Journal of Applied Horticulture, 26(3): 387-391, 2024
https://doi.org/10.37855/jah.2024.v26i03.74
Journal of Applied Horticulture
ISSN: 0972-1045

Optimization of manuring and fertigation in tuberose hybrid Arka Prajwal

P.M. Hasna*, M. Rafeekher, I. Priyakumari, C.R. Reshmi, N. Leno and P.P. Gopinath

Department. of Floriculture and Landscaping, College of Agriculture, Vellayani, Kerala, India.
**E-mail: hasna-2021-22-002@student.kau.in*

Abstract

A study was carried out in March 2023-January 2024 at the experimental field of the Department of Floriculture and Landscaping, College of Agriculture, Vellayani, Kerala, India, for the standardization of manuring, irrigation and fertilizer level in tuberose hybrid, Arka Prajwal under drip irrigation and fertigation. The experimental layout was carried out in a split-split plot design with four replications of 16 treatment combinations. Main plot consisted of manures, the subplot consisted of irrigation levels and the sub-sub plot consisted of fertilizer levels. Surface irrigation and manual fertilizer application were treated as control. The synergistic effect of poultry manuring, drip irrigation, and fertigation proved outstanding regarding their individual effects and control. The treatment of poultry manure along with drip fertigation of ½ N and full K at IW/CPE 0.8, recorded the highest plant height (65.62 cm) with a greater number of leaves (18.81) at the spike initiation stage. The same treatment noticed the longest spike (104.70 cm) along with greater number of florets spike^{-1} (47.55). However, greatest yield (89.67 g) was observed in the poultry manure treatment along with drip irrigation at IW/CPE 1 and 100% recommended dose of N and K through fertigation followed by poultry manure along with fertigation of ½ N full P and full K of recommended dose at IW/CPE 0.8. Considering overall performance, the application of poultry manure along with fertigation of ½ N and total K of recommended dose at deficit irrigation proved to be highly beneficial for growth and yield improvement in tuberose hybrid Arka Prajwal.

Key words: Tuberose, Arka Prajwal, poultry manuring, drip fertigation, surface irrigation

Introduction

Tuberose (*Agave amica* (Medik.)) from the Amaryllidaceae family is a key tropical ornamental bulbous flowering plant cultivated commercially across various Indian states. It holds a significant position among India's commercial flowers due to its versatility as a cut flower, loose flower and its potential use in the perfume industry (Singh *et al*., 2024). The flowers retain their freshness for a long time, tolerate long-distance shipping, and occupy a significant role in the flower market. There is a strong demand for loose flowers to make garlands, floral ornaments and for use in religious ceremonies and special events. The long-lasting spikes of these flowers are excellent for use as cut flowers in table arrangements, vases, and bouquets. Due to their strong aroma, the flesh-white, tubular flowers are grown on a large scale to extract their valuable natural oil. This aromatic oil of the flowers is in high demand within the essential oil industry and fetches a significant price in the global market (Hasna and Manjusha, 2021). West Bengal is the leading producer of cut tuberose, with 86.71 metric tonnes of production; Tamil Nadu is the leading producer of loose tuberose, with 67.54 metric tonnes of production (Indiastat, 2022).

As an exhaustive plant, tuberose needs a significant quantity of organic and inorganic fertilizers for optimal flower yield and quality (Rajaselvam *et al.,* 2024). Combining organic and inorganic fertilizers can be feasible and advantageous, enhancing both flower yield and quality. Organic substances are beneficial for stimulating growth and improving the production of premium-quality flower spikes. Nitrogen, phosphorus, and potassium are critical nutrients for maximizing flower quantity and quality traits. Effective nutrient management is pivotal in realizing a crop's inherent yield potential.

Maintaining the right balance of water and nutrients is the key to optimizing yields and ensuring quality crop production. The application method of fertilizers is crucial for enhancing nutrient efficiency. Dissolving fertilizers in irrigation water, a technique called fertigation, is the most efficient method, especially when using drip irrigation. This method of fertigation allows for precise timing and even distribution of water and nutrients, meeting the nutrient needs of crops. It also results in considerable reductions in fertilizer usage and minimizes leaching losses. (Mmolawa and Or, 2000)). Water scarcity is anticipated to become a significant challenge shortly. Under-water scarcity conditions, proper irrigation scheduling is seen as essential for achieving better water use efficiency in irrigation systems (Panigrahi *et al.,* 2011). Drip irrigation has emerged as the most effective pressurized irrigation method, surpassing others due to its ability to deliver water and nutrients precisely at the root zone (Vijayakumar *et al.,* 2010). Implementing drip fertigation has been shown to triple the yields of horticultural crops using the same amounts of water and nutrients.

