EFFECT OF INM ON THE PERFORMANCE OF TUBEROSE (*Polianthes tuberosa* L.) AND TINTING OF CUT TUBEROSE WITH NATURAL EXTRACTED DYES

THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE
OF DOCTOR OF PHILOSOPHY

BY

PALLAVI VERMA

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Nagaland

December, 2025

Ph.D Pallavi Verma 2025 HOR

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BY

Name of Candidate – Pallavi Verma

Name of Supervisor – Dr. Rokolhuü Keditsu

Submitted

In partial fulfilment of the requirements for the Degree of Doctor of Philosophy in Horticulture of Nagaland University

Nagaland University

July, 2025

I, Pallavi Verma, hereby declare that the subject matter of this thesis is the record of work done by me, that the contents of this thesis did not form the basis of the award of any previous degree to me or to the best of my knowledge to anybody else, and that the thesis has not been submitted by me for any research degree in any other University/Institute.

This is being submitted to School of Agricultural Sciences, Nagaland University for the degree of Doctor of Philosophy in Horticulture (Floriculture and Landscaping).

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CERTIFICATE – I

This is to certify that the thesis entitled **"Effect of INM on the performance of tuberose (*Polianthes tuberosa* L.) and tinting of cut tuberose with natural extracted dyes"** submitted to Nagaland University in partial fulfilment of the requirements for the award of degree of Doctor of Philosophy in Horticulture (Floriculture and landscaping), is the record of research work carried out by Pallavi Verma, Registration No. PhD/HOR/00454, under my personal supervision and guidance.

The result of the investigation reported in the thesis has not been submitted for any other degree or diploma. The assistance of all kinds received by the student has been duly acknowledged.

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CERTIFICATE – II

VIVA VOCE ON THESIS OF DOCTOR OF PHILOSOPHY IN HORTICULTURE (FLORICULTURE AND LANDSCAPING)

This is to certify that the thesis entitled **“Effect of INM on the performance of tuberose (*Polianthes tuberosa* L.) and tinting of cut tuberose with natural extracted dyes”** submitted by Pallavi Verma, Admission No. Ph-321/20, Registration No. PhD/HOR/00454, to the Nagaland University in partial fulfilment of the requirements for the award of degree of Doctor of Philosophy in Horticulture (Floriculture and landscaping) has been examined by the Advisory Board and External examiner on ……………………

The performance of the student has been found **Satisfactory/Unsatisfactory.**

Member	**Signature**
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2. Prof. Sunil Kamar (External Examiner)	..…..…………….…………
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Lastly, though many have not been mentioned, rest assured that none are forgotten.

Date: (Pallavi Verma)

Place: Medziphema

AFFECTIONATELY

DEDICATED

TO

MY FAMILY

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LIST OF ABBREVIATIONS

%	Percent
@	At the rate
₹	Rupee(s)
^{0}C	Degree Celsius
ANOVA	Analysis of variance
B:C	Benefit cost ratio
C	Carbon
C.D	Critical difference
Cm	Centimetre
CRD	Completely Randomized Design
Cv.	Cultivar
ds/m	Deci siemens per meter
EC	Electrical conductivity
FYM	Farm yard manure
Fig	Figure
G	Gram
Ha	Hectare
hrs.	. Hours
i.e.	That is
INM	Integrated Nutrient Management
K	Potassium
Kg	Kilogram
Ml	Millilitre
MOP	Muriate of Potash
MSS	Mean Sum of Squares
N	Nitrogen
No.	Number
NS	Non-Significant
P	Phosphorus
pH	Potential of hydrogen
PM	Poultry manure
RH	Relative humidity

RDF	Recommended dose of fertilizer
RBD	Randomized Block Design
SS	Sum of Squares
SEm±	Standard Error of the Mean
T	Tonnes
Viz	Namely
VC	Vermicompost

ABSTRACT

The present investigation entitled "Effect of INM on the performance of tuberose (*Polianthes tuberosa* L.) and tinting of cut tuberose with natural extracted dyes" was carried out in the Experimental Farm and Post-harvest Laboratory, Department of Horticulture, School of Agricultural Sciences, Nagaland University, Medziphema campus, Nagaland, during 2022-23 and 2023-24. Two experiments were carried out to study the effect of different sources of nutrients and their combination on the performance, economics of cultivation and tinting of tuberose with natural extracted dyes

The 1st experiment was laid out in Randomized Block Design with 12 treatments, replicated thrice. The treatments comprised of T_1 (Control 100% RDF $N_{200}P_{200}K_{150}$kg/ha), T_2 (75% RDF + FYM at 10 t /ha), T_3 (50% RDF + FYM at 20 t /ha), T_4 (75% RDF + Vermicompost at 5 t /ha), T_5 (50% RDF + Vermicompost at 10t /ha), T_6 (75% RDF + Poultry manure at 2 t /ha), T_7 (50% RDF + Poultry manure at 4 t /ha), T_8 (75% RDF + forest soil at 10 t /ha), T_9 (50% RDF + forest soil at 20 t /ha), T_{10} (75% RDF + Humic Acid at 1t /ha), T_{11} (50% RDF +Humic Acid at 2 t /ha), T_{12} (FYM at10 t /ha + Vermicompost at 5 t /ha + Poultry manure at 2 t /ha+ forest soil at 10 t /ha+ Humic Acid at 1t /ha). Application of integrated nutrient management showed significant variations on most of the parameters. Pooled results revealed that minimum days to sprouting (9.23), maximum number of leaves per plant (23.78), length of leaves (47.96 cm), plant height (56. 94 cm), and number of side shoot per plant (6.05) were obtained in T_4 (75% RDF + Vermicompost at 5 t /ha), followed by T_6 (75% RDF + Poultry manure at 2 t /ha). In case of flowering, bulb and post-harvest parameters such as minimum days to spike emergence (59.97), first floret opening (70.13), 50% floret opening (14.88), and maximum spike length (97.87 cm), rachis length (21.33 cm), number of floret per spike (24.18), diameter of the floret (4.33 cm), weight of individual floret (2.23 g), flower durability (18.50 days), number of bulb per plant (2.95), number of bulblets per plant (18.20), bulb diameter (3.82 cm), bulb weight (81.52 g), bulblet weight (122.85g), bulb yield (26.73 t/ ha), changes in fresh weight (73.24, 64.78, 53.92 g), water uptake (84.37 ml) and vase life (12.43 days) were registered in T_4 (75% RDF + Vermicompost at 5 t /ha) followed by T_6 (75% RDF + Poultry manure at 2 t /ha). Days to 50% flowering (77.00) was observed in T_6 (75% RDF + Poultry manure at 2 t /ha), while T_2 (75% RDF + FYM at 10 t /ha) exhibited maximum days to 50% floret opening (6.65) in post-harvest study. The highest total chlorophyl (0.429 mg/g) content on leaves was also recorded in T_4. The findings also revealed highest amount of N (3.77 %), P (0.193%), K (2.84 %) content in leaves, N (2.86%), P (0.22%), K (2.67%) content in bulb and available N (600.34 kg/ha), P (47.79 kg/ha), K (205.33kg/ha) in soil were observed with the application of T_4 (75% RDF + Vermicompost at 5 t /ha). T_{12} (FYM at10 t /ha + Vermicompost at 5 t /ha + Poultry manure at 2 t /ha+ forest soil at 10 t /ha+ Humic Acid at 1t /ha) recorded the maximum content of organic carbon (2.06 %). T_6 (75% RDF + poultry manure at 2 t /ha) was recorded maximum benefit cost ratio (2.49 and 3.02). It was concluded that the application of T_4 (75% RDF + Vermicompost at 5 t /ha) and T_6 (75% RDF + Poultry manure at 2 t /ha) recorded the best results in growth, flowering, bulb and post-harvest characters of tuberose.

The 2^{nd} experiment was carried out using two factorial completely randomized design with three replications. Three cut spikes were placed in 8 different natural extract dye solutions (Beetroot, Turmeric, Spinach, Pomegranate, Dragon fruit, Marigold, Hibiscus, Rhoeo) for 6, 9, and 12 hours. The highest score for the sensory characters was obtained in beetroot (A_1) followed by dragon fruit (A_5). Beetroot tinted spikes (A_1) recorded minimum days to 50% floret opening (4.28), maximum diameter of floret (3.71), floret length (5.73), spike elongation (47.33), rachis elongation (2.33), and vase life (9.17). The various dipping hours had a significant effect only in colour intensity, days to 50% floret opening and vase life. The interaction of natural extracted dyes and dipping hours showed the significant effect on colour (5), osverall acceptability (4.83), days to 50% floret opening (3.39), floret length (6.27 cm), water uptake (12.32 and 7.01 g) and vase life (8.40 days). The highest B:C ratio was obtained from beetroot extracted dye (1.2 and 1.3) when the spike were immersed for 12 hours.

Keywords: Tuberose, Prajwal, Organic Manure, Tinting, Natural extracted dye

CHAPTER - I

INTRODUCTION

INTRODUCTION

Flowers are one of nature's most beautiful creations, offering a universal language to express a range of human emotions-be it love, happiness, sorrow, friendship, or courtship. Floriculture is a fast-emerging major venture in the world. Today, floriculture is not only a thriving sector but also a highly profitable one, often yielding higher returns per unit area than traditional agricultural or horticultural crops. In India, floriculture has expanded its footprint by diversifying agricultural practices and has become a key contributor to the nation's foreign exchange earnings. India's varied agro-climatic zones provide ideal conditions for growing a wide array of delicate floriculture products.

Tuberose (*Polianthes tuberosa* L.), a popular tropical ornamental bulbous plant, belongs to the Amaryllidaceae family. Commonly known by various regional names-Sempengi in Tamil, Nishigandhi in Malayalam, Rajanigandha in Hindi and Bengali, Nishigandha in Marathi, and Gul-e-Lshabab in Urdu (Biswas *et al*., 2002). The genus name *Polianthes* derives from two Greek words "Polis" meaning white and "Anthos" which means flower, while the species name 'tuberosa' refers to the plant's tuberous nature. The plant's name is therefore pronounced as "tuber-ose," not "tube-rose."

It is native to Mexico but has been widely cultivated in Asia. There are approximately 15 species within the *Polianthes* genus, with 12 of them native to Mexico and Central America. Of these, nine species bear white flowers, one has white-tinged red flowers, and two species have red flowers. *Polianthes tuberosa* Linn. however, is the only species that has been extensively cultivated, with all other species growing wild (Kumar *et al*., 2019).

Tuberose is a half- hardy, bulbous perennial that reproduces through bulb-bulblets. The bulbs consist of scales and leaf bases, with the stem being a condensed structure hidden within the scales. Its roots are shallow and adventitious. The plant has long, narrow, grass-like, green leaves that form a rosette, while the florets are star-shaped, waxy, and typically 25mm long. They are arranged in spikes that can grow up to 30–45 cm in length. Tuberose flowers are either single (with one row of perianth) or double (with more than two rows of perianth). Single varieties are often used for loose flowers, garlands, buttonholes, and essential oil production, while double varieties are favored as cut flowers, for garden displays, and interior decorations. The overwhelming fragrance of the tuberose has been distilled for quite long and is widely used in perfumery since the 17^{th} century, when tuberose flower for the very firssst time transported to Europe. French "Queen Marie Antoinette" used a perfume called "Sillage de la Reine" also pronounced as Parfum de Trianon containing tuberose, orange blossom, and sandalwood, jasmine, iris and cedar. (Srivastava, 2024)

Tuberose is one of the most commercially important bulbous ornamentals in sub-tropical and tropical regions due to its fragrant spikes and its versatile use in both loose and cut flowers. The flower's beauty, elegance, and sweet fragrance make it highly sought after, while its essential oil remains one of the priciest raw materials in the perfume industry (Singh *et al*., 2010). The fragrance is also added with stimulants or sedatives to the favorite beverage prepared from chocolate and served either cold or hot as desired (Trueblood, 1973). Beyond its ornamental value, tuberose has medicinal uses as well, including treatment for headaches, diarrhea, rheumatism, and other related pains (Kusuma, 2000).

In India also, there is an increasing trend of flower consumption in various social and religious functions. In fact, India is the second-largest grower of flowers after China (Meghana and Wazeed, 2024). The country has approximately 297 thousand hectares under floriculture production, producing over 2284 thousand tons of loose flowers and more than 947 thousand tons of cut flowers (Anon, 2023). The major states producing tuberose include West Bengal, Tamil Nadu, Maharashtra, Andhra Pradesh, Karnataka, Assam, Rajasthan, Gujarat, Uttar Pradesh, Punjab, and Chhattisgarh.

The quality and yield of tuberose are greatly influenced by climatic, geographical, and nutritional factors. Among these, nutrition plays a crucial role. Currently, chemical fertilizers are commonly used to supply nutrients; however, the excessive and indiscriminate use of these fertilizers has led to nutrient imbalances in the soil, affecting both soil health and flower yield. To counter this, the integrated use of organic manures and chemical fertilizers is recommended, as this approach helps balance the nutrient requirements of both the crops and the soil. Tuberose, being a heavy feeder, requires substantial amounts of nitrogen, phosphorus, and potassium (NPK) both in the form of organic and inorganic fertilizers throughout its growth cycle (Amarjeet *et al*., 2000). These nutrients, when provided in both organic and inorganic forms, are essential for optimal spike production and high-quality florets. Using organic fertilizer have been shown to improve flower duration in the field (Kabir, 2009).

Integrated Nutrient Management needs incorporation of Farm yard manure (FYM) which refers to decomposed mixture of dung and urine of farm animals along with the litter and leftover material from roughages or fodder fed to cattle which improve the soil structure and is used as a natural fertilizer in farming. Use of organic manure increases the soil capacity to hold more water and nutrients. It also improves and increases the microbial activity of the soil to improve the mineral supply and also the plant nutrients (Stockdale *et al*., 2002). The well decomposed Farm yard manure (FYM) contains 0.5% N, 0.2% P2O5 and 0.5% K2O. Farm yard manure (FYM) helps in better plant growth and enhances the yield of the crop (Singh and Longkumer, 2018).

Vermicompost which is an organic fertilizer rich in NPK, micronutrients and beneficial soil microbes (nitrogen fixing and phosphate solubilizing bacteria and actinomycetes), is a sustainable alternative to chemical fertilizers, which is a very excellent growth promoter and protector for crop plants. Vermicompost is an important component of organic farming systems, because of its effectiveness, easy to preparation, has excellent properties, and is harmless to plants. Vermicompost is rich in NPK (Nitrogen 2-3%, Phosphorus 1.55-2.25% and Potassium 1.85-2.25%), micronutrients and beneficial soil microbes which is composed of „plant growth hormones and enzymes. It is scientifically proving as Miracle growth promoter and Plant protector‟ from pests and diseases (Mishra *et al*., 2022).

Poultry litter or poultry manure is widely regarded as an excellent source of plant nutrients and organic matter. Organic content in poultry manure enhance crop production by expanding the infiltration capillarity of water and water holding capacity, improving the maintenance and efficiency of nutrients in the soil, reducing wind, water erosion and promoting the growth of some beneficial organisms. Poultry droppings or Poultry manure have higher nutrient supplement substance among the animal-based manures. It contains notable level of Nitrogen (4.55-5.46%), Phosphorus (2.46-2.82%), Potassium (2.02-2.32%), Calcium (4.52-8.15%), Magnesium (0.52-0.73%) along with appreciable amounts of micronutrients such as Cu, Zn, Fe, Mn etc. additionally, poultry manure includes Cellulose (2.26-3.62%), hemicelluloses (1.89-2.77%) and lignin (1.07-2.16%) which contribute to the organic matter content and overall soil health (Nandhini, 2018).

Humic is part of the humus compounds which plays an important role in balance plant nutrition by improving physical, chemical and biological properties of soil. Humic acid is a natural antioxidant that has various biochemical effects in plants by increasing nutrient uptake, preserving essential vitamins and increasing amino acids level in plant tissues. Humic acid also improves the availability of soil nutrients especially micronutrients by chelating and co-transporting into plants (Yang *et al.*, 2021). Its application has been shown to increased respiration, improved roots and stem growth, fresh and dry weights, and enhanced the synthesis of plant enzymes and hormones. The higher the amount of humic acid is, the greater the antioxidant activity in plants resulting in increased the plant resistance against diseases as well as environmental stress such as heat and chilling stresses (El-Bassiouny Hala *et al.,* 2014; Syedabadi and Armin 2014). Humic acid positively affects both root and shoot growth, but its greatest impact is observed in root, where it increases root volume by influencing the root system (Sabzevari *et al.,* 2009).

forest soil is any soil that has developed primarily under the influence of a forest cover which significantly influences its physical, chemical, and biological characteristics. The forest cover and its resultant O horizon provide a micro climate and a spectrum of organisms very different from those associated with cultivated soils or horticultural plantations. Key ecological process such as nutrient cycling among components of the forest community and the formation of soluble organic compounds from decaying debris, with the subsequent eluviation of mineral ions and organic matter, give a distinctive character to soils developed beneath forest cover. (Binkley and Fisher, 2013) The forest soils have better soil texture, soil structure, increased porosity, lower bulk density, good aeration, reduced soil temperature, and better water retention capacity. (Gupta *et al.*, 2025) Forest soil is highly valued in horticulture due to its rich organic content and natural fertility. It is typically formed from the decomposition of leaves, twigs, and other plant material, which leads to a high level of humus and nutrients such as nitrogen, phosphorus, and potassium—essential elements for plant growth. This organic matter not only enhances nutrient availability but also improves soil structure, water retention, and aeration, making it an ideal medium for horticultural crops like fruits, vegetables, flowers, and herbs.

In India, the available tuberose cultivars predominantly bear white flowers, though some cultivars show slight color variations, such as pinkish (Prajwal, Shringar, Sikkim Selection, and Hyderabad Single) or greenish (Vaibhav, Phule Rajni, and Mexican Single) tinged buds. Despite these variations, fully opened flowers remain white across all varieties. The genetic variability in tuberose is very limited and it has very narrow genetic base (Anu *et al.*, 2003). This lack of genetic diversity, particularly in flower color, poses a challenge for growers who often struggle with marketing during peak flowering seasons. To address this challenge and enhance marketability, flower tinting has emerged as a promising solution. Tinting tuberose flowers with natural dyes can significantly increase their visual appeal, offering a variety of colors that can boost sales and improve the economic return for growers. Farmers can benefit from adopting this simple yet effective technique, as it enhances the vase life and marketability of the flowers, providing a valuable opportunity for greater profit.

Nature has provided over 500 plant species that yield dyes, many of which can be extracted from flowers, roots, barks, and leaves (Mahanta & Tiwari, 2005). These natural dyes are more environmentally friendly than synthetic dyes and have a broad range of applications, including in textiles, cosmetics, and even food coloring (Gulrajani, 2001). Natural dyes are biodegradable, non-toxic, and often sustainable, making them an ideal choice for enhancing the color of flowers like tuberose.

Natural colourants can be broadly classified based on the natural occurrence of pigments. They are chlorophylls, carotenoids, betalains and anthocyanins. Chlorophylls are responsible for the green colour in plants, are oil-soluble pigments but have limited practical application due to their heat sensitivity and instability

(Marquez and Sinnecker, 2008). Carotenoids also lipid-soluble pigments that contribute to the vibrant red, orange, and yellow hues seen in various fruits and flowers. In contrast, betalains, are water-soluble pigments that exhibit a range of colours from red-purple to yellow, depending on their structural composition. They are classified into two groups: betaxanthins, which produce yellow pigmentation, and betacyanins, responsible for red-purple hues (Chandrasekhar *et al.*, 2015). Anthocyanins, also water-soluble, are widely distributed in flowers, fruits, and leaves. They contribute to a diverse range of colours, including orange, red, and blue. These natural pigments, with their varying solubility and colour properties, are of significant interest in floriculture, especially for tinting applications.

By tinting tuberose flowers with natural dyes, farmers can add significant value to their produce, increasing its appeal and market price. With a relatively simple technique, growers can potentially earn higher profits by offering more colorful and aesthetically appealing flowers. This value addition could be a game-changer for tuberose producers, allowing them to overcome the seasonal market limitations associated with white-flowered varieties. Nevertheless, not much work on the use of natural extract in flower industry has been done. With the above perspective, the present investigation will be carried out with following objectives

I. To study the effect of INM on the performance of tuberose.

II. To find out the suitable INM practices for extending flower durability of tuberose.

III. To study the influence of different natural dyes on the post-harvest life of cut tuberose.

IV. To work out benefit cost ratio of INM and tinting in tuberose.

CHAPTER - II

REVIEW OF LITERATURE

REVIEW OF LITERATURE

The literature pertaining to the study has been reviewed here in this chapter. However, scanty research works available on "Effect of INM on the performance of tuberose (*Polianthes tuberosa* L.) and tinting of cut tuberose with natural extracted dyes". Therefore, the literature pertaining to other relevant ornamental crops have been included here in this chapter. The review is presented under the following heads.

2.1 Effect of FYM on growth, flowering and yield of tuberose

2.1.1 Vegetative growth

Haripriya and Sriramachandrasekharan (2002) found that application of FYM + mine soil at 1:2 ratio resulted in the better growth and yield of marigold as compared to leaf mould and pressmud.

Ahmed *et al.* (2004) reported that application of urea at 20 g/m^2, P_20_5 at 40 g/m^2 and FYM 4 kg/m^2 in combinations significant showed significant results on plant height, number of branches/plants, as compared to other doses of fertilizers in dahlia cv. Procyon.

Sonawane *et al.* (2008) concluded that the application of N at 200 kg/ha through urea, P at 75 kg/ha through single superphosphate and FYM at 10 t/ha with basal 50 kg K_2O kg/ha through MOP was found beneficial in increasing the growth parameters in China aster.

Field experiment was conducted by Kumar *et al*. (2016) to studied the effect of graded levels of farmyard manure and nitrogen on growth, flowering and bulb production of tuberose (*Polianthes tuberosa*) cv. Suvasini. The maximum plant height (47.25 cm), number of leaves/clump (91.56), was observed with nitrogen at 180 kg/ha which were at par with farmyard manure at 30 t/ha.

Diwivedi *et al.* (2018) studied the effect of organic and inorganic fertilizer on growth and flower yield of jasmine (*Jasminum grandiflorum* L.) and found that treatment T_8 (25% RDF+15.5 Kg FYM) was best in terms of maximum plant height, plant spread, number of branches.

Kumar *et al.* (2019) studied the effect of FYM, vermicompost and poultry manure on vegetative growth, spike quality and flower yield of gladiolus (*Gladiolus grandiflora* L). Integrated nutrients with 40% RDF+ FYM 60% were found to be the best treatment in terms of plant growth such as days taken for sprouting, Sprouting %, Plant Height, number of leaves per plant. yield and quality of gladiolus.

Choudhury and Sarangi (2020) carried out an experiment to study the effect of organic manures, inorganic fertilizers and biofertilizers on vegetative and floral characters of tuberose cv. 'Single' and found that application of 100% RDF along with FYM (2Kg/m^2) produced significantly maximum plant height (50.78 cm) and number of leaves (16.55/plant).

Siangshai *et al*. (2022) conducts the experiment on the effect of NPK, farm yard manure and vermicompost on vegetative growth, and flowering in tuberose (*Polianthes tuberosa* Linn) cv. Prajwal and found that the treatment T_{11} (FYM @ 75 t/ha + vermicompost @ 30 t/ha) performed best in terms of vegetative growth in earliness to days to 50% plant emergence (19.22 days), highest plant height (87.47 cm), numbers of leaves per clump (90.10), leaf area (207.82 cm2), number of plants per clump (11.91).

2.1.2 Flowering parameter

Ahmed *et al.* (2004) reported that application of Urea at 20 g/m^2, $P_2 0_5$ at 40 g/m^2 and FYM 4 kg/m^2 in combinations showed significant results on early flowering and number of flowers/plants, increased as compared to other doses of fertilizers in dahlia cv. Procyon.

Sonawane *et al.* (2008) concluded that the application of nitrogen at 200 kg /ha, phosphorus at 75 kg /ha and FYM at 10 t/ha was found efficient to achieve significantly maximum flower yield over other levels in China aster.

Masaye and Rangwala (2009) reported that application of 200 kg N+100 kg P_2O+50 kg K_2O and FYM at 5 t/ha as a basal dose improved flower quality of China aster var. Poornima Swathi.

Hadwani *et al.* (2013) observed that application of FYM at 30 t/ha + PSB at 2 g/m^2 + Azotobacter at 2 g/m^2 exhibited maximum length of spike, number of florets per spike, number of spikes per plant and longest vase life in tuberose cv. Double

An experiment was carried out by Sisodia *et al*. (2015) to studied the effect of farmyard manure, vermicompost and Trichoderma on flowering and corm attributes in gladiolus cv. Nova Lux and found that the maximum length of spike, number of florets/spike and duration of flowering was registered with application of farmyard manure.

Kumar *et al*. (2016) studied the effect of graded levels of farmyard manure and nitrogen on growth, flowering and bulb production of tuberose (*Polianthes tuberosa*) cv. Suvasini. Earliness in flowering (70.68 days), spike length (91.29 cm), rachis length (24.54 cm), prolonged vase-life (15.40 days), was observed with nitrogen at 180 kg/ha which were at par with farmyard manure at 30 t/ha.

Singh *et al.* (2016) studied the effect of farmyard manure, vermicompost and *Trichoderma* on plant growth and postharvest life of gladiolus and opinioned that plants treated with FYM had maximum weight of spike, length of spike, number of florets/spikes, vase life, weight of spike after withering and dry weight of spike.

Diwivedi *et al.* (2018) studied the effect of organic and inorganic fertilizer on growth and flower yield of jasmine (*Jasminum grandiflorum* L.) and found that treatment T_8 (25%RDF+15.5 Kg FYM) was best in terms of maximum weight of 50 flower bud, number of flower bud/plant, yield of flower/plant, yield of flower/ha.

Chandra *et al*. (2018) investigated the effect of different doses of FYM on flower yield of marigold (*Tagetes erecta* L.) cv. Hawaii and concluded that FYM at 11 tonne/ha registered the maximum yield.

Kumar *et al.* (2019) studied the effect of FYM, vermicompost and poultry manure on vegetative growth, spike quality and flower yield of gladiolus (*Gladiolus* *grandiflora* L). Integrated nutrients with 40% RDF+ FYM 60% was found to be the best treatment in terms of flowering parameters and quality of Gladiolus.

Sahu *et al.* (2021) studied the effect of NPK and Organic Manures of flowering and flower yield of Dahlia (*Dahlia variabilis* L.) cv. Kenora Sunburst. In Research Field, Department of Horticulture, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj and recorded that 80% RDF through NPK + 20% FYM was found best in terms of flower and flower yield.

Siangshai *et al*. (2022) conducts the experiment on the effect of NPK, farm yard manure and vermicompost on vegetative growth, and flowering in tuberose (Polianthes tuberosa Linn) cv. Prajwal and found that the treatment T_{11} (FYM @ 75 tonnes/ha + vermicompost @ 30 tonnes/ha) performed best in flowering character, earliness in emergence of spike (98.89 days), days to first floret opening (117.66), highest spike length (101.48 cm), rachis length (30.96 cm), highest florets/spike (39.76), floret diameter 4.29 cm, floret length (5.33 cm), number of spike/clump 5.72 and 49.44 per plot and maximum flower spike yield/ha.

2.1.3 Bulb parameter

In a study conducted by Jha *et al.* (2012) on the effect of FYM and vermicompost in combination with various doses of inorganic fertilizer in gladiolus variety 'Candyman' at Raipur (C.G.), reported that the treatment receiving 75% RDF+FYM 10 t/ha recorded better in diameter of corm, weight of single corm, total corm weights per plot and number of corms per plant.

Mazed *et al*. (2015) investigated the effect of manures and fertilizer on growth and flower and bulb production of tuberose at the Horticultural Farm of Sher-e Bangla Agricultural University, Dhaka, Bangladesh and found that Application of manures and fertilizer showed significant variations on most of the parameters. The highest yield of bulb (26.64 ton) and bulblet per hectare (23.63 ton) was recorded with the application of Cowdung 10 t + 250 kg Urea + 190 kg TSP + 190 kg MoP.

Sisodia *et al*. (2015) studied the effect of farmyard manure, vermicompost and Trichoderma on flowering and corm attributes in gladiolus cv. Nova Lux and maximum weight of corms/plant and diameter of corm was recorded with FYM + vermicompost + Trichoderma and FYM + vermicompost treatments respectively.

Kumar *et al*. (2016) studied the effect of graded levels of farmyard manure and nitrogen on growth, flowering and bulb production of tuberose (*Polianthes tuberosa*) cv. Suvasini. The maximum fresh weight of bulbs per clump (150.64g) and bulb yield (13.89 tonne/ha) was observed with nitrogen at 180 kg/ha which were at par with farmyard manure at 30 t/ha.

Chawla *et al.* (2018) study the effect of land configuration and integrated nutrient management on growth, quality and yield of tuberose (*Polianthes tuberosa*) var. Prajwal and found that the application of fertilizer dose (300:200:100 NPK kg/ha/year) along with FYM @ 15 t/ha/year recorded maximum bulbs/ plant (10.63), bulbs/ha (928560.00) and bulblets/plant (28.83).

2.2 Effect of vermicompost on growth, flowering and yield of tuberose

2.2.1 Vegetative growth

Kulkarni (1994) recorded increased growth and dry weight in China aster with application of vermicompost at 2.5 to 5.0 t /ha alone or in combination with inorganic fertilizers.

Gangadharan and Gopinath (2000) observed that the combination of vermicompost at 10 tonnes per hectare + 80 per cent recommended NPK increased the plant height, number of leaves, leaf area, leaf area index, fresh weight of whole plant of tuberose

Chaitra and Patil (2007) observed significant increase in plant height, number of leaves, number of branches, and total dry matter production in China aster with the application of vermicompost at 2.5 t /ha with 50 per cent RDF.

Kumar (2015) concluded that 75% RDF + 25% VC + 2.0 g/plant *Azospirillum*+ 2g/plant PSB, significantly induced earlier sprouting and also increased the height of plant, number of leaves per plant, length of longest leaf per plant and width of longest leaf, in chrysanthemum cv. Yellow Gold.

Pandey *et al.* (2017) investigated the effect vermicompost and biofertilizers on growth and flowering on dahlia cv. S.P. Kamala and findings revealed that the maximum plant height (65.07 cm), number of primary branches (9.67), number of leaves (33.67), plant spread (43.73 cm), were produced in the treatment with vermicompost at 2.5 t /ha + Azotobacter at 2.0 kg /ha + Phosphorous Solubilizing Bacteria at 2.0 kg /ha.

Preetham *et al*. (2017) studied the effect of organic manures and bio fertilizers on vegetative growth in tuberose (*Polianthes tuberosa*) var. Shringar. and found that the maximum plant height at 90 days and number of leaves per plant was in plot treated with vermicompost (2 kg/m^2).

Madhuri *et al.* (2018) studied the growth and flowering parameters of tuberose (*Polianthes tuberosa* L.) cv. Phule Rajani influenced by organic manures. The result revealed that vermicompost at 1kg/m^2 + mustard oil cake at 250g/m^2 recorded the maximum value for vegetative growth parameters like plant height, plant spread, number of leaves per plant, leaf length, breadth and leaf area.

Kumar *et al*. (2020) studied the influence of organic manure and bio-fertilizers on growth and yield of chrysanthemum cv. Poornima White. In the result of the present study, organic manure, bio-fertilizer and organic manure with bio-fertilizer combination of T_2 (VAM at 50g/plant), T_6 (Vermicompost at 250g/plant) & T_7 (VAM at 50g/plant + Vermicompost at 250g/plant) treatments significantly increased the plant height, plant spread, number of branches.

Sardoe *et al.* (2023) studies the effect of vermicompost on the properties of cut tuberose flowers. Four fertilizer treatments (control, 20%, 25%, and 30%) were used in the experiments. The result revealed that the use of vermicompost, particularly at a volume ratio of 30%, improved the growth status, and bulb output of the tuberose plant.

2.2.2 flowering parameter

Gangadharan and Gopinath (2000) observed that in gladiolus cv. White Prosperity, the combination of vermicompost at 10 tonnes per hectare + 80 per cent recommended NPK increased the length of spike, width of spike, length of rachis, number of florets per spike

Munikrishnappa *et al.* (2004) stated that the application of 50 per cent of recommended dose of fertilizer (RDF) along with vermicompost at 5 tonnes per hectare had improved the flower characters viz., spike length, rachis length, florets diameter, number of florets per spike and flower yield of tuberose.

Godse *et al.* (2006) revealed that plants receiving vermicompost at 8 t /ha + Azotobacter and PSB at 25 kg /ha each + 80% RDF significantly increased yield and quality attributes of gladiolus viz., number of spikes /ha, length of spike and number of florets per spike.

Chaitra and Patil (2007) observed that significant flower yield in China aster with the application of vermicompost at 2.5 t /ha with 50 per cent RDF.

According to the finding of research and regarding economic matters and environmental anxieties, it was recommended that vermicompost may be used as a soil amendment in the nursery or field production of flower plants (Nazari *et al*. 2008)

Mohd *et al*. (2006) studied the effect of INM practices in improving the flower yield of *Anthurium andreanum* cv. Meringue, the experiment was conducted with six kinds of organic substrates along with inorganic fertilizers. Better flowering attribute and flower yield was observed in the treatment combination of vermicompost 100 g/plant+ 50% RDF.

Kumar (2015) concluded that 75% RDF + 25% VC + 2.0 g/plant *Azospirillum*+ 2g/plant PSB, significant take minimum days to opening of first flower on the spike, emerged earlier spike in chrysanthemum cv. Yellow Gold.

Jana *et al.* (2015) conducted an experiment at the Horticultural Research Farm, Bidhan Chandra Krishi Viswavidyalaya, Mondouri to find out the influence of vermicompost, neem cake and groundnut cake on growth and flowering in tuberose (*Polianthes tuberosa* L.) var. Prajwal. In total, 7 treatments were replicated thrice using randomized block design with two levels each of vermicompost (2 & 4 kg/sq m), groundnut cake (200 & 400 g/sq m) and neem cake (200 & 400 g/sq m) along including control. Among the different organic manure applications Vermicompost application at 4kg/sq m. recorded the maximum field life (22.53 days) and vase life (11.56 days).

Kumar (2015) concluded that 50% RDF+50% vermicompost+2 g/plant *Azospirillum*+ 2 g/plant PSB produced maximum diameter of flower, number of flowers per spike, diameter of spikes per bulb, in tuberose cv. Vaibhav.

Pandey *et al.* (2017) investigated the effect vermicompost and biofertilizers on growth and flowering on dahlia cv. S.P. Kamala. The findings revealed that the maximum number of flowers (8.13), duration of flowering (10.53), flower yield /ha (33.65) were produced in the treatment with vermicompost at 2.5 t /ha + Azotobacter at 2.0 kg /ha + Phosphorous Solubilizing Bacteria at 2.0 kg /ha.

Madhuri *et al.* (2018) studied the growth and f lowering parameters of tuberose (*Polianthes tuberosa* L.) cv. Phule Rajani influenced by organic manures and the result revealed that vermicompost at 1kg/m^2 + mustard oil cake at 250g/m^2 recorded the better-quality spikes.

Kumar *et al*. (2020) studied the influence of organic manure and bio-fertilizers on growth and yield of chrysanthemum cv. Poornima White. In the result of the present study, organic manure, bio-fertilizer and organic manure with bio-fertilizer combination of T_2 (VAM at 50g/plant), T_6 (Vermicompost at 250g/plant) & T_7 (VAM at 50g/plant + Vermicompost at 250g/plant) treatments significantly increased the flower bud initiation, time taken for first flowering and days taken to 50 per cent flowering, flowering duration, weight of twenty fresh flowers and no. of flowers per plant.

Jokar and Asil (2021) studied the effect of gibberellic acid and vermicompost on growth and flowering of daffodil flower. They observed that the application of vermicompost at 20% level and gibberellic acid with a concentration of 300 mg/L have improved the growth and accelerated flowering with an average of 10 days, increasing the vase life of flowers with an average of four days with a noticeable difference, compared to the control.

2.2.3 Bulb parameter

Gangadharan and Gopinath (2000) studied the effect of organic and inorganic fertilizer on growth flowering and quality of gladiolus cv. White Prosperity, a significant increase weight of corms and weight of cormels were obtained when plants were treated with the combination of vermicompost @ 10 t/ha + 80% recommended NPK dosage compared to other combination**.**

Lal *et al.* (2010) reported that maximum weight of bulbs per plant, i.e. clump weight (283.58 and 295.90 g, respectively) with the application of vermicompost and PSB @ 1 kg/m2 and 2 g/bulb in tuberose cultivar Single.

Kumar (2015) concluded that 50% RDF+50% vermicompost+2g/plant *Azospirillum*+ 2g/plant PSB produced maximum number of bulblets, diameter of bulb, weight of bulb, yield of bulbs and bulblets per plant in tuberose cv. Vaibhav.

Satapathy *et al.* (2016) revealed that application of 75% RDF (100:50:60 kg NPK/ha) in combination with vermicompost and biofertilizer increased weight (75.66 g) and diameter (6.59 cm) of daughter corm as well as number (58.36) and weight (32.43 g) of cormels per plant.

Khanam *et al.* (2017) revealed that maximum number of corms per plant (3.5) was recorded with integration of 50% recommended dose of chemical fertilizers (RDF) with Vermicompost @ 2.5 t/ha.

Pandey *et al.* (2017) investigated the effect vermicompost and biofertilizers on growth and flowering on dahlia cv. S.P. Kamala. The findings revealed that the maximum weight of tuber (56.67 g), number of tubers (4.87) and tuber yield (13.80 t /ha) were produced in the treatment with vermicompost at 2.5 t /ha + Azotobacter at 2.0 kg /ha + Phosphorous Solubilizing Bacteria at 2.0 kg /ha.

Sardoei *et al.* (2023) studies the effect of vermicompost on the properties of cut tuberose flowers. Four fertilizer treatments (control, 20%, 25%, and 30%) were used in the experiments. found that the use of vermicompost, particularly at a volume ratio of 30%, improved the growth status, and bulb output of the tuberose plant

2.3 Effect of poultry manure on growth, flowering and yield of tuberose

2.3.1 Vegetative growth

Kabir *et al*. (2011) studied the response of tuberose to integrated nutrient management and obtained maximum plant height (95.6 cm), number of leaves (11.1) and length of leaves (45.9 cm) when plants received half of the (recommended) chemical fertilizers along with poultry litter 20 t $ha^{-1.}$

Ikram *et al.* (2012) studied the effect of different potting media combinations on growth and vase life of tuberose (*Polianthes tuberosa* Linn.) and maximum plant height, leaf area and spike length were recorded in sand + poultry manure in 1: 1 ratio.

