 0.5 % Poly feed + 0.6 % Humic acid + 150 ppm GA_3
T_5	Drone spray of MN mixture (control)
T_6	Knapsack spray of MN mixture + 0.5 % Poly feed + 0.4 % Humic acid + 100 ppm GA_3
T_7	Knapsack spray of MN mixture + 0.5 % Poly feed + 0.4 % Humic acid + 150 ppm GA_3
T_8	Knapsack spray of MN mixture + 0.5 % Poly feed + 0.6 % Humic acid + 100 ppm GA_3
T_9	Knapsack spray of MN mixture + 0.5 % Poly feed + 0.6 % Humic acid + 150 ppm GA_3
T_{10}	Knapsack spray of MN mixture (control)

MN mixture – Micro Nutrient mixture

Poly feed – All 19:19:19 (N: P: K /kg)

GA_3- Gibberellic acid

Table 2. Technical parameters of the drone and knapsack sprayer.

Classifications	Parameters (Drone)	Parameters (Knapsack sprayer)
Dimension	1520*1520*590 mm	41.9*17.8*53.3 cm
Nozzle type	Flood jet	Hollow cone
Tank capacity	10 L	10 L
Spraying width	3.5 m	0.75 – 1.0 m
Spraying height	0.75 – 1 m	20-30 cm above the crop
No. of nozzles	4	1

Table 3. Different parameters were determined using specific method.

Parameters	Analysis method
Leaf greenness	SPAD meter
soluble protein content	Lowery's method (27)
Nitrate reductase activity	Sinha and Nicholas (28)
Total phenol content	Bray and Thorpe (29)
carotenoid content	Arnon (30)
Nitrogen, phosphorus and potassium content	Micro Kjeldahl (31) and Triacid method (32)
Fe and Zn	Digestion method described by (33)
Boron	Dry ashing method (34)

Results and Discussion

Effect of foliar application on growth and flowering parameters

The experimental findings revealed that foliar application of nutrients and growth regulators had significant impact on the growth and flowering characters of tuberose. Plots treated with drone spray of MN mixture, 0.5 % poly feed, 0.6 % humic acid and 150 ppm GA_3 (T_4) exhibited increased plant height (69.89 cm), leaf count (26.76) and leaf area index (1.92) at first spike emergence. It was statistically on par with knapsack spray of MN mixture + Poly feed 0.5 % + 0.6 % Humic acid + 150 ppm GA_3 (T_9). Similarly, T_4 resulted in early spike emergence (77.18 days), increased rachis length (36.87cm), spike length (99.22 cm) and number of florets per spike (43.39). However, control (T_{10}) had lower values on tuberose growth and flowering parameters (Table 4).

Micronutrients play vital roles in plant physiology. Iron is crucial for chlorophyll and thylakoid synthesis and serves as a cofactor for enzyme activation. Zinc improves nitrogen uptake and metabolism, carbonic anhydrase activity, tryptophan synthesis and stress tolerance. Boron enhances the wall structure, apical growth and sugar translocation. Micronutrient application has been shown to enhance growth and flowering in various flower crops such as gladiolus, chrysanthemum and marigold (4, 5). The optimal micronutrient application enhances tuberose flowering characteristics through foliar treatment with Fe, Zn and B (6). Similarly, the micronutrient application induces early flowering and increases floret length in tuberose (7). Additionally, the application of gibberellic acid accelerates internodal length and increases crop growth by promoting cell division and enlargement. Foliar spray of gibberellic acid enhances the growth of tuberose and increases rachis length by elongating internodal lengths (8). The foliar application of primary nutrients via poly feed promoted increased tuberose growth by enhancing nutrient availability during critical growth stages. The stimulatory effect of humic acid on stem growth is attributed to its influence on root H-ATPase activity and the distribution of nitrates across roots and stems, thereby altering the distribution of cytokinins, polyamines and abscisic acid. These findings are consistent with similar results observed in China aster (9). Moreover, drone application was found superior over knapsack sprayer, which mainly due to uniform droplet deposition with increased penetration led to efficient translocation of nutrients in plant system. The obtained results align with the outcomes of the experiment by (2, 10).