Additionally, it has been found to enhance the quality of the produce, enabling growers to secure better prices. Drip-fertigation also results in 40-70% water savings and fertilizer savings of 30-50% (Jeyabhaskaran *et al.,* 2021). It dramatically lowers environmental pollution risk, enhances plant resistance, and help to prevent soil degradation (Hu *et al.,* 2021). Plastic mulch shields against moisture; this covering separates the soil from its surroundings. It regulates soil temperature and the microclimate near plant roots, increasing crop productivity and development. It also helps to retain soil moisture and suppress weed growth around plants.

Hence, the present study was carried out to study the influence of different manures and levels of drip irrigation on the growth and yield of tuberose and to standardize the fertigation levels for yield improvement of tuberose hybrid ‘Arka Prajwal’.

Materials and methods

A field experiment was conducted at the Department of Floriculture and Landscaping, College of Agriculture, Vellayani, Thiruvananthapuram, Kerala, India, from March 2023-January 2024 to elucidate the influence of manuring and drip fertigation on growth, flowering and yield of tuberose hybrid Arka Prajwal. The soil of the experimental field was sandy clay loam in texture having pH of 5.50, electrical conductivity (EC) 0.05 dS m^{-1}, organic carbon 1.6%, available nitrogen 263.4 kg ha^{-1}, available phosphorous 21.8 kg ha^{-1}, available potassium 198 kg ha^{-1}. The weather parameters of the experimental site during the cropping period are 35°C maximum temperature,18.3°C minimum temperature and 90% relative humidity.

The experiment used tuberose hybrid Arka Prajwal released from the Indian Institute of Horticultural Research (IIHR). The experiment consisted of 16 treatments replicated four times in a Split-split plot design. Main plot consisted of manuring (M_1=FYM, M_2=Poultry manure), subplot consisted of irrigation level (I_1= IW/CPE 1, I_2= IW/CPE 0.8) and sub subplot consisted of fertilizer level (F_1:75% RDF, F_2:100% RDF, F_3:125% RDF, F_4:1/2 N: Full P: Full K of 100% RDF). Beds of 1 m width and convenient length were prepared with two drip laterals bed^{-1}, one lateral line for two rows of tuberose and one emitter (8l ph) for two plants, under mulched condition using 30 µ silver black coloured black plastic mulch sheet. Thirty-six plants were maintained $plot^{-1}$ at a spacing of 20x25 cm. Manure used as FYM @30 t ha^{-1} and poultry manure were calculated based on nitrogen equivalence. The soil test-based recommendation was determined following the KAU POP guidelines (KAU, 2016) and was based on an NPK ratio of 100:50:50 kg per hectare. Fertilizer injection pump method was used for fertigation application. The full dose of phosphorous was applied at the time of bed preparation. Urea and sulphate of potash were used as fertilizer sources for fertigation. Fertigation was carried out as twelve equal splits at weekly intervals starting one month after planting. The depth of irrigation was 3 cm. The control plot was laid out based on the conventional farming practice. Different treatments are represented in Table 1.

Table 1. Treatment combination used for the study

Treatment	Particulars
T_0	Control
T_1: $M_1I_1F_1$	FYM, IW/CPE = 1, 75% N & K fertigation
T_2: $M_1I_1F_2$	FYM, IW/CPE = 1, 100% N & K fertigation
T_3: $M_1I_1F_3$	FYM, IW/CPE = 1, 125% N & K fertigation
T_4: $M_1I_1F_4$	FYM, IW/CPE = 1, 1/2 N, Full K fertigation
T_5: $M_1I_2F_1$	FYM, IW/CPE = 0.8, 75% N & K fertigation
T_6: $M_1I_2F_2$	FYM, IW/CPE = 0.8, 100% N & K fertigation
T_7: $M_1I_2F_3$	FYM, IW/CPE = 0.8, 125% N & K fertigation
T_8: $M_1I_2F_4$	FYM, IW/CPE = 0.8, 1/2 N, Full K fertigation
T_9: $M_2I_1F_1$	Poultry manure, IW/CPE = 1, 75% N & K fertigation
T_{10}: $M_2I_1F_2$	Poultry manure, IW/CPE = 1, 100% N & K fertigation
T_{11}: $M_2I_1F_3$	Poultry manure, IW/CPE = 1, 125% N & K fertigation
T_{12}: $M_2I_1F_4$	Poultry manure, IW/CPE = 1, 1/2 N, Full K fertigation
T_{13}: $M_2I_2F_1$	Poultry manure, IW/CPE = 0.8, 75% N & K fertigation
T_{14}: $M_2I_2F_2$	Poultry manure, IW/CPE = 0.8, 100% N & K fertigation
T_{15}: $M_2I_2F_3$	Poultry manure, IW/CPE = 0.8, 125% N & K fertigation
T_{16}: $M_2I_2F_4$	Poultry manure, IW/CPE = 0.8, 1/2 N, Full K fertigation

The effect of manuring, irrigation level and drip fertigation on growth, flowering and yield was studied in the experiment. Observations were taken from five randomly selected plants from each replication, and averages were taken.