Singh *et al.* (2015) studied the effect of organic manures and inorganic fertilizers on growth and flower yield of marigold (*Tagetes erecta* L.) var. Pusa Narangi Gainda. They concluded that vermicompost at 5t/ha and poultry manure at 3.16q/ha gave higher growth characters.

Suseela *et al.* (2016) carried out an experiment to study the effect of organic manures, inorganic fertilizers and micronutrients on vegetative and floral characters of tuberose cv. Suvasini and reported minimum number of days taken to initiation of sprouting and complete sprouting with RDF @ 50% along with poultry manure @ 50%.

Shahjahan *et al.* (2016) studied the influence on yield and yield contributing characters of tuberose by the application of bulb and fertilizers and stated that maximum plant height (69.75 cm), leaf length (49.50 cm) and number of leaves per plant (12.33) 90 DAP was recorded with large bulb size (2.6-3.0 cm in diameter) along with poultry litter @10 t ha-1 in comparison to control.

An experiment conducted by Preetham *et al.* (2017) to find out the effect of organic 6 manures and biofertilizers on vegetative growth in tuberose var. Shringar. The plant height at 60 days (37.67 cm) was maximum with 0.5 kg poultry manure and plant height and number of leaves were maximum at 90 days in 2 kg vermicompost.

Zwane *et al*. (2019) studied the effects of organic manures on growth, yield and quality of gypsophila (*Gypsophila paniculata* L.) and found that poultry manure at 40 t/ha registered the highest plant height of 54.7 cm and other vegetative parameters.

2.3.2 Flowering parameter

Bahadoran *et al*. (2011) conducted an experiment on the effect of poultry litter on vegetative growth and flower characteristics of tuberose (*Polianthes tuberosa* L.) and reported that poultry litter at 41.5 g/m^2 increase the height of flowering stem, flower diameter, diameter of flowering stem.

Kabir *et al.* (2011) studied the effect of organic fertilizers on floral characters in tuberose and observed that flowering parameters i.e., length of spike (32.1 cm), length of rachis (10.2 cm), number of florets per spike (35.1) and stem diameter (0.91 cm) were maximum with the application of half of chemical fertilizers along with poultry litter @ 20 t $ha^{-1.}$

Srivastava *et al*. (2013) studied the effect of organic manure and biofertilizers on vegetative, floral and postharvest attributes in tuberose (*Polianthes tuberosa*) var. Shringar. They found that application of 0.5 kg poultry manure/m^2 in tuberose registered the maximum spike weight, number of floret/ plant.

Singh *et al.* (2015) studied the effect of organic manures and inorganic fertilizers on growth and flower yield of marigold (*Tagetes erecta* L.) var. Pusa Narangi Gainda. They concluded that vermicompost at 5t/ha and poultry manure at 3.16q/ha gave higher yield attributing characters, flower yield.

Shahjahan *et al.* (2016) studied the influence on yield and yield contributing characters of tuberose by the application fertilizers and organic manure and reported that maximum length of spike (33.98 cm), length of rachis (10.18 cm), number of florets per spike (35.42) and stem diameter (0.97 cm) in poultry litter @ 10 t ha-1 in comparison to control.

Suseela *et al.* (2016) studied the effect of organic manures, inorganic fertilizers and micronutrients on vegetative and floral characters of tuberose (Polianthes tuberosa

L.) cv. Suvasini and reported that maximum spike length, number of florets and number of spikes per clump was obtained when plants received RDF @ 50% + Poultry manure @ 50% followed by RDF @ 50% + poultry manure @ 25% + neem cake @ 25%.

Zwane *et al.* (2019) studied the effects of organic manures on growth, yield and quality of gypsophila (*Gypsophila paniculata* L.) and found that poultry manure at 40 t/ha registered the highest cut flower length of 53.9 cm, and number of marketable cut flowers (7.1).

Himaja *et al.* (2021) studied the effect of organic manures on growth, flowering, yield and quality of African marigold (Tagetes erecta L.). Studies showed that, significant effect on fresh weight of flower (25.33gm), number of flowers per plant (27.67g), flower yield per plant (67.33g), flower yield per plot (1.41 kg), flower yield per hectare (14.1 t ha-1) was recorded maximum in treatment with poultry manure @ 1000g.

2.3.3 Bulb parameter

Kabir *et al.* (2011) carried out an experiment to study the response of tuberose to integrated nutrient management and found that the bulb parameters were significantly affected by organic fertilizers and maximum number of bulbs (15.9), bulb diameter (2.83 cm) and bulb weight (177.1 g) was observed with half of chemical fertilizers along with poultry litter @ 20 t ha-1.

Srivastava *et al*. (2013) studied the effect of organic manure and biofertilizers on vegetative, floral and postharvest attributes in tuberose (*Polianthes tuberosa*) var. Shringar. They found that application of 0.5 kg poultry manure/m^2 in tuberose registered the maximum diameter of mother bulb and number of bulblets / m^2.

Mohammad *et al.* (2016) conducted an experiment at the Horticultural farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh to investigate the influence of bulb size and fertilizers on yield and yield contributing characters of tuberose and found that large bulb size (2.6-3.0 cm) and 10 t /ha poultry litter is best for growth, bulb and flower production of tuberose.

Shahjahan *et al.* (2016) conducted an experiment to study the influence on yield and yield contributing characters of tuberose by the application of bulb size and fertilizers and observed the large bulb size (2.6-3.0 cm in diameter) with poultry litter @ 10 t ha-1 resulted in maximum diameter of bulb (3.10 cm) and maximum weight of bulb per plant (214.6 g).

Sultana *et al.* (2016) studied the morphological characteristics of tuberose as influenced by gibberellic acid incorporated with organic manures and noted that the maximum yield of spike (3,50,000 /ha) and bulb (21.72 t /ha) was recorded in poultry litter at 20 t /ha with 200 ppm GA_3 compared to other treatments which was more potential for production of tuberose

2.4 Effect of humic acid on growth, flowering and yield of tuberose

2.4.1 Vegetative growth

Ahmad *et al.* (2013) studied the humic acid and cultivar effects on growth, yield, vase life, and corm characteristics of gladiolus. They found that application of HA at 7000 ml/ha and NPK at 250 kg/ha at planting, 3-leaf, and 6-leaf stages of plant development were best for early and uniform sprouting, more foliage growth per plant, greater leaf area, and total leaf chlorophyll content in the cultivar Fado.

El-Bably *et al*. (2017) conducted a field experiment at Sakha Horticulture Research Station, Kafr El-Sheikh Governorate, Egypt, during the two successive seasons of 2013-2014 and 2014-2015 to study the effect of some natural materials, i.e. humic acid, yeast and garlic extracts, using two application methods, i.e. soil drench and foliar spray in tuberose (*Polianthes tuberosa,* L.). Results indicated that humic acid treatment followed by yeast then garlic extract significantly increased all traits under study. Soil drench method was superior for vegetative growth compared to the foliar spray one.

Muraleedharan *et al*. (2017) conducted an experiment during 2015-2016 to study the impact of Humic Acid along with growing media combination with azospirillum and FYM on the growth, flowering and quality of anthurium plants (*Anthurium andreanum*) in Flora-tech floriculture unit at Kottarakara, Kollam Dist, Kerala state, India. Treatment T_2 (coco peat + azospirillum + Humic Acid) was found to be best in growth characters highest plant height of 48.89 cm, plant spread of 74.76, 8.63 number of leaves, 89.21 g fresh weight respectively.

Archana *et al*. (2019) observed that application of 75% recommended doses of fertilizers (RDF) + Humic acid 12% (3ml/l) have shown significant effect on the vegetative growth parameters exhibiting maximum plant height and number of leaves, early spike emergence (65 days), maximum spike length (83.56 cm), maximum chlorophyll content (58.66 Spad units) in tuberose cv. Bidhan Rajini-1.

Bolagam and Natarajan, (2019) conducted a studied the effect of biostimulants on growth and flowering of cut gladiolus (*Gladiolus grandiflorus*L.) cv. Arka Amar. Application of humic acid at 4ml/l recorded significantly minimum number of days for 50% and 100% sprouting of corms (7.20 days), maximum plant height (32.93 cm, 51.26 cm and 81.53cm, at 30days, 45 days, and 60 days after corm sprouting respectively), longer leaf length (39.80 cm) and broader leaf width

Babarabie *et al.* (2020) studied the effect of different levels of humic and folic acids on yield and quantitative and qualitative traits of tuberose (*Polianthes tuberosa* L.). Result showed that the application of humic acid significantly influenced shoot fresh weight, leaf number and leaf area.

Trivedi *et al.* (2022) conducted an experiment to study the various biostimulants effect on gladiolus var. Psittacinus Hybrid. They found that Humic acid 0.2% + Panchgavya3% obtained maximum plant height (62.83 cm, 63.23 cm and 63.49 cm, respectively) at 60, 90 and 120 days after planting and maximum number of leaves per plant (16.93).

2.4.2 Flowering parameters

Nikbakht *et al*. (2008) studied the effect of humic acid on plant growth, nutrient uptake, and post-harvest life of gerbera cv. Malibu. Different levels of humic acid (0, 100, 500, and 1000 mg/L) were applied to nutrient solution. It was observed that root growth increased at 1000 mg/L HA incorporated into the solution. Macro and micronutrient contents of leaves and scapes such as nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), iron (Fe), and zinc (Zn) were significantly enhanced by HA. 500 mg/L HA increased the number of harvested flowers per plant (52%). Higher HA levels extended the vase life of harvested flowers by 2-3.66 days and could prevent and delay bent neck incidence. These post-harvest responses were most probably due to Ca accumulation in scapes and hormone-like activity of HA.

Ahmad *et al.* (2013) studied the humic acid and cultivar effects on growth, yield, vase life, and corm characteristics of gladiolus. They found that application of HA at 7000 ml/ ha and NPK at 250 kg/ha at planting, 3-leaf, and 6-leaf stages of plant development were best for earlier spike emergence, greater number of florets per spike, longer stems and spikes, and greater diameter of a spike, higher flower quality in the cultivar Fado.

Khodakhah *et al.* (2014) investigated the effect of different levels of humic acid and salicylic acid on growth characteristics and qualities of Tuberose. The results showed that application of 1500 ppm humic acid extended the time of blooming of second floret, harvest time (the blooming of the fourth floret), also increased flowering stalk diameter, chlorophyll content (CCI), the number of florets, the second floret diameter and post-harvest vase life.

El-Bably, (2017) conducted a field experiment at Sakha Horticulture Research Station, Kafr El-Sheikh Governorate, Egypt, during the two successive seasons of 2013-2014 and 2014-2015 to study the effect of some natural materials, i.e. humic acid, yeast and garlic extracts, using two application methods, i.e. soil drench and foliar spray in tuberose (*Polianthes tuberosa,* L.). Results indicated that humic acid treatment followed by yeast then garlic extract significantly increased all traits under study. Soil drench method was superior for flowering traits compared to the foliar spray one.

Muraleedharan *et al*. (2017) conducted an experiment during 2015-2016 to study the impact of Humic Acid along with growing media combination with azospirillum and FYM on the growth, flowering and quality of anthurium plants (*Anthurium andreanum*) in Flora-tech floriculture unit at Kottarakara, Kollam Dist, Kerala state, India. Treatment T_2 (coco peat + azospirillum + Humic Acid) was found to be best in yield characters, flowers with highest stalk length of 41.34 cm and quality characters of flowers like spathe length, spathe breadth and spadix length of 9.53, 9.62 and 7.39, respectively.

Archana *et al*. (2019) observed that application of 75% recommended doses of fertilizers (RDF) + Humic acid 12% (3ml/l) have shown significant effect on the vegetative growth parameters exhibiting promoted maximum duration of flowering (174.6 days) in tuberose cv. Bidhan Rajini-1.

Bolagam and Natarajan, (2019) conducted a studied the effect of biostimulants on growth and flowering of cut gladiolus (*Gladiolus grandifloras* L.) cv. Arka Amar. With respect to floral parameters except diameter of spike, humic acid at 4ml/l treatment resulted in earlier spike emergence (57.23 days), longer spike length, more number of florets per spike (13.60), increased length (9.90 cm) and diameter of floret, fresh weight of floret (3.73 g), duration of flowering (16.53 days), spike longevity on the plant, number of spikes per plant, number spikes per plot and further maximum number of spikes /ha(1.83 lakhs) was also recorded.

Babarabie *et al.* (2020) studied the effect of different levels of humic and folic acids on yield and quantitative and qualitative traits of tuberose (*Polianthes tuberosa* L.). Result showed that the application of humic acid significantly influenced spike length, stem length and diameter, shoot fresh weight, floret number, flower emergence time.

Ghani *et al*. (2021) studied the influence of humic acid and phosphorus doses on flowering attributes of tuberose under lath house condition. Results indicated that humic acid and phosphorus at 30 kg /ha and 150 kg /ha had significant effect on floret diameter, number of petals per floret, pre-harvest floret life and florets per spike of tuberose.

Trivedi *et al.* (2022) conducted an experiment to study the various biostimulants effect on gladiolus var. Psittacinus Hybrid. They found that Humic acid 0.2% + Panchgavya3% obtained maximum number of spikes per plant (2.60) and flower yield.

Application of 100 per cent of recommended dose of fertilizer through fertigation along with microbial consortium @ 12.5 kg ha-1, foliar spray of panchagavya @ 3 per cent and humic acid @ 0.4 per cent recorded highest number of spikes per plant (3.96), number of florets per spike (43.55), single flower weight (1.85 g) and estimated flower yield (15.87 t ha-1) in tuberose cv. Prajwal (Kumar and Ganesh, 2021)

2.4.3 Bulb parameters

Ahmad *et al.* (2013) studied the humic acid and cultivar effects on growth, yield, vase life, and corm characteristics of gladiolus. They found that application of HA at 7000 ml/ ha and NPK at 250 kg/ha at planting, 3-leaf, and 6-leaf stages of plant development were best for higher number of cormels per clump, and greater cormel diameter and weight were recorded in the cultivar Fado.

Hadi *et al.* (2016) carried out cultivation of tuberose in pot and field with humic acid treatments under a semi-arid climate. The results showed that humic acid application (2.5 and 5 kg/ha) improved some of the important characteristics such as flowering percentage in pot system and main bulb weight and total bulbs weight in field cultivation. Application of humic acid in pot culture was found as suitable cultivation system to enhance the flowering percentage. However, field culture system was more effective in bulb production.

El-Bably, (2017) conducted a field experiment at Sakha Horticulture Research Station, Kafr El-Sheikh Governorate, Egypt, during the two successive seasons of 2013-2014 and 2014-2015 to study the effect of some natural materials, i.e. humic acid, yeast and garlic extracts, using two application methods, i.e. soil drench and foliar spray in tuberose (*Polianthes tuberosa,* L.). Results indicated that humic acid treatment followed by yeast then garlic extract significantly increased all traits under study. Soil drench method was superior for bulbs productivity and chemical constituents compared to the foliar spray one.

Babarabie *et al.* (2020) studied the effect of different levels of humic and folic acids on yield and quantitative and qualitative traits of tuberose (*Polianthes* *tuberosa* L.). Result showed that the application of humic acid significantly influenced bulblet number, root development depth, N, P and K content.

Trivedi *et al.* (2022) conducted an experiment to study the various biostimulants effect on gladiolus var. Psittacinus Hybrid. They found that Humic acid 0.2% + Panchgavya 3% obtained maximum number of corms per plant (3.36), and number of cormels per plant (4.38).

2.5 Effect of forest top soil on growth, flowering and yield of tuberose

Chowdhury *et al*. (2008) conducted an experiment to study the addition of some tree leaf litters in forest soil and their effect on the growth, yield and nutrient uptake by red amaranth. Result showed the highest values of most of the parameters were recorded from the plant treated with chemical fertilizers whereas plant diameter, dry matter weight, S, Fe contents and the entire nutrient uptake were maximum in plants amended with *Teak* leaf litters.

Khatun *et al*. (2010) conducted a study on effect of different tree leaf litters and chemical fertilizer on the growth and yield of okra in Modhupur forest soil and reported that the different leaf litters had significant effect on the growth and yield of okra.

Sarkar *et al.* (2010) carried out an experiment on the effect of different forest tree leaf litters on growth, yield, and nutrient contents of red amaranth cv. Altapety and opined that plant height, number of leaves plant^{-1}, dry weight plant^{-1} and moisture content (%) were significantly influenced by the addition of teak leaf litter.

Sarkar *et al*. (2011) studied the effect of different forest tree leaf litters and chemical fertilizer on growth yield and nutrient contents of gima kalmi cv. BARI Gima Kalmi -1 and found that different leaf litters showed its significant positive effect on growth, yield and nutrient content of gima kalmi (*Ipomoea reptans* Poir).

Singh *et al.* (2017) studied the influence of growing media and NPK on growth and flowering of Alstroemeria cv. Capri at the Research Farm of Department of Floriculture and Landscaping, Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan. The results revealed that plants grown in rhododendron forest soil recorded maximum values for plant height (110.30 cm), maximum shoots per plant at peak flowering (20.45),maximum yield of cut stems per plant (38.44 cut stems) and maximum vase life (19.20 days).

Kausadikar *et al.* (2017) studied the effect of teak leaf litter decomposition on yield of *Abelmoschus moschatus* and soil properties and found that the application of 5 t /ha teak leaf litter + cow dung at 50% and bio-decomposer increase yield and quality of kasturi bhindi and improved the soil fertility status.

Das and sheeba, (2024) conducted an experiment to assess the efficacy of litter composts as nitrogen sources in vegetable cow pea (*Vigna unguiculata* subsp. *unguiculata*) in terms of the agronomic efficiencies and nutrient uptake and observed that treatment involving mango leaf litter composted with glyricidia leaves gives the highest vegetable yields (7.80 t /ha).

2.6 Effect of INM on growth, flowering and yield of tuberose

2.6.1 Vegetative growth

Kusuma (2000) observed that the golden rod plants supplied with vermicompost (10 tons/ha) and 100% recommended NPK (100:50:50 kg/ha) produced greater plant height, maximum number of leaves.

Kabir *et al*. (2011) conducted an experiment at the farmer's field of Sutiakhali, Mymensingh Sadar Upazilla, Mymensingh during the period from April, 2009 to March, 2010 to investigate the effect of organic fertilizers along with half chemical fertilizers on the growth, bulb and flower yield of tuberose *cv.* single. The experiment consisted of four different sources of fertilizers *viz.*, (i) recommended chemical fertilizers at 400, 300, 300 and 100 kg /ha of urea, TSP, MP and gypsum, respectively; (ii) vermicompost at 5 t /ha along with half of chemical fertilizers; (iii) poultry litter at 20 t /ha along with half of chemical fertilizers and (iv) cowdung at 20 t /ha along with half of chemical fertilizers. Results revealed that plant height, leaf number per plant, leaf length and breadth and number of side shoots per plant were greater in organic fertilizers along with half chemical fertilizers (T_3) than absolute use of chemical fertilizers.

Mayuri *et al*. (2013) studied the effect of integrated nutrient management on growth, yield and quality of ratoon tuberose cv. Double at Department of Horticulture, Junagadh Agricultural University, Junagadh. Sixteen treatment combinations of different nutrients were comprised with three replications. Result showed that application of FYM at 30 t /ha + PSB at 2 g/m^2 + *Azotobacter* at 2 g/m^2 (T_{13}) took minimum days to sprouting (18.47 days), registered maximum plant height (61.67 cm) and plant spread at E-W and N-S (37.93 cm and 37.07 cm, respectively).

Elisheba and Sudhagar (2019) studied the effect of integrated nutrient management in tuberose (*Polianthes tuberosa* L.) cv. Prajwal. The treatments consisted of foliar spray of panchagavya, humic acid and EM with a combination of FYM and vermicompost. Among the various treatments, the plants receiving a combination of 75 % RDF + Vermicompost at 5 t /ha + Humic Acid at 0.2 % (T_9) was found to be best in all the growth characters *viz.*, plant height (65.45 cm); number of side shoots per plant (9.19), number of leaves per plant (95.34), leaf area (65.85 cm^2), chlorophyll content (0.921 mg/g) and dry matter production (28.75 g/plant).

Basant *et al*. (2020) investigated the effect of nutrient management on growth, flowering and flower yield of tuberose (*Polianthes tuberosa* L.) under Chhattisgarh plain condition at the Department of Floriculture and Landscape Architecture, IGKV, Raipur, Chhattisgarh. Results showed that the maximum number of florets per spike, length of spike, length of rachis and flower yield were recorded under T_9 (75% RDF + FYM at 3.5 t /ha + Vermicompost at 1.5 t /ha + Poultry manure at 2 t /ha).

An experiment was conducted by Mohanty *et al*. (2020) to investigate the effect of organic and inorganic sources of nitrogen on plant growth, bulb characteristics and yield of tuberose (*Polianthes tuberosa* L.) cv. Prajwal. The result of the study revealed that among all the organic manures and their combinations with inorganic fertilizers, the best results were recorded in T_9 [75% N (Urea) + 25% N (Mustard oil cake)] with respect to vegetative parameters (plant height, number of leaves per plant, leaf length) compared to other treatments.

Sahana *et al*. (2020) revealed that combine application of 50 per cent RDF (100:100:100 kg NPK/ ha) plus vermicompost (5 t/ha) plus humic acid (0.2%) plus boron (1%) recorded significantly maximum values of plant height (48.78 cm) and number of leaves (44.65/plant) in tuberose.

Gangwar *et al*. (2021). Conducted the investigation entitled effect of integrated nutrient management in tuberose (*Polianthes tuberosa* L.) was carried out in the Department of Horticulture, CCR(PG) CLG, Muzaffarnagar. The experiment was laid out in randomized block design comprising of eleven treatment combinations of different nutrients with three replications and found that 75 % RDF + 25 % Vermicompost + Azospirllum + PSB is superior for the overall growth of tuberose

Ashwini *et al.* (2024) studies the effect of gypsum and integrated nutrient management practices on soil fertility and flower yield of tuberose (*Polianthes tuberosa* L.) in saline soils at post graduate research farm of college of Horticulture, Mojerla during the rabi season of 2019 in factorial randomized block design with sixteen treatments replicated three times. Observed that topping of native saline soil with tank silt+gypsum @2.5t/ha+poultry refuse@ 5t/ha+¼dose of recommended dose fertilizers (200kg N: 200kg P2O5+200kg K2O) proved to be the best treatments for increase in growth of tuberose var Prajwal.

Tomar *et al*. 2024. Observed that the application of 75% RDF + 2 kg FYM/m^2 + 300g VC/m^2 + PSB + Azospirillum reduced days to sprouting (12.10 and 14.18), and improved plant height (40.8 and 41.7 cm), leaf length (48.0 and 48.6 cm), leaf width (1.78 and 1.80 cm), and leaf number (60.8 and 61.4) of tuberose.

2.6.2 Flowering parameter

Shashikanth (2005) noticed in marigold that application of vermicompost at 5.0 t /ha along with recommended dose of fertilizer had increased flower yield (13.9 t /ha).

In the same crop, maximum number of flower buds/plant, individual flower weight and flower yield/m^2 were recorded with the application of vermicompost at 1000 g/m^2

Kusuma (2000) observed that the golden rod plants supplied with vermicompost (10 tons/ha) and 100% recommended NPK (100:50:50 kg/ha) produced greater flower yield.

Padaganur *et al.* (2005) conducted a field experiment at the University of Agricultural Sciences, Dharwad to study the response of tuberose to vermicompost at different levels (1, 2 and 3 kg/sq. m.) alone and in combination with 50% recommended dose of fertilizer (RDF) and recommended dose of FYM and revealed that plants which received vermicompost either alone or in combination with 50% RDF were early to initiate flowering. Significantly higher flower spike yield (1.12 and 1.16 lakhs/ha in 2000 and 2001, respectively) was obtained with the application of 3 kg vermicompost/sq m along with 50% RDF.

Kabir *et al*. (2011) conducted an experiment at the farmer's field of Sutiakhali, Mymensingh SadarUpazilla, Mymensingh during the period from April, 2009 to March, 2010 to investigate the effect of organic fertilizers along with half chemical fertilizers on the growth, bulb and flower yield of tuberose *cv*. single. The experiment consisted of four different sources of fertilizers *viz.*, (i) recommended chemical fertilizers at 400, 300, 300 and 100 kg /ha of urea, TSP, MP and gypsum, respectively; (ii) vermicompost at 5 t /ha along with half of chemical fertilizers; (iii) poultry litter at 20 t /ha along with half of chemical fertilizers and (iv) cowdung at 20 t /ha along with half of chemical fertilizers. Results revealed that rachis length, spike length and diameter, number of florets per spike and flower yield both per spike and per hectare were greater in organic fertilizers along with half chemical fertilizers (T_3) than absolute use of chemical fertilizers.

Tripathi *et al*. (2012) observed that maximum spike yield (205030.71 spikes/ha) was obtained with the application of 75% recommended dose of NPK + 500 q/ha vermicompost in tuberose cv. Single.

Mayuri *et al*. (2013) studied the effect of integrated nutrient management on growth, yield and quality of ratoon tuberose cv. Double at Department of Horticulture, Junagadh Agricultural University, Junagadh. Sixteen treatment combinations of different nutrients were comprised with three replications. Result showed that application of FYM at 30 t /ha + PSB at 2 g/m^2 + *Azotobacter* at 2 g/m^2 (T13) recorded maximum length of spike (78.00 cm), number of florets per spike (44.07), number of spikes per plant (4.26), number of spikes per net plot (127.67), number of spikes per hectare (4.73 lacks),

Basant *et al*. (2020) investigated the effect of nutrient management on growth, flowering and flower yield of tuberose (*Polianthes tuberose* L.) under Chhattisgarh plain condition at the Department of Floriculture and Landscape Architecture, IGKV, Raipur, Chhattisgarh. Results showed that the maximum number of florets per spike, length of spike, length of rachis and flower yield were recorded under T_9 (75% RDF + FYM at 3.5 t /ha + Vermicompost at 1.5 t /ha + Poultry manure at 2 t /ha).

An experiment was conducted by Mohanty *et al*. (2020) to investigate the effect of organic and inorganic sources of nitrogen on plant growth, bulb characteristics and yield of tuberose (*Polianthes tuberose* L.) cv. Prajwal. The result of the study revealed that among all the organic manures and their combinations with inorganic fertilizers, the best results were recorded in T_9 [75% N (Urea) + 25% N (Mustard oil cake)] with respect to yield attributing parameters (maximum flower number and minimum days taken for the opening of first flower from planting, including number of spikes per plot, spike length) compared to other treatments.

Ashwini *et al.* (2024) studies the effect of gypsum and integrated nutrient management practices on soil fertility and flower yield of tuberose (*Polianthes tuberosa* L.) in saline soils at post graduate research farm of college of Horticulture, Mojerla during the rabi season of 2019 in factorial randomized block design with sixteen treatments replicated three times. Observed that topping of native saline soil with tank silt+gypsum @2.5t/ha+poultry refuse@ 5t/ha+¼dose of recommended dose fertilizers (200kg N: 200kg P2O5+200kg K2O) proved to be the best treatments for increase in flower yield of tuberose var Prajwal.

2.6.3 Bulb parameter

Gupta *et al.* (2008) conducted a study on performance of INM in Gladiolus and he reported that among the three treatments i.e. Vermicompost (125 gm/sqm.), NPK (75 gm/sqm) and FYM (2.5 kg/sqm) recorded best results for corm yield parameters.

Kabir *et al*. (2011) conducted an experiment to investigate the effect of organic fertilizers along with half chemical fertilizers on the growth, bulb and flower yield of tuberose cv. Single. The experiment consisted of four different sources of fertilizers *viz.*, (i) recommended chemical fertilizers at 400, 300, 300 and 100 kg /ha of urea, TSP, MP and gypsum, respectively; (ii) vermicompost at 5 t /ha along with half of chemical fertilizers; (iii) poultry litter at 20 t /ha along with half of chemical fertilizers and (iv) cowdung at 20 t /ha along with half of chemical fertilizers. Results revealed that bulb production per plant, bulb length, bulb diameter and bulb yield both per plant and per hectare were greater in organic fertilizers along with half chemical fertilizers (T_3) than absolute use of chemical fertilizers.

Tripathi *et al.* (2012) reported that tuberose cv. Single treated with 75 % RDF + 500q FYM + 250q vermicompost/ha recorded the maximum number of bulbs/clump (7.70 and 7.767) maximum weight of bulb/clump (131.87 and 132.63g) highest bulb yield (52.60 and 53.10 tonnes/ ha).

A study was carried out by Rao *et al.* (2015) on impact of integrated nutrient management on bulb characters of tuberose and observed bulb yield (32.60 bulbs plant-1), maximum weight of bulbs (86.0 g) and weight of bulbils (21.92 g) of individual plant in treatment combination of 75% RDF + FYM + V.C + AZO + PSB.

Meena *et al. (*2015) assessed the response of integrated nutrient management on floral, bulb, and economic parameters in tuberose cv. Phule Rajani. An application of neem cake + vermi-compost + Azotobacter + PSB + 60% of the recommended dose of NPK through inorganic fertilisers showed significant influence on bulb parameters.

Gangwar *et al*. (2021). Conducted an investigation entitled effect of integrated nutrient management in tuberose (*Polianthes tuberosa* L.) and found that 75 % RDF

+ 25 % Vermicompost + Azospirllum + PSB is superior for the overall growth of tuberose.

2.7 Effect on INM on the vase life of tuberose

Ahmed *et al.* (2004) reported that application of Urea at 20 g/m^2, P_20_5 at 40 g/m^2 and FYM 4 kg/m^2 in combinations increased vase life as compared to other doses of fertilizers in dahlia cv. Procyon.

Mohd *et al*. (2006) studied the effect of INM practices in improving the flower yield of *Anthurium andreanum* cv. Meringue, the experiment was conducted with six kinds of organic substrates along with inorganic fertilizers. Better vase life was observed in the treatment combination of vermicompost 100 g/plant+ 50% RDF.

Nikbakht *et al*. (2008) studied the effect of humic acid on plant growth, nutrient uptake, and post-harvest life of gerbera cv. Malibu. Different levels of humic acid (0, 100, 500, and 1000 mg/L) were applied to nutrient solution. It was observed that 500 mg/L HA increased the number of harvested flowers per plant (52%). Higher HA levels extended the vase life of harvested flowers by 2-3.66 days and could prevent and delay bent neck incidence. These post-harvest responses were most probably due to Ca accumulation in scapes and hormone-like activity of HA.

Ahmad *et al.* (2013) studied the humic acid and cultivar effects on growth, yield, vase life, and corm characteristics of gladiolus. They found that application of HA at 7000 ml/ ha and NPK at 250 kg/ha at planting, 3-leaf, and 6-leaf stages of plant development were best for longer vase life recorded in the cultivar Fado.

Hadwani *et al.* (2013) observed that application of FYM at 30 t/ha + PSB at 2 g/m^2 + Azotobacter at 2 g/m^{2}exhibited maximum length of spike, number of florets per spike, number of spikes per plant and longest vase life in tuberose cv. Double

Mayuri *et al*. (2013) studied the effect of integrated nutrient management on growth, yield and quality of ratoon tuberose cv. Double at Department of Horticulture, Junagadh Agricultural University, Junagadh. Sixteen treatment combinations of different nutrients were comprised with three replications. Result showed that application of FYM at 30 t /ha + PSB at 2 g/m^2 + *Azotobacter* at 2 g/m^2 (T_{13}) took minimum days to sprouting (18.47 days), registered longest vase life (12.33 days) and *in situ* longevity of spike (20.80 days).

Meena *et al*. (2014) studied the effect of integrated nutrient management on vase life of tuberose cv. Phule Rajani The maximum days taken to open basal floret (1.53 days), vase life of spike (7.33 days), floret diameter (4.13 cm), longevity of opened floret (3.23 days) and uptake of water (39.66 ml) were recorded with the application of neem cake 12 q/ha + vermicompost 20 q/ha + *Azotobacter* + PSB + 60% recommended dose of NPK

Khodakhah *et al.* (2014) investigated the effect of different levels of humic acid and salicylic acid on growth characteristics and qualities of tuberose. The results showed that application of 1500 ppm humic acid extended the post-harvest vase life.

Singh *et al.* (2014) observed that application of 75%RDF + 2 tones VC + PSB + Azatobactor, was found to be most effective in the improving the flowering and vase life in gladiolus cv. "White Prosperity"

Kumar *et al.* (2015) studied the effect of integrated nutrient management on vase-life of tuberose (*Polianthes tuberosa* Linn) spikes cv. Hyderabad Double. The maximum vase life ((8.00 days) revealed in plants treated with PSB + Azotobacter + 50% N + 50% P + K + FYM.

Singh *et al.* (2016) studied the effect of farmyard manure, vermicompost and *Trichoderma* on plant growth and postharvest life of gladiolus and opinioned that plants treated with FYM had maximum vase life, weight of spike after withering and dry weight of spike.

Suseela *et al.* (2016) studied the Effect of organic manures, inorganic fertilizers and micronutrients on vegetative and floral characters of tuberose (Polianthes tuberosa L.) cv. 'Suvasini' and revealed that the higher vase life with application of 50% RDF in combination with 25% poultry manure along with 25% neem cake may be attributed to consistent and slow release of nutrients throughout the growing period.

Chawla *et al*. (2018) found that the significantly maximum vase life (12.07 days) were recorded with application of fertilizers (300:200:100 kg NPK/ha/year) along with FYM @ 15 t/ha in tuberose (*Polianthes tuberosa*) var. Prajwal

Sathyanarayana *et al.* (2018) conducted the experiment on effect of INM on gladiolus (*Gladiolus grandiflorus* L.) cv. American Beauty and the maximum vase life was observed in the plant treated with 100% RDF + FYM @ 7.5 t/ha + Azotobacter + PSB + KMB + 1% foliar spray of Nauroji Novel Organic Liquid Fertilizer.

Bohra, (2019) conducted their experiment on effect of organic manures and biofertilizers on growth and floral attributes of Kamini China aster. Data showed that the maximum vase life (9.73 days) was recorded in FYM @18 t/ha (50%) + Vermicompost @ 06 t/ha (50%) + PSB @ (50 ml/15L) + Azotobacter @ (30 ml/15L).

Jokar and Asil (2021) studied the effect of gibberellic acid and vermicompost on growth and flowering of daffodil flower. They observed that the application of vermicompost at 20% level and gibberellic acid with a concentration of 300 mg/L have increasing the vase life of flowers with an average of four days with a noticeable difference, compared to the control.

Ashwini *et al.* (2024) studies the effect of gypsum and integrated nutrient management practices on soil fertility and flower yield of tuberose (*Polianthes tuberosa* L.) in saline soils and observed that topping of native saline soil with tank silt + gypsum @2.5t/ha + poultry refuse@ 5t/ha + ¼dose of recommended dose fertilizers (200kg N: 200kg P2O5+200kg K2O) proved to be the best treatments for increase in vase life of tuberose var Prajwal.

Singh *et al.* (2024) Studied the effect of different INM packages on vegetative, flowering, yield and economics of china aster cv Kamini under High Hill Condition of Uttarakhand and found that the maximum shelf and vase life (4.50 and 12.300 days, respectively) were recorded from the plants grown in plots applied with 50% RDF + 25% FYM + 25% Neem cake + Azotobacter (5 mL L^{-1}).

2.8 Effect of INM on availability of NPK in soil after harvest

Microbial dynamics and physico-chemical properties of soil in the rhizosphere of chrysanthemum (*Dendranthema grandiflora*) as influenced by integrated nutrient management was studied by Laishram *et al.* (2013) and observed that the highest N (373.04 Kg/ha) and K (283.18 Kg/ha) build up was recorded with 30 g/m2 each of NPK + vermicompost + biofertilizers and maximum P (39.86 Kg/ha) build up in the soil was obtained with the application of 22.5 g/m2 each of NPK + vermicompost + biofertilizers.

Shirsat *et al.* (2015) recorded maximum total nutrient content (N, P and K) in flower and plant of tuberose with the application of 50% N through vermicompost + 50% N through urea + P and K (RDF) followed by application of 50% N through FYM + 50% N through urea + P and K (RDF) and application of recommended dose of fertilizer.

Harshavadhan *et al.* (2016) observed that the maximum available soil nutrients (305.60, 34.46 and 273.30 kg/ha N, P_2O_5 and K_2O, respectively) NPK content in leaves (5.03% N, 0.56% P, 4.08% K) were recorded in plants receiving 75% RD NP and 100% K + Azospirillum brasilense + Bacillus megaterium + VAM + Vermicompost + Panchagavya + Jeevamrutha + Trichoderma harzianum

Jagtap *et al.* (2017) observed that application of 300 kg N, 250 kg P_2 O_5 and 300 kg K_2O ha-1 + FYM 20 t ha^{-1} to tuberose helped to maintain nutrient status in respect of available NPK in soil.

Khanam *et al.* (2017) found the improvement in the available N, P and K nutrients by the integrating use of 50% recommended dose of fertilizers (RDF) with 2.5 ton/ha of vermicompost in harvested soil of gladiolus.

Sathyanarayana *et al.* (2017) studied the effect of integrated nutrient management on gladiolus (*Gladiolus grandiflorus* L.) cv. American Beauty who recorded the minimum soil electrical conductivity (0.67 dSm^{-1}) and highest available nitrogen (178.73 kg/ha), available phosphorus (19.48 kg/ha), available potash (314.13 kg/ha), soil organic carbon (0.80%) and microbial population (90.67 x 10- 7 CFU/g soil) with 100% RDF + FYM at 7.5 t/ha + Azotobacter + PSB + KMB + 1% foliar spray of Nauroji Novel Organic Liquid Fertilizer.

An experiment was conducted by Sharma *et al.* (2017) at Indian Agricultural Research Institute, New Delhi to study the effect of efficient micro-organism compost on plant growth and soil health in calendula and marigold. The results showed that the application of EM compost improves the humus content, organic carbon and available nitrogen status of soil which in turn increased the soil fertility over the control receiving chemical fertilizer only.

Dubliya *et al.* (2018) observed that the application of 100% RDF + Vermicompost (2.5 t ha-1) + Azotobacter recorded the maximum organic carbon content (0.76%), the maximum values of available nitrogen (220 kg/ha), phosphorus (19.33 kg/ ha), potassium (380 kg/ha), sulphur (22.70 ppm), zinc (1.70 ppm), copper (2.30 ppm), iron (5.20 ppm) and manganese (8 ppm) in harvested soil of tuberose.

Durga *et al.* (2018) observed that the integrated use of fertilizer NPK with organic FYM significantly increased the soil available NPK.