Effect of foliar application on yield and quality parameters of tuberose

Drone application of MN mixture + Poly feed 0.5 % + Humic acid 0.6 % + GA_3 at150 ppm was noticed with higher 100 floret weight (221.57 g), spike weight (126.89 cm) and yield/plot (28.90 kg). Similarly, it had improved quality attributes such as floret length (6.88 cm) and diameter (4.36 cm). Lower yield and flower quality was observed in control (Table 5).

Positive effects on yield and quality parameters resulted from foliar application of nutrients and plant growth promoters, leading to increased assimilate synthesis and efficient partitioning for flower growth. This led to elevated flower production and overall yield, as reported (11) in marigold and (12) in chrysanthemum. Humic acid, containing active phenolic groups, can inhibit peroxidase activity, prolonging the persistence of indole-3-acetic acid (IAA) in plants. This increased production of auxin and growth substances contributes to more floral bud production, consistent with findings in *Nicotiana plumbaginifolia* (13). Additionally, GA_3 enhances floret size by promoting metabolite translocation at the floret development site, potentially through cell elongation, thus increasing floret diameter in tuberose (14). Gibberellins are known for boosting the sink strength of actively growing parts of the gladiolus (15).

Table 4. Effect of different nutrient formulations on growth and flowering parameters of tuberose.

Traits/ Treatments	Plant height (cm)	Number of leaves	LAI	Days for first spike emergence	Spike length (cm)	Rachis length (cm)	Number of florets per spike
T_1	63.84	21.14	1.59	80.33	93.97	33.48	37.65
T_2	68.49	24.88	1.82	78.28	97.82	35.75	41.68
T_3	66.01	23.21	1.7	79.69	94.58	34.52	39.96
T_4	69.89	26.76	1.92	77.18	99.22	36.87	43.39
T_5	60.70	19.68	1.45	83.59	93.18	32.26	37.24
T_6	62.29	19.67	1.49	81.35	93.53	32.95	37.41
T_7	68.09	24.67	1.747	78.96	97.14	35.07	41.04
T_8	65.27	22.28	1.66	80.24	95.87	34.21	39.67
T_9	69.52	26.15	1.89	77.93	98.59	36.18	43.03
T_{10}	59.53	17.82	1.41	85.46	91.78	30.82	36.86
CD (0.05)	0.742	0.836	0.032	0.650	0.293	0.571	0.271
SE(d)	0.353	0.398	0.015	0.309	0.139	0.272	0.129

Table 5. Effect of different nutrient formulations on yield and quality parameters of tuberose.

Traits/ Treatments	Hundred floret weight (g)	Floret length (cm)	Floret diameter (cm)	Weight of spike (g)	Yield/plant (g)	Yield/plot (kg)
T_1	197.04	6.54	4.15	105.12	296.21	21.92
T_2	216.14	6.83	4.30	119.63	358.45	26.53
T_3	201.81	6.57	4.23	110.86	321.44	23.79
T_4	221.57	6.88	4.36	126.89	390.51	28.90
T_5	189.16	6.47	4.09	101.38	281.53	20.84
T_6	192.27	6.49	4.13	102.67	281.31	21.26
T_7	213.48	6.68	4.27	117.66	350.39	25.93
T_8	206.16	6.58	4.21	112.31	328.47	24.31
T_9	220.17	6.79	4.34	124.25	377.04	27.91
T_{10}	186.86	6.42	3.98	97.21	271.37	20.08
CD (0.05)	1.16	0.021	0.015	1.128	7.76	0.744
SE(d)	0.55	0.01	0.007	0.537	3.71	0.351

The increased yield observed with drone spraying, compared to manual application, is due to enhanced nutrient absorption. Turbulence from the propellers creates a downward airflow, causing leaves to flutter and flip, resulting in greater droplet deposition on active leaf sites. This leads to a more uniform distribution of finer droplets, facilitating increased penetration and efficient nutrient translocation compared to manual spraying. This combined effect enhances crop growth and yield, aligning with previous studies (16, 17).