Plant height was measured from the base to the tip using a meter scale and recorded in centimeters. The number of fully expanded leaves per hill was counted. Days to spike emergence were recorded from the planting date. Spike length was measured from ground level to the top floret and recorded in centimeters. The number of florets per spike was counted, and the loose flower yield was recorded by weighing florets from each harvest in grams. Fresh weight of each harvested spike was also measured and expressed in grams.

Statistical analysis: The data was analyzed statistically using R-Studio software and applying the Fisher-LSD techniques.

Results and discussion

The responses of various treatments on plant characters were recorded and analyzed statistically. The salient findings are discussed below. The results are presented in Table 2.

Main effect: Poultry manuring recorded the highest plant height (54.53 cm) and a more significant number of leaves (13.96). Improved vegetative growth by applying poultry manure might be due to a higher concentration of essential nutrients, faster mineralization and a more balanced C:N ratio. Sankar (2008) also reported improved vegetative characteristics in tuberose by applying poultry manure. Poultry manure more readily supplies phosphorus to plants than other organic sources (Garg and Bahl, 2008). Among all the animal manures, poultry manure recorded the highest content of NPK (Priya *et al.,* 2022; Halder *et al.,* 2023).

Poultry manuring recorded minimum days to spike emergence (88.24 days), highest spike length (99.51 cm), number of florets $spike^{-1}$ (41.68) and lose flower yield (72.75 g). Early spike emergence in treatment involving manuring with poultry might be due to increased availability of nutrients, especially nitrogen, from this organic source. Translocation of phytohormones to shoot may be promoted by a balanced nitrogen supply, which may result in early spike emergence (Bankar and Mukhopadhyay, 1990). Poultry manuring recorded highest fresh weight of spike (121.53 g). Superior spike quality under poultry manuring might be due to better plant growth by increased uptake of nutrients and the ready supply of photosynthates from leaves to flowering as influenced by growth hormones this manure produces (Sivakumar *et al.,* 2005). Srivastava *et al.* (2014 reported that poultry manure is an ample nitrogen source and releases nutrients slowly for a prolonged period.

Response of various levels of drip irrigation in tuberose showed that irrigation at IW/CPE=0.8 recorded the highest values for plant height (53.72) and number of leaves (14.40). These results indicated that optimal irrigation scheduling in the important growth stages is necessary for increasing the vegetative

Table 2. Effects of manures, irrigation levels, fertilizer levels and their interaction effects on plant characteristics of tuberose