Kumar *et al*. (2019) conducted an experiment on chrysanthemum (*Dendranthema grandiflora* Tzvelev) cv. Guldasta and reported that maximum nitrogen, phosphorus and potassium were recorded with vermicompost (10 ton /ha).

2.9 Effect of INM on the Nutrient uptake by plant

Prakash *et al.* (2002) investigated the effect of phosphorous and FYM on NPK content of marigold in chloride dominated soil and observed that highest nitrogen, phosphorus and potassium content in marigold leaves were associated with the application of FYM.

Ghosh and Pal (2010) studied the response of African marigold cv. Siracole to organic and inorganic nitrogen sources and revealed that application of 50% N as (mustard oil cake) and 50% N as (urea) resulted in maximum chlorophyll content in the leaf tissues.

Sonmez *et al.* (2013) observed the impact of organic manures on nutrient content in gladiolus and opined maximum phosphorus content (0.30%) in leaves with the application of farmyard manure.

Khanam *et al.* (2017) evaluated the influence of integrated nutrient management on growth, quality, yield and soil fertility of gladiolus and observed that highest nutrient content in leaves N-1.20% P-0.44%and K-2.54% with the application of vermicompost (5t/ha) as compared to control.

Sathyanarayana *et al.* (2017) conducted an experiment on effect of integrated nutrient management on gladiolus (*Gladiolus grandiflorus* L.) cv. American beauty and revealed that application of 50% RDF+FYM @ 15 t/ha resulted in increased leaf nutrient content N-1.03 %, P-0.67% and K-0.83% as compared to 100% RDF.

Durga *et al.* (2018) observed that the integrated use of fertilizer NPK with organic FYM significantly increased the nutrient uptake over their corresponding sole applications in gladiolus. Application of FYM 10 t ha-1 and 300, 120 and 120 kg NPK ha^{-1} was found to be a balanced optimal dose for sustained productivity and better quality of gladiolus spikes in Inceptisols of Delhi.

Dhakar *et al.* (2019) studied the effect of organic and inorganic sources of fertilizer on corm yield and nutrient uptake of gladiolus and found that the uptake of N (2.43%), P (0.189%) and K (2.38%) was significantly higher with the application of 75% RDF + FYM @ 5 t/ha + Vermicompost @ 5 t/ha + Azospirillum + PSB.

Chaupoo and Kumar (2021) recorded the effect of organics, inorganic and biofertilizers on growth, quality, yield, soil and plant nutrient status of marigold (*Tagetes erecta* L.) cv. Pusa Narangi Gaindaand revealed that maximum nutrient uptake in leaves, stem and flower as well as enhanced nutrient uptake efficiency, Nitrogenuse efficiency and apparent nutrient recovery were associated with application of vermicompost+ 50% RDF.

2.10 Effect of INM on Chlorophyll content in the leaves of tuberose

Basoli *et al.* (2015) studied an Impact of integrated nutrient management on growth and flowering of gladiolus (*Gladiolus hybrida*) cv Novalux. Observed that Application of 3/4th N, P and K+ Azotobacter +PSB + KSB (T24) was found most effective in enhancing chlorophyll content (70.98 SPAD), photosynthetic rate (17.73 µmol/m2/sec), and N content (4.43%) in leaves of gladiolus (Gladiolus hybrida).

Archana *et al.* (2019) studied the effect of nutrients and biostimulants on growth and flowering of loose flowers of tuberose (*Polianthes tuberosa* L.) cv. Bidhan Rajini-1. The data revealed that nutrients and bio stimulants have significantly influenced the chlorophyll content of leaf. By the application of 75% RDF + Humic acid 12% (3ml/l) maximum chlorophyll content (58.66 spad units) was recorded.

Elisheba and Sudhagar (2019) stated that the application of 75 per cent of recommended dose of fertilizer along with vermicompost @ 5 t ha-1 and humic acid @ 0.2 per cent registered the maximum plant height (65.45 cm), number of side shoots plant-1 (9.19), number of leaves plant-1 (95.34), leaf area (65.85 cm2) and chlorophyll content (0.921 mg g-1) when compared to 100 per cent of recommended dose of fertilizer alone in tuberose cv. Prajwal.

Sahana *et al*. (2020) stated that the 50 per cent recommended dose of fertilizer @ 100: 100:100 kg NPK ha-1 along with vermicompost @ 5 t ha-1, humic acid @ 0.2 per cent and boron @ 1 per cent recorded the highest value of chlorophyll content (0.933 mg g-1) in tuberose cv. prajwal.

Rajaselvam *et al.* (2024) studied the effect of integrated nutrient management on growth and flower yield of tuberose cv. Prajwal and highest value of chlorophyll content (0.99 mg/ g) was found by application of 75 % RDF + *Azotobacter* @ 2 kg/ ha + PSB @ 2 kg/ ha**.**

2.11 Economics of INM in tuberose

Angadi (2014) evaluated the influence of integrated nutrient management on yield and relative economics of garland chrysanthemum. The treatment T_9 (Azospirillum + PSB + 50 per cent vermicompost equivalent to RDN + 50 %

recommended NPK) recorded maximum net returns (Rs. 1, 95,135/ha) and high B:C ratio (4.23).

Meena *et al*. (2015) studied the response of integrated nutrient management on floral, bulb and economic parameters in tuberose cv. Phule Rajani under sub-humid southern plains of Rajasthan. They found that an application of neem cake 12 q /ha + vermi-compost 20 q /ha + *Azotobacter* at 2 g plant^{-1} + PSB at 2 g plant^{-1} + 60% recommended dose of NPK through inorganic fertilizers showed, gross return (Rs. 8,61,777 /ha), net return rupees (Rs. 6,20,000 /ha) and benefit : cost ratio (2.56) highest trends in this treatment.

Rao *et al*. (2015) studied the impact of integrated nutrient management on growth, flowering, yield and economics of tuberose. Result showed that the B: C ratio ranged between 2.09 -2.60 with its maximum exhibited by 75% RDF with FYM, VC, AZO and PSB.

Tirkey *et al.* (2017) studied the effect of organic and inorganic source of N.P.K on growth and yield parameters of gladiolus *(Gladiolus grandiflorus*) cv. Jester and observed that75% RDF + 25% Vermicompost under Allahabad agro-climatic conditions registered the highest benefit cost ratio (2.35:1).

Adhikari *et al.* (2018) studied the effect of INM on vegetative growth, floral attributes, corm yield and economics of gladiolus cv. Arka Amar. The treatment containing 50% RDF + 50% FYM + Azotobacter at 25 g/l + Trichoderma harzianumat 20 g/m^2 was found most profitable in terms of economics of cultivation with a cost: benefit ratio of 1:2.12.

Diwivedi *et al.* (2018) studied the effect of organic and inorganic fertilizer on growth and flower yield of jasmine (*Jasminum grandiflorum* L.) and found that treatment T_8 (25%RDF+15.5 Kg FYM) was best in terms cost benefit ratio, maximum gross return, net return and cost benefit ratio was also found in treatment T_8.

Sathyanarayana *et al.* (2018) studied on the effect of INM on economics of gladiolus (*Gladiolus grandiflorus* L.) cv. American beauty. The results revealed that application of 100% RDF + FYM at 7.5 t/ha + Azotobacter + PSB + KMB + 1% foliar spray of Nauroji Novel Organic Liquid Fertilizer (T_{10}) was found most effective in benefit cost ratio (1: 1.02).

Wararkar *et al.* (2020) conducted the experiment to study effect of integrated nutrient management on growth, flowering and yield dahlia (*Dahlia variabilis* L.) cv. Kenya White. T_7 (27:18:11.25 gm NPK/Plot + Azospirullum + PSB) was found to be most economically viable in terms of benefit cost ratio (2.88:1).

Rajaselvam *et al.* (2024) conduct the experiment to study the effect of integrated nutrient management (INM) on growth and flower yield of tuberose (*Polianthes tuberosa* L.) cv. Prajwal. Result reveal that the effect of different sources of nutrient significantly imparted the effect on B:C ratio. The maximum B: C ratio (2.93) was recorded in the treatment T_{10} (75 % RDF + Azotobacter @ 2 kg /ha + PSB @ 2 kg/ ha).

Singh *et al.* (2024) revealed that maximum gross returns (₹4,73,400/ha), net returns (₹3,25,359/ha) and CB ratio 1: 2.19 were recorded with the application of 50% RDF + 25% FYM + 25% Neem cake + Azotobacter (5 mL L^{-1}) in China aster.

2.12 Tinting of tuberose

Jain *et al.* (2015) studied on post-harvest attributes of tuberose *(Polianthes tuberosa)* cultivars as influenced by tinting with edible colours. They found that maximum volume of dye uptake (6.89 ml) was recorded with 0.2% green dye; while Calcutta Double showed maximum dye uptake (5.29 ml). Maximum water uptake (32.80 ml) was recorded in flowers treated with 0.2% yellow dye +200 ppm 8HQC. Among three cultivars, maximum water uptake (31.46 ml) was recorded in cv. Shringar. Minimum floret drying (26.26%) throughout the studies was observed in flowers treated with 0.2% raspberry red dye+200ppm 8HQC. Among cultivars, Prajwal showed minimum floret wilting (24.63%). The maximum vase life (12.58 days) was observed with 0.2% raspberry red the cultivar Calcutta Double flowers exhibited maximum vase life (12.60 days).

Safeena *et al.* (2016) conducted experiment to evaluate the influence of colouring agents on vase life of cut spikes of two tuberose cultivars viz., Mexican Single and Pearl Double. The experiment was laid separately for both the cultivars. Treatments consisted of six different edible dyes viz., Tartrazine, Sunset yellow + Carmosine, Tartrazine + Brilliant blue, Tartrazine + Carmosine + Sunset yellow, Royal blue and Brilliant blue at three different concentrations (0.5%, 1 % and 1.5 %). They concluded that higher time of immersion (24 hours) and maximum concentration (1.5 %) allowed more dye to be translocated throughout the flower spike.

Ranchana *et al.* (2017) studied the standardization of tinting techniques in China aster cv. Local White. In this study, the food dyes *viz.,* Apple Green, Lemon Yellow and Orange Red were used in three different concentrations including control. The tinted flowers at 4% concentration expressed full bright coloured flowers in the inflorescence with quick uptake of colours in a short period of two hours duration.

Sowmeya *et al.* (2017) studied the effect of multi colours in tinting techniques in cut flowers (Rose and Carnation). In this study, the food dyes viz., Apple Green, Lemon Yellow, Blue, Pink and Orange Red were used in two different cut flowers with combination of colours. They revealed that the tinted flowers at the concentration rate of 5% express brightly coloured inflorescence with rapid uptake of colours in a short period of two hours duration in cut Rose and one hour in cut Carnation.

Kumari and Deb (2018) studied the effect of tinting on value addition of tuberose (*Polianthes tuberosa* L.) cv. Prajwal. Six different food dyes were used as tinting agent in the experiment all in powder form viz, Blue, Apple Green, Tomato red, Orange red, Lemon yellow and Rose pink at a concentration of 1%, 2% and 3% for all. Results showed that the darkest shades of colours were obtained in 3% concentration while lightest shades in 1%. The maximum vase-life was found in tuberose spikes which were treated with 1% Lemon yellow whereas minimum vase life recorded for Tomato red food dye (3%).

Sneha *et al.* (2019) carried out an experiment to standardized the tinting techniques in gerbera, carnation and gladiolus. They concluded that the flowers treated with blue, green and orange which were immersed for 7.5 hrs were found best with regard the colour intensity, colour distribution which results in the formation of bright coloured attractive flowers and maximum consumer acceptability.

Baidya and Chakrabarty, (2020) conducted an experiment to prolong the post-harvest life of tinted tuberose by using food dyes in combination with floral preservatives. Dipping the spikes in Apple green 3% + sucrose 2% + HQS 200 ppm for 2 hours was the best treatment in terms of maintenance of fresh weight, opened florets, vase life and acceptability. Sucrose 2% + aluminum sulphate showed a maximum diameter of florets as compared to sucrose 2% + HQS 200ppm. Among food dye, apple green 3% showed the best result as compared to the other two.

Prasanth *et al.* (2020) conducted an experiment to study the effect of food dyes in tinting of tuberose spikes, The results of the experiment revealed that maximum number of florets open per spike was recorded in orange red 4 % (18.40) and tuberose flower spikes dipped in kesar yellow, apple green and orange red at 8% had shown maximum intensity of colour in two hours of dipping time.

Jyothi *et al.* (2022) studied the effect of tinting methods with various food dyes on vase life of gypsophila (*Gypsophila paniculata*) cv. Crystal White. They found that the maximum quantity of dye uptake (ml), percentage of tinted florets, maximum vase life (5.00 days) was recorded in lemon yellow. Among the different food dyes and methods of absorption, lemon yellow at 3% by stem absorption had shown best vase life of gypsophila flowers.

Pavan *et al.* (2022) conducted the experiment to study the vase life, colour intensity, moisture content of tinted chrysanthemum, tuberose and Lilium flowers. The results revealed that flowers treated with food dye blue and immersed for 7.50hrs had recorded higher vase life (7.13 days) in chrysanthemum and flowers treated with distilled water (Control) and immersed for 5.00 hrs had recorded the higher vase life (7.00 and 6.13 days) in tuberose and lilium respectively. Maximum mean moisture content (69.64%) was observed in chrysanthemum flowers treated with yellow dye, immersed for 7.50 hrs and tuberose and Lilium flowers treated with distilled water immersed for 5.00 hrs (65.73 and 59.76%) respectively. Chrysanthemum, tuberose and lilium tinting with blue, green and orange which were immersed for 10.00hrs duration had gained the maximum consumer preference with bright attractive flowers.

CHAPTER - III

MATERIALS AND METHODS

MATERIALS AND METHODS

The present investigation entitled "Effect of INM on the performance of tuberose (*Polianthes tuberosa* L.) and tinting of cut tuberose with natural extracted dyes" was carried out in the Experimental Farm and and Post-harvest Laboratory, Department of Horticulture, School of Agricultural Sciences (SAS), Nagaland University, Medziphema Campus, Nagaland during the consecutive years 2022-2023 and 2023-2024. Materials and methods that were used for conducting the experiment are presented in this chapter under following heads.

3.1. General information

3.1.1. Geographical location

The Experimental Farm of Horticulture, School of Agricultural Sciences, Medziphema, Nagaland is located at 25°45′43″ N latitude and 93°53′04″ E longitude at an elevation of 305 m above mean sea level.

3.1.2. Climatic condition

Medziphema lies in humid sub-tropical zone with moderate temperature and medium to high rainfall ranging from 200 to 250 cm. The mean temperature ranges from 21ºC to 32ºC during summer while in winter it varies between 13ºC to 26ºC which rarely goes below 8ºC. The meteorological data recorded during the entire period of investigation is depicted in Fig 3.1.

3.1.3. Soil

The soil of the experimental field was categorized as sandy loam and acidic in nature. The results for the initial soil fertility status of experiment plot are presented in Table 3.1. While the Table 3.2 depicts the nutrient profile of the various source of organic inputs used in the experiment.

3.1.4 Source of planting materials

Healthy diseased free bulbs of single flowered tuberose cultivar Prajwal were procured from BCKV, West Bengal. The bulbs were medium sized having a diameter of 2.3-3 cm.

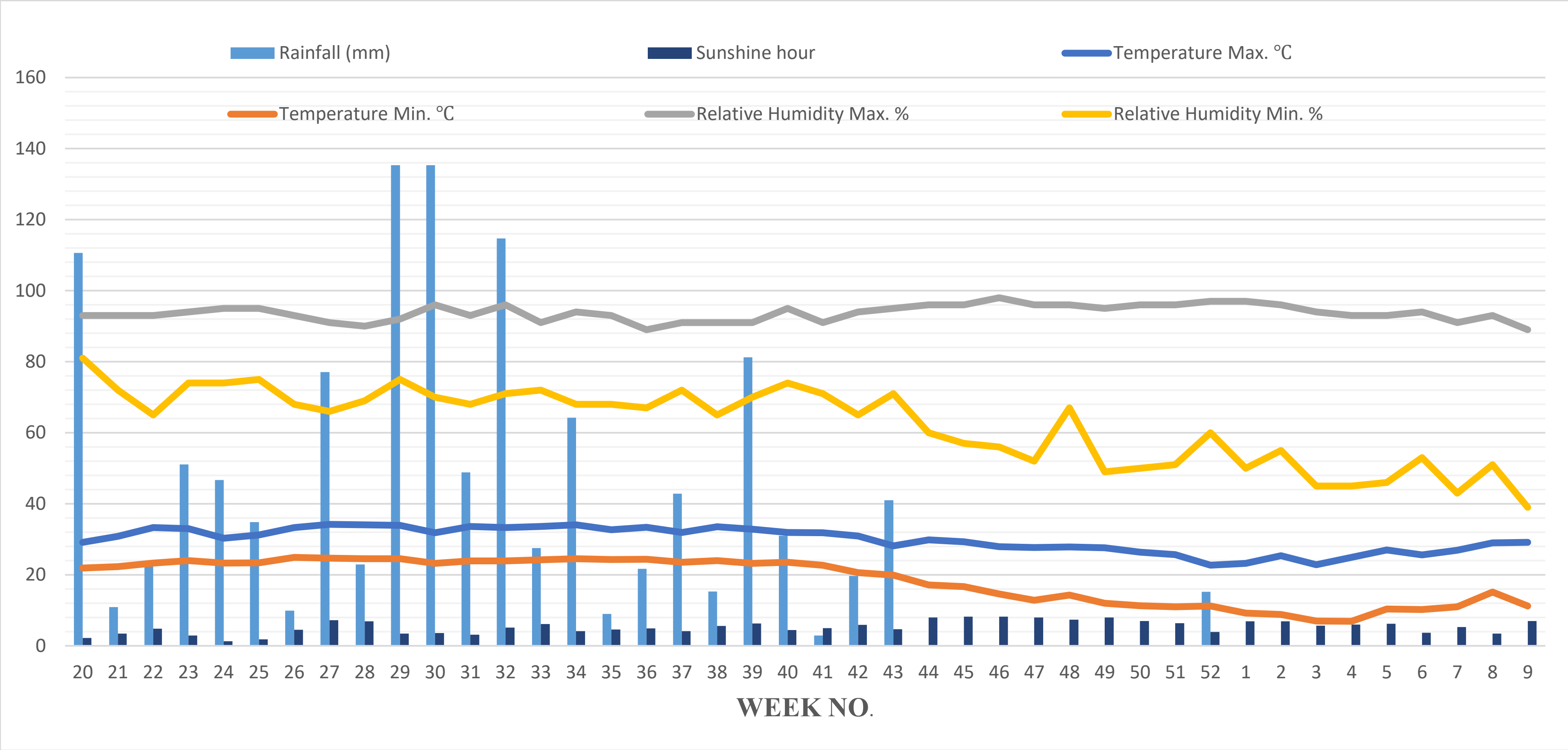

Fig 3.1(a) Meteorological data during the cropping season (2022-2023)

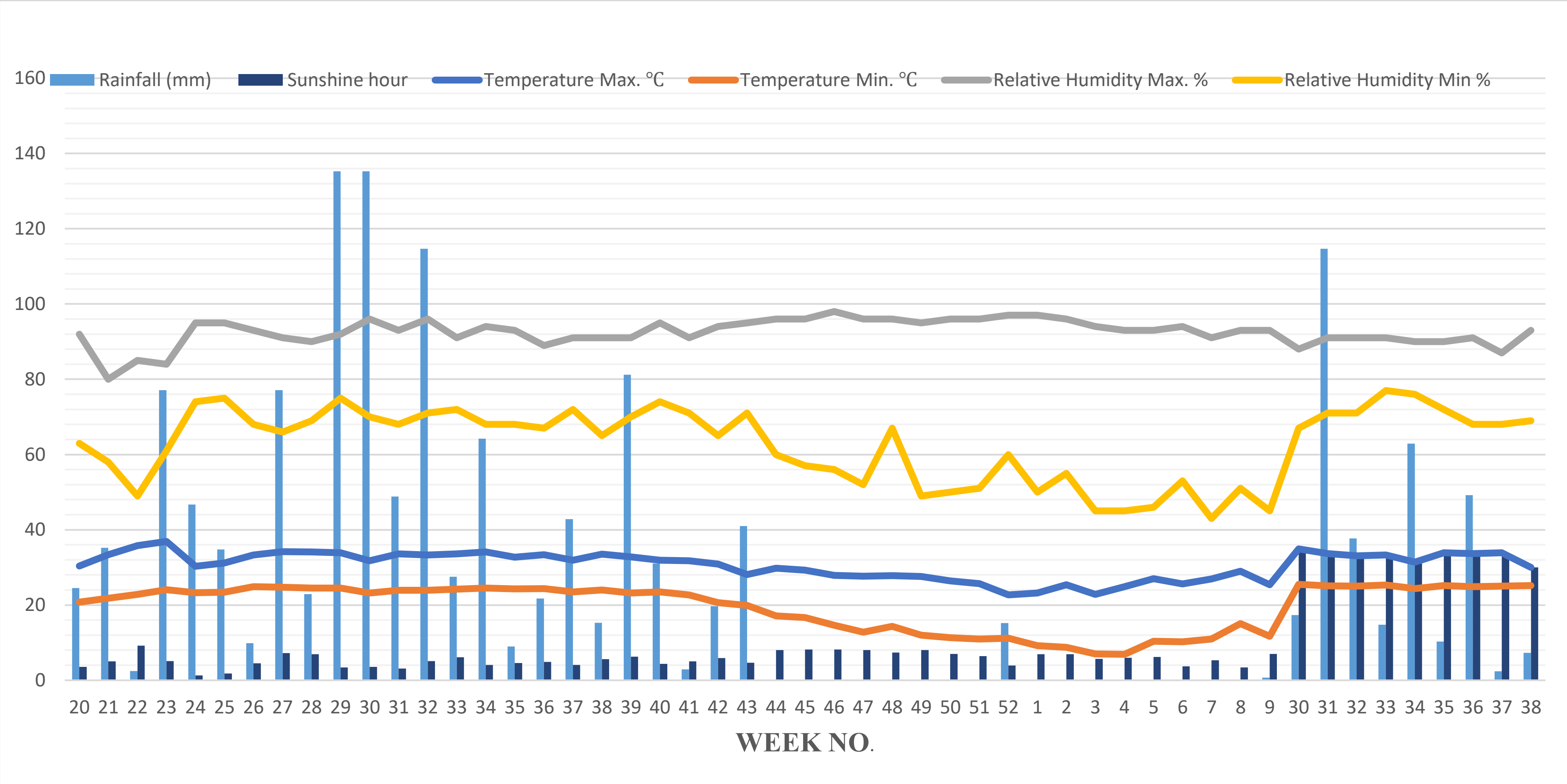

Fig 3.1(b) Meteorological data during the cropping season (2023-2024)

Table 3.1: Initial soil fertility status of experimental plots

Parameter	Value	Interpretation		Status	Method employed
		Availability	Comments		
pH	5.23	< 6.5 6.5 – 7.5 7.5 – 8.5 >8.7	Acidic Normal Saline/calcareous Alkaline	Acidic	Potentiometric method
Organic carbon (%)	1.56	< 0.5 0.5 – 0.75 >0.75	Low Medium High	High	Walkley and Black titration method (1934)
Available N (kg/ha)	501.76	<202 202-251 251-504 >504	Very low Low Medium High	Medium	Alkaline potassium permanganate method (Subbiah and Asija, 1956)
Available P (kg/ha)	33.6	< 22.5 22.5 – 56.0 >56.0	Low Medium High	Medium	Bray and Kurtz method, 1945
Available K (kg/ha)	145.6	< 136 136 – 337.5 >337.5	Low Medium High	Medium	Neutral Normal Ammonium Acetate method (Hanway and Heidal, 1952)

Table 3.2: Nutrient profiling of different organic manures

Organic fertilizers	Nutrient concentration %		
	N	P	K
FYM	0.5	0.3	0.5
Vermicompost	1.6	1.1	1.5
Poultry Manure	3.05	2.2	1.3
Forest Soil	0.8	0.3	0.6

3.1.5 Field preparation

The site for planting is ploughed thoroughly with Mould Board plough once, followed by harrowing, levelling and collecting the remain of the weeds and stubbles. Then field were divided into three blocks one meter away. Each block was divided into twelve plots at a distance of 60 cm.

3..6 Manures and fertilizers

Well decomposed FYM, vermicompost, poultry manure, forest soil was applied during the final land preparations as per treatment. The recommended dosage of N, P and K @ 200:200:150 kg/ha was supplied through urea, single super phosphate and muriate of potash respectively. Full dose of potassium and phosphorus was given as basal application at the time of planting and nitrogen was given in two split doses *i.e.* at 35 and 55 days after planting of bulbs. Whereas, humic acid was given in three split doses *i.e.* at final land preparation, 30 and 60 days after planting of bulbs.

3.2 Experimental details

3.2.1 Experiment I-Effect of INM on the performance of tuberose (*Polianthes tuberosa* L.)

3.2.2 Technical details

Crop	:	Tuberose
Cultivar	:	Prajwal
Design	:	Randomized Block Design (RBD)
Replications	:	3
Number of treatments	:	12

Treatments:

T_1	Control (RDF $N_{200}P_{200}K_{150}$kg/ha)
T_2	75% RDF + FYM at 10 t /ha
T_3	50% RDF + FYM at 20 t /ha
T_4	75% RDF + Vermicompost at 5 t /ha
T_5	50% RDF + Vermicompost at 10 t /ha
T_6	75% RDF + Poultry manure at 2 t /ha
T_7	50% RDF + Poultry manure at 4 t /ha
T_8	75% RDF + forest soil at 10 t /ha
T_9	50% RDF + forest soil at 20 t /ha
T_{10}	75% RDF + Humic Acid at 1t /ha
T_{11}	50% RDF +Humic Acid at 2 t /ha
T_{12}	FYM at10 t /ha + Vermicompost at 5 t /ha + Poultry manure at 2 t /ha+ forest soil at 10 t /ha+ Humic Acid at 1t /ha

Plot size	:	1.2m×1.2m
Total number of plots	:	36
Spacing	:	30cm x 30cm
Distance between plots	:	60 cm
Distance between replication	:	1m
Number of bulbs planted per plot	:	16
Period of first experiment	:	May 2022 – February 2023
Period of second experiment	:	May 2023 – February 2024

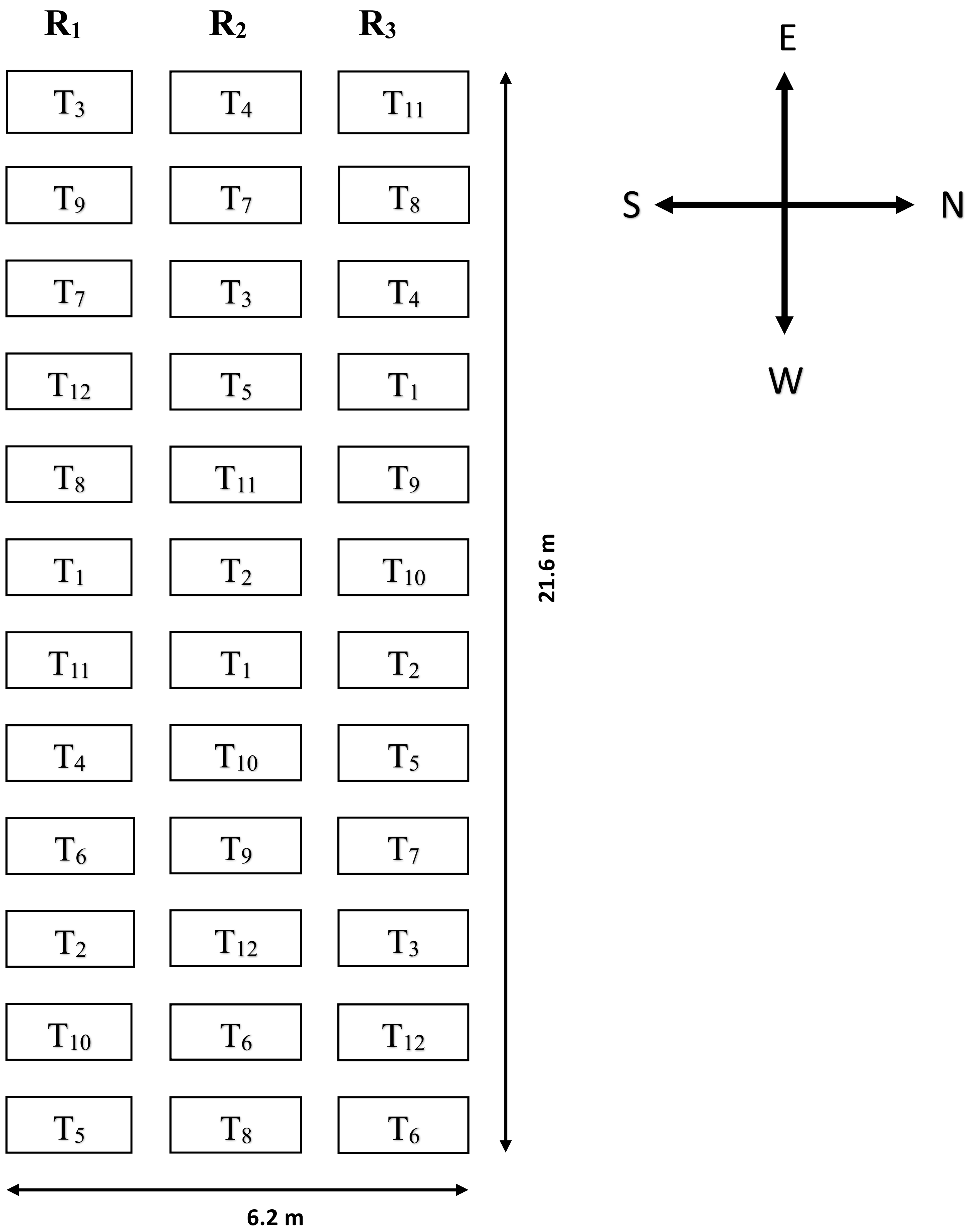

Fig. 3.2: Field layout of experiment

3.2.3 Planting

Bulb were thoroughly treated with fungicide carbendazime @ 2g/litre of water for 10-15 minutes and planted at the depth of 5 cm. Spacing at 30 cm from row to row and 30 cm from plant to plant is maintained.

3.2.4 Intercultural operations

The plots were kept weed free by periodic hand weeding. The field was irrigated depending on the seasonal conditions, as and when required. Earthing up was carried out at 40, 60 and 80 days respectively, after planting to cover up the exposed bulb and also prevent crops from lodging.

3.2.5 Plant protection measures

No plant protection measures were needed during both the year.

3.2.6 Harvesting of flower, bulb and bulbets

The spike of tuberose became ready for harvesting at 80 days after planting of bulbs. The spikes were harvested when the bottom 2-3 floret open. Immediately after harvesting the spikes were then subjected to Precooling in a bucket of cool water to remove the field heat. Bulb and bulblets were harvested at 280 days after planting when the leaves become yellow and dry.

3.3 Sampling and observations recorded

Random sampling technique was adopted and five plants were selected from net plot for each treatment in all the replication for recording various observations on growth, flowering, bulbs and post harvest studies.

The following observations were recorded during the period of experimentation.

3.3.1 Growth parameters:

3.3.1.1 Days to sprouting

Number of days taken for sprouting was recorded by counting the days from the day of planting bulbs till the bulbs sprouted in each treatment and then the average was worked out.

3.3.1.2 Number of leaves per plant

The total number of leaves on 5 tagged plants on each plot was counted at the time of spike emergence and the average was recorded.

3.3.1.3 Length of leaves

The length of the longest leaf at the time of spike emergence was measured with the help of measuring tape and average was worked out and presented in centimeter.

3.3.1.4 Plant height

The height of the plants was estimated in each treatment from the base of the plant to the tip of the longest leaves with the help of a meter scale at time of spike emergence and their average was calculated and represented in centimeter.

3.3.1.5 Number of side shoots per plant

The total number of side shoots on 5 tagged plants on each plot was counted at the time of spike emergence and the average was calculated.

3.3.2 Flowering parameters

3.3.2.1 Days to spike emergence

The number of days taken from planting of bulbs to spike initiation in the tagged plants was counted and the average was worked out.

3.3.2.2 Days to first floret opening

The number of days taken from planting of bulbs to the opening of 1st basal floret in each spike were recorded, and average days was worked out.

3.3.2.3 Days to 50% floret opening

Day taken for 50% flower bud on the spike to open fully was recorded from the date of spike initiation as 50% florets opening.

3.3.2.4 Days to 50% flowering

Days to 50 % flowering was determined by recording the number of days following planting until 50% of the plants in a plot produces flowers.

3.3.2.5 Length of spike

The spike length was measured from the base of the spike to the top most floret at the time of the 50% floret opening. The average was worked out and presented in centimeter.

3.3.2.6 Rachis length

Rachis length was measured from the first emergence point of the floret up to the last at the time of 50 % floret opening and expressed in centimeter.

3.3.2.7 Number of floret per spike

The total number of opened and unopened florets per spike was counted at the time of 50 % floret opening and the mean number of florets was recorded.

3.3.2.8 Diameter of the floret

Diameter of the 1^{st}, 3^{rd} and 5^{th} floret from five tagged plants were measured with the help of vernier caliper, and the average will be calculated and expressed in centimeter.

3.3.2.9 Weight of an individual floret

Weight of 1^{st}, 3^{rd} and 5^{th} floret from five tagged plants were weighed with the help of an electronic balance and the average was calculated and recorded in gram.

3.3.2.10 Flower durability

Flower durability was recorded from the time of first floret opening to the withering of 70 % floret in field condition and expressed in days.

3.3.3 Bulb parameters:

3.3.3.1 Number of bulbs per plant

Number of bulbs per plant was counted from five tagged plant and then average was calculated.

3.3.3.2 Number of bulblets per plant

Number of bulblets per plant was counted from five tagged plants and then average was calculated.

3.3.3.3 Bulb diameter

The diameter of bulbs was measured with the help of vernier caliper, and the average was worked out and expressed in centimeter.

3.3.3.4 Bulb weight

The bulb of five tagged plants were weighed on the electronic balance, and then average was represented in gram.

3.3.3.5 Bulblet weight

Weight of bulblets per plant was weighed on the electronic balance and then average was recorded and represented in gram.

3.3.3.6 Bulb yield

Bulb yield per hectare was computed from weighting the bulbs per plot and converted to hectare and presented in quintal per hectare.

3.3.4 Post harvest studies

3.3.4.1 Changes in fresh weight

The weight of the spike was taken on every 3rd day with the help of an electronic weighing balance and the changes in fresh weight was worked out and recorded in gram.

3.3.4.2 Days to 50% floret opening

The number of days taken from harvesting of spike to the opening of 50% florets on each spike during its vase life was counted and the average was worked out.

3.3.4.3 Total volume of water uptake

Total volume of water absorbed by the cut spike during the vase life period was done at 70% floret wilting stage. The volume of water taken up by the cut spikes was determined by measuring the volume of water in the measuring cylinder and the average was expressed in millilitre.

3.3.4.4 Vase life

Vase life of cut marketable tuberose spikes was observed in tap water and expressed in days. The vase life in days was calculated from the date of harvesting to 70%wilting of florets on spike.

3.3.5 Biochemical parameters

1. Chlorophyll content in leaves (mg/g)

3.3.5.1 Estimation of chlorophyll content by acetone incubation method

To estimate the chlorophyll content, 200 mg of fresh tuberose leaf tissue was weighed and placed into a clean test tube containing 5 ml of 80% acetone. The test tube was then sealed with a piece of polythene secured by a rubber band to prevent evaporation, and incubated in a refrigerator at approximately 4°C for 72 hours to allow complete extraction of chlorophyll pigments. After the incubation period, the contents were filtered to remove the leaf debris, and the clear acetone extract was collected. From the filtered extract, 1 ml was taken and diluted with 4 ml of 80% acetone. This diluted sample was then analyzed using a spectrophotometer by measuring absorbance at two specific wavelengths: 643 nm for chlorophyll b and 665 nm for chlorophyll a. The concentrations of chlorophyll a, chlorophyll b, and total chlorophyll were calculated using Arnon's equations:

chlorophyll a (mg/L) = $12.7 \times A_{665} - 2.69 \times A_{643}$;

chlorophyll b (mg/L) = $22.9 \times A_{643} - 4.68 \times A_{665}$; and

total chlorophyll (mg/L) = $20.2 \times A_{643} + 8.02 \times A_{665}$.

To express the chlorophyll content per gram of fresh tissue, the final concentration was adjusted using the formula:

$$\text{Chlorophyll (mg/g)} = \frac{C \times V}{1000 \times W}$$

Where:

- C = chlorophyll concentration in mg/L (from Arnon's equation)
- V = total volume of the extract in ml
- W = weight of fresh leaf tissue in grams
- 1000 = factor to convert ml to L

3.3.6 To study the chemical properties and nutrient status of the soil and nutrient content in Bio-inputs

The soil samples were collected from the experimental site at 0-15 cm depth and air dried in shade, ground with pestle and mortar, passed through 2mm sieve and stored in polythene lined bags. The study was done before planting and after harvest of the crop. The chemical properties of soil were analyzed as per the recommended methods. Also, the nutrient content in bio-inputs was analyzed.

3.3.6.1 Available nitrogen (Subbiah and Asija, 1956)

Five grams of the ground sample was moistened with 20ml of distilled water and was added to Kjeldahl distillation flask. 50 ml of 0.32% $KMnO4$ and 50 ml of 2.5% NaOH solution were added to the assembly and the cork was filled immediately. 25 ml of 2.5% boric acid with 5-6 drops of mixed indicator were taken in a 250 ml conical flask and the end of receiving tube was dipped into it to collect the released ammonia. Start the automatic distillation set and the content was distilled for 9-12 minutes. The distillate in the conical flask was titrated against 0.1 N HCl and the change in colour (pinkish) was noted.

Where,

Available nitrogen percentage = $\frac{(10-A) \times 0.00028 \times 100}{\text{Weight of soil}}$

A = Volume of 0.1 N HCl used

ppm of available nitrogen in sample = Available nitrogen percentage × 10000

Available nitrogen kg/ha = ppm × 2.24

3.3.6.2 Available phosphorus (Bray and Kurtz method, 1945)

5 grams of the ground sample was taken in a 150ml conical flask. 3-4 scoops of activated charcoal were added to the sample. Then 50ml P-extractant solution was added to it. The contents were shaken for 5 minutes and thereafter filtered to obtain clear filtrate. Pipette out 5 ml aliquot into a 25 ml volumetric flask, to which 5 ml of Dickman and Bray's reagent was added. Mix thoroughly, the contents of the flask with little amount of distilled water, washing the neck down, to let ammonium molybdate wash down. One ml of working solution of $SnCl2$ was added and its volume was made to 25 ml in the volumetric flask. The contents were mixed thoroughly and the blue colour intensity was measured after 20 minutes at 660 nm and appropriate blank was also run simultaneously.