Effect of foliar application on physiological parameters and nutrient composition of tuberose

Physiological parameters such as SPAD (Soil Plant Analysis Development) value (57.72), total soluble protein (136.55 mg/g), nitrate reductase activity (51.93 NO_2 $g^{-1}h^{-1}$), carotenoid (0.39 mg/g) and total phenol content (18.74 mg/ 100 g) were noticed higher in the treatment with MN mixture + Poly feed 0.5 % + 0.6 % Humic acid + 150 ppm GA_3 through drone. The control plot had lower values on physiological parameters (Table 6).

Chlorophyll content in leaves is crucial for photosynthesis, as it enables the conversion of solar energy into chemical energy within chloroplasts. Nitrogen and iron are essential for increasing chlorophyll content, with iron serving as a vital cofactor for enzymes involved in chlorophyll synthesis (18). Soluble proteins, which are indicative of heightened carboxylation during growth are essential for effective photosynthesis. Humic acid, rich in minerals, can elevate protein content in plants. The nitrate reductase enzyme catalyses the conversion of nitrate to nitrite, a critical step for amino acid synthesis. Its activity is often correlated with plant growth and yield, reflecting the plant's metabolic state (19). Enhanced nitrate reductase activity improves nitrogen use efficiency, boosting crop productivity. Additionally, humic acid increases leaf area by promoting intracellular metabolism and enhancing chlorophyll content (20).

Table 6. Effect of different nutrient formulations on physiological parameters of tuberose.

Traits/ Treatments	SPAD meter chlorophyll values 90 DAP	Total soluble protein (mg/g) at 90 DAP	Nitrate reductase activity (NO_2 $g^{-1}h^{-1}$)	Carotenoids (mg/g)	Total phenol content (mg/ 100 g) at 90 DAP
T_1	51.12	128.35	46.48	0.27	15.88
T_2	53.65	132.67	49.48	0.35	17.84
T_3	54.23	129.72	47.67	0.32	16.97
T_4	57.72	136.55	51.93	0.39	18.74
T_5	47.82	126.54	44.38	0.23	14.76
T_6	50.85	127.41	45.36	0.26	15.39
T_7	52.86	131.56	48.94	0.34	17.43
T_8	53.48	128.68	47.18	0.31	16.38
T_9	55.97	135.92	50.84	0.37	18.35
T_{10}	47.18	119.42	42.16	0.19	12.24
CD (0.05)	1.598	2.593	1.304	0.01	0.321
SE(d)	0.755	1.225	0.616	0.005	0.151

The nutrient analyses revealed that maximum content of macronutrients (N, P and K) and micronutrients (Fe, Zn and B) were found in plants applied with MN mixture + Poly feed 0.5 % + Humic acid 0.6 % + GA_3 at150 ppm through drone and followed by manual spraying (T_9). Lower nutrient content was noticed in control (Fig. 1 and Fig. 2). Increased nutrient content in leaves results from the interaction of a micronutrient mixture, which promotes mineral absorption and root growth, enhancing physiological processes and nutrient utilization. Similarly, humic materials positively impact nutrient uptake and plant growth (21). Additionally, drone application ensures uniform deposition of fine droplets, improving nutrient absorption in plants (2). Due to the labour shortage drones used for spraying of foliar nutrients at the critical stage of the crop to improve the yield and quality parameters (22). These findings align with studies of (23, 24) which highlight the advantages of drone spraying in terms of coverage uniformity and reduced chemical usage. As agricultural technology advances, drone applications present a promising solution for efficient and effective crop management, particularly in ornamental horticulture where precise nutrient management is crucial for optimal flower quality and yield.

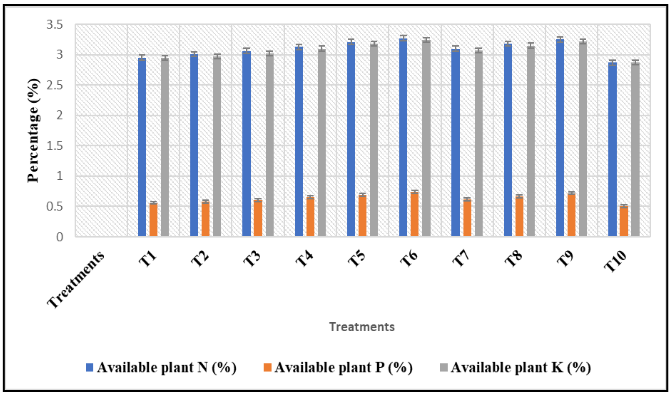

Fig. 1. Effect of different nutrient formulations on available macro nutrients % of tuberose leaves.