	Plant height (cm)	No. of leaves	Days to spike emergence	Spike length (cm)	No. of florets per spike	Loose flower yield (g)	Fresh weight of spike (g)
Manures							
M_1	50.36^{b}	12.24^{b}	99.80^{a}	93.33^{b}	39.92^{a}	56.06^{b}	84.41^{b}
M_2	54.53^{a}	13.96^{a}	88.24^{b}	99.51^{a}	41.68^{a}	72.75^{a}	121.53^{a}
SEm±	0.44	0.38	0.59	0.59	0.58	0.55	3.81
CD (P=0.05)	1.96	1.70	2.68	2.67	2.60	2.48	17.10
Irrigation levels							
I_1	51.17^{b}	11.81^{b}	96.64^{a}	95.86^{b}	40.45^{a}	64.67^{a}	100.76^{a}
I_2	53.72^{a}	14.40^{a}	91.40^{b}	96.98^{a}	41.15^{a}	64.14^{a}	105.19^{a}
SEm±	0.48	0.24	0.66	0.13	0.83	0.75	1.37
CD (P=0.05)	1.67	0.84	2.29	0.45	2.87	2.59	4.74
Fertilizer levels							
F1	53.41^{ab}	12.42^{b}	93.56^{b}	97.46^{a}	38.29^{c}	63.02^{bc}	101.00^{ab}
F2	51.54^{bc}	12.72^{b}	95.98^{ab}	97.64^{a}	40.66^{b}	69.48^{a}	108.54^{a}
F3	50.38^{c}	12.62^{b}	96.48^{a}	94.46^{b}	42.95^{a}	59.27^{c}	105.71^{a}
F4	54.45^{a}	14.64^{a}	90.07^{c}	96.13^{ab}	41.30^{ab}	65.84^{ab}	96.63^{b}
SEm±	0.96	0.39	1.01	0.81	0.60	1.75	2.78
CD (P=0.05)	2.76	1.12	2.90	2.31	1.71	5.01	7.99
M×I Interaction							
M_1I_1	50.92^{b}	11.75^{b}	103.23^{a}	94.25^{c}	40.55^{a}	54.17^{d}	80.07^{c}
M_1I_2	49.80^{b}	12.73^{b}	96.36^{b}	92.42^{d}	39.29^{a}	57.95^{c}	88.75^{b}
M_2I_1	51.42^{b}	11.86^{b}	90.05^{c}	97.48^{b}	40.35^{a}	75.17^{a}	121.44^{a}
M_2I_2	57.63^{a}	16.06^{a}	86.44^{d}	101.54^{a}	43.01^{a}	70.32^{b}	121.62^{a}
SEm±	0.68	0.34	0.94	0.18	1.17	1.06	1.94
CD (P=0.05)	2.36	1.19	3.24	0.63	4.05	3.67	6.70
M×F Interaction							
M_1F_1	50.59^{cd}	11.78^{cd}	100.00^{b}	50.59^{cd}	36.73^{d}	51.44^{e}	84.12^{c}
M_1F_2	49.34^{d}	11.16^{d}	104.72^{a}	49.34^{d}	40.15^{bc}	58.03^{cde}	95.51^{b}
M_1F_3	51.64^{cd}	13.19^{bc}	103.75^{ab}	51.64^{cd}	43.45^{a}	54.49^{de}	85.71^{bc}
M_1F_4	49.86^{cd}	12.84^{bc}	90.73^{c}	49.86^{cd}	39.36^{c}	60.28^{cd}	72.29^{d}
M_2F_1	56.22^{ab}	13.06^{bc}	87.12^{c}	56.22^{ab}	39.85^{c}	74.61^{ab}	117.88^{a}
M_2F_2	53.74^{bc}	14.28^{b}	87.23^{c}	53.73^{bc}	41.18^{abc}	80.93^{a}	121.58^{a}
M_2F_3	49.13^{d}	12.06^{cd}	89.21^{c}	49.13^{d}	42.45^{ab}	64.05^{c}	125.71^{a}
M_2F_4	59.03^{a}	16.44^{a}	89.41^{c}	59.03^{a}	43.25^{a}	71.40^{b}	120.98^{a}
SEm±	1.36	0.55	1.43	1.14	0.84	2.47	3.94
CD (P=0.05)	3.90	1.58	4.10	3.27	2.42	7.09	11.30
I×F Interaction							
I_1F_1	54.66^{b}	11.44^{c}	95.50^{bc}	98.90^{a}	39.05^{d}	72.98^{a}	98.83^{ab}
I_1F_2	51.23^{bc}	11.44^{c}	100.70^{a}	98.18^{a}	41.62^{bc}	72.78^{a}	107.89^{a}
I_1F_3	48.83^{c}	11.25^{c}	99.52^{ab}	92.73^{c}	42.76^{ab}	53.79^{c}	106.28^{a}
I_1F_4	49.97^{c}	13.09^{b}	90.84^{de}	93.65^{bc}	38.37^{d}	59.13^{bc}	90.03^{b}
I_2F_1	52.16^{bc}	13.41^{b}	91.62^{cde}	96.02^{ab}	37.53^{d}	53.07^{c}	103.17^{a}
I_2F_2	51.84^{bc}	14.00^{b}	91.25^{de}	97.10^{a}	39.70^{cd}	66.17^{ab}	109.20^{a}
I_2F_3	51.94^{bc}	14.00^{b}	93.44^{cd}	96.20^{ab}	43.14^{ab}	64.75^{b}	105.15^{a}
I_2F_4	58.92^{a}	16.19^{a}	89.29^{e}	98.60^{a}	44.23^{a}	72.55^{a}	103.23^{a}
SEm±	1.36	0.55	1.43	1.14	0.84	2.47	3.94
CD (P=0.05)	3.90	1.58	4.10	3.27	2.42	7.09	11.30

characteristics. The lowest level of irrigation recorded the earliest spike emergence at 91.40 days and produced the longest spike, measuring 96.98 cm. Irrigation levels did not affect loose flower yield, number of florets spike^{-1} and fresh weight of spike. Optimal irrigation at spike development might have resulted in increased spike quality.

Response of various fertigation levels in tuberose showed that among the various levels of fertigation 1/2 N, Full K of 100% recommended dose through fertigation (F_4) produced the highest plant height and number of leaves. Minimum days to spike emergence (90.07 days) was observed in treatment F_4. Highest spike length was recorded in F_2 (97.64 cm), which was on par with F_1 and F_4. A greater number of florets spike^{-1} was observed in F_3 (42.95), which was on par with F_4. The highest yield for loose flowers were recorded in F_2 (69.48 g), which was on par with F_4. F_2 (108.54 g) recorded the highest fresh weight of the spike, which was on par with F_3 (105.71 g) and F_1 (101.00 g).