Available P_2O_5 (kg/ha) = A × V × 2.24 × 2.29

Where,

Concentration of P read from the standard curve = A

Volume of extractant used (ml) = V

Conversion from ppm to kg/ha = multiply by 2.24

Conversion from P to P_2O_5 kg/ha = multiply by 2.29

3.3.6.3 Available potassium (Hanway and Heidal, 1952)

Available K_2O was extracted with neutral normal ammonium acetate, after shaking 5 gm of the ground sample with 25 ml of neutral NH_4OAc solution on an electric shaker for 5 minutes and then filtered. The filtrate was fed into the atomizer of the flame photometers, 100 of which has been set with 40 ppm K solution and the reading was noted. The reading was located on the standard curve, which gave the K-concentration in the extract. From this concentration measurement, the amount of K in the sample was calculated.

Available K_2O (kg/ha) = C × Dilution factor × 2.24 × 1.20

Where,

C = Concentration of K as read from the curve against R.
Dilution factor = Total volume of extract / weight of soil

3.3.6.4 Estimation of pH

For estimation of pH in soil-water suspension (1:2.5 ratio), 10 g of the sample was taken in a 150 ml beaker and 25 ml of the distilled water was added to it. The beaker was stirred at least four times with in a period of half an hour.

This time was required for the soil and water to attain equilibrium. After half an hour again the soil suspension was stirred and pH was measured on a digital pH-meter (Jackson, 1973).

3.3.6.5 Estimation of electrical conductivity (EC)

20 g of the sample was taken in a 50 ml beaker and 40 ml of the distilled water was added to it. The beaker was stirred intermittently 4-5 times and left overnight for getting a clear supernatant solution. The Electrical conductivity (EC) of the supernatant solution was measured by systronic conductivity meter and was expressed in dSm^{-1} (Jackson, 1973).

3.3.6.6 Organic carbon

Organic carbon content of the sample was determined by Chromic acid titration method suggested by Walkley and Black method (1934). 1 g of soil sample was taken in a 500 ml conical flask. Add 10 ml $K_2Cr_2O_7$ to the soil and gently rotate the flask to mix. To the mixture 20 ml concentrate H_2SO_4 was added and the flask was rotated for a minute to mix. The flask was allowed to stand for about 30 minutes in dark place and then add 200 ml distilled water and the flask was rotated to mix the content. 10 ml phosphoric acid and 1 ml of diphenylamine indicator was added. Then the content was titrated with 0.5 N ferrous ammonium sulphate solution till the colour changes from blue-violet to green.

Organic carbon (%) in soil = 0.5 x (B-C) × 0.003 × (200/Weight of soil sample)

3.3.7 To study the effect of integrated nutrient management (INM) on nutrient uptake by the plants

3.3.7.1 Leaf sampling and nutrient analysis

Leaves were collected from the sample plants at the time of spike emergence for leaf nutrient analysis. The leaf sample were thoroughly washed, cut and dried in hot air oven. Dried leaf samples were then ground using grinder machine. The samples were then analyzed for determination of NPK contents. The result, thus, obtained was represented in terms of percentage on dry weight bassis.

3.3.7.1.1 Nitrogen

Nitrogen in plant sample was determined by KEL PLUS nitrogen estimation system (PELICAN Equipments). Pelicans KEL PLUS System are developed and designed to perform the Micro-Kjeldahl method (Jackson, 1973) for estimation of nitrogen which consists of the following three processes viz. digestion, distillation and titration.

Digestion process: In this process, 0.5 g of plant sample was transferred to the digestion tube. 10 ml of concentrated sulphuric acid and 2 g of digestion activator (salt mixture) to the sample were added. Digestion tubes were loaded in to the digester and the digestion block was heated. At the end of digestion process, the sample turned colour less or light green colour.

Distillation process: During distillation, the ammonium radicals are converted to ammonia under excess alkali condition after neutralizing the acid in the digested sample with 40% alkali (NaOH) on heating. In KELPUS CLASSIC-DX VATS (B), the digested samples were heated by passing steam and the ammonia liberated due to the addition of 40% NaOH was dissolved in 4% boric acid. The boric acid consisting of ammonia was taken for titration.

Titration process: The solution of boric acid and mixed indicator containing the "distilled off" ammonia was titrated with the standardized H_2SO_4. The titration value of a blank solution of boric acid and mixed indicator was determined.

$$\text{Nitrogen (\%)} = \frac{(\text{Sample titer} - \text{Blank titer}) \times \text{Normality of } H_2SO_4 \times 14 \times 100}{\text{Sample weight (g)} \times 1000}$$

3.3.7.1.2 Phosphorus and potassium

One gram oven dried leaf sample was taken and digested in 100 ml conical flask with 10 ml of di-acid mixture (2:5) consisting of chemically pure concentrated perchloric acid and nitric acid respectively and digested material was filtered through whatman no. 40 filter paper in 100 ml volumetric flask and filtrate was diluted to mark as outlined by Johnson and Ulrich (1959). This was used for estimation of P and K.

Phosphorus

The phosphorus content in the digested leaves sample was determined by vanado molybdophosphoric acid yellow colour method using spectrophotometer at 660 nm (Jackson, 1973). 5 ml of aliquot from the colourless filtrate was taken in 25 ml volumetric flask for determination and then 5 ml of ammonium molybdate vanadate mixture was added to it and volume was made up to 25 ml after shaking well. It was kept for 30 minutes and colour intensity was measured in Spectronic-20 at 430 nm wave length, after setting the instrument to zero with blank.

Potassium

10 ml aliquot of the filtrate was taken in 100 ml volumetric flask and it was diluted to mark with distilled water. The potassium content in extract was estimated by flame photometer (Jackson, 1973).

3.3.7.3 Bulb sampling and nutrient analysis

The bulbs were lifted from the ground 60 days after flowering. The maturity of bulbs was identified by browning of leaves and wilting of plants. The bulb were thoroughly washed, cut and dried in hot air oven. Dried bulb samples were then ground using grinder machine. The samples were then analyzed for determination of NPK contents. Same method as mentioned earlier was followed for the nutrient analysis of the corms. The result, thus, obtained was represented in terms of percentage on dry weight basis.

3.3.8 To study the economics for different treatments

3.3.8.1 Cost of cultivation

The cost of cultivation (fixed cost + treatment cost) in each treatment combination was worked out based on the actual expenditure incurred on each item (Appendix - B). The cost of corms, manures, fertilizers, labour charges and the cultural practices including harvesting was worked out based on the prevailing prices and wages during the cropping season and expressed as cost of cultivation per hectare.

3.3.8.2 Gross income

The gross income was calculated on the basis of sale price of gladiolus spikes and corms prevailing during the study period. The total yield of tuberose cut flowers and bulbs was multiplied with the average price prevailed in the market for each grade and the sum revenue was expressed as total income per hectare.

3.3.8.3 Net income

Gross income minus cost of cultivation in each treatment was recorded as corresponding net income.

3.3.4 Benefit cost ratio

The ratio of net income to the total cost of cultivation was calculated and recorded as benefit-cost ratio for a particular treatment combination. It was computed by dividing the net income by corresponding cost of cultivation.

$$\text{Benefit cost ratio} = \frac{\text{Net return}}{\text{Total cost of cultivation}}$$

3.4 Experiment II-Tinting of cut tuberose with natural extracted dyes

Design	: Factorial Completely Randomized Design (FCRD)
Number of treatment	: 24
Replications	: 3

Treatments details are as follows:

Factor A: Natural dyes (A)

Treatment		Source
A_1	:	Beetroot pulp
A_2	:	Turmeric rhizome
A_3	:	Spinach leaves
A_4	:	Pomegranate peel
A_5	:	Dragon fruit pulp
A_6	:	Marigold flower
A_7	:	Hibiscus flower
A_8	:	Rhoeo leaves

Factor B: Dipping time (D)

D_1 : 6 hours

D_2 : 9 hours

D_3 : 12 hours

3.4.1 Dye extraction procedure

A desired plant material is taken from different plant sources and cut into small pieces and ground to a fine paste. Then the paste is filtered to remove the non-colouring matters from the dye liquor.

3.4.2 Method of tinting

Uniform spikes of 45 cm length with basal 2 -3 florets open were harvested. A slant cut at the base of the spike was given before placing them in different tinting solution. The spikes were immersed in test solution for 6, 9 and 12 hours respectively under ambient condition. After 6, 9 and 12 hours of dipping duration, the spikes are taken out and transferred into distilled water for further post harvest studies.

3.4.3 Sampling and observations recorded

3.4.3.1 Sensory evaluation

Sensory evaluation was carried with a panel of judges. Panel of judges assessed the different flower quality parameters by scoring on a five-point scale *i.e.* very poor, poor, good, very good and excellent with the weightage of 1, 2, 3, 4, 5, respectively. The following attributes were evaluated:

1. Effect of colour/ colour intensity (RHS colour chart)
2. Appearance/shape
3. Freshness
4. Petal retention
5. Over all acceptability

3.4.3.2 Quantitative evaluation

3.4.3.2.1 Changes in fresh weight

The weight of the spike was taken on every 3rd day with the help of an electronic weighing balance and the changes in fresh weight were worked out and recorded in gram.

3.4.3.2.2 Days taken to 50% floret opening

The number of days taken from harvesting of spike to the opening of 50% floret in each spike was recorded and average was worked out.

3.4.3.2.3 Diameter of floret

Diameter of the 1st, 3rd and 5th floret on the spike were measured with the help of vernier caliper and the average was calculated and expressed in centimeter.

3.4.3.2.4 Floret length

The length of 1st, 3rd and 5th floret were measured with the help of linear scale at full bloom and the average was calculated and expressed in centimeter.

3.4.3.2.5 Spike elongation

The difference between the length of the spike at the start of experiment and 50% floret opening was worked out and the average was expressed in centimeter.

3.4.3.2.6 Rachis elongation

The difference between the length of the rachis at the start of experiment and 50 % floret opening was recorded.

3.4.3.2.7 Water uptake

The volume of water taken up by the flowers during the vase life studies was worked out in grams as a different between the consecutive measurements of container with solution (without flower). It was recorded on every third day from the date of transferring the tinted spikes in the vase water.

3.4.3.2.8 Water loss

The volume of water loss of the flower during the vase life studies was worked out in grams as the difference between consecutive measurements of container with solution and spike. It was recorded on every third day from the date of transferring the tinted spikes in the vase water.

3.4.3.2.9 Water balance

The water balance ratio of cut spikes was calculated by dividing the water uptake by water loss of cut spikes.

Water balance = water uptake/ water loss

3.4.3.2.10 Vase life

The end of vase life was determined when 70% florets on spike show signs of wilting. The duration from opening of the first basal floret till wilting of the 70 % florets on the spike was recorded and represented as days of vase life.

3.5 Statistical analysis

The data on various observations recorded during the course of investigation was statistically analyzed. Analysis of variance technique (ANOVA) for different characters was worked out. The appropriate standard error of mean (SEm ±) and the critical difference (CD) was calculated at 5 percent level of probability. Data was depicted by suitable graphs at the appropriate tables.

Standard Error of Mean was computed as-

$$\text{SEm}\ (\pm) = \frac{\sqrt{EMS}}{r}$$

Then, critical difference (CD) at 5% level of significance was computed as-

CD at 5% = SEd × t_{value} where, SEd = SEm × √2

= SEm × √2 × $t_{(0.025,\ \text{error df})}$

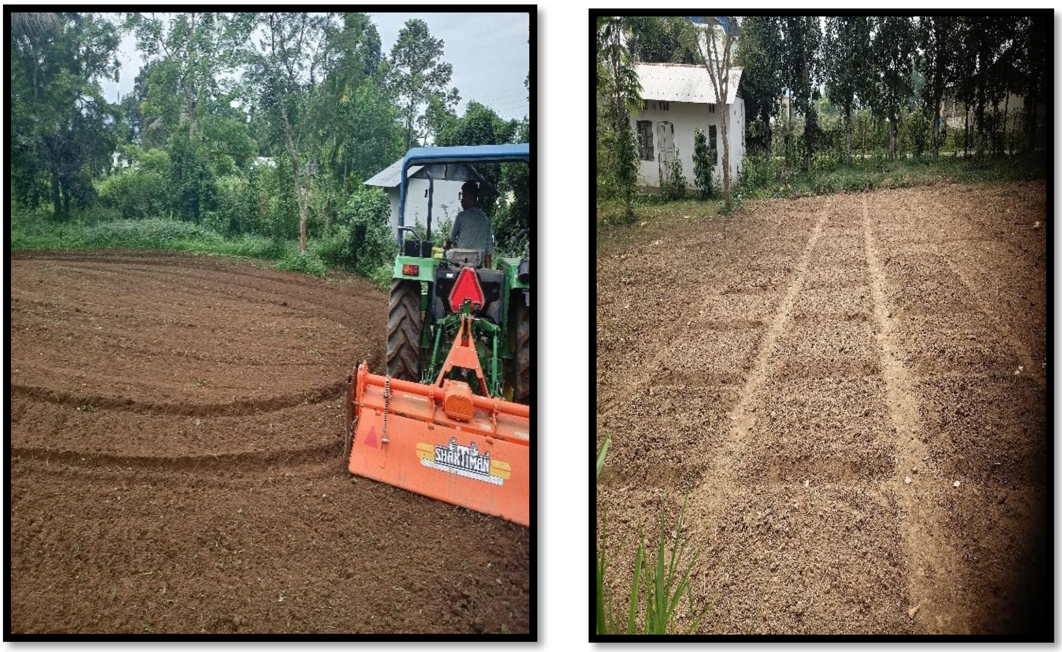

Plate No. 1 Primary ploughing of the experimental field and field preparation

Plate No. 2 Procured planting material ready for planting

Plate No. 3 Planting of bulbs

a. Vegetative stage

b. Flowering stage

Plate No. 4 General view of experimental field

CHAPTER - IV

RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

The results obtained from present investigation entitled "Effect of INM on the performance of tuberose (*Polianthes tuberosa* L.) and tinting of cut tuberose with natural extracted dyes" are presented and discussed in this chapter along with appropriate tables and figures.

4.1 Experiment I: Effect of INM on the performance of tuberose (*Polianthes tuberosa* L.)

4.1.1 Growth parameters

The data recorded on growth characters *viz*. days to sprouting, number of leaves per plant, length of leaves, plant height, number of side shoots per plant at flowering stage as influenced by organic and inorganic source of nutrients are discussed below.

4.1.1.1 Days to sprouting

The data presented in Table 4.1 and Fig 4.1 revealed that integrated use of organic manure and inorganic fertilizer had significant influence on days to sprouting of bulbs during two seasons i.e. 2022-23 and 2023-24 including pooled data analysis.

The minimum days (9.30) to sprouting during the 1st season was recorded with T_4 (75% RDF + Vermicompost at 5 t/ha) which was statistically at par with T_6 (75% RDF + Poultry manure at 2 t /ha), T_2 (75% RDF + FYM at 10 t/ha) and T_{10} (75% RDF + Humic Acid at 1t/ha) recorded 9.53, 9.83 and 9.93 days respectively. The last to sprout (11.83) among all the treatment was observed in control T_1 (RDF $N_{200}P_{200}K_{150}$kg/ha).

The response on INM during the 2nd season was nearly of similar magnitude as observed in 1st season. T_4 (75% RDF + Vermicompost at 5 t/ha) took minimum days (9.17) to sprouting of the bulb, which was statistically at par with other treatments like T_6 (75% RDF + Poultry manure at 2 t /ha), T_2 (75% RDF + FYM at 10 t/ha) and T_{10} (75% RDF + Humic Acid at 1t/ha) recording 9.40, 9.87 and 9.87 days respectively. Similarly, T_1 (RDF $N_{200}P_{200}K_{150}$kg/ha) took maximum days of 11.73 to sprout.

The pooled data followed almost the same pattern of response when compared with the result obtained season wise. Considering the response of both the season, T_4 (75% RDF + Vermicompost at 5 t/ha) took 9.23 days for sprouting which statistically at par with T_6 (75% RDF + Poultry manure at 2 t /ha), T_2 (75% RDF + FYM at 10 t/ha) and T_{10} (75% RDF + Humic Acid at 1t/ha) recording 9.47,9.85 and 9.90 days respectively, while T_1 (RDF $N_{200}P_{200}K_{150}$kg/ha) took maximum days of 11.78 to sprout among all the treatments.

The observed enhancement in early bulb sprouting may be attributed to the synergistic effect of vermicompost combined with 75% of the Recommended Dose of Fertilizers and also due to the presence of plant growth-promoting microorganisms commonly found in vermicompost, which are known to enhance phytohormone activity in soil (Tomati & Galli, 1995; Edwards, 1998) thereby encouraging early physiological responses such as sprouting. Additionally, vermicompost ensures a balanced uptake of nitrogen and improves the availability of micronutrients (Vasanthi & Kumaraswamy, 1999; Siangshai *et al*., 2022). Present result corroborates with the finding of Padaganur *et al*. (2005), Kabir *et al*. (2011) and Hadwani *et al*. (2013) in tuberose, Gangwar *et al.* (2021) in tuberose

4.1.1.2 Number of leaves per plant

The number of leaves per plant significantly influenced by integrated use of organic and inorganic fertilizer during the both season, 2022-23 and 2023-24 including the data when analysed on pool basis as shown in Table 4.1 and Figer 4.1.

During the first season in 2022-23, the maximum number of leaves per plant (23.50) was observed in T_4 (75% RDF + Vermicompost at 5 t/ha) which was at par with T_6 (75% RDF + Poultry manure at 2 t /ha) and T_2 (75% RDF + FYM at 10 t/ha) with 22.23 and 20.60 number of leaves per plant. The minimum number of leaves per plant (17.93) was noted in T_1 (RDF $N_{200}P_{200}K_{150}$kg/ha).

In the following season 2023-24, the results obtained were almost of same pattern where, T_4 (75% RDF + Vermicompost at 5 t/ha) recorded maximum number of leaves per plant (24.07) which was statistically at par with T_6 (75% RDF + Poultry manure at 2 t /ha), T_2 (75% RDF + FYM at 10 t/ha) recording 23.50 and

Table 4.1 Effect of INM on the days to sprouting and number of leaves per plant of tuberose

Treatment	Days to sprouting			Number of leaves per plant		
	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
T_1	11.83	11.73	11.78	17.93	19.73	18.83
T_2	9.83	9.87	9.85	20.60	22.77	21.68
T_3	10.83	10.77	10.80	19.10	20.60	19.85
T_4	9.30	9.17	9.23	23.50	24.07	23.78
T_5	10.37	10.37	10.37	19.87	21.37	20.62
T_6	9.53	9.40	9.47	22.23	23.50	22.87
T_7	11.00	10.87	10.93	18.67	20.90	19.78
T_8	10.53	10.43	10.48	19.50	20.87	20.18
T_9	11.57	11.53	11.55	18.43	19.90	19.17
T_{10}	9.93	9.87	9.90	21.00	21.93	21.47
T_{11}	10.63	10.57	10.60	18.87	19.93	19.40
T_{12}	11.53	10.97	11.25	19.07	20.20	19.63
SEm±	0.37	0.37	0.26	1.06	0.55	0.60
CD at 5%	1.08	1.07	0.74	3.12	1.63	1.71

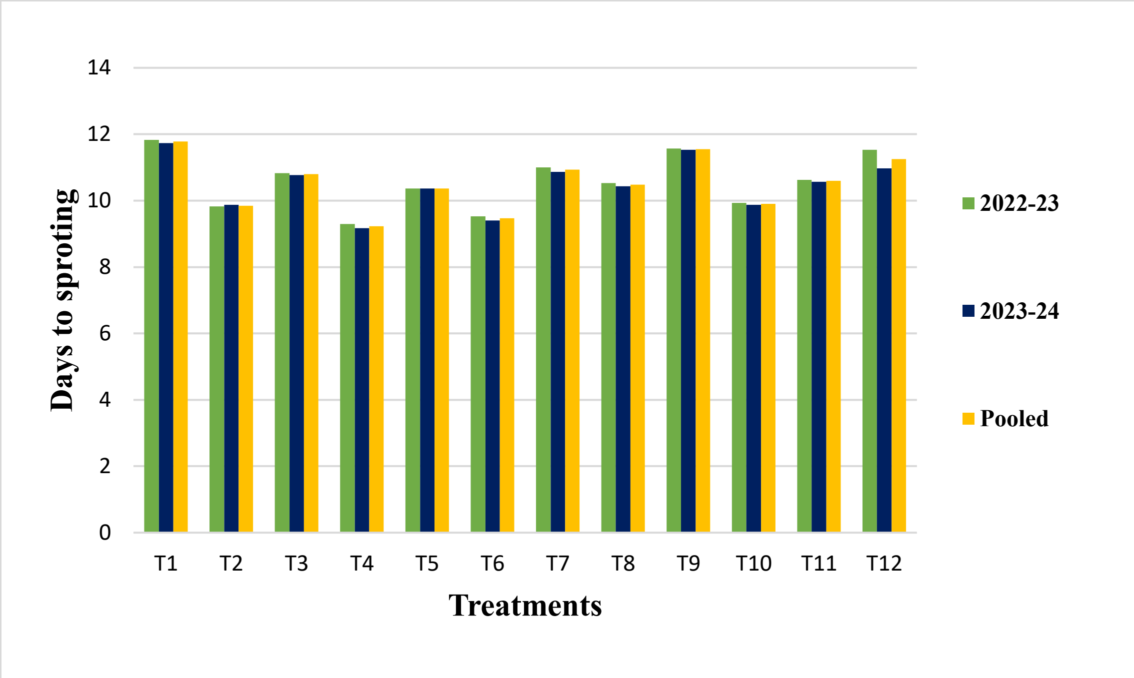

Fig. 4.1 Effect of INM on days to sprouting of tuberose bulb

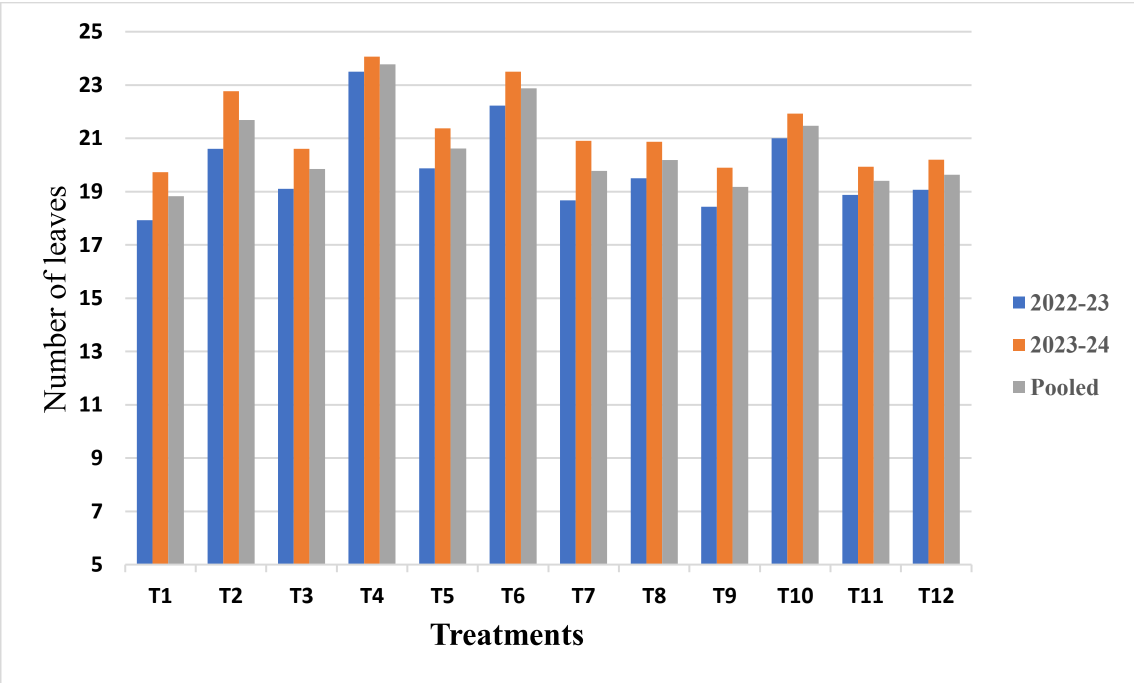

Fig. 4.2 Effect of INM on number of leaves per plant of tuberose

22.77 number of leaves, while the minimum number of leaves (19.73) was observed in control.

The pooled data produced almost similar result with maximum number of leaves per plant (23.78) in T_4 (75% RDF + Vermicompost at 5 t/ha) and T_1 (RDF $N_{200}P_{200}K_{150}$kg/ha) with minimum number of leaves per plant (18.83) at time of spike emergence.

Combined application of organic and inorganic fertilizers contributes in activation of photosynthesis system, which enhances biological efficiency through improved synthesis, translocation, and assimilation of photosynthates resulting in increased number of leaves. Notably, vermicompost improved the nutrient solubilization and uptake, particularly nitrogen (Abusaleha and Shanmungavelu, 1988; Joshi and Prabhakarasetty, 2006) which is an essential element for formation of chlorophyl and protein, eventually increased number of leaves per plant (Atiyeh *et al*., 200; Kumar and Singh, 2007, Siangshai *et al*., 2022). Tripathy *et al*. (2012) in tuberose, Kumar *et al*. (2018) in gladiolus and Mohanty *et al*. (2020) in tuberose, Gangwar *et al.* (2021) in tuberose also reported similar results.

4.1.1.3 Length of leaves

The variation in length of leaves was significantly influenced by organic and inorganic fertilizer during the both season 2022-23 and 2023-24 and pooled data which are presented in Table 4.2 and Fig 4.2.

The maximum length of leaves (47.80 cm) during the season of 2022-23 were recoded under the treatment T_4 (75% RDF + Vermicompost at 5 t/ha) which was at par with T_6 (75% RDF + Poultry manure at 2 t/ha) and T_2 (75% RDF + FYM at 10 t/ha) having a value of 45.80 and 45.70 cm respectively. The minimum length of leaves (40.50 cm) was observed in control.

The result of the second season was nearly of the same order as observed in 1st season. The maximum length of leaves (48.12 cm) was noted in T_4 (75% RDF + Vermicompost at 5 t/ha), which was at par with T_6 (75% RDF + Poultry manure at 2 t /ha), T_2 (75% RDF + FYM at 10 t/ha) and T_{10} (75% RDF + Humic Acid at 1t/ha) recording 46.17, 45.93 and 45.91 cm respectively. while least length of leaves (41.93 cm) was recorded in control.

Pooled data for both season (2022-23 and 2023-24) showed that maximum length of leaves (47.96 cm) was obtained in T_4 (75% RDF + Vermicompost at 5 t/ha) which was at par with T_6 (75% RDF + Poultry manure at 2 t/ha), T_2 (75% RDF + FYM at 10 t/ha) having 45.80 and 45.70 cm respectively and minimum length of leaves (41.22 cm) was recorded in control.

In the present experiment, maximum length of leaves obtained in plant treated with RDF + Vermicompost, which might be due to integration of both easily available inorganic fertilizers with slow-release organic manure which improved vegetative growth parameters, specially leaf elongation (Khanam *et al.*, 2017 in gladiolus). Similar finding was reported by Singh *et al.* (2013) in gladiolus, Karim *et al.* (2017) in tuberose, Kumar (2019) in tuberose and Shukla and Bahadur (2023) in gladiolus.

4.1.1.4 Plant height

Plant height of tuberose influenced by the different treatments are depicted in Table 4.2 and Fig 4.2. thorough scanning of the data showed that the all the integrated treatments significantly increase the height of the plant in both the season of the experiment.

During the 1st season (2022-23) maximum plant height (56.75cm) was observed in T_4 (75% RDF + Vermicompost at 5 t/ha) which was statistically at par with T_6 (75% RDF + Poultry manure at 2 t /ha), T_2 (75% RDF + FYM at 10 t/ha) and T_{10} (75% RDF + Humic Acid at 1t/ha) with 55.17, 54.63 and 54.33 cm plant height and the shortest plant (49.97 cm) was recorded in control.

In the 2nd season also T_4 (75% RDF + Vermicompost at 5 t/ha) recorded highest plant height (57.13 cm) which was at par with T_6 (75% RDF + Poultry manure at 2 t /ha), T_2 (75% RDF + FYM at 10 t/ha) and T_{10} (75% RDF + Humic Acid at 1t/ha) having 55.87, 55.10 and 54.80 cm respectively and the shortest plant (50.90 cm) was recorded in control.

Pooled data revealed that the maximum plant height (56.94 am) was recorded in T_4 (75% RDF + Vermicompost at 5 t/ha) and minimum plant height (50.43) observed in control

Tuberose is gross feeder require high amount of NPK in the form of organic and inorganic fertilizers and increase in plant height in T_4 might be due to the beneficial effect of vermicompost and inorganic fertilizer which enhanced the nutritional environment both in root zone as well within the plant system. The gibberellins present in the vermicompost is responsible for both cell elongation and division and might be the reason for better pant height (Srivastava *et a*l., 2014 and Preetham *et al.,* 2017). These findings are close conformity with Gaur *et al*. (2006) in gladiolus, Verma *et al.* (2012) in chrysanthemum, Hadwani *et al.* (2013) in tuberose, Elisheba and Sudhagar (2019) in tuberose, Gangwar *et al.* (2021) in tuberose, Kant *et al.* (2021) in African marigold, Kumar *et al*. (2022) in gladiolus.

4.1.1.5 Number of side shoots per plant

It is evident from the data presented in Table 4.2 and Fig 4.3 that number of side shoots per plant was significantly increased with the application of organic and inorganic fertilizers.

the results revealed that the maximum number of side shoots per plant (5.90) was observed in T_6 (75% RDF + Poultry manure at 2 t/ha) during the 1st season 2022-23 and was statistically at par with the T_4 (75% RDF + Vermicompost at 5 t/ha) with 5.77 number of side shoot, while the minimum number of side shoots per plant (3.17) recorded in control.

During the 2nd season (2023-24), maximum number of side shoots per plant (6.33) was recorded in T_4 (75% RDF + Vermicompost at 5 t/ha) which was at par with T_6 (75% RDF + Poultry manure at 2 t/ha) with 6.07 number of side shoot and minimum number of side shoots per plant (3.67) was produced in control.

Pooled data of both seasons reveal that the T_4 (75% RDF + Vermicompost at 5 t/ha) recorded maximum number of side shoots per plant (6.05) which was at par

Table 4.2 Effect of INM on the length of leaves (cm), plant height (cm) and number of side shoots per plant of tuberose

Treatments	Length of leaves (cm)			Plant height (cm)			Number of side shoots per plant		
	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
T_1	40.50	41.93	41.22	49.97	50.90	50.43	3.17	3.67	3.42
T_2	45.70	45.93	45.82	54.63	55.10	54.87	5.20	5.40	5.30
T_3	42.40	42.75	42.57	52.70	53.05	52.87	3.83	4.30	4.07
T_4	47.80	48.12	47.96	56.75	57.13	56.94	5.77	6.33	6.05
T_5	44.87	44.95	44.91	52.96	53.07	53.01	4.13	4.50	4.32
T_6	45.80	46.17	45.99	55.17	55.87	55.52	5.90	6.07	5.98
T_7	43.20	44.17	43.68	52.63	53.60	53.12	4.10	4.53	4.32
T_8	43.80	43.93	43.87	53.43	53.93	53.68	4.43	4.63	4.53
T_9	41.97	42.99	42.48	52.43	53.07	52.75	3.43	4.03	3.73
T_{10}	44.03	45.91	44.97	54.33	54.80	54.57	4.93	5.03	4.98
T_{11}	41.90	42.51	42.21	52.83	52.87	52.85	3.77	3.83	3.80
T_{12}	42.70	43.63	43.16	50.33	52.30	51.32	4.23	4.87	4.55
SEm±	1.10	1.05	0.76	1.16	0.95	0.75	0.28	0.40	0.24
CD at 5%	3.24	3.08	2.17	3.41	2.78	2.14	0.82	1.16	0.69

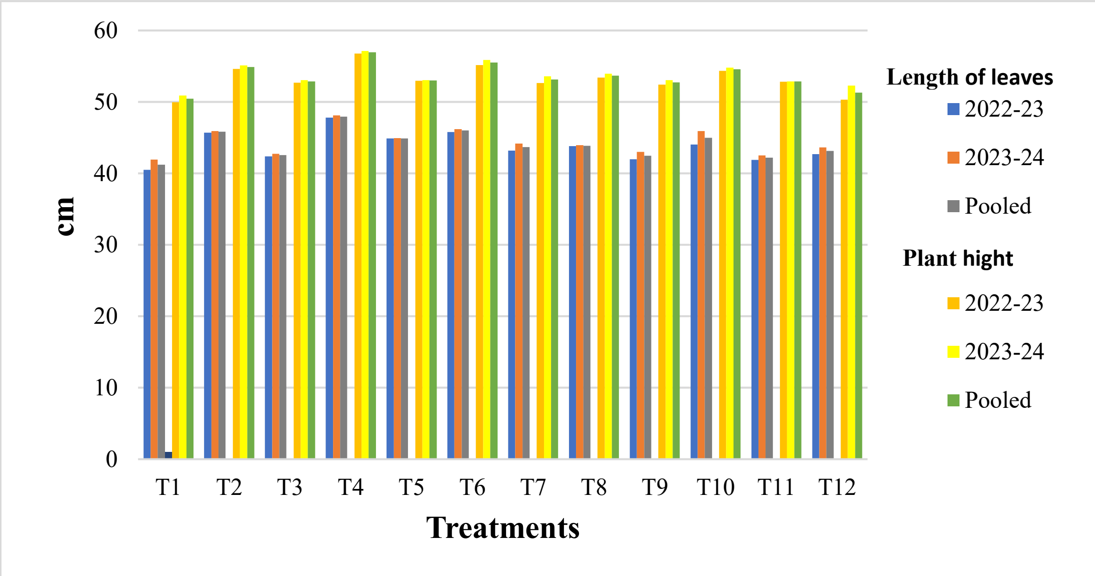

Fig 4.3 Effect of INM on the length of leaves (cm) and plant height (cm) of tuberose

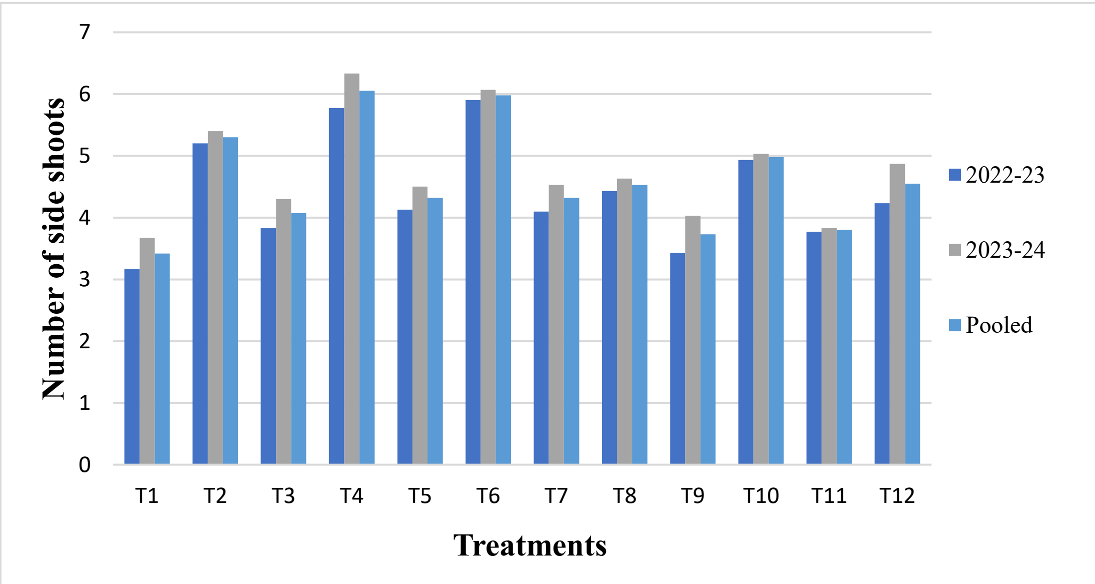

Fig 4.4 Effect of INM on number of side shoots per plant of tuberose

Plate No. 5 Sprouting of bulb

Plate No. 6 Plant height

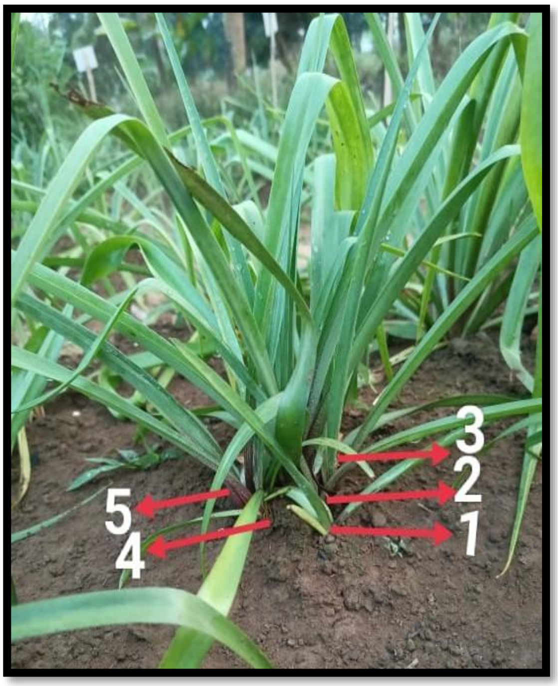

Plate No. 7 Number of leaves

Plate No. 8 Number side shoots

with T_6 (75% RDF + Poultry manure at 2 t/ha) (5.98). While minimum number of side shoots per plant (3.42) among the all treatment was recorded in control.

Increased in the number of side shoots with vermicompost application might be due to the steady and higher supply of easily available NPK nutrients, along with essential micronutrients and growth-promoting substances released gradually throughout the growth stages. Vermicompost enhances the nutritional environment and supports better vegetative development, which likely contributes to the proliferation of lateral shoots. These findings are supported by the results of Nagalakshmi *et al.* (2010) in anthurium, Verma *et al*. (2011), who observed an increase in the number of side shoots in chrysanthemum with the use of vermicompost. Elisheba and Sudhagar (2019) and Kumar (2019) in tuberose.