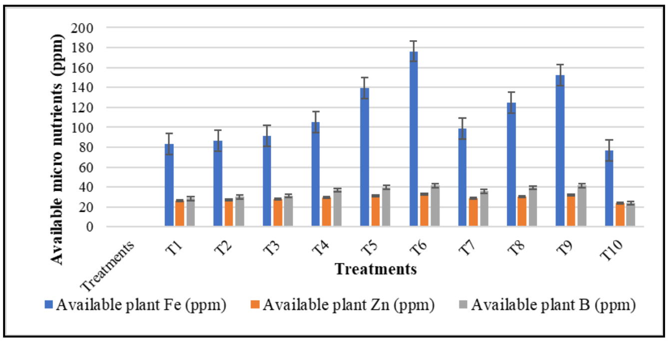

Fig. 2. Effect of different nutrient formulations on available micro nutrients (ppm) of tuberose leaves.

Multivariate analysis:

Principal Component Analysis (PCA) reduces complex datasets to uncorrelated principal components, capturing the most variance in the data (25). PCA was employed to examine the phenotypic diversity of different traits under drone and knapsack spray applications of various nutrient mixtures across 2 seasons. This statistical approach aimed to identify the primary plant attributes contributing to the observed variances within the population. Through PCA, our objective was to reveal patterns in the data that could elucidate the effects of different treatments on plant characteristics.

A biplot representation, displayed in (Fig. 3) was employed to visually explore the relationships among parameters and treatments. This graphical representation revealed significant differences among treatments, providing insights into the impact of different nutrient mixtures and application methods on the observed traits.

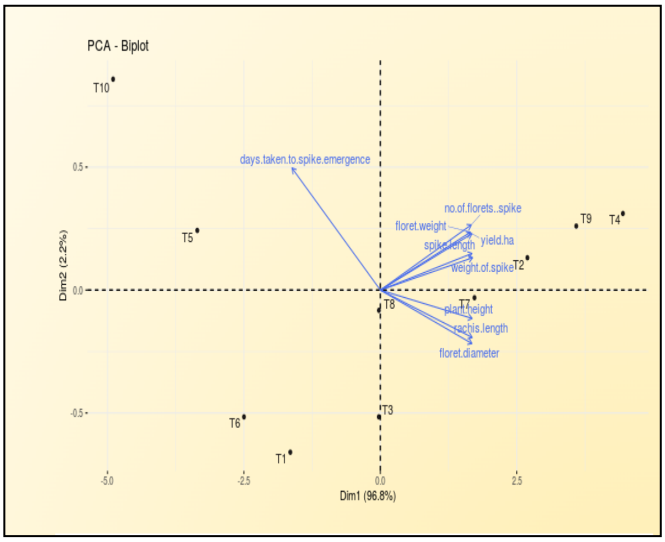

Fig. 3. Graph representing a PCA biplot.

Additionally, a correlation plot (Fig. 4) was examined to understand the relationships between variables and principal component groups. Notably, the duration of spike emergence exhibited negative correlations, while other growth and flowering parameters showed positive correlations with the PC groups. This suggests potential associations between certain variables and the predominant patterns of phenotypic diversity observed across treatments and seasons.