The possible reason for the better growth parameters can be attributed to the better solubility and availability of water-soluble fertilizers at the rhizosphere with reduced nutrient losses by leaching and efficient use of nutrients through fertigation (Paul *et al.,* 1992). Similar results were given by Sujatha *et al.* (2002) in gerbera and Munikrishnappa *et al.* (2002) in tuberose. Increased availability of nutrients through fertigation near the root zone with minimum loss due to leaching during spike development might have contributed to improved spike quality (Munikrishnappa *et al.,* 2002).

M x I interaction: The combined effect of manures and drip irrigation significantly affected plant characters. Poultry manuring, along with IW/CPE= 0.8 (M_2I_2) recorded higher plant height and number of leaves. Early emergence of the spike (86.44 days), longest spike (101.54 cm) with a greater number of florets (43.01) and spike weight (121.62 g) was recorded in M_2I_2. Loose flower yield recorded highest in M_2I_1 (75.17 g).

Micro irrigation by a drip system helps achieve efficient water use by frequent application of water in and around the root zone, thereby enhancing crop yield. With its high water use efficiency, micro-irrigation has the potential to save water compared to conventional irrigation methods (Patel, 2017). Mulched drip irrigation effectively maintains moderate soil matric potential, manages weeds, and promotes higher crop yields (Burt and Isbell 2005). Selim *et al.* (2013) suggested that issues related to salinity can be effectively managed with mulched drip irrigation due to controlled leaching.

M x F interaction: Organic manuring and drip fertigation of water-soluble fertilizers significantly affect plant characteristics. M_2F_4 recorded the highest plant height (59.03 cm) and number of leaves (16.44). Minimum days to spike emergence was noticed in M_2F_1, which was on par with M_2F_2, M_2F_3 and M_2F_4. M_2F_4 recorded the longest spike (59.03 cm). M_1F_3 recorded more florets spike^{-1} (43.45), which was on par with M_2F_4 (43.25). Loose flower yield was highest in M_2F_2 (80.93 g) followed by M_2F_4 (71.40). M_2F_3 (125.71 g) recorded a greater fresh weight of spike, which was on par with M_2F_2, M_2F_4 and M_2F_1 (121.58 g, 120.98 g and 117.88 g, respectively).

Integrated use of organic manures and chemical fertilizers improves soil health, enhancing crop growth and yield. Application of organic manures increases the population of beneficial microbes, improves the physio-chemical properties of the soil, and increases the nutrient availability through mineralization (Reddy and Swamy, 2000). Application of inorganic fertilizers along with poultry might have contributed to faster decomposition of organic manure by microorganisms, thereby greater availability of nutrients, especially nitrogen, resulting in higher growth rate (Sivakumar *et al.,* 2005). According to Okoli and Nweke (2015), poultry manure ameliorates the toxic compounds produced by chemical fertilizers. Integrating organic and inorganic nutrient sources is becoming more popular as a strategy to enhance nutrient use efficiency by aligning soil nutrient availability with crop needs (Graham *et al.,* 2017).

I x F interaction: Drip fertigation significantly affected tuberose's growth and floral parameters. I_2F_4 recorded the highest plant (58.92 cm) with more leaves (16.19). Early spike emergence (89.29 days) was found in treatment I_2F_4. Treatment I_1F_1 observed the longest spike (98.9 cm) followed by I_2F_4 (98.60 cm). I_2F_4 recorded a greater number of florets spike^{-1} (44.23). I_1F_1 (72.98 g) recorded the highest yield, and it was on par with I_1F_2 and I_2F_4 (72.78 and 72.55 g, respectively).

Since drip irrigation at regular intervals provides constant moisture to soil, roots will remain active longer. Absorption and translocation of nutrients increase at a consistent moisture regime (Mishra *et al.,* 2008). Frequent water-soluble fertilizers through drip systems will increase plant nutrient uptake, enhancing plant growth (Kabariel and Kannan, 2015). The optimal application of fertilizers through fertigation ensures that crop nutrient demands are met at various growth stages with minimal leaching beyond the root zone. This boosts overall crop growth, resulting in maximum PAR absorption, an increased rate of photosynthesis, and more significant dry matter accumulation. Efficient translocation of photosynthates to the reproductive parts ultimately yields a higher yield (Kharde *et al.,* 2017).