4.1.2 Flowering parameters

Flowering parameters are critical indicators of plant vigor, productivity, and aesthetic quality in tuberose. These parameters not only reflect the genetic potential and physiological status of the crop but also directly influence its commercial value and consumer preference. Accurate assessment of these traits helps growers determine the optimal harvesting time, thereby maximizing postharvest quality, enhancing vase life, and ensuring market. The data pertaining to flower parameters *viz* days to spike emergence, days to first floret opening, days to 50% floret opening, days to 50% flowering, length of the spike (cm), rachis length (cm), number of florets per spike, diameter of floret (cm), weight of individual floret (g), flower durability as influenced different organic and inorganic source of nutrients are discussed below.

4.1.2.1 Days to spike emergence

Data presented in Table 4.3 and illustrated in Fig 4.4 showed that the days to spike emergence was significantly influenced by the various organic and inorganic fertilizer during the season 2022-23 and 2023-24 and the pooled data.

In 1st season, it was noticed that T_4 (75% RDF + Vermicompost at 5 t/ha) took the minimum days (60.10) for spike emergence, which was at par with T_6 (75% RDF + Poultry manure at 2 t/ha), T_2 (75% RDF + FYM at 10 t/ha) and T_{10} (75% RDF +

Humic Acid at 1t/ha) (61.67, 62.03 and 62.75), while control took maximum (70.20) day to spike emergence.

Similarly in the following season, similar pattern was observed where, T_4 (75% RDF + Vermicompost at 5 t/ha) took 59.83 days to spike emergence, which was at par with T_6 (75% RDF + Poultry manure at 2 t/ha), T_2 (75% RDF + FYM at 10 t/ha) and T_{10} (75% RDF + Humic Acid at 1t/ha) (61.33, 61.80 and 62.13) while control was recorded maximum (69.53) day to spike emergence.

Pooled data of both years reveal that the T_4 (75% RDF + Vermicompost at 5 t/ha) observed minimum days taken for spike emergence (59. 97) which was at par with T_6 (75% RDF + Poultry manure at 2 t/h) (61.50) and control was recorded maximum days of 69.87 to spike emergence.

The early emergence of spike observed in present study might be due to application of organic manures, which likely improved soil texture by making soil loose, thereby increasing the water holding capacity of the soil which promotes the favorable condition for early growth and development. This improvement indirectly helped in early emergence of spike. Additionally, the application of 75% of the Recommended Dose of Fertilizers (RDF) may have contributed to improved nutrient accumulation in the bulbs, thereby enhancing the plant's early vegetative vigor. This enhanced growth during the initial stages likely facilitated earlier spike emergence by promoting overall physiological readiness and development. These findings are in accordance with the results of Kumar (2014) in tuberose, Kuotsu *et al.* (2018) in gladiolus, Gangwar *et al*. (2021) in tuberose and Meher and Tirkey (2022) in gladiolus, who reported similar results under integrated nutrient management practices.

4.1.2.2 Days to first floret opening

Days to first floret opening was markedly influenced by various organic and inorganic fertilizer during the season 2022-23 and 2023-24 and there means as presented in Table 4.3 and Fig 4.4.

Table 4.3 Effect of INM on days to spike emergence and first floret opening of tuberose

Treatments	Days to spike emergence			Days to first floret opening		
	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
T_1	70.20	69.53	69.87	83.60	82.07	82.83
T_2	62.03	61.80	61.92	71.60	71.17	71.38
T_3	64.53	64.43	64.48	76.33	75.20	75.77
T_4	60.10	59.83	59.97	70.33	69.93	70.13
T_5	63.07	63.17	63.12	74.87	74.43	74.65
T_6	61.67	61.33	61.50	71.50	71.30	71.40
T_7	65.57	65.13	65.35	75.37	75.23	75.30
T_8	65.13	64.83	64.98	74.63	73.23	73.93
T_9	67.90	66.73	67.32	79.07	78.10	78.58
T_{10}	62.75	62.13	62.44	73.40	72.50	72.95
T_{11}	67.63	67.23	67.43	78.50	77.93	78.22
T_{12}	64.50	64.33	64.42	76.67	76.30	76.48
SEm±	1.67	1.14	1.01	1.00	0.77	0.63
CD at 5%	4.89	3.34	2.88	2.94	2.25	1.80

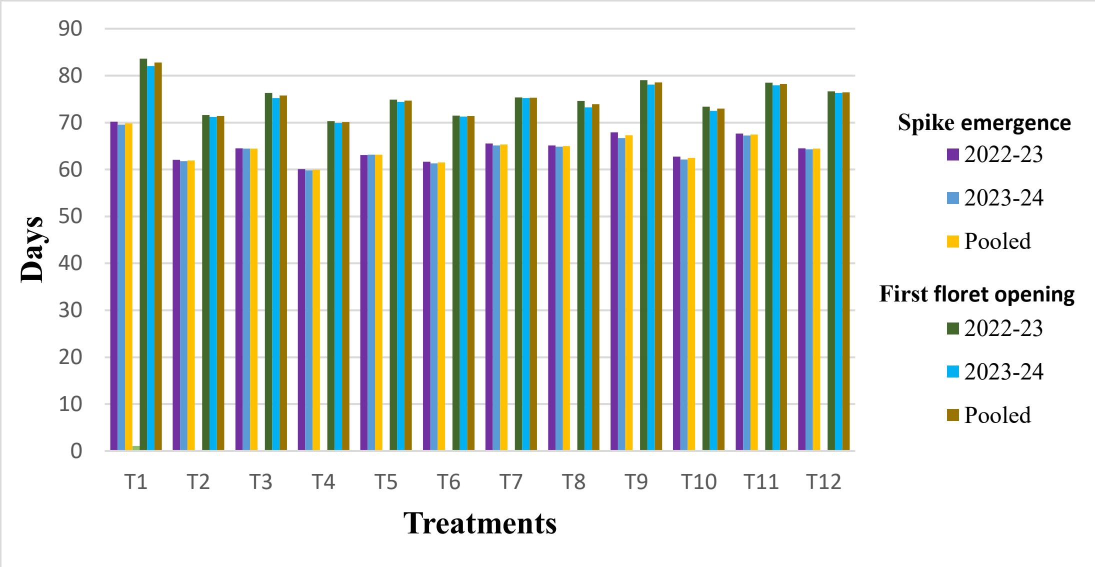

Fig. 4.5 Effect of INM on days to spike emergence and first floret opening of tuberose.

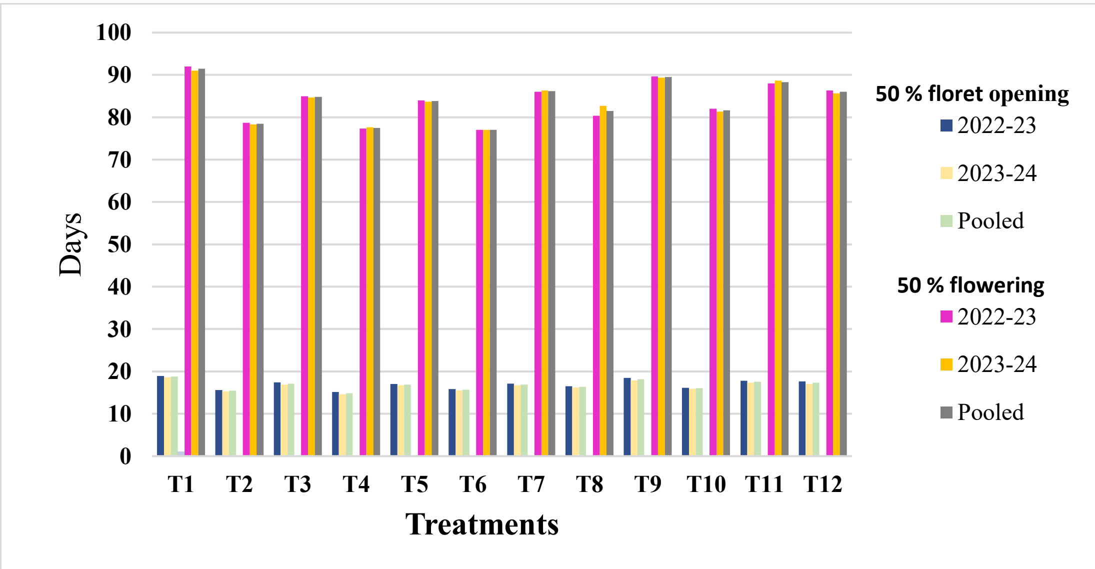

Fig. 4.6 Effect of INM on days to 50% floret opening and 50 % flowering of tuberose

A critical examination of the data with regard to 1st season revealed that T_4 (75% RDF + Vermicompost at 5 t/ha) took the minimum days (70.33) to first floret opening and was found to be statistically at par with T_6 (75% RDF + Poultry manure at 2 t/ha) and T_2 (75% RDF + FYM at 10 t/ha), taking 71.37 and 71.60 days respectively. While T_1 (control) recorded a maximum of 86.60 days to first floret opening.

Similarly in the 2nd season, T_4 (75% RDF + Vermicompost at 5 t/ha) recorded minimum days to first floret opening (69.93) which was at par with T_2 (75% RDF + FYM at 10 t/ha) and T_6 (75% RDF + Poultry manure at 2 t/ha), which took 71.17 and 71.30 days respectively while the maximum days (82.07) to first floret opening was noted in control.

The Pooled data when analyzed for both the season revealed that T_4 (75% RDF + Vermicompost at 5 t/ha) took minimum days 70.13 and T_1 (control) maximum days (82.83) to first floret opening

In the present study, plants treated with RDF along with vermicompost (T_4) were found to be superior in earliness to opening of first floret. It might be due to the effective absorption of nutrient by bulbs or primary roots, which leading to more stimulation of bulb metabolism and thereby accelerating transition of plant from vegetative to reproductive phase earlier. This observation is similar to the findings of Singh *et al*., (2014) in gladiolus, Choudhary and Sarangi, (2020) in tubrose. Furthermore, the combined application of the recommended dose of fertilizers with vermicompost significantly enhanced the earliness of floret opening. This synergistic effect likely provided a balanced nutrient supply, further supporting early flowering.

4.1.2.3 Days to 50% floret opening

Data presented in Table 4.4 and graphically shown in Fig 4.5 revealed that the different organic, inorganic fertilizers and their combination had significant effect on the days to 50% floret opening in tuberose spike during both season and also in pooled data.

In the first season of experiment, minimum days taken for 50% floret opening (15.17) was recorded in T_4 (75% RDF + Vermicompost at 5 t/ha) which was at par with T_2 (75% RDF + FYM at 10 t/ha) T_6 (75% RDF + Poultry manure at 2 t/ha) and T_{10} (75% RDF + Humic Acid at 1t/ha) taking 15.60, 15.80 and 16.10 days respectively. Whereas T_1 (control) took maximum days (18.90) to 50% flowering.

Similar result was obtained even in the following season, where the minimum days to 50% floret opening (14.60) was recorded in T_4 (75% RDF + Vermicompost at 5 t/ha), which was significantly at par with T_2 (75% RDF + FYM at 10 t/ha) T_6 (75% RDF + Poultry manure at 2 t/ha) and T_{10} (75% RDF + Humic Acid at 1t/ha) took 15.27, 15.50 and 15.93 days to 50 % floret opening. While Maximum days (18.63) to 50% floret was found in T_1 (control).

Pooled data of both seasons also revealed the similar trend with T_4 (75% RDF + Vermicompost at 5 t/ha) taking minimum days (14.88), while T_1 (control) took maximum 18.77 days to 50% floret opening.

Minimum days to 50% floret opening was observed with application of 75% RDF + Vermicompost at 5 t/ha in tuberose, it might be due to increased nutrient accessibility and presence of growth promoting substances in the soil, resulting from the application of higher dose of recommended chemical fertilizer in combination with lower dose of organic manure (vermicompost). Such combined nutrient enhanced the uptake of nutrients and water by the plants, which encouraged early flowering. These findings are in alignment with the results reported by Gangadharan and Gopinath (2000) in gladiolus and Krushnaiah *et al.* (2018) in aster, and Kumar and Prashad, (2023) in marigold, who also observed early flowering under similar regimes.

4.1.2.4 Days to 50% flowering

Data shown in Table 4.4 and graphically presented in Fig 4.5 confirmed a considerable variation in days to 50% flowering of tuberose in plot with the different treatment. Minimum days taken for 50% flowering (77) in first season 2022-23 was found in T_6 (75% RDF + Poultry manure at 2 t /ha) which was at par with T_4 (75% RDF + Vermicompost at 5 t/ha) and T_2 (75% RDF + FYM at 10 t/ha) (77.33 and 78.67). Maximum number of days taken for 50% flowering recorded in control T_1 (92).

Table 4.4 Effect of INM on the days to 50% floret opening and days to 50 % flowering of tuberose

Treatments	Days to 50% floret opening			Days to 50% flowering		
	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
T_1	18.90	18.63	18.77	92.00	91.00	91.50
T_2	15.60	15.27	15.43	78.67	78.33	78.50
T_3	17.40	16.90	17.15	85.00	84.67	84.83
T_4	15.17	14.60	14.88	77.33	77.67	77.50
T_5	17.03	16.70	16.87	84.00	83.67	83.83
T_6	15.80	15.50	15.65	77.00	77.00	77.00
T_7	17.10	16.73	16.92	86.00	86.33	86.17
T_8	16.50	16.17	16.33	80.33	82.67	81.50
T_9	18.47	17.87	18.17	89.67	89.33	89.50
T_{10}	16.10	15.93	16.02	82.00	81.33	81.67
T_{11}	17.83	17.33	17.58	88.00	88.67	88.33
T_{12}	17.63	17.03	17.33	86.33	85.67	86.00
SEm±	0.64	0.66	0.46	1.43	1.31	0.97
CD at 5%	1.87	1.93	1.31	4.19	3.84	2.76

Similarly, in the second season of the experiment, minimum numbers of days (77) to 50 % flowering were recorded in T_6 (75% RDF + Poultry manure at 2 t/ha), which was at par with T_4 (75% RDF + Vermicompost at 5 t/ha) and T_2 (75% RDF + FYM at 10 t/ha) (77.67 and 78.33), while control T_1 took maximum days for 50% flowering (91).

According to pooled data analyzed for both seasons, T_6 (75% RDF + Poultry manure at 2 t/ha) recorded minimum days (77) to 50% flowering with was significantly at par with T_4 (75% RDF + Vermicompost at 5 t/ha) and T_2 (75% RDF + FYM at 10 t/ha) which took 77.50 and 78.50 days respectively, while T_1 (control) took maximum days (91.50) to 50% flowering.

Poultry manure is known for its high nutrient content, particularly nitrogen, phosphorus, and potassium, along with micronutrients and organic matter, which help improve soil structure, water retention, and microbial activity. These improvements in soil health likely enhanced the root development and nutrient absorption capacity of tuberose plants, leading to faster transition from vegetative to reproductive phase. The earliness may be due to increased nutrient availability and growth promoting substances in the soil from combined application of poultry manure and inorganic fertilizers which might have enhanced the uptake of nutrients and water by the plants in turn favored the boosting of initial growth of the plant which might have stimulated the early flowering (Suseela *et al.,* 2016 in tuberose

4.1.2.5 Length of spike

Table 4.4 and Fig 4.6 displayed data indicating the substantial difference in the length of spike between the various treatments in the both season 2022-23, 2023-24 including pooled data analysis.

In the 1st season of experiment, longest spike length (97.60 cm) was found in T_4 (75% RDF + Vermicompost at 5 t/ha) which was significantly at par with, T_6 (75% RDF + Poultry manure at 2 t/ha), T_2 (75% RDF + FYM at 10 t/ha) recording 95.97 and 95.30 cm respectively. The shortest length of spike (85.63 cm) was recorded in control.

During the second season of the experiment, the longest spike (98.13 cm) was obtained in T_4 (75% RDF + Vermicompost at 5 t/ha), which was found to be at par with T_6 (75% RDF + Poultry manure at 2 t/ha), T_2 (75% RDF + FYM at 10 t/ha) exhibiting 96.63 and 96.10 cm spike length respectively. While minimum length of spike (85.90 cm) was observed by control.

Pooled data analysis showed longest spike length (97.87 cm) in T_4 (75% RDF + Vermicompost at 5 t/ha) which was at par with T_6 (75% RDF + Poultry manure at 2 t/ha), T_2 (75% RDF + FYM at 10 t/ha) having a spike length of 96.30 and 95.62 cm respectively. While the plant grown only with the application of RDF displayed the shortest spike length (85.77 cm).

The increase in length of spike in present study might be primarily due to the role of nitrogen, which is essential for the synthesis of assimilates required for vegetative and reproductive growth. The higher nitrogen level may have contributed to division and elongation of meristem cells, formation of protoplasm, enhancing the biosynthesis of carbohydrates and proteins which lead to promote the growth and spike length. Similar findings have been reported by Hadwani *et al*. (2013) in ratoon tuberose, Khanam *et al*. (2017) in gladiolus, Kuotsu *et al*. (2018) in gladiolus, Kumar, (2015) in tuberose, Elisheba *et al*. (2019) in tuberose, and Kumar *et al*. (2019) in tuberose.

4.1.2.6 Rachis length

Data presented in Table 4.5 and Fig 4.6 revealed that the organic and inorganic fertilizer and their combination had a significant effect on the rachis length in both the seasons 2022-23 and 2023-24, including the pooled data analysis.

During the 1st season, the longest rachis length (21.23 cm) was observed in T_4 (75% RDF + Vermicompost at 5 t/ha) which was statistically at par with T_6 (75% RDF + Poultry manure at 2 t/ha), T_2 (75% RDF + FYM at 10 t/ha), T_{10} (75% RDF + Humic Acid at 1t/ha) and T_8 (75% RDF + forest soil at 10 t/ha) exhibiting a rachis length of 20.87, 20.60, 19.87 and 19.67 cm respectively, while the minimum rachis length (17.47 cm) was noted in control.

In the 2nd season of 2023-24, similar pattern of results was observed. The maximum rachis length (21.43 cm)was found in T_4 (75% RDF + Vermicompost at 5 t/ha) which was found to be at par with T_6 (75% RDF + Poultry manure at 2 t/ha), T_2 (75% RDF + FYM at 10 t/ha), T_{10} (75% RDF + Humic Acid at 1t/ha) and T_8 (75% RDF + forest soil at 10 t/ha) with values of 21.30, 20.80, 20.37 and 19.53 cm respectively. The plant grown only with RDF application (control) registered the minimum rachis length (18.03 cm).

Pooled data analysis showed a significant variation in rachis length with T_4 (75% RDF + Vermicompost at 5 t/ha) recording a maximum rachis length (21.33 cm) which was significantly at par with T_6 (75% RDF + Poultry manure at 2 t /ha), T_2 (75% RDF + FYM at 10 t/ha), and T_{10} (75% RDF + Humic Acid at 1t/ha) having 21.08, 20.70 and 20.12 cm rachis length, while control (T_1) presented the shortest rachis length(17.75 cm).

This enhancement in rachis length can be attributed to the combined application of inorganic fertilizers (N, P, and K) and organic manures such as vermicompost, which synergistically improve overall plant growth and development. The increased rachis length may be due to enhanced cell size and cell elongation, facilitated by better nutrient availability and uptake. Vermicompost, in particular, not only supplies macronutrients but is also rich in micronutrients such as calcium (Ca), magnesium (Mg), iron (Fe), boron (B), zinc (Zn), and molybdenum (Mo), which are essential for various physiological and metabolic processes in plants (Chopde *et al*., 2007 in tuberose). The present result is in agreement with the findings of Lal *et al.* (2010) in tuberose, Srivastava *et al.* (2014) in tuberose, Kumar (2015) in tuberose, Kumar *et al.* (2019) in tuberose and Gangwar *et al*. (2021) in tuberose, where they stated that the length of rachis in flowers was increased with the use of organic manure with fertilizer instead of only synthetic fertilizer.

Table 4.5 Effect of INM on the length of spike (cm) and rachis length (cm) of tuberose

Treatments	Length of spike (cm)			Rachis length (cm)		
	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
T_1	85.63	85.90	85.77	17.47	18.03	17.75
T_2	95.13	96.10	95.62	20.60	20.80	20.70
T_3	91.87	92.90	92.38	19.17	19.03	19.10
T_4	97.60	98.13	97.87	21.23	21.43	21.33
T_5	92.33	92.50	92.42	19.27	19.43	19.35
T_6	95.97	96.63	96.30	20.87	21.30	21.08
T_7	90.83	90.60	90.72	18.77	18.63	18.70
T_8	92.17	92.57	92.37	19.67	19.53	19.60
T_9	87.90	87.90	87.90	18.13	18.50	18.32
T_{10}	93.67	93.77	93.72	19.87	20.37	20.12
T_{11}	88.47	89.80	89.13	18.60	19.13	18.87
T_{12}	90.80	91.20	91.00	18.73	19.37	19.05
SEm±	1.25	1.42	0.94	0.65	0.65	0.46
CD at 5%	3.65	4.16	2.69	1.91	1.92	1.31

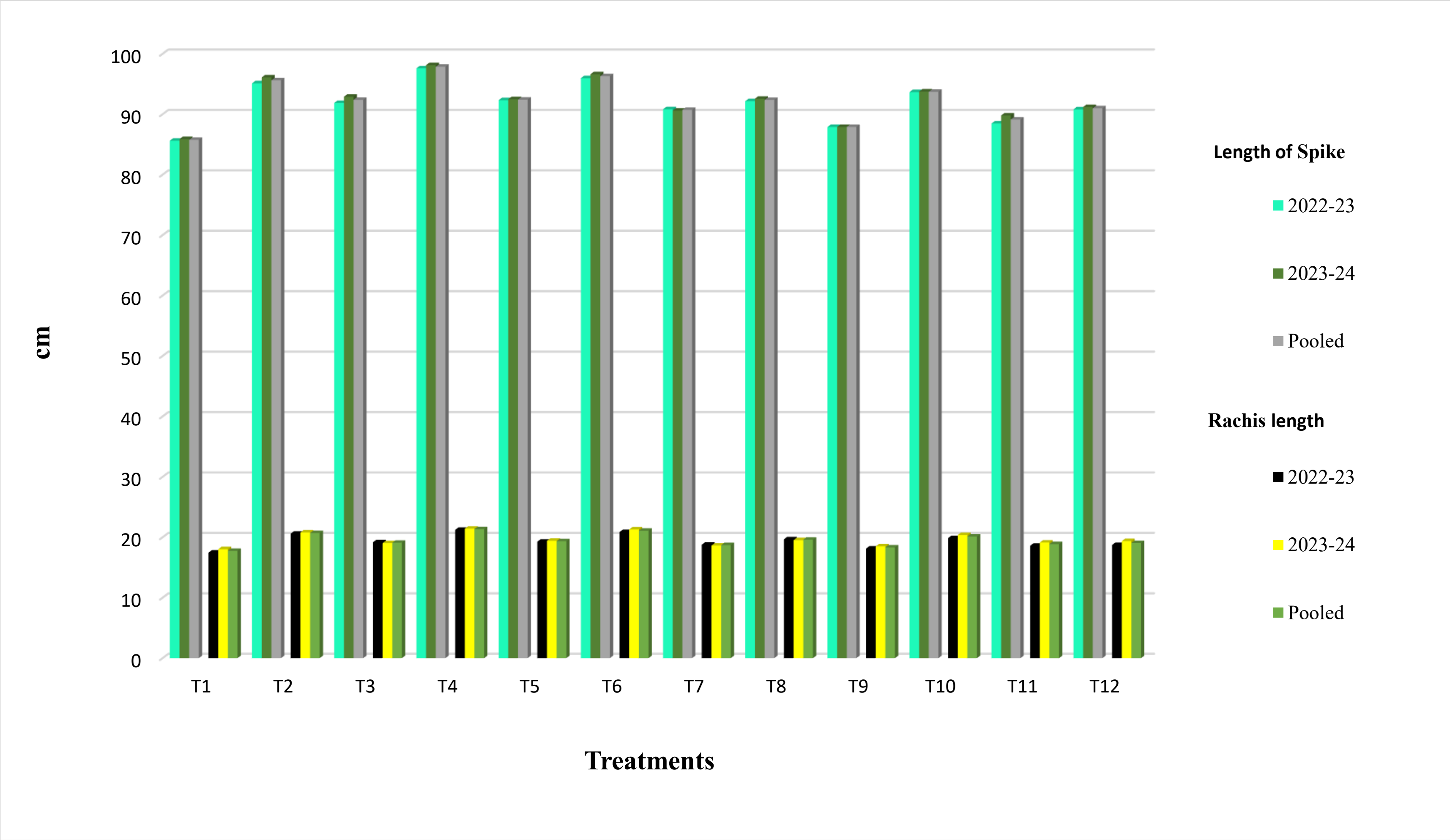

Fig. 4.7 Influence of INM on length of spike (cm) and rachis length (cm) of tuberose.

4.1.2.7 Number of florets per spike

Number of florets per spike was significantly influenced by the organic and inorganic fertilizers and their combination as presented in Table 4.6 and Fig 4.7.

In the 1st season of experiment, highest number of florets per spike (24.23) was obtained in T_4 (75% RDF + Vermicompost at 5 t/ha) which was found to be statistically at par with T_6 (75% RDF + Poultry manure at 2 t/ha), T_2 (75% RDF + FYM at 10 t/ha) recording 22.73 and 22.33 number of florets per spike. The lowest number of spike floret (17.13) was observed in control.

Similarly, in the 2nd season of experiment, T_4 (75% RDF + Vermicompost at 5 t/ha) produced maximum number of florets per spike (24.13) and was significantly at par with T_6 (75% RDF + Poultry manure at 2 t/ha), T_2 (75% RDF + FYM at 10 t/ha) bearing 23.53 and 22.53 number of florets, while control registered the least number of florets per spike (17.23).

Regarding the pooled data analysis, number of florets per spike was maximum (24.18) in T_4 (75% RDF + Vermicompost at 5 t/ha), while control registered minimum number of florets per spike (17.18).

The enhanced number of florets per spike might be due to the application of higher recommended dose of fertilizer combined with vermicompost. This synergistic effect of this input promotes faster nutrient release and availability, and increase the level of micro and macro nutrient and increase root absorption area. This factor collectively improved overall plant growth and leaf area, which in turn increased the synthesis of photosynthates, ultimately leading to the production of a higher number of florets per spike. Similar findings were quoted by Patel *et al.* (2011), Kumar (2014) in tuberose, Hadwani *et al.* (2013) in ratoon tuberose), Kumar (2015) in tuberose, Meena *et al.* (2015) in tuberose, Khanam *et al.* (2017) in gladiolus, Choudhary and Sarangi (2020) in tuberose, Gangwar *et al*. (2021) in tuberose and Kumar and Prashad (2023) in marigold.

4.1.2.8 Diameter of floret

Data shown in Table 4.6 and graphically illustrated in Fig 4.8 depicted that the diameter of floret indicate significant difference among the different treatments in both the season and pooled data**.**

In the 1st season, maximum diameter of floret (4.30 cm and 4.30 cm) was found in T_4 (75% RDF + Vermicompost at 5 t/ha) and T_6 (75% RDF + Poultry manure at 2 t/ha) which was at par with, T_2 (75% RDF + FYM at 10 t/ha) having 4.01 cm diameter and minimum diameter of floret (2.65 cm) observed in control.

In the following season of the experiment, T_4 (75% RDF + Vermicompost at 5 t/ha) recorded highest diameter of floret (4.36 cm) which was significantly at par with T_6 (75% RDF + Poultry manure at 2 t/ha) and T_2 (75% RDF + FYM at 10 t/ha) with values of 4.10 and 4.03 cm respectively, while control showed minimum diameter of floret (2.78 cm).

Similarly in pooled data analysis, highest diameter of floret (4.33 cm) was observed in, T_4 (75% RDF + Vermicompost at 5 t/ha) with was at par with T_6 (75% RDF + Poultry manure at 2 t/ha) and T_2 (75% RDF + FYM at 10 t/ha) having diameter 4.20 and 4.03 cm respectively, while control had smallest diameter of floret (2.71).

The improvement in flowering parameters might be attribute to an application of adequate nutrient through inorganic fertilizer combine with organic manure like vermicompost, poultry manure which promote the greater number of leaves per plant that would have resulted in greater number of flowers with bigger size. Similar finding was recorded by Lal *et al*. (2010) in tuberose, Kumar (2014) in tuberose, Meena *et al*. (2015) in tuberose, Kumar*,* (2015) in tuberose, Khanam *et al.* (2017) in gladiolus, Elisheba *et al.* (2019) in tuberose, Kumar *et al.* (2019) in tuberose, Choudhary and Sarangi (2020) in tuberose. When a plant is regularly supplied with nitrogen and phosphorus, its photosynthetic area increases, resulting in increased synthesis and storage of photosynthates and that could have enhanced the quality of plant like floret diameter (Aghera *et al.,* 2019).

Table 4.6 Effect of INM on the number of spike and diameter of floret (cm) of tuberose

Treatment	Number of florets per spike			Diameter of the floret (cm)		
	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
T_1	17.13	17.23	17.18	2.65	2.78	2.71
T_2	22.33	22.53	22.43	4.01	4.04	4.03
T_3	20.67	22.13	21.40	3.23	3.25	3.24
T_4	24.23	24.13	24.18	4.30	4.36	4.33
T_5	20.73	20.93	20.83	3.44	3.37	3.41
T_6	22.73	23.53	23.13	4.30	4.10	4.20
T_7	19.93	19.53	19.73	3.21	3.22	3.21
T_8	21.00	21.17	21.08	3.40	3.53	3.47
T_9	18.77	19.17	18.97	3.15	3.10	3.12
T_{10}	21.53	22.00	21.77	3.92	3.61	3.77
T_{11}	18.37	17.73	18.05	3.25	3.23	3.24
T_{12}	19.67	20.70	20.18	3.43	3.50	3.47
SEm±	0.91	0.72	0.58	0.14	0.18	0.11
CD at 5%	2.66	2.12	1.65	0.41	0.52	0.32

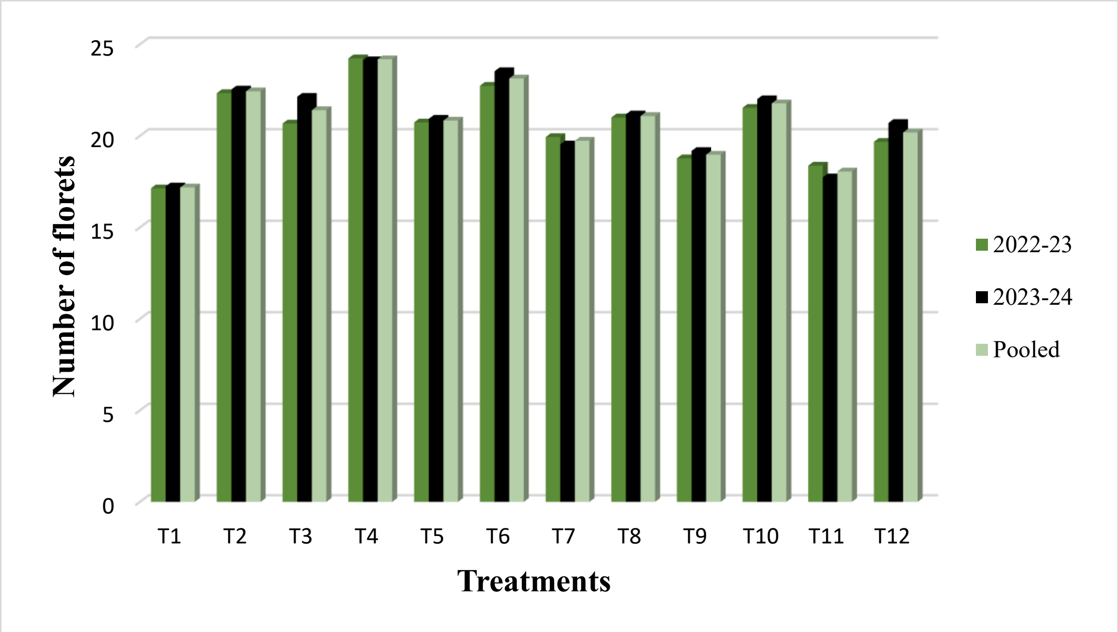

Fig. 4.8 Effect of INM on the number of florets per spike

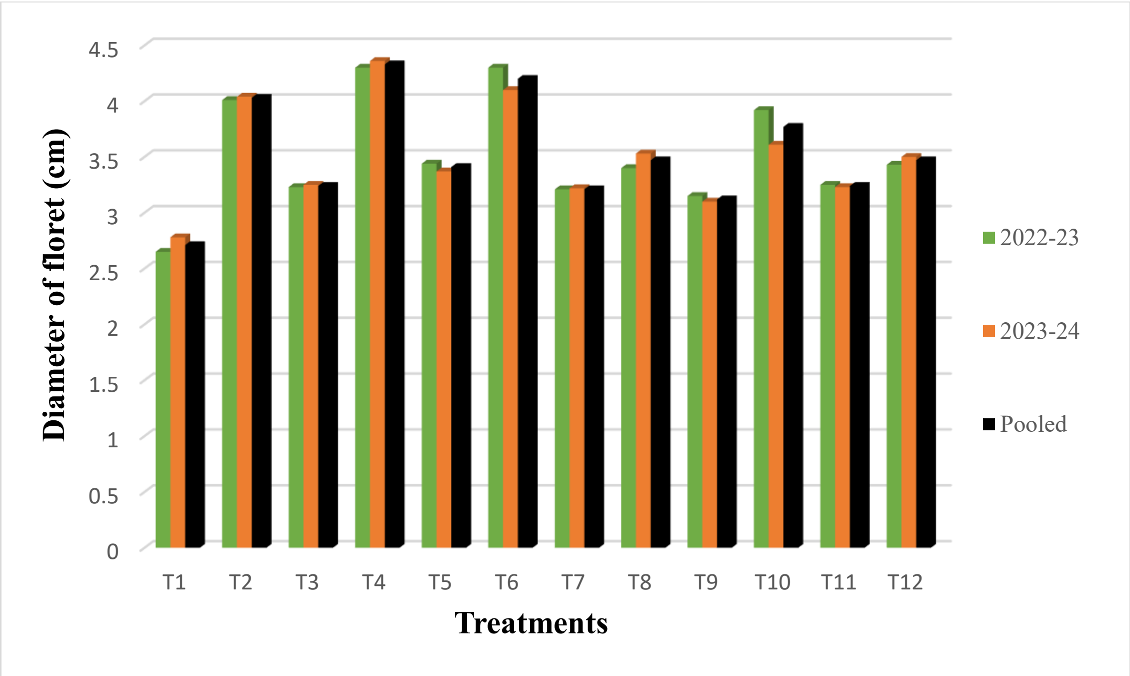

Fig. 4.9 Influence of INM on diameter of floret (cm) of tuberose

4.1.2.9 Weight of individual floret (g)

According to the data presented in Table 4.7 and Fig 4.9, a noticeable variation in weight of individual floret was observed in various treatments.

In first season of experiment, maximum weight of individual floret (2.23 g) was recorded in, T_4 (75% RDF + Vermicompost at 5 t/ha), which was at par with T_6 (75% RDF + Poultry manure at 2 t/ha) with 2.15 g floret weight, while the lowest weight of individual floret (0.97 g) found in control.

Similarly in the 2nd season, T_4 (75% RDF + Vermicompost at 5 t/ha) had highest weight of individual floret (2.24 g) which was at par with T_6 (75% RDF + Poultry manure at 2 t/ha) (2.15 g) and T_2 (75% RDF + FYM at 10 t/ha) with values of 2.18 and 2.09 g respectively, while the least weight of individual floret (0.95 g) found in control.

In pooled data analysis, maximum weight of individual floret (2.23 g) was observed in T_4 (75% RDF + Vermicompost at 5 t/ha) which was found to be at par with T_6 (75% RDF + Poultry manure at 2 t/ha) (2.17 g), while the lowest weight of individual floret (0.96 g) found in control.

Increase in weight of floret might be due to combine application of organic and inorganic fertilizer where high level of available nitrogen from inorganic fertilizer increases synthesis of amino acid and chlorophyll formation and better carbohydrates translocation to flowering stalk which resulted to heavier tuberose florets. Additionally, vermicompost contain essential macronutrients, micronutrients, plant growth-promoting hormones, and humic acids. These components contribute to improved soil structure, enhanced microbial activity, and a steady, gradual release of nutrients throughout the crop growth period. This balanced and sustained nutrient availability likely provided proper nutrition to the plants at critical growth stages, thereby enhancing floret development and increasing their individual weight. These results are in harmony with those obtained by Meena *et al*. (2015) in tuberose, Choudhury and Sarangi (2020) and Sahana *et al.* (2020) in tuberose and Kumar and Prashad (2023) in marigold.

4.1.2.10 Flower durability

Data presented in Table 4.7 and Fig 4.10, indicate that the organic and inorganic fertilizer and their combination had significant effect on the flower durability of tuberose under field condition in the both the season of experiment.

Flowering duration of tuberose under field condition during first season was recorded highest (18.50 days) with 75% RDF + Vermicompost at 5 t/ha (T_4) which was at par with T_6 (75% RDF + Poultry manure at 2 t/ha) and T_2 (75% RDF + FYM at 10 t/ha) with 18.23 and 17.73 days respectively. Whereas control registered the minimum flowering duration (15.10 days).

In the second season, longest flower durability (18.50 days) was observed in T_4 (75% RDF + Vermicompost at 5 t/ha) which was at par with T_2 (75% RDF + FYM at 10 t/ha) and T_6 (75% RDF + Poultry manure at 2 t/ha) displaying values of 18.30 and 18.03 days respectively, while the shortest flowering duration (15.17 days) was recorded in control.

Pooled data analysis of both the seasons also showed longest flower durability (18.50 days) in T_4 (75% RDF + Vermicompost at 5 t/ha) which was at par with T_6 (75% RDF + Poultry manure at 2 t/ha) and T_2 (75% RDF + FYM at 10 t/ha) having values 18.13 and 18.02 days respectively, while control exhibited the minimum flowering duration (15.13 days).