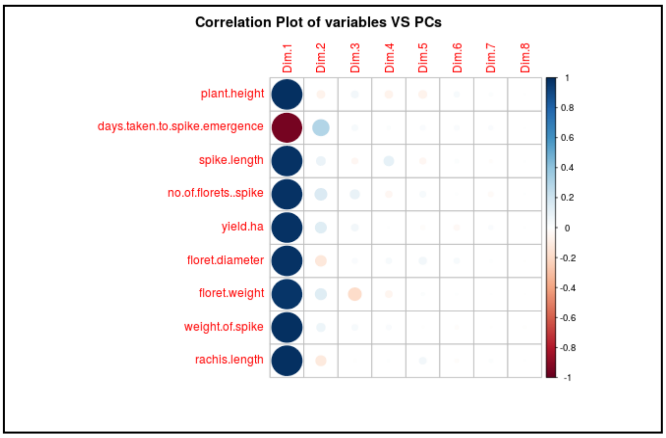

Fig. 4. A correlation plot between variables and PCs.

Eigen values, % of variation and % contribution of each variable

In the study, eigenvalues greater than 1 were observed in the principal component (PC_1) for tuberose cv Arka Prajwal with 8.708 (96.756 % of total divergence). The percentage of variation in relation with each principal component could be demonstrated by a screen plot, obtained by a graph between eigen values and principal component numbers (Table 7) (Fig. 5).

Table 7. Eigen values of different principal component.

PC	Eigenvalue	Percentage of variance	Cumulative percentage of variance
PC_1	8.708	96.756	96.756
PC_2	0.195	2.168	98.924
PC_3	0.052	0.578	99.502
PC_4	0.022	0.244	99.746
PC_5	0.016	0.175	99.921
PC_6	0.005	0.054	99.975
PC_7	0.002	0.024	99.999
PC_8	0	0.001	100
PC_9	0	0	100

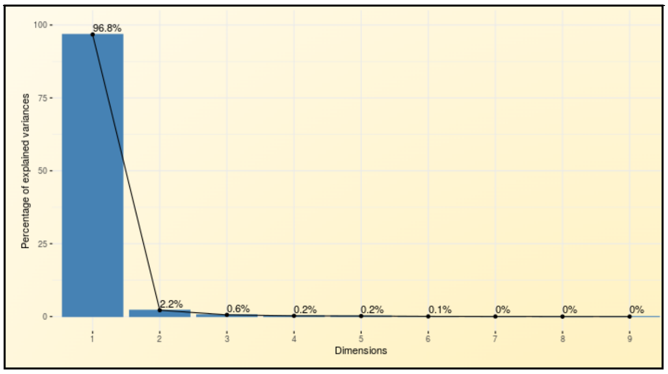

Fig. 5. Graph representing the percentage of variance in different PC.

Fig. 6. Foliar application of nutrient spray through drone in the research field.

The graph shows that in the first principal component (PC_1) had an eigenvalue of 8.708 (96.756 % of total divergence) in tuberose cv Arka Prajwal. Eigenvalues gradually decreased with increasing principal components. The maximum contribution to the variance was due to PC_1 followed by PC_2. The PC_1 showed maximum contribution of variables on principal components with parameters *viz.*, such as days taken for spike emergence, plant height, spike length, rachis length, floret weight and weight of spike as given (Fig. 3 and Fig. 5). These findings align with the principal component analyses of key traits in calla lily (26).

Conclusion

In conclusion, the study suggests that foliar application of various macro and micro nutrient combinations, alongside growth regulators through UAVs, leads to enhanced growth, flowering, yield, quality and leaf mineral concentrations in tuberose flowers. In essence, it highlights the potential of UAV technology to revolutionize agricultural practices, offering a more efficient and precise method for nutrient delivery and ultimately contributing to improved crop productivity and quality in tuberose cultivation.

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Authors' contributions

MA carried out the experiment, took observations and analysed the data. DK guided the research by formulating the research concept, helped in securing research funds and approved the final manuscript. RC contributed by developing the ideas, reviewed the manuscript and helped in procuring research grants. SP contributed by imposing the experiment, helped in editing, summarizing and revising the manuscript. MR helped in summarizing and revising the manuscript. VV helped in editing, summarizing and revising the manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

Ethical issues: None

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the author(s) not used AI tools and the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the publication.