M x I x F interaction: Results revealed that the combined effect of poultry manuring, drip irrigation and fertigation proved superior to their individual effects. Among different treatment combinations, poultry manuring along with irrigation at IW/CPE=0.8 and 1/2 N, Full K of 100% recommended dose through fertigation ($M_2I_2F_4$) recorded the highest values for plant height (65.62 cm) and number of leaves (18.81) at spike initiation stage. Early spike emergence (84.56 days) was noticed in $M_2I_2F_2$, and it was on par with $M_2I_1F_1$, $M_2I_2F_3$, $M_2I_2F_4$, $M_2I_2F_1$, $M_2I_1F_2$ and $M_1I_1F_4$. A greater spike length was recorded in $M_2I_2F_4$ (104.70 cm), which is on par with $M_2I_1F_3$, $M_2I_2F_1$ and $M_2I_2F_2$. The number of florets spike-1 was recorded as the highest in $M_2I_2F_4$ (47.55). The greater yield was observed in $M_2I_2F_2$ (89.67 g) followed by $M_2I_1F_1$ and $M_2I_2F_4$. Among the interaction effects, $M_2I_1F_3$ recorded the highest fresh weight of spike (135.12 g).

The interaction effect showed that tuberose productivity and quality could be greatly improved by maintaining optimal soil moisture through irrigation scheduling according to crop water needs, combined with adequate and timely nutrient supply

Table 2. continued (M × I × F Interaction)

Interaction	Plant height (cm)	No. of leaves	Days to spike emergence	Spike length (cm)	No. of florets per spike	Loose flower yield (g)	Fresh weight of spike (g)
$M_1I_1F_1$	52.87^{bcd}	12.00^{defg}	105.00^{bc}	101.02^{ab}	37.20^{gh}	61.12^{ef}	81.41^{ef}
$M_1I_1F_2$	50.91^{cd}	10.06^{gh}	111.50^{a}	99.35^{bc}	41.95^{bcd}	55.90^{ef}	100.52^{cd}
$M_1I_1F_3$	52.41^{bcd}	12.81^{cdef}	106.75^{ab}	84.75^{f}	45.27^{ab}	44.57^{g}	77.42^{f}
$M_1I_1F_4$	47.50^{de}	12.12^{defg}	89.69^{fghi}	91.85^{e}	37.80^{fgh}	55.06^{f}	60.92^{g}
$M_1I_2F_1$	48.31^{de}	11.56^{efgh}	95.00^{def}	91.52^{e}	36.26^{h}	41.75^{g}	86.83^{def}
$M_1I_2F_2$	47.78^{de}	12.25^{cdefg}	97.94^{de}	92.80^{de}	38.35^{efgh}	60.15^{ef}	90.50^{def}
$M_1I_2F_3$	50.87^{cd}	13.56^{bcde}	100.75^{cd}	92.85^{de}	41.62^{cde}	64.40^{def}	94.00^{de}
$M_1I_2F_4$	52.22^{bcd}	13.56^{bcde}	91.77^{fgh}	92.50^{de}	40.91^{def}	65.50^{de}	83.67^{ef}
$M_2I_1F_1$	56.44^{b}	10.87^{fgh}	86.00^{hi}	96.77^{bcd}	40.90^{def}	84.82^{ab}	116.25^{bc}
$M_2I_1F_2$	51.56^{bcd}	12.81^{cdef}	89.90^{fghi}	97.00^{bcd}	41.30^{cde}	89.67^{a}	115.25^{bc}
$M_2I_1F_3$	45.25^{e}	9.69^{h}	92.30^{efg}	100.70 ^{ab}	40.25^{defg}	63.00^{def}	135.12 ^{a}
$M_2I_1F_4$	52.44^{bcd}	14.06^{bcd}	92.00^{fg}	95.45^{cde}	38.95^{defgh}	63.20^{def}	119.15 ^{ab}
$M_2I_2F_1$	56.00^{bc}	15.25^{b}	88.25^{ghi}	100.52^{ab}	38.80^{defgh}	64.40^{def}	119.50^{ab}
$M_2I_2F_2$	55.91^{bc}	15.75^{b}	84.56^{i}	101.40^{ab}	41.05^{def}	72.20^{cd}	127.90^{ab}
$M_2I_2F_3$	53.00^{bcd}	14.44^{bc}	86.12^{hi}	99.55^{bc}	44.65^{abc}	65.10^{de}	116.30^{bc}
$M_2I_2F_4$	65.62^{a}	18.81^{a}	86.81^{ghi}	104.70^{a}	47.55^{a}	79.60^{bc}	122.80^{ab}
SEm±	1.92	0.78	2.02	1.61	1.19	3.50	5.57
CD (P=0.05)	5.51	2.23	5.80	4.63	3.40	10.02	15.98

*Treatment means having similar alphabets in superscript, do not differ significantly

via fertigation of water-soluble fertilizers (Kumawat *et al.,* 2024). The synergy between water and nutrients led to improved plant establishment, vegetative growth, photosynthesis, spike emergence, and the flowering process, ultimately boosting flower yields (Sharma *et al.,* 2024). Similar findings were reported by Kapoor *et al.,* 2022 in vegetable crops. Thentu *et al.* (2015) also reported the combined effect of drip irrigation and integrated nitrogen management in gladiolus. Drip fertigation can provide identical or even higher yield than traditional methods of irrigation by increasing water productivity and nitrogen use efficiency (Li *et al.,* 2021).