The application of vermicompost in combination with chemical fertilizers positively influenced flower durability under field condition. This effect may be attributed to enhanced nutrient uptake by the plant and improved development of water-conducting tissues, which support sustained hydration of the floral parts. Additionally, the presence of ethylene inhibitors or cytokinins in vermicompost may have contributed to delayed senescence of florets, thereby prolonging their freshness and vitality. These findings are in agreement with the observations of Kusuma (2000) in golden rod, Chopde *et al*. (2007) in tuberose, Hadwani *et al.* (2013) in ratoon tuberose, Singh *et al.* (2013) in gladiolus, Meena *et al*. (2015) in tuberose, Khanam *et al.* (2017) in gladiolus, Gangwar *et al*. (2021) in tuberose and Paikra *et al*. (2022) in

Table 4.7 Effect of INM on the weight of individual floret (g) and flower durability of tuberose

Treatments	Weight of individual floret (g)			Flower durability (days)		
	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
T_1	0.97	0.95	0.96	15.10	15.17	15.13
T_2	1.95	2.09	2.02	17.73	18.30	18.02
T_3	1.38	1.36	1.37	16.57	16.47	16.52
T_4	2.23	2.24	2.23	18.50	18.50	18.50
T_5	1.44	1.37	1.41	17.27	16.83	17.05
T_6	2.15	2.18	2.17	18.23	18.03	18.13
T_7	1.24	1.21	1.22	16.20	16.30	16.25
T_8	1.55	1.40	1.47	17.20	17.13	17.17
T_9	1.18	1.19	1.19	15.17	15.67	15.42
T_{10}	1.76	1.77	1.76	17.10	17.67	17.38
T_{11}	1.23	1.29	1.26	15.60	15.73	15.67
T_{12}	1.27	1.38	1.33	16.07	16.57	16.32
SEm±	0.09	0.09	0.06	0.30	0.29	0.21
CD at 5%	0.26	0.27	0.18	0.88	0.86	0.60

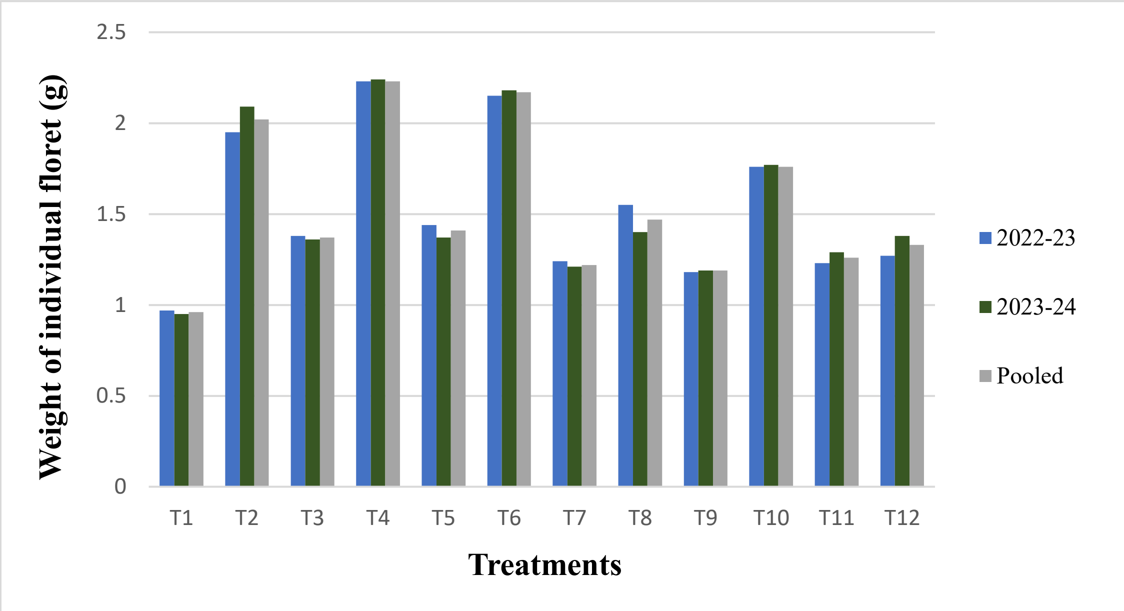

Fig. 4.10 Effect of INM on weight of individual floret (g) of tuberose

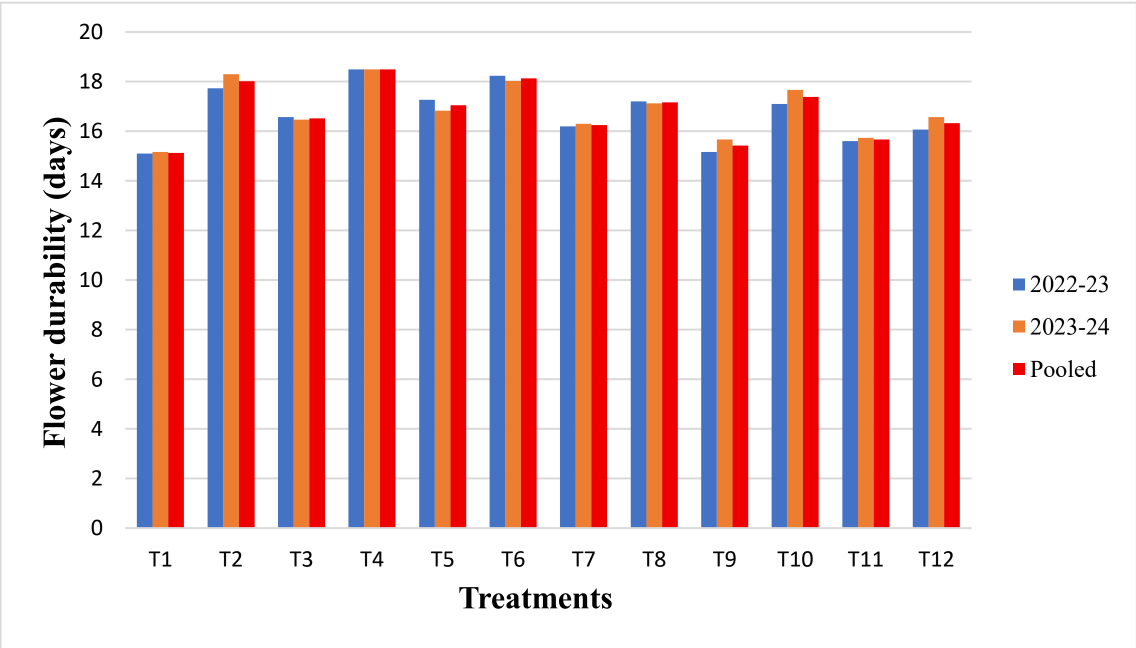

Fig. 4.11 Effect of INM on flower durability of tuberose.

Plate No.9 Spike initiation

Plate No. 10 First floret opening

Plate No. 11 50% floret opening

Plate No. 12 Spike length

Plate No. 13 Rachis length

Plate No. 14 Floret diameter

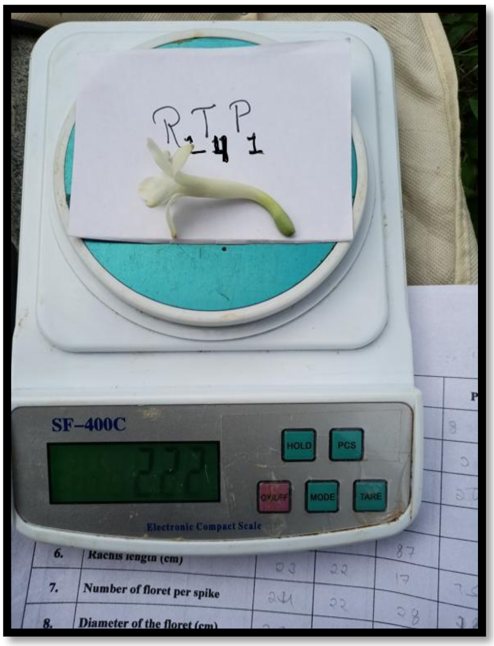

Plate No. 15 weight of floret

african marigold, who also reported increase in flower durability under integrated nutrient management practices.

4.1.3 Bulb parameters

The bulb plays an important role in the successful production of tuberose, and serve aa a critical source of energy for plant growth and development. It is use as planting material for commercial cultivation of tuberose, where the size and quality of the bulb directly influence the number and quality of flower spikes produced. Additionally, bulbs store nutrients that support the plant during its initial growth stage and allow for re-growth in subsequent seasons. The performance of tuberose is significantly influenced by the availability of key nutrients such as nitrogen, phosphorus, and potassium. The application of balance doses of both organic and inorganic fertilizers greatly enhances the vegetative growth of the tuberose, which in turn directly influences the flowering and bulb development of the plant. Bulb and bulblet characters were significantly influenced by organic and inorganic fertilizer and their combination which are discussed below with tables and fingers.

4.1.3.1 Number of bulb per plant

Number of bulbs per plant significantly influenced by the organic and inorganic fertilizers and their combination during both the season, 2022-23 and 2023-24 including the data when analyzed on pool basis as shown in Table 4.8 and graphically illustrated in Fig 4.11.

During the 1st season in, the maximum number of bulb per plant (2.90) was recorded in T_4 (75% RDF + Vermicompost at 5 t/ha) which was at par with T_2 (75% RDF + FYM at 10 t/ha) and T_6 (75% RDF + Poultry manure at 2 t/ha) with 2.70 and 2.57 number of bulb per plant, while the control produced minimum number of bulb per plant (1.07).

In the following season during 2023-24, similar pattern was obtained where, T_4 (75% RDF + Vermicompost at 5 t/ha) registered maximum bulb per plant (3.0), which was found to be at par with T_6 (75% RDF + Poultry manure at 2 t/ha) and T_2 (75%

RDF + FYM at 10 t/ha) recording 2.73 and 2.57number of bulbs. While the minimum number of bulb per plant (1.17) was noted in control.

The pooled data produced almost similar result with maximum number of bulb per plant (2.95) in T_4 (75% RDF + Vermicompost at 5 t/ha), which was at par with T_6 (75% RDF + Poultry manure at 2 t/ha) and T_2 (75% RDF + FYM at 10 t/ha) with 2.65 and 2.63 number of bulbs respectively and minimum number of bulbs (1.12) was obtained in control.

The integration of both easily available inorganic fertilizers and slowly available organic manure like vermicompost plays a crucial role in enhancing bulb growth parameters including number of bulbs per plant in tuberose, where the RDF ensures the immediate availability of essential macronutrients, and vermicompost contributes to the gradual and sustained release of nutrients. Das *et al*. (2011) and Yadav *et al*. (2023) also stated that the maximum number of bulbs under vermicompost application might be caused by different growth hormones and nutrients contributed to raising the amount of assimilation required to increase the number of bulbs. Similar findings were recorded by the Kumar *et al.* (2015) in tuberose, Tirkey *et al.* (2017) in gladiolus, Kumar *et al.* (2018) in gladiolus, Elisheba and Sudhagar, (2019) in tuberose, Kumar *et al.* (2022) in gladiolus.

4.1.3.2 Number of bulblets per plant

Number of bulblets per plant showed a statistically significant variation among the different treatment in both the season which is presented in Table 4.8 and Fig 4.12.

In the 1st season of experiment, maximum number of bulblets per plant (18.07) was obtained in T_4 (75% RDF + Vermicompost at 5 t/ha), which was found to be at par with T_2 (75% RDF + FYM at 10 t/ha) and T_6 (75% RDF + Poultry manure at 2 t/ha), recording 18.87 and 18.43 number of bulblets per plant, the lowest number of bulblets per plant (12.53) was recorded in control.

Similarly, in the 2nd season of experiment, T_4 (75% RDF + Vermicompost at 5 t/ha) produced maximum number of bulblets per plant (18.33). It was found to be at par with T_2 (75% RDF + FYM at 10 t/ha) with 17.37 bulblets per plant. While minimum number of bulblets per plant (12.73) was noted in control observed

Regarding the pooled data analysis, the maximum number of bulblets per plant (18.20) was found in T_4 (75% RDF + Vermicompost at 5 t/ha), closely followed by T_2 (75% RDF + FYM at 10 t/ha) having 17.12 bulblets per plant. While plant grown with RDF registered least number of bulblets per plant (12.63).

The beneficial impact of 75 % inorganic fertilizer with 25% vermicompost on increased number of bulblets per plant, can be attributed to the steady and enhanced supply of essential nutrients throughout the crop growth cycle. The combination of readily available NPK from inorganic sources and the slow-release nutrients, micronutrients, and growth-promoting substances present in vermicompost ensures a balanced nutrient regime to increase the number of bulblets. Singh *et al.* (2013) reported similar findings, emphasizing that the sustained nutrient supply from such integrated practices contributes to better vegetative growth and ultimately leads to a greater number of corms and cormels per plant in gladiolus. Similar results were reported by Kumar *et al.* (2015) in tuberose, Kumar *et al*. (2022) in gladiolus, Ayoub and Masoodi, (2023) in hyacinth.

4.1.3.3 Bulb diameter

The data presented in Table 4.8 and Fig 4.12 depicted that the bulb diameter exhibited a profound variation amongst the different treatment during both the season of experiment and pooled data analysis.

In the 1st season, maximum bulb diameter (3.77 cm) was found in T_4 (75% RDF + Vermicompost at 5 t/ha), which was found to be at par with T_2 (75% RDF + FYM at 10 t/ha), T_6 (75% RDF + Poultry manure at 2 t/ha) and T_{10} (75% RDF + Humic Acid at 1t/ha) having bulb diameter of 3.57 cm, 3.43 cm and 3.24 cm respectively and the smallest bulb diameter (2.13 cm) was recorded in control.

During the 2nd season of the experiment, T_4 (75% RDF + Vermicompost at 5 t/ha) showed maximum bulb diameter (3.87 cm), which was at par with T_2 (75% RDF + FYM at 10 t/ha), T_6 (75% RDF + Poultry manure at 2 t/ha) and T_{10} (75% RDF +

Humic Acid at 1t/ha) with 3.77 cm, 3.63cm and 3.27 cm bulb diameter, while control recorded minimum bulb diameter (2.20 cm).

Similarly in the pooled data analysis, highest bulb diameter (3.82 cm) was recorded in T_4 (75% RDF + Vermicompost at 5 t/ha), which was found to be at par with T_2 (75% RDF + FYM at 10 t/ha), T_6 (75% RDF + Poultry manure at 2 t/ha) and T_{10} (75% RDF + Humic Acid at 1t/ha) with values of 3.67 cm, 3.53 cm and 3.23 cm respectively , while minimum bulb diameter (2.17 cm) was recorded in control.

the application of inorganic fertilizer with vermicompost might have significantly enhanced the vegetative growth of plants, which in turn contributed to an increase in bulb diameter. Vermicompost is rich in essential macro- and micronutrients, as well as beneficial microorganisms and growth-promoting substances, all of which play a vital role in plant physiological processes. This may have resulted in healthy plants with huge food storage bulbs, increasing bulb diameter (Yadav *et al*., 2005 and Kumar, 2015 in tuberose). The present study partially agrees to the previous findings of Tripathi *et al*. (2013) in tuberose, Kumar *et al*. (2022) in gladiolus, Ayoub and Masoodi, (2023) in hyacinth.

Result from the pooled data analysis revealed that the highest weight of bulb (81.52 g) was recorded in T_4 (75% RDF + Vermicompost at 5 t/ha), which was at par with T_2 (75% RDF + FYM at 10 t/ha), T_6 (75% RDF + Poultry manure at 2 t/ha) and T_{10} (75% RDF + Humic Acid at 1t/ha) and the least weight of bulb (70.32 g) was obtained in control.

The result indicates that the application of inorganic fertilizers along with organic manures were found highly beneficial which might have attributed to healthy vegetative growth responsible for higher photosynthates which might account for increased weight of bulbs (Sable, 2018). Sufficient N and P continuously maintain vegetative growth leading to increase in photosynthetic area, resulting in more accumulation of assimilates and partitioning to the developing bulb. Organic manure specially vermicompost has ability to produce growth promoting substances such as IAA and gibberellins etc. which might have helped in increasing weight of bulb.

Table 4.8 Effect of INM on number of bulb, bulblets per plant and bulb diameter (cm) of tuberose

Treatments	Number of bulb per plant			Number of bulblets per plant			Bulb diameter (cm)		
	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
T_1	1.07	1.17	1.12	12.53	12.73	12.63	2.13	2.20	2.17
T_2	2.70	2.57	2.63	16.87	17.37	17.12	3.57	3.77	3.67
T_3	1.33	1.40	1.37	14.63	15.00	14.82	2.78	2.83	2.81
T_4	2.90	3.00	2.95	18.07	18.33	18.20	3.77	3.87	3.82
T_5	1.30	1.50	1.40	15.43	15.53	15.48	3.03	2.97	3.00
T_6	2.57	2.73	2.65	16.43	16.83	16.63	3.43	3.63	3.53
T_7	1.63	1.78	1.71	14.43	14.67	14.55	2.70	2.73	2.72
T_8	1.83	1.93	1.88	15.30	15.73	15.52	3.17	3.23	3.20
T_9	1.33	1.27	1.30	12.77	12.97	12.87	2.23	2.37	2.30
T_{10}	2.27	2.53	2.40	15.60	15.83	15.72	3.24	3.27	3.26
T_{11}	1.17	1.23	1.20	14.03	14.20	14.12	2.47	2.53	2.50
T_{12}	2.03	2.07	2.05	15.53	15.77	15.65	2.93	3.00	2.97
SEm±	0.18	0.18	0.13	0.61	0.37	0.36	0.24	0.23	0.17
CD at 5%	0.54	0.51	0.36	3.41	2.78	2.14	0.82	1.16	0.69

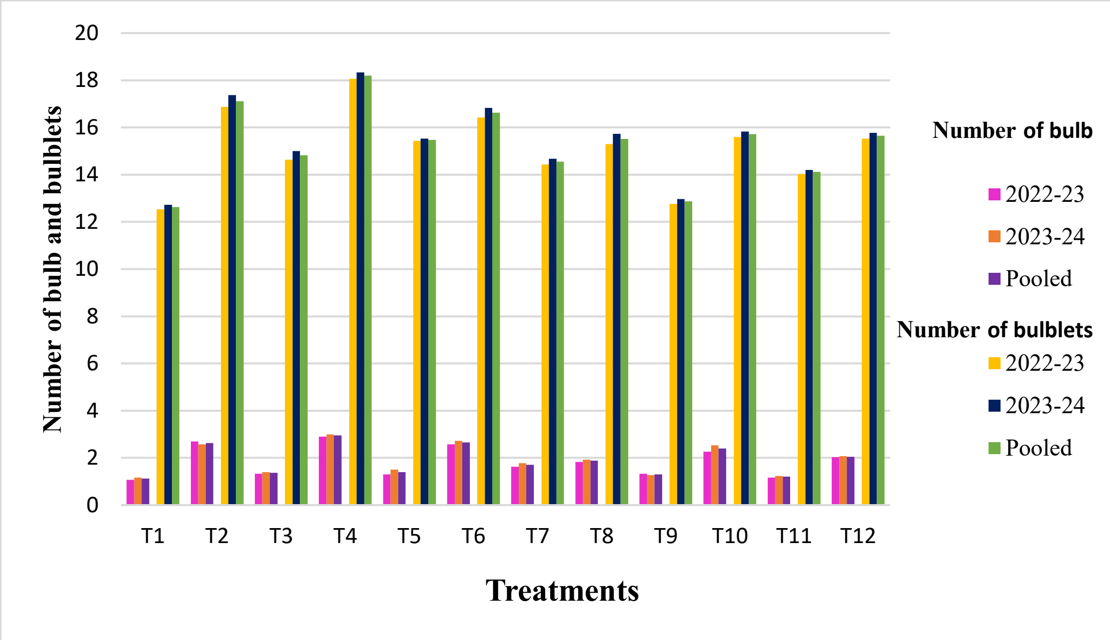

Fig 4.12 Effect of INM on number of bulb and bulblets per plant

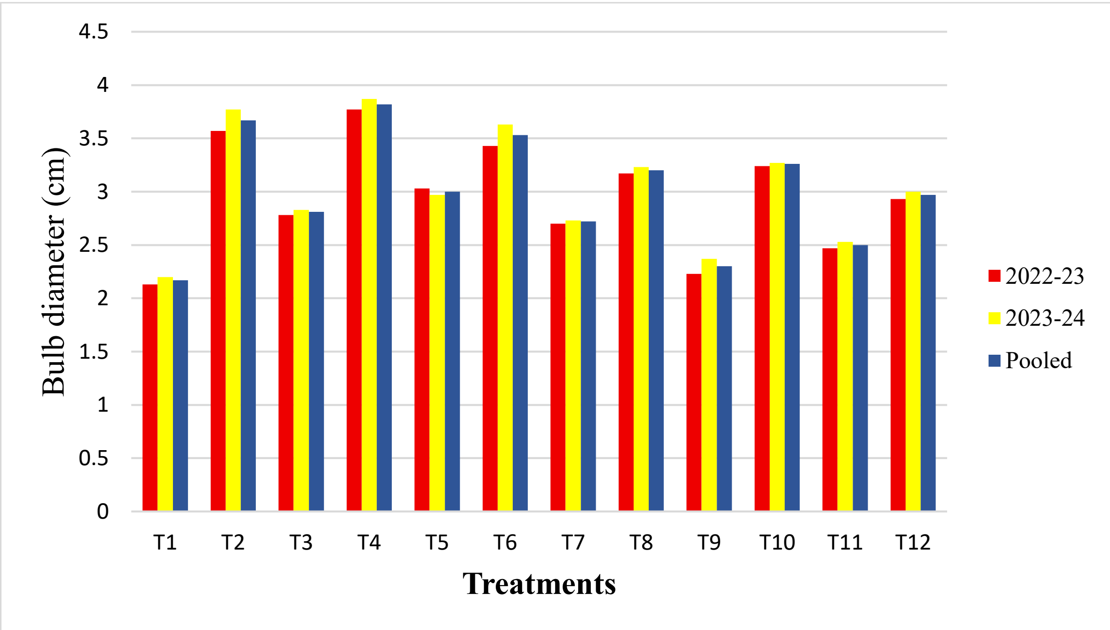

Fig. 13 Effect of INM on bulb diameter (cm) of tuberose

The present results were in line with the reports of Kumar, (2015) in tuberose, Kumar *et al.* (2022) in gladiolus, Ayoub and Masoodi, (2023) in hyacinth.

4.1.3.5 Bulblets weight

Bulblets weight showed a significant variation among the different treatments in during both the season of experiment which is presented in Table 4.9 and Fig 4.13.

A critical examination of the data with regard to 1st season revealed that T_4 (75% RDF + Vermicompost at 5 t/ha), was recorded maximum bulblets weight (122.27 g) which was found to be at par with T_2 (75% RDF + FYM at 10 t/ha), T_6 (75% RDF + Poultry manure at 2 t/ha) and T_{10} (75% RDF + Humic Acid at 1t/ha) having bulb weight of 121.73 g, 120.57g and 120.53 g respectively. While control gave lowest bulblets weight (113.10 g).

Similarly in 2nd season, maximum bulblets weight (123.43 g) was found in T_4 (75% RDF + Vermicompost at 5 t/ha), which was found to be at par with T_2 (75% RDF + FYM at 10 t/ha), T_6 (75% RDF + Poultry manure at 2 t/ha) and T_{10} (75% RDF + Humic Acid at 1t/ha) recording 121.80 g, 121.20 g and 120.50 g respectively , while the minimum bulblets weight (113.30 g) was noted in control.

Pooled data of both seasons also revealed that the highest bulblets weight (122.85 g) in T_4 (75% RDF + Vermicompost at 5 t/ha), which was found to be at par with T_2 (75% RDF + FYM at 10 t/ha), T_6 (75% RDF + Poultry manure at 2 t/ha) and T_{10} (75% RDF + Humic Acid at 1t/ha) with values of 121.77 g, 120.80 g and 120.52 g bulblets weight. While control recorded minimum bulblets weight (113.20 g).

Maximum bulblets weight was obtained in T_4, It might be due to application of inorganic fertilizer combined with organic manure (vermicompost), where vermicompost increase the uptake of NPK as nitrogen is constituent of protein and component of chlorophyll results in increase rate of photosynthesis and increases growth and also enhance the higher rate of transpiration, temperature of lower leaf promotes phytohormone and additionally, phosphorus from vermicompost and inorganic fertilizer take the part in basic reaction of photosynthesis and active number of enzyme and translocation of phytohormone which may lead to increase in bulbs weight (Sable, 2018) in gladiolus. Organic manure specially vermicompost has ability to produce growth promoting substances such as IAA and gibberellins etc. which might have helped in increasing weight of bulb. The present results were in line with the reports of Kumar, (2015) in tuberose, Kumar *et al.* (2022) in gladiolus, Ayoub and Masoodi, (2023) in hyacinth.

4.1.3.6 Bulb yield

The data pertaining to bulb yield as shown in Table 4.9 and Fig 4.14. significantly revealed a marked differences in whole the treatments during both the season of experiment and pooled data analysis.

During the 1st season of experiment, highest yield of bulb (26.22 ton) was obtained in T_4 (75% RDF + Vermicompost at 5 t/ha), which was at par with the T_2 (75% RDF + FYM at 10 t/ha), and T_6 (75% RDF + Poultry manure at 2 t/ha) recording 23.59 ton and 22.80 ton respectively. The lowest bulb yield (3.17) was found in control.

Similarly, in the 2nd season, T_4 (75% RDF + Vermicompost at 5 t/ha) produced maximum yield of bulb (27.24 ton), which was at par with T_6 (75% RDF + Poultry manure at 2 t/ha) and T_2 (75% RDF + FYM at 10 t/ha) with 24.39 ton and 23.97 ton respectively and minimum bulb yield (9.12 ton) recorded in control.

Regarding the pooled data analysis bulb yield was maximum in T_4 (75% RDF + Vermicompost at 5 t/ha) while control registered minimum bulb yield (8.74 ton)

A significant increase in bulb yield in tuberose under integrated nutrient management, may be attributed to the increase in bulb yield attributing characters such as diameter of bulbs, number of bulbs per plant, weight of bulb, yield of bulbs per plot and per hectare. The beneficial role of vermicompost in enhancing the physical, chemical and biological properties of soil is well documented, which in turn helps in better absorption of nutrients by plants and resulting higher yield of bulbs. Organic manure helps in maintaining C: N ratio in the soil which also increases the fertility and productivity of the soil (Jadeja *et al.,* 2021). All these factors may be responsible for increased yield of bulbs per hectare.

Table 4.9 Effect of INM on bulb weight (g), bulblet weight (g) and bulb yield (tonn) of tuberose

Treatments	Bulb weight (g)			Bulblet weight (g)			Bulb yield (t/ha)		
	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
T_1	70.30	70.33	70.32	113.30	113.10	113.20	8.35	9.12	8.74
T_2	80.73	80.80	80.77	121.80	121.73	121.77	23.59	23.97	23.78
T_3	76.50	76.23	76.37	116.57	115.90	116.23	11.36	11.91	11.63
T_4	81.27	81.77	81.52	123.43	122.27	122.85	26.22	27.24	26.73
T_5	76.13	76.57	76.35	120.00	119.50	119.75	11.03	12.77	11.90
T_6	80.17	80.23	80.20	121.03	120.57	120.80	22.80	24.39	23.60
T_7	74.27	74.03	74.15	115.63	115.70	115.67	13.54	14.75	14.14
T_8	77.63	78.73	78.18	120.40	120.27	120.33	15.86	16.96	16.41
T_9	72.32	72.03	72.18	114.53	113.23	113.88	10.67	10.14	10.41
T_{10}	78.73	78.97	78.85	120.50	120.53	120.52	19.80	22.22	21.01
T_{11}	72.20	73.03	72.62	114.30	114.77	114.53	9.34	10.01	9.67
T_{12}	76.50	76.67	76.58	116.10	115.97	116.03	17.31	17.63	17.47
SEm±	1.73	1.23	1.06	1.24	1.40	0.94	1.70	1.56	1.15
CD at 5%	5.09	3.60	3.03	3.41	2.78	2.14	5.00	4.57	3.29

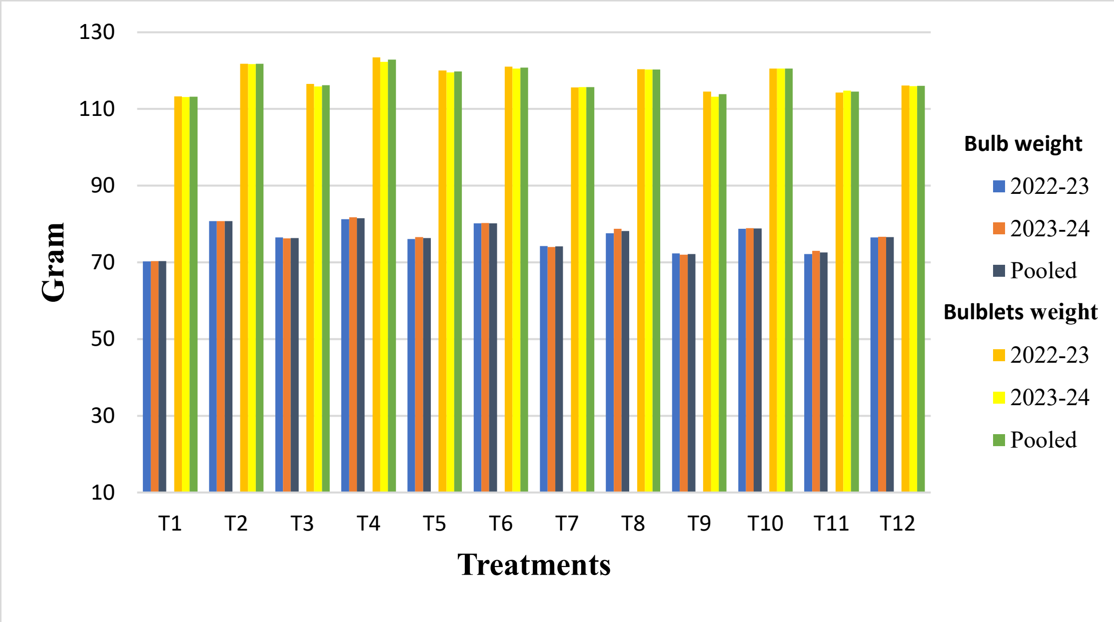

Fig.4.14 Effect of INM on bulb (g) and bulblets weight (g) of tuberose

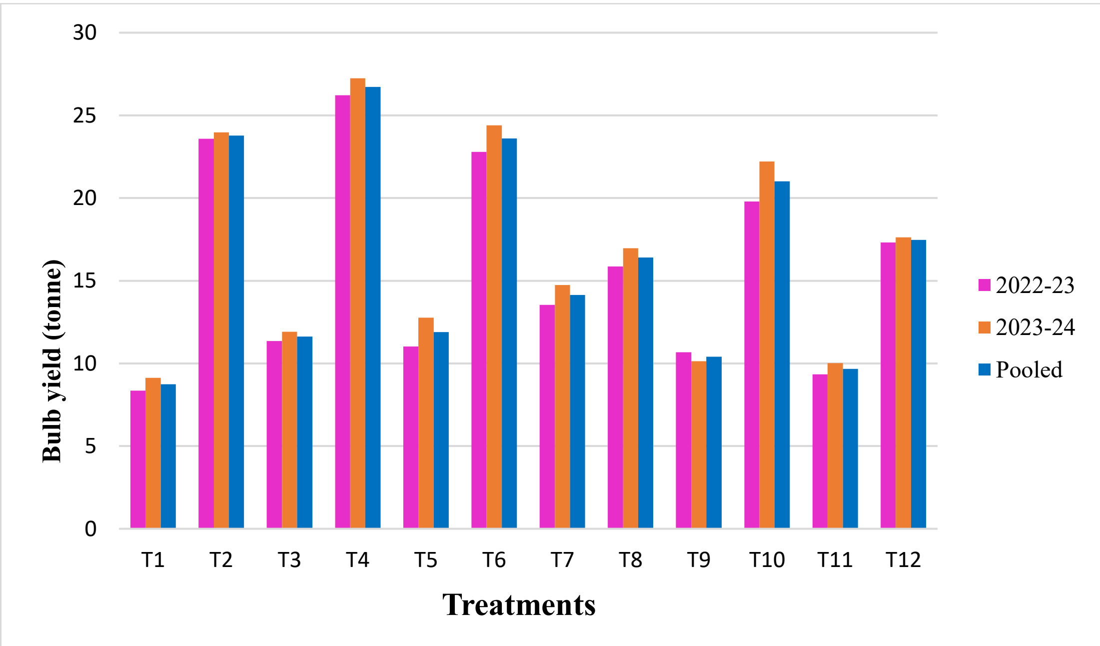

Fig. 4.15 Effect of INM on bulb yield (Ton) of tuberose.

Plate No. 16 Total number of bulbets in T_4 and T_1

Plate No. 17 Weight of bulb and bulblets per clumb

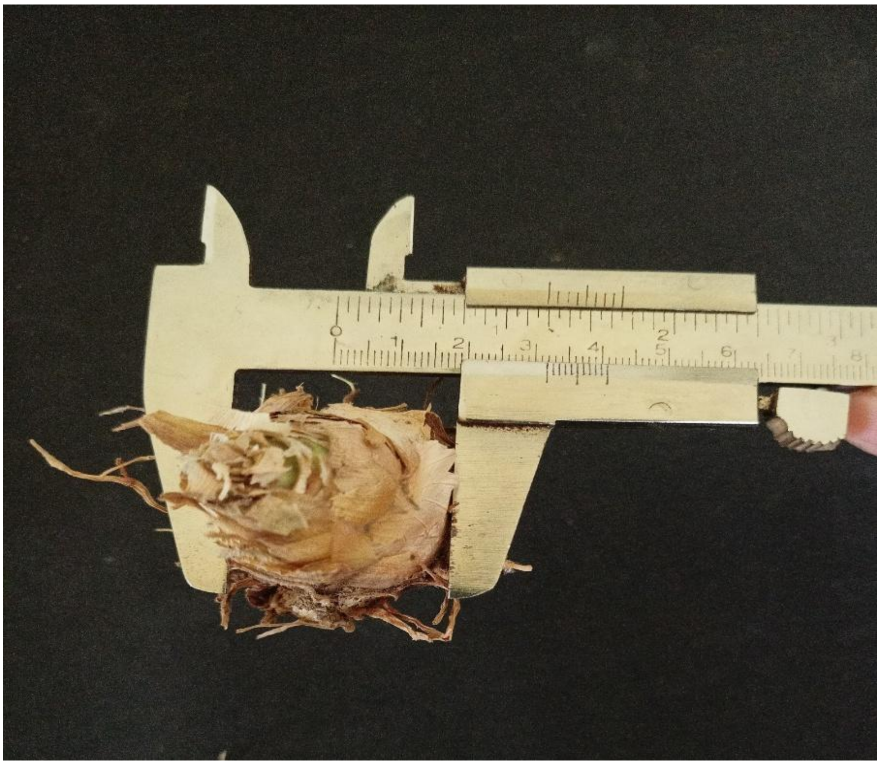

Plate No. 18 Diameter of bulb

Plate No. 19 Sorting and grading of bulb and bulblets

Similar findings were reported by Tripathi *et al.* (2013) in tuberose, Tirkey *et al.* (2017) in gladiolus, Kumar *et al*. (2015) in tuberose.

4.1.4 Post harvest studies

The data recorded under post-harvest studies *viz*. changes in fresh weight (g), days to 50% floret opening, total volume of water uptake (ml) and vase life (days) as influenced by the organic and inorganic source of nutrients are discussed below.

4.1.4.1 Changes in fresh weight

Data depicted in Table 4.10 and Fig 4.14 clearly indicates that the changes in fresh weight of tuberose spike were significantly affected by the different organic and inorganic fertilizer during both the season of experiment and their pooled data analysis. further scanning of the data revealed that the weight of cut spike increased till the 3rd day and gradually decreases thereafter during vase life period.

During 1st season of experiment, maximum fresh weight (71, 63.60 and 53.08 g) of cut spikes was registered in T_4 (75% RDF + Vermicompost at 5 t/ha), while minimum fresh weight (54.63, 51.98 and 43.40 g) was recorded in control on 2nd, 4th, and 6th day respectively.

Similarly in the following season, T_4 (75% RDF + Vermicompost at 5 t/ha) exhibited maximum fresh weight of spike (75.48, 65.96 and 54.75 g), while minimum (56.34, 52.34 and 43.78 g) was observed in control on 2nd, 4th, and 6th day respectively

Similar pattern of result was observed in pooled data analysis, where higher fresh weight (73.24, 64.78, 53.92 g) was observed in T_4 (75% RDF + Vermicompost at 5 t/ha), while control recorded minimum fresh weight (55.49, 52.16 and 43.59 g) on 2nd, 4th, and 6th day of vase life period.