References

1. https://www.indiastat.com/data/agriculture/tuberose-rajnigandha/data-year. 2023.
2. Nandhini P, Muthumanickam D, Pazhanivelan S, Kumaraperumal R, et al. Intercomparision of drone and conventional spraying nutrients on crop growth and yield in black gram. Int J of Plant and Soil Science. 2022;34(20):845-52. https://doi.org/10.9734/ijpss/2022/v34i2031231.
3. Kaniska K, Jagadeeswaran R, Kumaraperumal R, Ragunath KP, et al. Impact of drone spraying of nutrients on growth and yield of maize crop. International Journal of Environment and Climate Change. 2022;12(11):274-82. https://doi.org/10.9734/ijecc/2022/v12i1130972. .
4. Sharma UB, Khare RK. Effect of bio fertilizers and foliar spray of zinc under different levels of N, P on floral characteristics and economics of *Gladiolus grandiflorus*. Bhartiya Krishi Anusandhan Patrika. 2014;29(2):78-81.

5. Vanlalruati V, SS Sindhu, Prativa A, Gunjeet Kumar. Effect of micronutrients (Fe and Zn) on flowering and yield attributes of chrysanthemum (*Chrysanthemum morifolium*) cv. Mayur 5. Indian Journal of Agricultural Sciences. 2019;89(8):1282-86. https://doi.org/10.56093/ijas.v89i8.92846.

6. Mudassir S, Ahmad R, Anjum MA. Foliar application of micronutrients enhances growth, flowering, minerals absorption and postharvest life of tuberose (*Polianthes tuberosa* L.) in calcareous soil. J Hortic Sci Technol. 2021; 4:41-47. https://doi.org/10.46653/jhst2142041.

7. Borah N, Deka J, Deka NC, Barua IC, et al. Soil fertility and nutrient management in tuberose (*Polianthes tuberosa* L.) through substitution of chemical fertilizer with comlizer. Journal of Soil and Water Conservation. 2015;14 (3):248-54.

8. Ladhi DP, Raut VU, Thakare AA, Ingole AR, Bijewar AL. Effect of foliar spray of GA_3 and KNO_3 on growth and yield of tuberose. Journal of Pharmacognosy and Phytochemistry. 2020;9(6):2139-41.

9. Chaitra R, Patil VS. Integrated nutrient management studies in China aster (*Callistephus chinensis* (L.) Nees). Karnataka Journal of Agricultural Sciences. 2007;20(3):689.

10. Shi X, Yang C, Xi, W, Liang C, et al. Anti-drone system with multiple surveillance technologies: Architecture, implementation and challenges. IEEE Communications Magazine. 2018;56(4):68-74. https://doi.org/10.1109/MCOM.2018.1700430

11. Balakrishnan V, Jawaharlal M, Kumar TS, Ganga M. Response of micro-nutrients on flowering, yield and xanthophyll content in African marigold (*Tagetes erecta* Linn.). Journal of Ornamental Horticulture. 2007;10(3):153-56.

12. Ganga M, Jegadeeswari V, Padmadevi K, Jawaharlal M. Response of chrysanthemum cv Co. to the application of micronutrients. Journal of Ornamental Horticulture. 2008;11 (3):220-23.

13. Muscolo A, Felici M, Concheri G, Nardi S. Effect of earthworm humic substances on esterase and peroxidase activity during growth of leaf explants of *Nicotiana plumbaginifolia*. Biology and Fertility of Soils. 1993;15:127-31. https://doi.org/10.1007/BF00336430

14. Nilima Bhosale NB, Barad AV, Nilesh Bhosale NB. Effect of storage period and GA_3 soaking of bulbs on growth and flowering of tuberose (*Polianthes tuberosa* L.) cv. Double. 2014.

15. Rana P, Kumar J, Kumar M. Response of GA_3, plant spacing and planting depth on growth, flowering and corm production in gladiolus. Journal of Ornamental Horticulture. 2005;8(1):41- 44.

16. Martin D, Singh V, Latheef MA, Bagavathiannan M. Spray deposition on weeds (Palmer Amaranth and Morning glory) from a remotely piloted aerial application aystem and backpack sprayer. Drones. 2020;4(3):59. https://doi.org/10.3390/drones4030059.