Poultry manuring, along with drip fertigation of ½ N and full K at IW/ CPE 0.8, was the best for growth and floral characteristics of tuberose hybrid Arka Prajwal. The synergistic effect of organic manuring, drip irrigation, and fertigation with water-soluble fertilizers paved the way for the plants' effective and efficient utilization of water and nutrients, thereby facilitating better plant growth.

Acknowledgements

The study formed as a part of the Ph.D. (Hort) programme of the first author and financial support from Kerala Agricultural University is gratefully acknowledged.

References

Bankar, G.J. and A. Mukhopadhyay, 1990. Response of *Polianthes tuberosa* L *cv.* Single to high doses of NPK. *S. Indian Hortic.*, 33(3): 214–216.

Burt, C.M. and B. Isbell, 2005. Leaching of accumulated soil salinity under drip irrigation. *Transactions of the ASAE*, 48: 2115–21.

Garg, S. and G.S. Bahl, 2008. Phosphorus availability to maize as influenced by organic manures and fertilizer P associated phosphatase activity in soils. *Bioresour. Technol.,* 99: 5773–5777.

Graham, R.F., S.E. Wortman and C.M. Pittelkow, 2017. Comparison of organic and integrated nutrient management strategies for reducing soil N_2O emissions, *Sustainability,* 9(4): 1-14.

Halder, R.K., S.D. Gupto, A.S. Antu, M.A. Fariha, J. Deb and M.K. Rahman, 2023. Influence of different organic manures on the growth and yield of marigold (*Tagetes erecta* L.) plants, *J. Biodivers. Conserv. Bioresour. Manag.,* 9(2): 39-48.

Hasna, P.M. and M.A.V. Manjusha, 2021. Varietal evaluation of tuberose (*Polianthes tuberosa* L.) for growth and yield characters. *J. Trop. Agric.* 59(2): 302-305.

Hu, J., G. Gettel, Z. Fan, H. Lv, Y. Zhao, Y. Yu, J. Wang, B.K. Bahl, G. Li, S. Lin, 2021. Drip fertigation promotes water and nitrogen use efficiency and yield stability through improved root growth for tomatoes in plastic greenhouse production. *Agric. Ecosystems Environ.,* 313: 107379.

Indiastat. 2022. Selected state wise area and production of tuberose in India. Available at: https://www.indiastat.com. Accessed on 15th December 2023.

Jeyabaskaran, K.J., P.S. Shirgure, V. Pandey, A.K. Srivastava and S. Uma, 2021. Fertigation in Horticulture: A Guarantee to Economized Quality Production. *Indian J. Fertilisers,* 17(4): 364-383.

Kabariel, J. and M. Kannan, 2015. Effect of irrigation regimes and fertigation levels on growth parameters of tuberose (*Polianthes tuberosa*) 'Prajwal' under black polythene sheet mulched ecosystem. Life Sciences Leaflets, 62-66.

Kapoor, R., A. Kumar, S.K. Sandal, A. Sharma, R. Raina and K.S. Thakur, 2022. A review of water and nutrient economy in vegetable crops through drip fertigation and mulching techniques. *J. Plant Nutr.,* 45(15): 2389-2403.

KAU [Kerala Agricultural University]. 2016. Package of Practices Recommendations: Crops. (14th Ed.). Kerala Agricultural University. Thrissur. 335p.

Kharde, R.P., S.A. Ranpise and M.N. Bhalekar, 2017. Effect of fertigation and irrigation scheduling studies on growth and yield of Brinjal (*Solanum melongena* L.) *cv.* Phule Arjun. *Trends in Biosciences,* 10(3): 1053-1056.

Kumawat, P., M. Ram, P. Kumar, V. Kumari and R.S. Khedwal, 2024. Maximizing productivity, profitability and water use efficiency in Indian mustard (*Brassica juncea*) through hydrogel and salicylic acid. *Indian J. Agric. Sci.,* 94(2): 145–149.

Li, H., X. Mei, J. Wang, F. Huang, W. Hao and B. Li, 2021. Drip fertigation significantly increased crop yield, water productivity and nitrogen use efficiency concerning traditional irrigation and fertilization practices: A meta-analysis in China. *Agric. Water Mgt.,* 244(6223): 106534.