Availability of optimum amount of nutrient from inorganic fertilizer in combination with vermicompost positively influenced the fresh weight of flower spike, because it enhanced the plant's nutrient uptake efficiency while forming more water-conducting tissues. These physiological benefits have likely resulted in spikes with higher cell turgidity and water content, reducing desiccation and water loss after harvest. Furthermore, the presence of plant growth regulators such as cytokinin's or

Table 4.10 Effect of INM on changes in fresh weight of cut tuberose spike

Treatments	Initial			Day 2			Day 4			Day 6		
	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
T_1	50.47	51.86	51.16	54.63	56.34	55.49	51.98	52.34	52.16	43.40	43.78	43.59
T_2	59.72	59.83	59.77	69.30	71.63	70.47	62.47	65.99	64.23	52.92	54.85	53.88
T_3	55.97	55.91	55.94	61.67	64.94	63.30	56.29	58.66	57.48	48.81	49.70	49.25
T_4	60.08	64.48	62.28	71.00	75.48	73.24	63.60	65.96	64.78	53.08	54.75	53.92
T_5	56.36	57.58	56.97	63.40	65.68	64.54	54.70	57.08	55.89	47.98	46.05	47.01
T_6	58.73	61.03	59.88	68.97	72.27	70.62	61.22	64.41	62.82	53.65	53.44	53.55
T_7	55.54	56.38	55.96	61.33	63.72	62.53	55.84	56.42	56.13	47.23	46.66	46.95
T_8	57.81	58.55	58.18	64.97	65.74	65.35	57.19	57.81	57.50	48.57	47.64	48.11
T_9	52.90	52.52	52.71	55.90	56.33	56.12	51.67	52.42	52.04	43.99	43.16	43.57
T_{10}	57.13	59.83	58.48	65.10	67.77	66.44	57.57	59.27	58.42	47.08	48.14	47.61
T_{11}	52.15	53.41	52.78	57.30	58.03	57.67	53.63	54.03	53.83	46.04	47.86	46.95
T_{12}	54.23	55.17	54.70	60.03	62.25	61.14	55.08	56.34	55.71	46.32	45.56	45.94
SEm±	0.99	1.54	0.91	0.89	1.49	0.87	1.26	1.57	1.01	1.41	1.47	1.02
CD at 5%	2.90	4.52	2.61	2.61	4.37	2.47	3.70	4.60	2.87	4.14	4.32	2.91

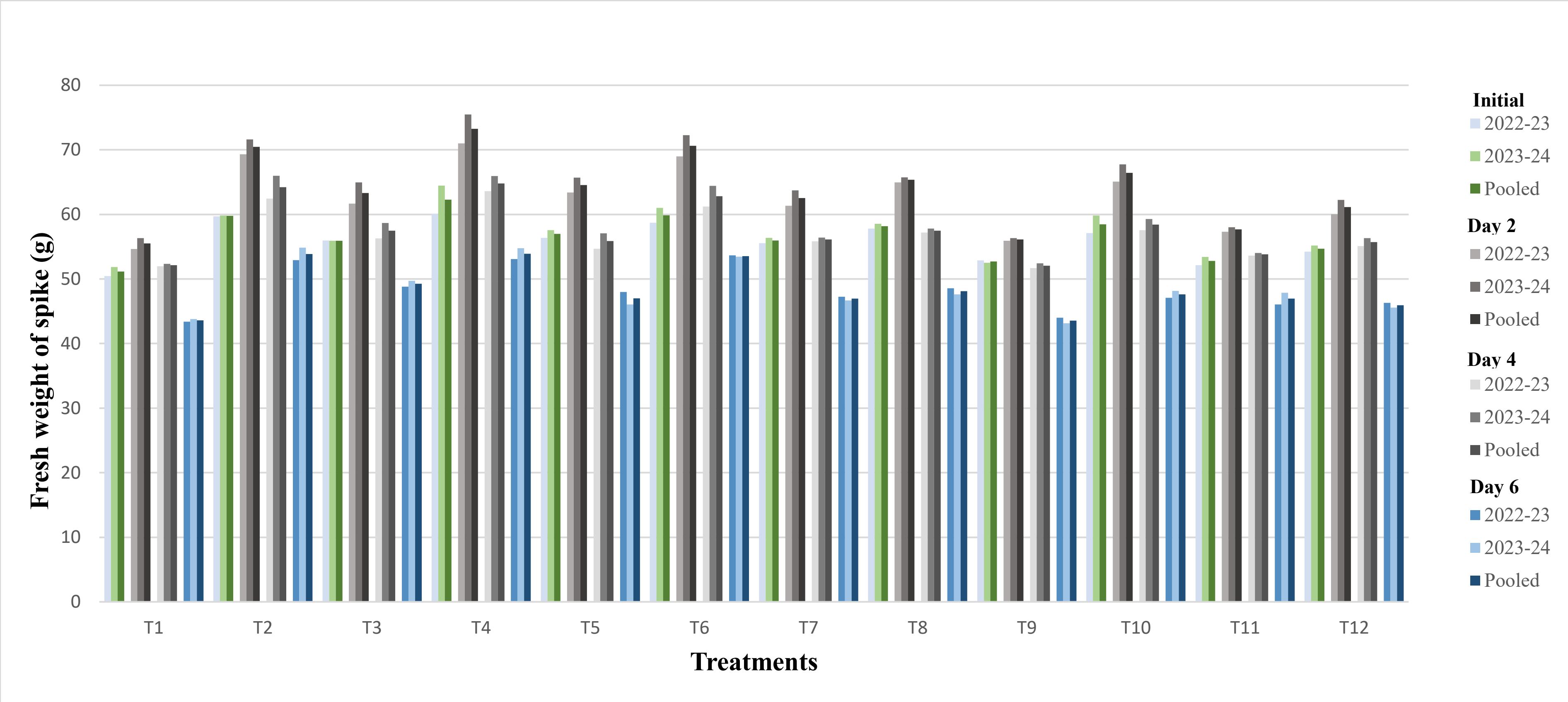

Fig. 4.16 Effect of INM on changes in fresh weight of cut tuberose spike.

ethylene inhibitors in vermicompost may also play a critical role in delaying floret senescence, as suggested by Bhalla *et al.* (2006).

4.1.4.2 Days to 50% floret opening

According to the data presented in the Table 4.11 and Fig 4.14, there was noticeable variation in Days to 50% floret opening in various treatment.

In the 1st season of experiment the treatment combination 75% RDF + FYM at 10 t/ha (T_2) was took maximum days (6.67) to 50 % floret opening, which was at par with T_4 (75% RDF + Vermicompost at 5 t/ha), T_6 (75% RDF + Poultry manure at 2 t/ha) and T_{10} (75% RDF + Humic Acid at 1t/ha) taking 6.43, 6.10 and 5.77 days, while minimum days (4.03) to 50 % floret opening was recorded in plant treated with only recommend dose of fertilizer .

During the 2nd season of experiment, maximum days (6.77) to 50% floret opening was recorded in T_4 (75% RDF + Vermicompost at 5 t/ha), which was found to be at par with T_2 (75% RDF + FYM at 10 t/ha), T_6 (75% RDF + Poultry manure at 2 t/ha) and T_{10} (75% RDF + Humic Acid at 1t/ha) which took 6.63, 6.53 and 6.27days. while control took minimum days (4.40)

According to pooled data analysis, T_2 (75% RDF + FYM at 10 t/ha) recorded maximum days (6.65) to 50% floret opening, which was at par with T_4 (75% RDF + Vermicompost at 5 t/ha), T_6 (75% RDF + Poultry manure at 2 t/ha) and T_{10} (75% RDF + Humic Acid at 1t/ha) taking 6.60, 6.32 and 6.02 days respectively, while control took minimum days (4.22) to 50% floret opening.

The incorporation of organic manure like FYM with chemical fertilizers thus greatly helped in improving the flower attributes. the increased water uptake observed in these spikes likely supports sustained hydration and turgor in the developing florets, facilitating proper petal expansion and delay in senescence (Tripathi *et al*., 2012).

4.1.4.3 Total volume of water uptake (ml)

The variation in total volume of water uptake was significantly influenced by organic and inorganic fertilizer during both the season, 2022-23 and 2023-24 and pooled data as presented in Table 4.11 and illustrated in Fig 4.14

During the 1st season, maximum water uptake (83.37 ml) was recoded under the treatment T_4 (75% RDF + Vermicompost at 5 t/ha), which was at par with T_2 (75% RDF + FYM at 10 t/ha) and T_6 (75% RDF + Poultry manure at 2 t/ha) recording 83.63 ml and 81.90 ml respectively. While minimum water uptake (57.97 ml) was observed in control.

In 2nd season, similar pattern of result was observed. The maximum water uptake (85.37 ml) was noted in T_4 (75% RDF + Vermicompost at 5 t/ha) which was at par with T_2 (75% RDF + FYM at 10 t/ha) and T_6 (75% RDF + Poultry manure at 2 t/ha) with values of 83.50 ml and 82.43 ml, while control recorded minimum water uptake (60.93 ml).

Regarding pooled data analysis of both season (2022-23 and 2023-24), the maximum water uptake (84.37 ml) was recorded in T_4 (75% RDF + Vermicompost at 5 t/ha), which was at par with T_2 (75% RDF + FYM at 10 t/ha) and T_6 (75% RDF + Poultry manure at 2 t/ha) (83.07 and 82.17 ml), while minimum water uptake (59.45 ml) was observed in control.

The enhanced water absorption capacity during the post-harvest phase is likely due to improved physiological and structural characteristics of the spikes developed under integrated nutrient management. The presence of vermicompost contributes to better nutrient availability and uptake during the growth period, promoting the development of more functional xylem tissues and maintaining vascular integrity. Hauser and Aswala (1999) supports the hypothesis, that addition of vermicompost favourably removed micropores in the soil which had direct impact on the turgidity maintenance of plants. Similar result was reported by Meena *et al.* (2014) in tuberose.

4.1.4.4 Vase life

Data shown in Table 4.11 and Fig 4.15 depicted that the application of different source of nutrients have significantly influenced the vase life of tuberose.

During the 1st season, longest vase life (12.47 days) was observed in T_4 (75% RDF + Vermicompost at 5 t/ha) which was statistically at par with T_6 (75% RDF +

Table 4.11 Effect of INM on days to 50% floret opening, total volume of water uptake (ml) and vase life (days) of tuberose spike.

Treatments	Days to 50% floret opening			Total volume of water uptake (ml)			Vase life (days)		
	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
T_1	4.03	4.40	4.22	57.97	60.93	59.45	8.53	9.07	8.80
T_2	6.67	6.63	6.65	82.63	83.50	83.07	11.47	11.97	11.72
T_3	5.37	5.63	5.50	67.27	69.20	68.23	10.03	9.83	9.93
T_4	6.43	6.77	6.60	83.37	85.37	84.37	12.47	12.43	12.45
T_5	5.57	5.70	5.63	73.37	73.47	73.42	9.73	10.43	10.08
T_6	6.10	6.53	6.32	81.90	82.43	82.17	11.50	12.47	11.98
T_7	5.20	5.40	5.30	67.03	68.93	67.98	9.37	10.30	9.83
T_8	5.73	5.93	5.83	77.13	77.93	77.53	10.63	10.20	10.42
T_9	4.93	4.87	4.90	60.50	61.50	61.00	9.13	9.67	9.40
T_{10}	5.77	6.27	6.02	77.37	78.83	78.10	10.80	10.50	10.65
T_{11}	4.87	5.13	5.00	59.87	62.03	60.95	8.77	9.47	9.12
T_{12}	5.33	5.47	5.40	73.27	73.33	73.30	9.10	10.10	9.60
SEm±	0.39	0.37	0.27	2.52	1.81	1.55	0.57	0.64	0.43
CD at 5%	5.09	3.60	3.03	7.38	5.31	4.42	1.66	1.88	1.22

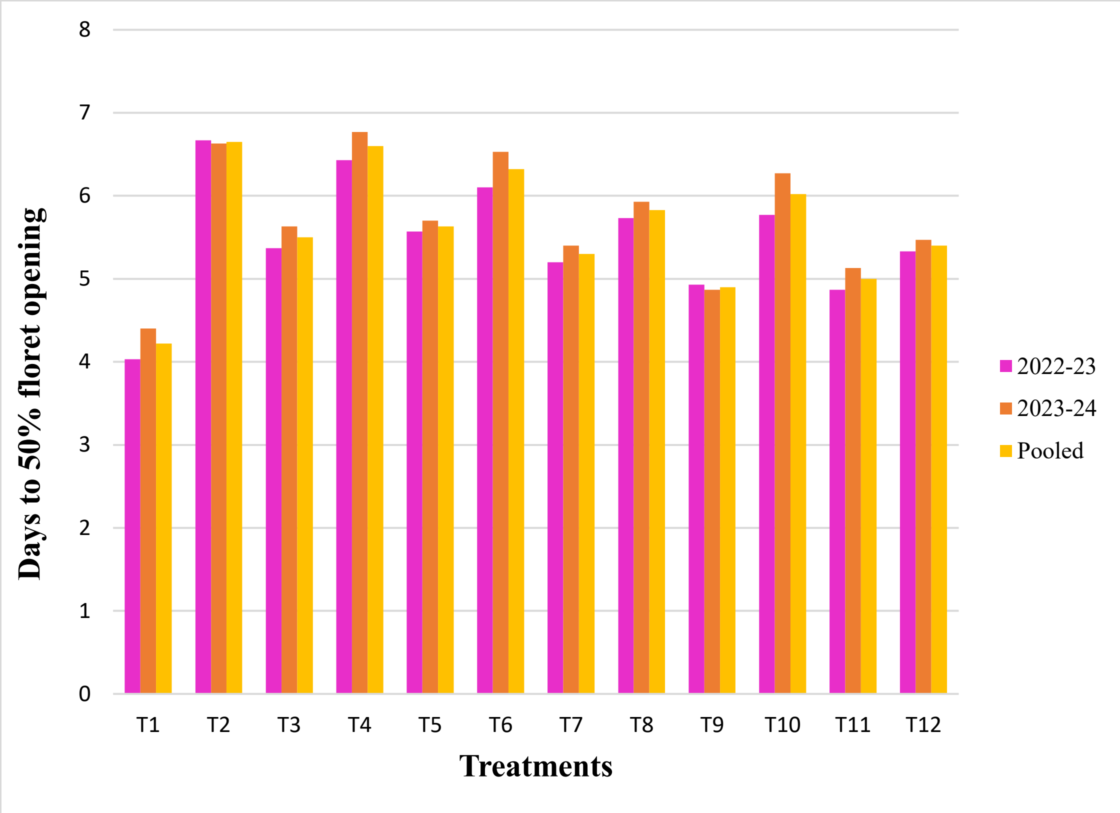

Fig. 4.17 Effect of INM on days to 50% floret opening.

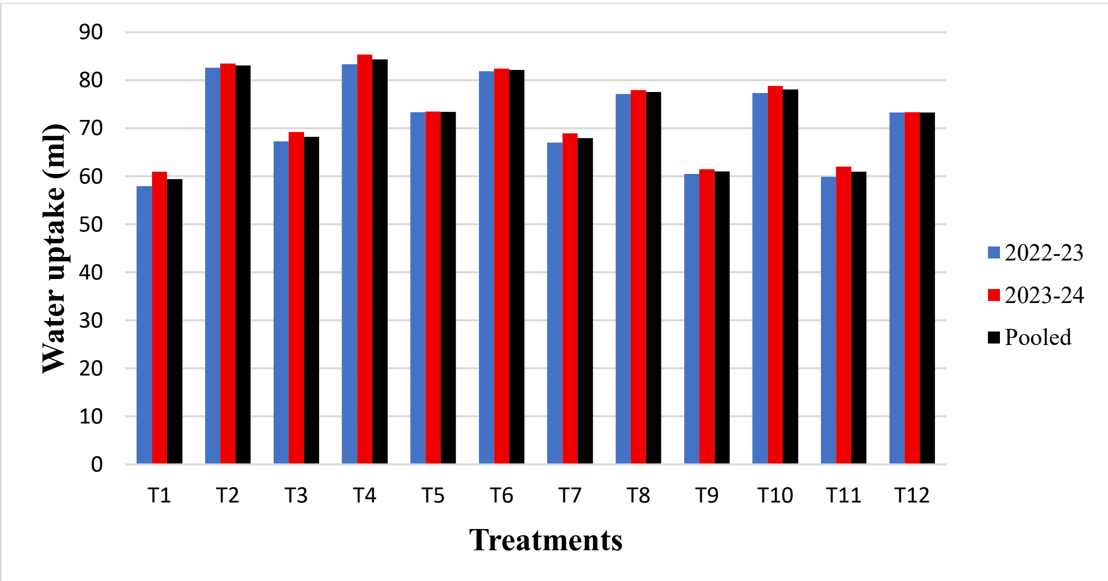

Fig. 4.18 Effect of INM on total volume of water uptake (ml) of tuberose spike.

Poultry manure at 2 t/ha), and T_2 (75% RDF + FYM at 10 t/ha), recording 11.50 and 11.47 days and the minimum vase life (8.53 days) was found in control.

In the following year also, T_4 (75% RDF + Vermicompost at 5 t/ha), recorded maximum vase life (12.43 days), which was at par with T_6 (75% RDF + Poultry manure at 2 t/ha), and T_2 (75% RDF + FYM at 10 t/ha) (12.40 and 11.97), while control noticed minimum vase life (9.07days).

Pooled data analysis revealed that the highest vase life (12.45 days) was recorded in T_4 (75% RDF + Vermicompost at 5 t/ha) which was found to be at par with T_6 (75% RDF + Poultry manure at 2 t/ha) and T_2 (75% RDF + FYM at 10 t/ha) with 11.98 and 11.72 days respectively, whereas minimum vase life (8.80 days) was observed in control.

Availability of optimum amount of nutrient from inorganic fertilizer in combination with vermicompost can serve as soil amendments to improve soil nutrient status, resulting more accumulation of carbohydrates and higher WHC resulting prolonged vase life in tuberose spike. Similar findings were earlier reported by Singh *et al.* (2014) in gladiolus, Meena *et al.* (2014) in tuberose, Khanam *et al*. (2017) in gladiolus, Patel *et al*. (2023) in tuberose.

4.1.5 Biochemical parameters

4.1.5.1 Chlorophyll content in leaves

According to the data presented in Table 4.12 and Fig 4.16, the application of integrated nutrient management significantly increased the chlorophyll content in leaves of tuberose during both the season of experiment.

In the 1^{st} season, maximum chlorophyll content (0.419 mg/g) in leaves was noted with the application of 75% RDF + Vermicompost at 5 t/ha (T_4) followed by 75% RDF + Poultry manure at 2 t /ha (T_6) with 0.409 mg/g, meanwhile the control recorded minimum chlorophyll content in leaves (0.281 mg/g).

Similarly, during the 2^{nd} season of experiment, T_4 (75% RDF + Vermicompost at 5 t/ha) showed maximum chlorophyll content (0.439 mg/g) in the leaves followed

Table 4.12 Influence of INM on total chlorophyll content (mg/g) in leaves of tuberose

Treatments	Total chlorophyll content in leaves (mg/g)		
	2022-23	**2023-24**	**Pooled**
T_1	0.281	0.299	0.290
T_2	0.386	0.396	0.391
T_3	0.324	0.325	0.325
T_4	0.419	0.439	0.429
T_5	0.374	0.378	0.376
T_6	0.409	0.428	0.419
T_7	0.326	0.331	0.329
T_8	0.376	0.380	0.378
T_9	0.308	0.312	0.310
T_{10}	0.380	0.389	0.385
T_{11}	0.327	0.328	0.328
T_{12}	0.337	0.345	0.341
SEm±	0.003	0.002	0.002
CD at 5%	0.009	0.005	0.005

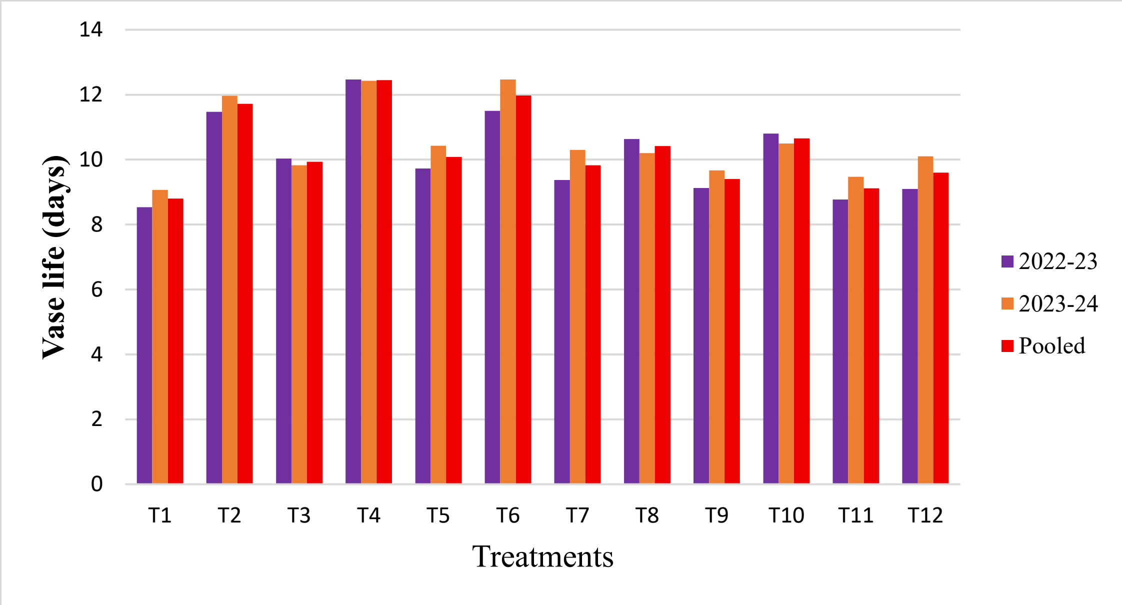

Fig. 4.19 Effect of INM on vase life (days) of tuberose spike.

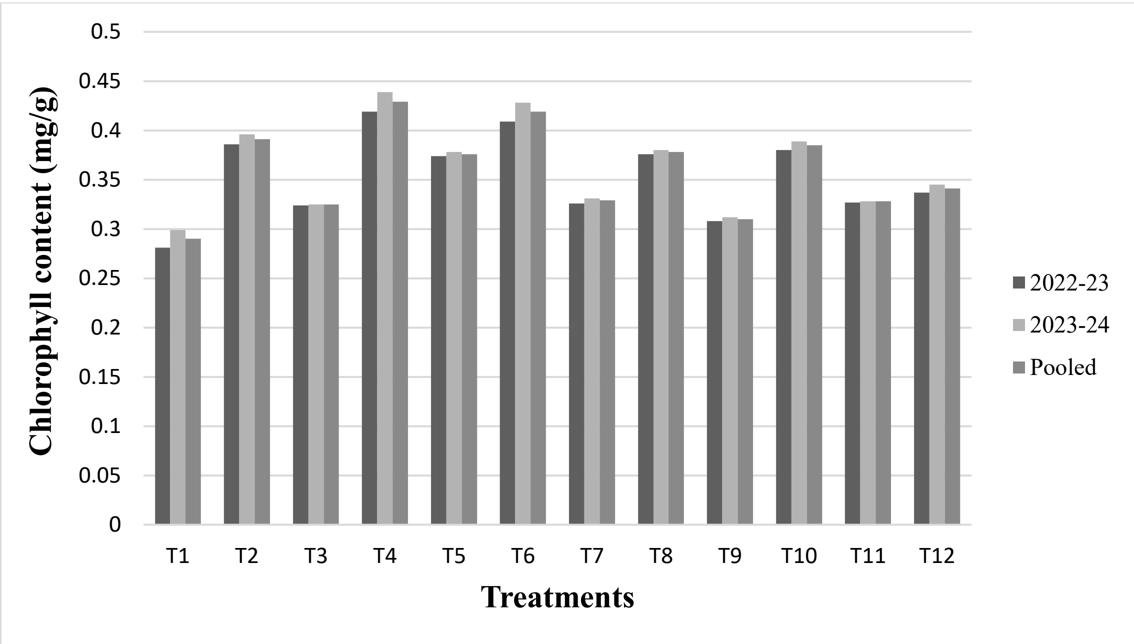

Fig. 4.20 Influence of INM on total chlorophyll content (mg/g) in leaves of tuberos

by T_6 (75% RDF + Poultry manure at 2 t/ha) which recording 0.428 mg/g. while minimum chlorophyll content (0.299 mg/g) in leaves was observed in control.

According to the pooled data analysis, maximum chlorophyl content (0.429 mg/g) was noted in T_4 (75% RDF + Vermicompost at 5 t/ha) and minimum (0.290mg/g) was recorded in control.

In the present experiment highest total chlorophyll content in leaves of tuberose was recorded in treatment T_4, it might be due to increased nutrient accessibility and presence of growth promoting substances in the soil, resulting from the application of higher dose of recommended chemical fertilizer and combination with organic manure (vermicompost). Additionally, the soil application of vermicompost improves the absorption of nitrogen and Magnesium, which are the important components required for the formation of the chlorophyll molecule (Massoud *et al.,* 2022). Similar results were noticed by Elisheba and Sudhagar (2019) in tuberose, Sahana *et al*. (2020) in tuberose.

4.1.5.2 NPK content in leaves

Nutrient analysis of tuberose leaves plays an important role in ensuring healthy plant growth and serves as a diagnostic and decision-support tool in Integrated Nutrient Management. It is important in understanding both the chemical composition of fertilizers and the nutrient uptake by the plant. This analysis is valuable for identifying nutrient deficiencies and determining the most effective fertilization methods. The data recorded for nitrogen, phosphorus, and potassium content in leaves as effect by organic and inorganic source of nutrients are discussed below.

4.1.5.2.1 Nitrogen content in leaves

Data presented in Table 4.13 and Fig 4.16 showed that the nitrogen content in leaves was significantly affected by the application of organic and inorganic fertilizer application during both the season of experiment.

During the 1st season of experiment, maximum nitrogen content in leaves (3.75%) was observed in T_4 (75% RDF + Vermicompost at 5 t/ha), which was was found to be at par with T_6 (75% RDF + Poultry manure at 2 t/ha), T_2 (75% RDF +

FYM at 10 t/ha) and T_{10} (75% RDF + Humic Acid at 1t/ha) with values 3.70, 3.53 % and 3.44 % respectively. Whereas control was registered minimum nitrogen content in leaves (2.47 %).

Similar result was obtained in the following season, where the highest nitrogen content in leave (3.78 %) was obtained in T_4 (75% RDF + Vermicompost at 5 t/ha), which was significantly at par with T_6 (75% RDF + Poultry manure at 2 t/ha), T_2 (75% RDF + FYM at 10 t/ha) and T_{10} (75% RDF + Humic Acid at 1t/ha) having 3.69 %, 3.66% and 3.46 % nitrogen content. while minimum (2.44 %) was obtained in control.

Pooled data analysis of both seasons also revealed the similar trend. T_4 (75% RDF + Vermicompost at 5 t/ha) was exhibited observed maximum nitrogen content in leaves (3.77 %), which was at par with T_6 (75% RDF + Poultry manure at 2 t/ha), T_2 (75% RDF + FYM at 10 t/ha), and T_{10} (75% RDF + Humic Acid at 1t/ha), whereas control recorded minimum nitrogen content (2.46 %) in leaves.

The maximum nitrogen uptake by tuberose leaves observed in treatment T_4, might be due to the combined application of organic and inorganic fertilizers which significantly increased nitrogen content, and thereby could have attributed to the rapid absorption of these elements by the plant surface and their translocation in the plant as reported by Singh *et al.,* (2002) in gladiolus. It might also be due to improvement of the physical and chemical properties of the soil by application of vermicompost which ultimately increased the availability of plant nutrients, thus enhanced nutrient uptake. The result is in partial agreement with Waheeduzzama *et al*. (2013) in anthurium, Khanam *et al.* (2017) in gladiolus, Dhakar *et al.* (2019 in gladiolus, Chaupoo and Kumar (2021) in marigold

4.1.5.2.2 Phosphorus content in leaves

According to the data showed in Table 4.13 and Fig 4.16, phosphorus content in leaves noticed significant variation among the different treatment. During the 1st season, maximum phosphorus content in leaves (0.19 %) was observed in T_4 (75% RDF + Vermicompost at 5 t/ha), which was statistically at par with T_6 (75% RDF + Poultry manure at 2 t/ha), T_2 (75% RDF + FYM at 10 t/ha) and T_{10} (75% RDF + Humic

Acid at 1t/ha) with values 0.18 %, 0.10 % and 0.16 % respectively and the minimum 0.07 % phosphorus content in leaves was recorded in control.

In the following season, T_6 (75% RDF + Poultry manure at 2 t/ha) recorded highest phosphorus content in leaves (0.20 %), which was at par with T_4 (75% RDF + Vermicompost at 5 t/ha), T_2 (75% RDF + FYM at 10 t/ha) and T_{10} (75% RDF + Humic Acid at 1t/ha) recording 0.19% and 0.18 % phosphorus content. While control noticed minimum phosphorus content in leaves (0.08 %).

Pooled data revealed that the maximum phosphorus content in leaves of 0.193 % was recorded in T_4 (75% RDF + Vermicompost at 5 t/ha), which was found to be at par with T_6 (75% RDF + Poultry manure at 2 t/ha), T_2 (75% RDF + FYM at 10 t/ha) and T_{10} (75% RDF + Humic Acid at 1t/ha) having 0.192, 0.183 and 0.170 % respectively. While minimum phosphorus content in leaves (0.075 %) observed in control.

In present experiment maximum phosphorus in tuberose leaves was recorded in T_4 (75% RDF + Vermicompost at 5 t/ha). this might be due to easily available nutrient through RDF with combination of vermicompost. Additionally, vermicompost releases nitrogen, phosphorus, potassium and other nutrient at a slow rate in the soil and also improves the uptake of these nutrients by the plants, which may be the reason for higher NPK content in the Tuberose leaves (Atiyeh *et al.,* 2002) The result is in partial agreement with Waheeduzzama *et al*. (2006) in anthurium, Khanam *et al.* (2017) in gladiolus, Dhakar *et al.* (2019 in gladiolus, Chaupoo and Kumar (2021) in marigold.

4.1.5.2.3 Potassium content in leaves

Potassium content in leaves shown significant variation among the different treatment during both the season of experiment as presented in Table 4.13 and Fig 4.16.

In 1st season of experiment, T_4 (75% RDF + Vermicompost at 5 t/ha) recorded maximum potassium content in leaves (2.83 %), which was found to be at par with T_6 (75% RDF + Poultry manure at 2 t/ha), T_2 (75% RDF + FYM at 10 t/ha), and T_{10} (75%

RDF + Humic Acid at 1t/ha). While control gave lowest potassium content in leaves (1.79 %).

Almost similar result was recorded during the following season where maximum potassium content in leaves (2.86 %) was found in T_4 (75% RDF + Vermicompost at 5 t/ha), which was found to be at par with T_6 (75% RDF + Poultry manure at 2 t/ha), T_2 (75% RDF + FYM at 10 t/ha), and T_{10} (75% RDF + Humic Acid at 1t/ha) having values of 2.74 %, 2.73 % and 2.70 % respectively, while the minimum potassium content in leaves (1.84 %) was recorded in control.

In pooled data analysis, highest potassium content in leaves of 2.84 % was obtained in T_4 (75% RDF + Vermicompost at 5 t/ha), which was found to be at par with T_6 (75% RDF + Poultry manure at 2 t /ha), T_2 (75% RDF + FYM at 10 t/ha), and T_{10} (75% RDF + Humic Acid at 1t/ha). While control recorded minimum potassium content in leaves (1.82 %).

Positive interaction between organic (vermicompost) and inorganic (NPK) nutrients resulted in initial buildup of vigorous growth and higher photosynthetic rate which led to better uptake of nutrients during the crop growth period and also increase in microbial population which eventually made more availability of nutrients by the process of mineralization (Bagyaraj and Rangaswami, 1967) and (James *et al*., 2011). Similar results were recorded by Khanam *et al.* (2017) in gladiolus, Dhakar *et al.* (2019 in gladiolus, Chaupoo and Kumar, (2021) in marigold.

Table 4.13 Effect of INM on NPK content in leaves of tuberose

Treatments	Nitrogen (%)			Phosphorus (%)			Potassium (%)		
	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
T_1	2.47	2.44	2.46	0.07	0.08	0.075	1.79	1.84	1.82
T_2	3.53	3.66	3.60	0.18	0.19	0.183	2.71	2.73	2.72
T_3	2.81	2.83	2.82	0.11	0.12	0.117	2.31	2.34	2.32
T_4	3.75	3.78	3.77	0.19	0.19	0.193	2.83	2.86	2.84
T_5	3.29	3.36	3.32	0.15	0.17	0.157	2.56	2.57	2.56
T_6	3.70	3.69	3.69	0.18	0.20	0.192	2.73	2.74	2.74
T_7	2.95	2.96	2.96	0.14	0.15	0.143	2.44	2.48	2.46
T_8	3.34	3.37	3.36	0.16	0.16	0.163	2.64	2.68	2.66
T_9	2.66	2.66	2.66	0.09	0.10	0.095	1.89	1.92	1.90
T_{10}	3.44	3.46	3.45	0.16	0.18	0.170	2.67	2.70	2.69
T_{11}	2.64	2.66	2.65	0.10	0.11	0.103	1.93	1.99	1.96
T_{12}	2.75	2.73	2.74	0.08	0.10	0.090	2.10	2.13	2.11
SEm±	0.22	0.16	0.14	0.01	0.02	0.01	0.11	0.12	0.08
CD at 5%	0.65	0.47	0.39	0.04	0.05	0.03	0.33	0.35	0.23

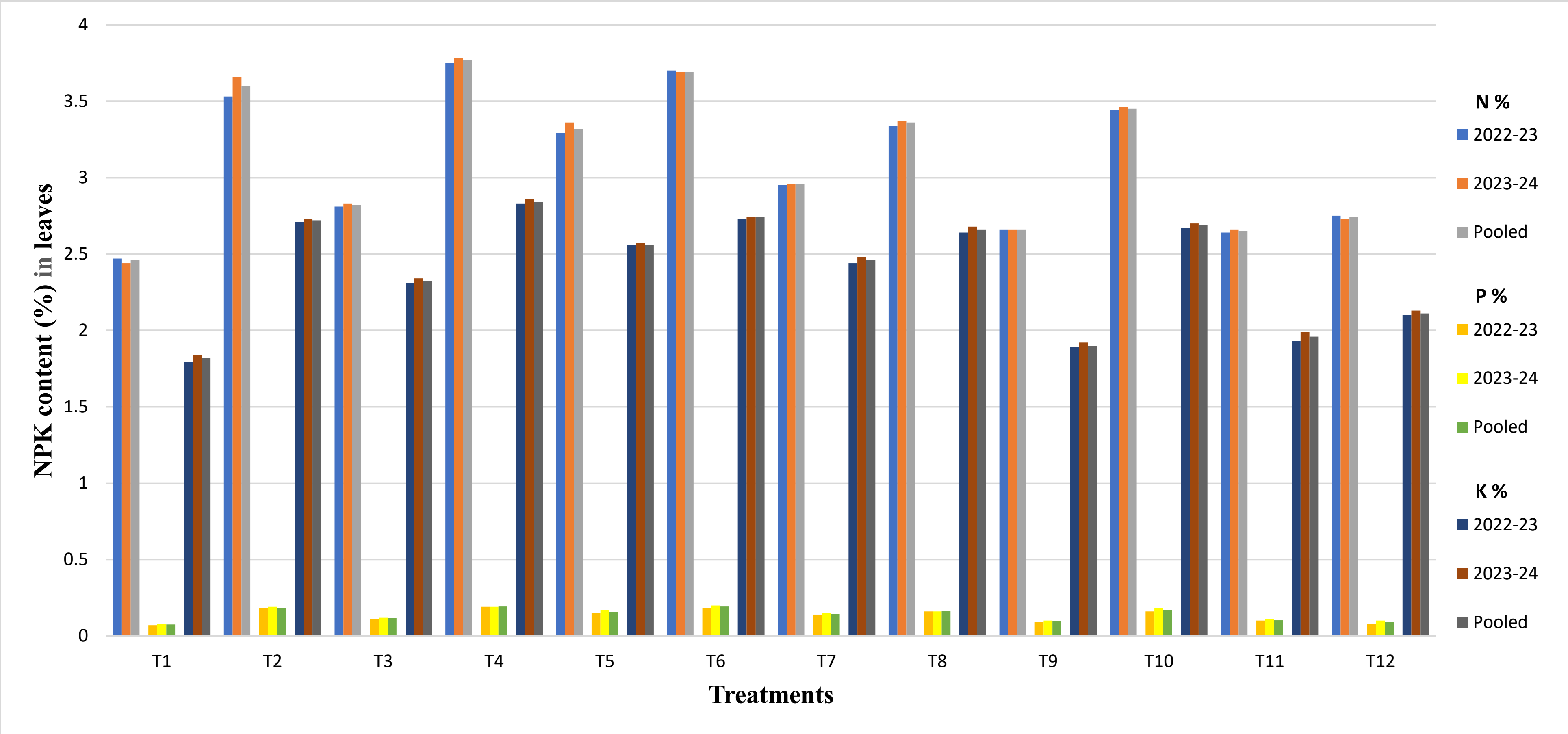

Fig. 4.21 Effect of INM on NPK content in leaves of tuberose

4.1.5.3 NPK content in bulb

Analysis of NPK content in tuberose bulb is important because its direct effect the growth, flowering and bulb production. Nutrient analysis helps to understand the requirement of the plant and aids to design nutrient management plans for better results. This helps to trace the availability or deficiency of certain elements and manage the nutrient requirements for healthy growth. The NPK content in tuberose bulbs can vary depending on the factors like soil quality, climate and cultivars. The data pertaining to nitrogen, phosphorus and potassium content in bulbs of tuberose are discussed below.

4.1.5.3.1 Nitrogen content in bulb

Data presented in Table 4.14 and Fig 4.18 revealed that the organic and inorganic fertilizer and their combination had a significant effect on the nitrogen content in bulb of tuberose in both the season and pooled data.

During 1st season of experiment, highest nitrogen content in bulb (2.83 %) was observed with T_4 (75% RDF + Vermicompost at 5 t/ha), which was statistically at par with T_2 (75% RDF + FYM at 10 t/ha), T_6 (75% RDF + Poultry manure at 2 t/ha) and T_{10} (75% RDF + Humic Acid at 1t/ha) which contented 2.73%, 2.73% and 2.69 % of nitrogen respectively, while the lowest nitrogen content in bulb (1.60 %) was noted in control.

In the season of 2023-24, T_4 (75% RDF + Vermicompost at 5 t/ha) was exhibited maximum nitrogen content in bulb (2.89 %), which was at par with T_2 (75% RDF + FYM at 10 t/ha), T_6 (75% RDF + Poultry manure at 2 t/ha), and T_{10} (75% RDF + Humic Acid at 1t/ha) with values 2.80 %, 2.70% and 2.53 % respectively. The plant grown only with the application of RDF was had minimum nitrogen content in bulb (1.62 %).

According to the pooled data of both years, T_4 (75% RDF + Vermicompost at 5 t/ha) recorded maximum nitrogen content in bulb (2.86 %), which was significantly at par with T_2 (75% RDF + FYM at 10 t/ha) and T_6 (75% RDF + Poultry manure at 2 t

/ha) having 2.76 and 2.69 % nitrogen content, while control showed the minimum nitrogen content in bulb (1.61 %).

The maximum nitrogen content recorded in T_4, it might be due to the optimal supply of NPK nutrients through conjugal use of inorganic fertilizers and organic manure during the growth period which ensured the uniform translocation of nutrients in plant (Singh *et al.,* 2011).

4.1.5.3.2 Phosphorus content in bulb

Phosphorus content in bulb was significantly influenced by various organic and inorganic fertilizer during the season of 2022-23 and 2023-24 and there means as presented in Table 4.14 and Fig 4.18

During the 1st season, maximum phosphorus content in bulb (0.22 %) was recorded in T_4 (75% RDF + Vermicompost at 5 t/ha), which was found to be at par with T_6 (75% RDF + Poultry manure at 2 t/ha) and T_2 (75% RDF + FYM at 10 t/ha) having 0.21% and 0.19 % phosphorus respectively, while control obtained minimum phosphorus content in bulb (0.11).

Similarly in the 2nd season, T_4 (75% RDF + Vermicompost at 5 t/ha) recorded highest phosphorus content in bulb (0.22 %), which was at par with T_6 (75% RDF + Poultry manure at 2 t/ha) and T_2 (75% RDF + FYM at 10 t/ha) with values of 0.22 % and 0.20 %, while minimum (0.12 %) was found in control.

The pooled data analysis revealed similar result, where T_4 (75% RDF + Vermicompost at 5 t/ha) showed maximum phosphorus content in bulb (0.22 %) and control had minimum phosphorus content in bulb (0.11 %).

It may be concluded that level of soil nutrients records a positive relationship with the bulb nutritional status and availability of the nutrients in usable form. This may be due to presence of increased micro-organism's population and formation of organic acids after decomposition of organic manures which causes better availability of soil nutrients hence plant uptake becomes easy and specially in case of phosphorus, various phenolic and aliphatic acids are produced during decomposition of vermicompost, which solubilize phosphatase and other phosphate bearing minerals hence retards the fixation of phosphorus and increase its availability (Meena *et al.,* 2015).