17. Dayana K, Ramesh T, Avudaithai S, Sebastian SP, Rathika S. Foliar application of nutrients using agricultural drone on yield and quality of green gram. The Pharma Innovation Journal. 2021;69-72.

18. Engels C, Marschner H. Plant uptake and utilization of nitrogen. Nitrogen Fertilization in the Environment. 1995;41-81.

19. Srivastava HS. Regulation of nitrate reductase activity in higher plants. Phytochemistry. 1980;19(5):725-33. https://doi.org/10.1016/0031-9422(80)85100-4.

20. Nardi S, Pizzeghello D, Muscolo A, Vianello A. Physiological effects of humic substances on higher plants. Soil Biology and Biochemistry. 2002;34(11):1527-36. https://doi.org/10.1016/S0038-0717(02)00174-8.

21. Oktem A, Celik A, Oktem AG. Effect of humic acid seed treatment on yield and some yield characteristic of corn plant (*Zea mays* L. *indentata*). Journal of Agricultural, Food and Environmental Sciences, JAFES. 2018;72(2):142-47. https://doi.org/10.55302/JAFES18722142o

22. Dayana K, Ramesh T, Avudaithai S, Sebastian SP, Rathika S. Feasibility of using drone for foliar spraying of nutrients in irrigated green gram (*Vigna radiata* L.). Ecology, Environment and Conservation. 2022;28:589-94. https://doi.org/10.53550/EEC.2022.v28i01s.064

23. Qin W, Xue X, Zhang S, Gu W, Wang B. Droplet deposition and efficiency of fungicides sprayed with small UAV against wheat powdery mildew. International Journal of Agricultural and Biological Engineering. 2018;11(2):27-32. https://doi.org/10.25165/j.ijabe.20181102.3157

24. Giles D, Billing R. Deployment and performance of a UAV for crop spraying. Chemical Engineering Transactions. 2015;44:307-12.

25. Parker ML, Reeves JN, Matzeu GA, Buisson DJ, Fabian AC. Using principal component analysis to understand the variability of PDS 456. Monthly Notices of the Royal Astronomical Society. 2018;474(1):108-14. https://doi.org/10.1093/mnras/stx2803

26. Chandel A, Thakur M, Rakwal A, Chauhan S, Bhargava B. Exogenous applications of gibberellic acid modulate the growth, flowering and longevity of calla lily. Heliyon. 2023;9(5). https://doi.org/10.1016/j.heliyon.2023.e16319

27. Lowry O, Rosebrough N, Farr A, Randall R. Protein measurement with the Folin phenol reagent. Journal of Biological Chemistry. 1951;193:265-75. https://doi.org/10.1016/S0021-9258(19)52451-6

28. Sinha SK, Nicholas JD. Nitrate reductase in Paleg, L.G. and D. Aspinall (Eds.). The physiology and biochemistry of drought resistance in plants. Academic Press, Australia. 1981;145-68.

29. Bray HG, Thorpe W. Analysis of phenolic compounds of interest in metabolism. Methods of Biochemical Analysis. 1954;27-52. https://doi.org/10.1002/9780470110171.ch2

30. Arnon DI. Copper enzymes in isolated chloroplasts polyphenol oxidase in *Beta vulgaris*. Plant Physiol. 1949;24:1-15. https://doi.org/10.1104/pp.24.1.1.

31. Humphries EC. Mineral components and ash analysis. Moderne Methoden der Pflanzenanalyse/Modern Methods of Plant Analysis: Erster Band/Volume I. 1956;468-502. https://doi.org/10.1007/978-3-662-25300-7_17

32. Jackson ML. Soil chemical analysis. Second edition. Prentice Hall of India, New Delhi. 1973;498.

33. Rashid A, Rafique E. Zinc requirement of corn grown on two calcareous soils of Pakistan. Zeitschrift fur Pflanzenernahrung und Bodenkunde. 1986;152(5):405-08. https://doi.org/10.1002/jpln.19891520501.

34. Bingham FT. Boron. Methods of Soil Analysis: Part 2 Chemical and Microbiological Properties. 1983;9:431-47. https://doi.org/10.2134/agronmonogr9.2.2ed.c25