Mishra, J.N., J.C. Paul, P.C. Pradhan, 2008. Response of cashew to drip irrigation and mulching in coastal Orissa. *J. Soil Water Conserv.,* 7(3): 36–40.

Mmolawa, K. and D. Or, 2000. Root zone solute dynamics under drip irrigation: a review. *Plant and Soil,* 222(1): 163–190.

Munikrishnappa, P.M., C.M. Gowda, A.A. Farooqi and N.Y.A. Reddy, 2002. Fertigation studies in tuberose *cv.* Single. *Indian J. Hortic.,* 59(1): 106–110.

Okoli, P.S.O. and I. Nweke 2015. Effect of poultry manure and mineral fertilizer on the growth performance and quality of cucumber fruits. *J. Expt. Biol. Agric. Sci.,* 3(4): 362-367.

Panigrahi, P., N.N. Sahu and S. Pradhan, 2011. Evaluating partial root-zone irrigation and mulching in okra (*Abelmoschus esculentus* L.) under a sub-humid tropical climate. *J. Agric. Rural Dev. Trop. Subtrop.,* 112(2): 169–175.

Patel, N., 2017. Precision farming development centres research findings on fertigation techniques. Department of Agriculture, Cooperation & Farmers Welfare, Ministry of Agriculture & Farmers Welfare, Government of India, 104p.

Paul, R.C., T. Higalu and J. Simamura, 1992. Season and fertilization after the post-harvest flower life of anthurium. *Scientia Hortic.,* 49: 125–134.

Priya, G. S., R. Sureshkumar, M. Rajkumar, R. Sendhilnathan, T. R. Barathkumar, 2020. Studies on the effect of organic manures, biostimulants and micronutrients on certain growth and physiological characters of tuberose (*Polianthes tuberosa* L.) *cv.* Prajwal. *Plant Arch.,* 20(1): 941-944.

Rajaselvam, M., R. Sudhagar and M. Kumaresan, 2024. Determining the effect of integrated nutrient management (INM) on growth and flower yield of tuberose (*Polianthes tuberosa* L.) *cv.* Prajwal. *Int. J. Plant Soil Sci.,* 36(6): 1-9.

Reddy, B.P. and S.N. Swamy, 2000. Effect of FYM, phosphate solubilizing bacteria and phosphorus on yield and economics of black gram. *Indian J. Agric. Sci.,* 70(10): 694–696.

Sankar, M. 2008. *Response of tuberose (Polianthes tuberosa L.) to organic manures and growth-promoting microorganisms.* PhD thesis. Kerala Agricultural University. Thrissur, 227.

Selim, T., F. Bouksila, R. Berndtsson and M. Persson. 2013. Soil water and salinity distribution under different treatments of drip irrigation. *Soil Sci. Soc. Amer. J.,* 77 (4): 1144–56.

Sharma, V., N.M. Changade, S.B. Tarate and B. Yadav, 2024. Response of tomato (*Solanum lycopersicum*) to varying irrigation and nitrogen levels under trickle fertigation. *Indian J. Agric. Sci.,* 94(2): 161–166.

Singh M., M. Bala, R. Sharma and R.K. Dubey, 2024. Varietal evaluation of double type tuberose (*Agave amica*) under Punjab conditions and their categorization using DUS Guidelines. *J. Ornament. Hortic.,* 27 (1): 51-57.

Sivakumar, V., A. Shakila and R. Rajeswari, 2005. Response of bhindi to combined application NPK with organic manure and zinc on growth and yield. *S. Indian Hortic.,* 53(1–6): 316–319.

Srivastava, R., S.P. Preetham and S. Chand, 2014. Effect of organic manures and biofertilizers on vegetative, floral and post-harvest attributes in tuberose (*Polianthes tuberosa*) var. Shringar. *Asian J. Biol. Life Sci.,* 3(1): 6-9.

Sujatha, N., J.V. Gowda and M.M. Khan, 2002. Effect of different fertigation levels on gerbera under low-cost greenhouse. *J. Ornament. Hortic.,* 5: 54–59.

Thentu, T.L., D. Dutta, D. Mudi and A. Saha, 2015. Drip Irrigation and nitrogen management in Gladiolus (*Gladiolus grandiflorus* L.). *Int. J. Biores. Stress Mgmt.,* 6(6): 644-650.

Vijayakumar. G., D. Tamilmani1 and P. K. Selvaraj, 2010. Irrigation and fertigation scheduling under drip irrigation in Brinjal (*Solanum melongena* L.) crop. *Int. J. of Bioresour. Stress Mgmt.,* 1(2): 72-76.

Received: April, 2024; Revised: May, 2024; Accepted: June, 2024