4.1.5.3.3 Potassium content in bulb

Data presented in Table 4.14 and Fig 4.18 revealed that the organic and inorganic fertilizer and their combination marked at significant effect on the potassium content in bulb in both season and pooled data.

During 1st season, highest potassium content in bulb (2.50 %) was observed, in T_4 (75% RDF + Vermicompost at 5 t/ha), which was statistically at par with, T_2 (75% RDF + FYM at 10 t/ha), T_6 (75% RDF + Poultry manure at 2 t/ha) and T_{10} (75% RDF + Humic Acid at 1t/ha) with values 2.39, 2.28 and 2.13 % respectively, while the minimum potassium content in bulb (1.53 %) was noted in control.

In the 2nd season also, maximum potassium content in bulb (2.28 %) was found in T_4 (75% RDF + Vermicompost at 5 t/ha), which was found to be at par with T_2 (75% RDF + FYM at 10 t/ha) and T_6 (75% RDF + Poultry manure at 2 t/ha) recording 2.73 and 2.67 % respectively. while plant grown only with the application of RDF registered minimum potassium content in bulb (1.60 %).

According to pooled data of both seasons, T_4 (75% RDF + Vermicompost at 5 t/ha) was recorded maximum potassium content in bulb of 2.67 %, which was significantly at par with T_2 (75% RDF + FYM at 10 t/ha) and T_6 (75% RDF + Poultry manure at 2 t/ha), while the control showed the minimum of 1.57 % potassium content in bulb.

With respect to potassium content, maximum potassium content was observed with the application of 75% RDF and Vermicompost at 5 t/ha, which might be due to the solubilizing action of organic acids produced during decomposition of the organic

Table 4.14 Effect of INM on NPK content in bulb of tuberose

Treatments	Nitrogen (%)			Phosphorus (%)			Potassium (%)		
	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
T_1	1.60	1.62	1.61	0.11	0.12	0.11	1.60	1.53	1.57
T_2	2.73	2.80	2.76	0.19	0.20	0.20	2.73	2.39	2.56
T_3	2.11	2.14	2.13	0.15	0.16	0.16	2.11	2.00	2.06
T_4	2.83	2.89	2.86	0.22	0.22	0.22	2.83	2.50	2.67
T_5	2.20	2.29	2.24	0.16	0.17	0.17	2.20	2.00	2.10
T_6	2.67	2.70	2.69	0.21	0.22	0.21	2.67	2.28	2.48
T_7	2.02	2.05	2.04	0.16	0.17	0.17	2.02	1.82	1.92
T_8	2.39	2.40	2.40	0.17	0.19	0.18	2.39	2.12	2.25
T_9	1.69	1.77	1.73	0.13	0.15	0.14	1.69	1.64	1.67
T_{10}	2.46	2.53	2.49	0.17	0.18	0.18	2.46	2.13	2.29
T_{11}	1.79	1.84	1.81	0.13	0.15	0.14	1.79	1.66	1.73
T_{12}	1.87	1.89	1.88	0.16	0.17	0.17	1.87	1.74	1.81
SEm±	0.19	0.15	0.12	0.01	0.02	0.01	0.19	0.13	0.11
CD at 5%	0.55	0.44	0.34	0.04	0.06	0.03	0.55	0.38	0.32

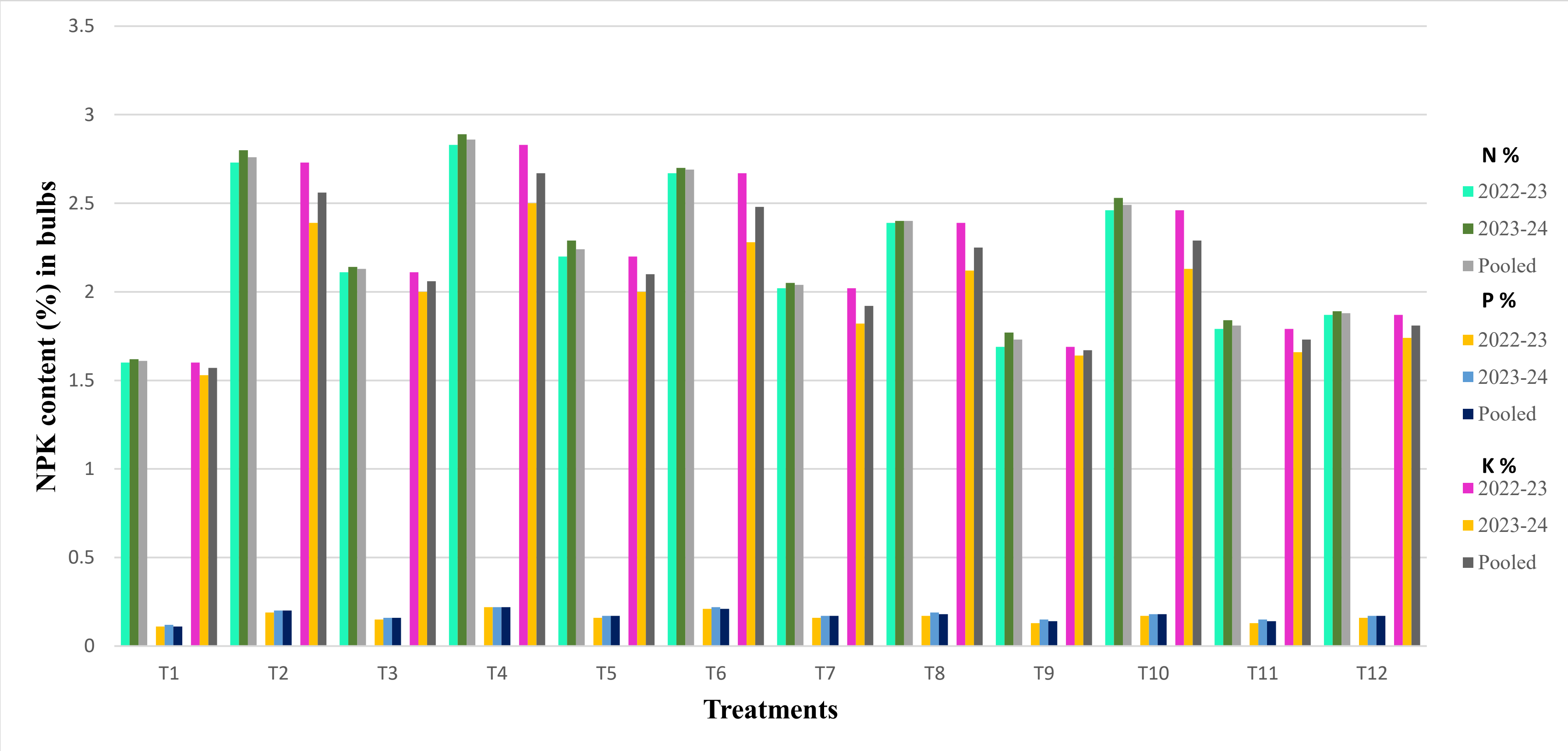

Fig. 4.22 Effect of INM on NPK content in bulb of tuberose

matter and its higher capacity to hold K in available form, also help nutrients absorption from inorganic fertilizer. Increase in soil available potash with the application of vermicompost may be due to the direct addition of potash to the available K pool of the soil and also due to the retardation of K fixation (Laishram *et al.,* 2013).

4.1.6 Physio-Chemical properties of soil

4.1.6.1 Available nitrogen in soil

Data pertaining on available nitrogen in soil are presented in Table 4.15 and Fig 4.19 which depicts that organic and inorganic fertilizers had significant effect on available nitrogen in soil after harvesting of bulb during both the season of experiment.

In the 1st season of experiment, maximum available nitrogen in soil was recorded in T_4 (75% RDF + Vermicompost at 5 t/ha), which was found to be at par with T_2 (75% RDF + FYM at 10 t/ha), T_6 (75% RDF + Poultry manure at 2 t/ha), and T_{10} (75% RDF + Humic Acid at 1t/ha) having values 564.48 kg/ha, 543.57kg/ha and 522.67 kg/ha available nitrogen, respectively whereas control recorded minimum available nitrogen in soil (379.36 kg/ha).

During 2nd season of experiment, T_4 (75% RDF + Vermicompost at 5 t/ha) recorded maximum (615.29 kg/ha) available nitrogen in soil which was at par with T_2 (75% RDF + FYM at 10 t/ha), T_6 (75% RDF + Poultry manure at 2 t/ha), T_{10} (75% RDF + Humic Acid at 1t/ha) and T_8 (75% RDF + forest soil at 10 t/ha) with values of 580.96, 572.72, 564.48 and 543.57 kg/ha. Lowest available nitrogen (385.20 kg/ha) was recorded in control.

Regarding the pooled data of both season, available nitrogen in soil was recorded maximum (600.34 kg/ha) in T_4 (75% RDF + Vermicompost at 5 t/ha) which was found to be at par with T_2 (75% RDF + FYM at 10 t/ha), T_6 (75% RDF + Poultry manure at 2 t /ha) and T_{10} (75% RDF + Humic Acid at 1t/ha) recording 572.72 kg/ha, 558.15kg/ha and 543.57 kg/ha nitrogen in soil, while the control showed minimum available nitrogen in soil (382.28 kg/ha).

Maximum available nitrogen in soil recorded in T_4 (75% RDF + Vermicompost at 5 t/ha) might be due to application of inorganic fertilizer with organic manure (vermicompost), where vermicompost improved organic matter status in soil, which further improved soil physical as well as microbiological activities and ultimately increased the availability of plant nutrients. Vermicompost have greater role in releasing nitrogen and enhancing nitrogen availability in soil for plants use. Similar results were observed by Laishram *et al.* (2013) in chrysanthemum, Khanam *et al.* (2017) in gladiolus, Dubliya *et al.* (2018) in tuberose.

4.1.6.2 Available phosphorus in soil

According to data presented in Table 4.15 and Fig 4.19, notable variation was found in various treatment regarding the available phosphorus in soil after harvesting of bulb.

During the 1st season, the maximum available phosphorus in soil (46.67 kg/ha) was observed in T_4 (75% RDF + Vermicompost at 5 t/ha), which was at par with T_6 (75% RDF + Poultry manure at 2 t/ha), T_2 (75% RDF + FYM at 10 t/ha) and T_{10} (75% RDF + Humic Acid at 1t/ha). The minimum available phosphorus in soil (23.52 kg/ha) was recorded in control.

In the following season, T_4 (75% RDF + Vermicompost at 5 t/ha) recorded maximum available phosphorus in soil (48.91 kg/ha) which was statistically at par with T_6 (75% RDF + Poultry manure at 2 t/ha), T_2 (75% RDF + FYM at 10 t/ha) having values 45.55kg/ha and 43.68 kg/ha respectively, while the minimum (25.01 kg/ha) available phosphorus in soil was found in control.

The pooled data in Table 4.15 clearly expressed that the maximum available phosphorus in soil (47.79 kg/ha) was observed in T_4 (75% RDF + Vermicompost at 5 t/ha) which was at par with T_6 (75% RDF + Poultry manure at 2 t/ha) with values of 44.75 kg/ha and control registered minimum available phosphorus in soil (24.27 kg/ha).

The increased availability of phosphorus (P) in the soil could be attributed to the combined application of organic (vermicompost) and inorganic fertilizer, where solubilization of unavailable forms of P, facilitated by the organic acids released during the decomposition of vermicompost. These organic acids may enhance P availability through the complexation of cations such as calcium (Ca), magnesium (Mg), and aluminium (Al), which are known to contribute to P fixation in the soil. As a result, both native soil P and P from applied fertilizers may become more accessible to plants (Singh *et al.,* 2011). Similar findings were observed by Laishram *et al.* (2013) in chrysanthemum, Khanam *et al.* (2017) in gladiolus, Dubliya *et al.* (2018) in tuberose.

4.1.6.3 Available potassium in soil

Available potassium in soil was significantly influenced by the organic and inorganic fertilizers and their combination as presented in Table 4.15 and Fig 4.9.

In the 1st season of experiment, highest available potassium in soil (201.60 kg/ha) was recorded in T_4 (75% RDF + Vermicompost at 5 t/ha), which was found to be at par with T_2 (75% RDF + FYM at 10 t/ha), T_6 (75% RDF + Poultry manure at 2 t/ha) and T_{10} (75% RDF + Humic Acid at 1t/ha) recording 186.67, 179.20 and 171.73 kg/ha respectively. While lowest available potassium in soil (130.67 kg/ha) observed in control.

During the 2nd season of experiment, T_4 (75% RDF + Vermicompost at 5 t/ha) observed maximum available potassium in soil (209.07 kg/ha), which was significantly at par with T_2 (75% RDF + FYM at 10 t/ha), T_6 (75% RDF + Poultry manure at 2 t/ha) having values 186.67 kg/ha and 182.93 kg/ha available potassium, while control depicted minimum available potassium in soil (134.40 kg/ha).

Regarding the pooled data analysis, available potassium in soil was maximum (205.33 kg/ha) in T_4 (75% RDF + Vermicompost at 5 t/ha) and minimum (132.53 kg/ha). was recorded in control .

In present experiment maximum, available potassium recorded in T_4 (75% RDF + Vermicompost at 5 t/ha). Might be due to the organic acids which were released by increased microbial population in soil due to application of vermicompost.

Table 4.15 Influence of INM on available NPK in the soil.

Treatments	Nitrogen (kg/ha)			Phosphorus (kg/ha)			Potassium (kg/ha)		
	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
T_1	379.36	385.20	382.28	23.52	25.01	24.27	130.67	134.40	132.53
T_2	564.48	580.96	572.72	41.07	43.68	42.37	186.67	186.67	186.67
T_3	480.85	522.67	501.76	30.24	31.73	30.98	160.53	164.27	162.40
T_4	585.39	615.29	600.34	46.67	48.91	47.79	201.60	209.07	205.33
T_5	501.76	522.67	512.21	34.72	37.33	36.03	164.27	168.00	166.13
T_6	543.57	572.72	558.15	43.96	45.55	44.75	179.20	182.93	181.07
T_7	459.95	501.76	480.85	32.48	34.72	33.60	156.93	160.53	158.73
T_8	501.76	543.57	522.67	35.09	37.71	36.40	172.00	171.73	171.87
T_9	439.04	418.13	428.59	25.39	27.25	26.32	138.13	141.87	140.00
T_{10}	522.67	564.48	543.57	40.69	40.69	40.69	171.73	175.47	173.60
T_{11}	439.04	459.95	449.49	26.92	29.87	28.39	145.60	149.33	147.47
T_{12}	459.95	522.67	491.31	28.04	30.61	29.33	153.07	156.80	154.93
SEm±	25.88	42.48	24.87	2.13	2.14	1.51	13.23	12.36	9.06
CD at 5%	75.89	124.59	70.89	6.25	6.27	4.30	38.81	36.27	25.81

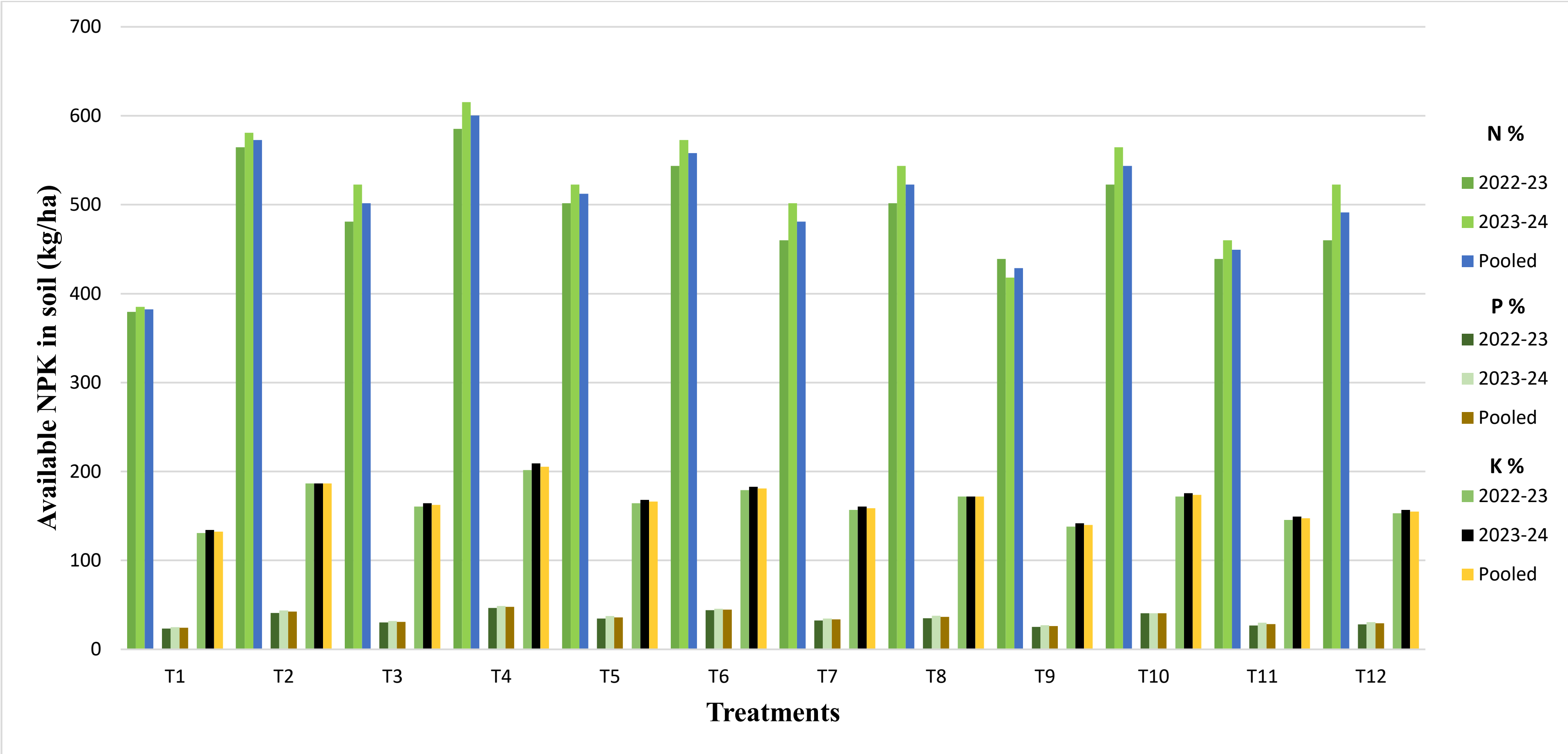

Fig. 4.23 Influence of INM on available NPK in the soil.

Application of chemical fertilizer also enhanced the nutrient availability in soil but at lower amount as compared to combined use of organic and chemical fertilizer. Similar finding observed by Laishram *et al.* (2013) in chrysanthemum, Khanam *et al.* (2017) in gladiolus, Dubliya *et al.* (2018) in tuberose.

4.1.6.4 Changes in soil pH

Data presented in Table 4.16 and graphically shown in Fig 4.20 revealed that there were no significant changes in soil pH due to organic and inorganic fertilizers during the both season of experiment. however, it recorded an increase in the pH from its initial value (5.23) in all the treatments. From the result of pooled data analysis of both season, maximum pH value (6.01) was recorded in T_5 (50% RDF + Vermicompost at 10 t/ha) and minimum pH value (5.40) was observed in control.

4.1.6.5 Soil organic carbon

According to the data presented in Table 4.16 and Fig 4.20, application of integrated nutrient management significantly increases the soil organic carbon in both the seasons of experiment.

The results reveal that the maximum soil organic carbon (2.04 %) was observed in T_{12} (FYM at10 t/ha + Vermicompost at 5 t/ha + Poultry manure at 2 t /ha+ forest soil at 10 t/ha+ Humic Acid t/ha) during the first season. It was at par with the T_5, (50% RDF + Vermicompost at 10 t/ha), T_3 (50% RDF + FYM at 20 t/ha), T_9 (50% RDF + forest soil at 20 t/ha) and T_7 (50% RDF + Poultry manure at 4 t/ha) having values 1.94 %, 1.84 %, 1.83% and 1.81 % organic carbon, while the minimum soil organic carbon (1.47 %) was recorded in control.

During the 2nd season, maximum soil organic carbon (2.08 %) was recorded in T_{12} (FYM at10 t /ha + Vermicompost at 5 t /ha + Poultry manure at 2 t /ha+ forest soil at 10 t/ha+ Humic Acid t/ha) which was at par with T_5 (50% RDF + Vermicompost at 10 t /ha), T_3 (50% RDF + FYM at 20 t/ha), T_9 (50% RDF + forest soil at 20 t/ha) and T_7 (50% RDF + Poultry manure at 4 t/ha) with values of 2.02 %, 1.84%, 1.84 % and 1.81 % respectively and minimum soil organic carbon (1.53 %) was recorded in control.

Pooled data analysis of both years revealed that the T_{12} (FYM at10 t /ha + Vermicompost at 5 t /ha + Poultry manure at 2 t /ha+ forest soil at 10 t /ha+ Humic Acid t /ha) was recorded maximum soil organic carbon (2.06 %) and control was showed minimum soil organic carbon (1.50 %).

In present study, application of organic manures increased the organic carbon in the soil. Organic manure is very effective for increasing soil organic carbon. The soil organic carbon after harvesting of crop was reported to be higher than the initial value (1.56 %). Organic manures are used to enrich the soil, improve its fertility and help increase soil organic carbon levels. This result was in line with the findings of Wu *et al.* (2020) in grape where application of organic fertilizer increases the soil carbon content.

4.1.6.6 Changes in soil EC

Data presented in Table 4.16 and Fig 4.20 revealed that the organic and inorganic fertilizers had no significant changes in soil EC during both the season of experiment but it was reported to be higher after the crop harvest in comparison with the initial value (0.12 dS/m). From the result of pooled data analysis of both season, maximum EC value (0.26 dS/m) recorded in T_5 (50% RDF + Vermicompost at 10 t/ha) and minimum EC value (0.15 dS/m) was observed in T_{12} (FYM at10 t/ha + Vermicompost at 5 t /ha + Poultry manure at 2 t/ha+ forest soil at 10 t/ha+ Humic Acid t/ha).

4.1.7 Economic analysis

Economic data of tuberose, including cost of cultivation, gross return, net return and benefit cost ratio as influenced by different organic and inorganic fertilizer and their combination is highlighted in Table 4.18, 4.and graphically illustrated in Fig 4.23.

4.1.7.1 Cost of cultivation (Rs/ha)

Cost of cultivation was worked out based on all direct cost applied in cultivation of tuberose and is presented in Table 4.18 and Fig 4.23, the maximum cost of cultivation Rs 8,65,235 during the 1st season of experiment, was calculated in treatment T_{11} (50% RDF +Humic Acid at 2 t/ha) and minimum cost of cultivation,

Table 4.16 Effect of INM on pH, organic carbon (%) and EC (dS/m) in the soil of tuberose

Treatments	pH			Organic carbon (%)			EC (dS/m)		
	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
T_1	5.40	5.39	5.40	1.47	1.53	1.50	0.15	0.17	0.16
T_2	5.61	5.64	5.62	1.70	1.70	1.70	0.16	0.18	0.17
T_3	5.74	5.75	5.75	1.84	1.84	1.84	0.27	0.27	0.27
T_4	5.79	5.83	5.81	1.75	1.77	1.76	0.17	0.19	0.18
T_5	6.00	6.03	6.01	1.94	2.02	1.98	0.25	0.27	0.26
T_6	5.55	5.57	5.56	1.71	1.74	1.72	0.21	0.23	0.22
T_7	5.65	5.66	5.66	1.83	1.84	1.83	0.24	0.25	0.25
T_8	5.61	5.62	5.62	1.61	1.62	1.61	0.20	0.22	0.21
T_9	5.63	5.63	5.63	1.81	1.81	1.81	0.22	0.23	0.23
T_{10}	5.51	5.51	5.51	1.58	1.59	1.59	0.15	0.17	0.16
T_{11}	5.61	5.62	5.62	1.78	1.80	1.79	0.18	0.20	0.19
T_{12}	5.47	5.48	5.48	2.04	2.08	2.06	0.14	0.16	0.15
SEm±	0.17	0.17	0.12	0.09	0.10	0.07	0.04	0.04	0.03
CD at 5%	NS	NS	NS	0.25	0.30	0.19	NS	NS	NS

amounting to Rs 3,74,520 was calculated in control followed by Rs 3,77,235 in T_6 (75% RDF + Poultry manure at 2 t /ha).

Similarly in 2nd season of experiment, the maximum cost of cultivation Rs 8,86,035 was calculated in T_{11} (50% RDF +Humic Acid at 2 t/ha) and minimum (Rs 3,83,320) was calculated in control followed by Rs 3,84,677.50 in T_6 (75% RDF + Poultry manure at 2 t/ha).

4.1.7.2 Gross return (Rs/ha)

Data showed in Table 4.18 depicted that maximum gross return (15,52,067 Rs/h) during the 1st season was found in T_4 (75% RDF + Vermicompost at 5 t/ha) followed by T_6 (75% RDF + Poultry manure at 2 t/ha) (1466520 Rs/ha) and minimum gross return (680841 Rs/ha) was obtained in control.

Similarly, the following season, the maximum gross return (18,33,403 Rs/ha) was found in T_4 (75% RDF + Vermicompost at 5 t/ha) followed by T_6 (75% RDF + Poultry manure at 2 t/ha) (15,46,512 Rs/ha) and minimum gross return (8,09,464.5 Rs/ha) was obtained in control.

4.1.7.3 Net income

Net income was worked out by taking into consideration the prevailing market price of spikes and bulbs of tuberose and inputs used during experiment.

In the 1st season of experiment, among all treatments, T_4 (75% RDF + Vermicompost at 5 t/ha) recorded maximum net return (11,07,189.50 Rs/ha), followed by T_6 (10,90,642.50 Rs/ha) and minimum net return (68005 Rs/ha) was found in T_{11} (50% RDF +Humic Acid at 2 t /ha).

During the 2nd season of experiment also, maximum net return (13,547,25 Rs/ha) was found in T_4 (75% RDF + Vermicompost at 5 t/ha) followed by T_6 (75% RDF + Poultry manure at 2 t/ha) with value of 11,61,834.5 Rs/ha respectively, while the minimum net return (124975 Rs/ha) was obtained in T_{11} (50% RDF + Humic Acid at 2 t/ha).

4.1.7.4 Benefit cost ratio

Data presented in Table 4.18 revealed that the all treatments had huge effect on the benefit cost ratio. In the 1st season of experiment, T_6 (75% RDF + Poultry manure at 2 t /ha) recorded maximum benefit cost ratio (2.90) followed by T_4 (75% RDF + Vermicompost at 5 t/ha) and T_2 (75% RDF + FYM at 10 t/ha) having values 2.49 and 2.45 respectively, while minimum (0.03) was recorded in T_{11} (50% RDF + Humic Acid at 2 t /ha).

During the 2nd season, maximum benefit cost ratio (3.02) was found in T_6 (75% RDF + Poultry manure at 2 t/ha) followed by T_4 (75% RDF + Vermicompost at 5 t/ha) and T_2 (75% RDF + FYM at 10 t/ha) recording 2.83 and 2.78 and the T_{11} (50% RDF +Humic Acid at 2 t/ha) recorded minimum benefit cost ratio (0.14).

The economic parameters ultimately determine the acceptance of any technology that farmer can use. The current study showed highest economic parameters like gross return and net return under the application of (T_4) 75% RDF + Vermicompost at 5 t/ha, which might be due to higher growth and yield attributing characters in these treatments, whereas the treatment (T_6) 75% RDF + Poultry manure at 2 t/ha recorded the maximum benefit-cost ratio, mainly due to maximum yield potential and comparatively lower cost of inputs. The results clearly indicate that the integrated use of organic and inorganic fertilizers not only improves soil fertility and crop yield but also enhances economic returns. Organic inputs such as vermicompost and poultry manure are generally more affordable than synthetic fertilizers, and when used judiciously, they contribute to lowering input costs without compromising yield. Additionally, organic fertilizers improve soil structure, microbial activity, and long-term fertility, which can lead to sustainable yield improvements over time. Similar result was recorded by Tirkey *et al.* (2017) in gladiolus.

Table 4.17 Effect of INM on the economics of tuberose (2022-23)

Treatments	Spike yield per ha (no.)	Returns from spike Rs/ha	Bulb yield per ha (no.)	Returns from bulb (Rs/ha)	Cost of cultivation (Rs/ha)	Gross income (Rs/ha)	Net income (Rs/ha)	B:C ratio
T_1	108070.00	324210.00	118877	356631	3,74,520	680841	306321.00	0.82
T_2	203683.33	611050.00	244420	733260	389877.5	1344310	954432.50	2.45
T_3	141400.00	424200.00	155540	466620	405235.0	890820	485585.00	1.20
T_4	235161.67	705485.00	282194	846582	444877.5	1552067	1107189.50	2.49
T_5	154530.00	463590.00	169983	509949	515235.0	973539	458304.00	0.89
T_6	222200.00	666600.00	266640	799920	375877.5	1466520	1090642.50	2.90
T_7	164966.67	494900.00	181463	544390	377235.0	1039290	662055.00	1.76
T_8	185166.67	555500.00	203683	611050	389877.5	1166550	776672.50	1.99
T_9	137360.00	412080.00	151096	453288	405235.0	865368	460133.00	1.14
T_{10}	228933.33	686800.00	251827	755480	619877.5	1442280	822402.50	1.33
T_{11}	155540.00	466620.00	155540	466620	865235.0	933240	68005.00	0.08
T_{12}	212100.00	636300.00	233310	699930	726950.0	1336230	609280.00	0.84

Table 4.18 Effect of INM on the economics of tuberose (2023-24)

Treatment	Spike yield per ha (no.)	Returns from spike Rs/ha	Bulb yield per ha (no.)	Returns from bulb (Rs/ha)	Cost of cultivation (Rs/ha)	Gross income (Rs/ha)	Net income (Rs/ha)	B:C ratio
T_1	118170.00	354510.00	129987.0	454954.5	383320.00	809464.5	426144.5	1.11
T_2	209238.33	627715.00	251086.0	878801	398677.50	1506516	1107838.5	2.78
T_3	149480.00	448440.00	164428.0	575498	414035.00	1023938	609903.0	1.47
T_4	267650.00	802950.00	294415.0	1030453	478677.50	1833403	1354725.0	2.83
T_5	163620.00	490860.00	179982.0	629937	574035.00	1120797	546762.0	0.95
T_6	214793.33	644380.00	257752.0	902132	384677.50	1546512	1161834.5	3.02
T_7	165106.94	495320.83	198128.3	693449.2	375235.00	1188770	813535.0	2.17
T_8	187860.00	563580.00	206646.0	723261	398677.50	1286841	888163.5	2.23
T_9	140390.00	421170.00	154429.0	540501.5	414035.00	961671.5	547636.5	1.32
T_{10}	225230.00	675690.00	247753.0	867135.5	634677.50	1542826	908148.0	1.43
T_{11}	155540.00	466620.00	155540.0	544390	886035.00	1011010	124975.0	0.14
T_{12}	218160.00	654480.00	239976.0	839916	766750.00	1494396	727646.0	0.95

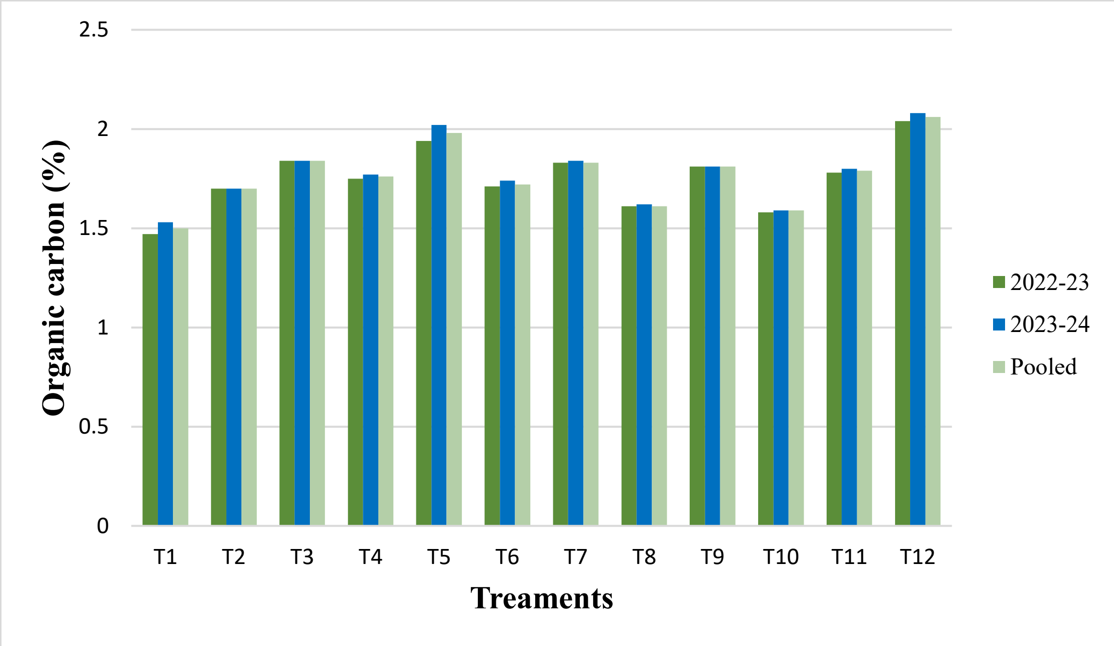

Fig. 2.24 Effect of INM on organic carbon (%) in the soil of tuberose.

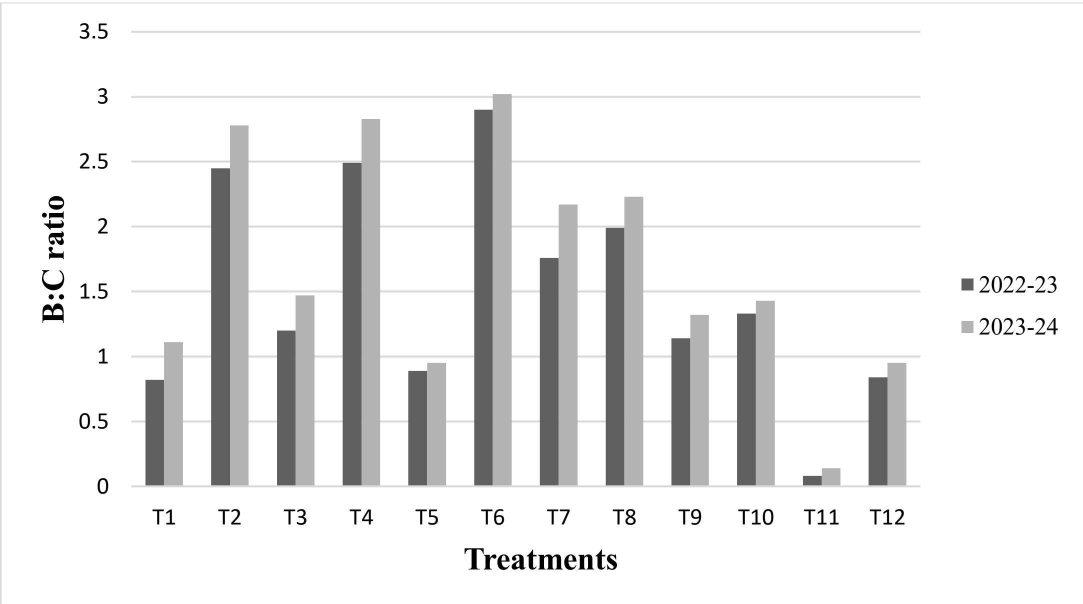

Fig. 4.25 Effect of INM on the economics of tuberose.

44.2 Experiment II- Tinting of cut tuberose with natural extracted dyes

4.2.1 Sensory evaluation

The data recorded under sensory characteristics includes effect of colour, appearance/shape, freshness, petal retention and overall acceptability as influenced by natural extracted dyes at different dipping hours are discussed below.

4.2.1.1 Effect of colour

The sensory evaluation for effect of colour was done after tinting the spikes with natural extracted dyes in different dipping hours and the corresponding data is presented in Table 4.19 and illustrated in Fig 4.24. Perusal of the data revealed that different natural extracted dyes, various dipping hours and their interaction had significant effect on the colour of tuberose spike.

The maximum effect of colour (4.22, 4.11 and 4.17) found in beet root (A_1) followed by dragon fruit (A_5) with score of 4, 4.11 and 4.06 respectively and the remaining natural extracted dyes solutions did not impart any colour to the floret and they remained white in colour during the both year of experiment (2023 and 2024) and pooled data analysis. Natural dyes such as anthocyanins, betalains, and buteins are highly water-soluble, whereas carotenoids and certain flavonoids are lipid-soluble (Ngamwonglumlert *et al*., 2017). This difference in solubility likely influenced the uptake and coloration observed in the treated tuberose flower spikes. Therefore, the tinting treatments namely beetroot and dragon fruit contains water soluble pigment betacyanin's which might have been absorbed by the tuberose flower spikes and imparted respective colour. Similar result was recorded by Ushasri *et al*. (2023) in tuberose.

Among the different dipping hours, the spikes tinted for 12 hours (B_3) showed maximum colour retention with 3.38, 3.33 and 3.35 score. While the spikes tinted for 6 hours (B_1) imparted least colour retention with score 3.04, 2.96 and 3.00 respectively during both year of experiment as well as in pooled data analysis. The colour intensity increases when the spikes are dipped for longer duration (12 hours), which enhanced the uptake of dye solution. It was observed that lesser time of immersion (4 hours) showed the lightest shade of dyes. The shades of the colour deepened as the time of immersion was increased. The result corroborates with the findings of Prasanth *et al*. (2020) and Bhatt *et al*. (2023) in tuberose.

The interaction between natural extracted dyes and dipping hours showed significant effect on colour of tuberose spike. Maximum effect of colur was recorded when the spikes immersed in beet root extract for 12 hours (A_1B_3), while the minimum was recorded with the treatment combination A_3B_3. It might due to the colour shade obtained depends on the concentration and solubility of the dye used and the time of immersion. The findings are supported by Prasanth *et al*. (2020) and Bhatt *et al*. (2023) in tuberose.

4.2.1.2 Appearance and shape

Data pertaining to the appearance and shape of tinted spikes was significantly influenced by various natural extracted dyes as presented in Table 4.19 and Fig 4.24. A maximum score of 4.22, 4.44 and 4.33 was observed in beet root extract (A_1) and minimum was recorded in A_3 (spinach extract) with score of 2.33, 2.11 and 2.22 respectively, during both the year and pooled data analysis.

The antioxidant activity of beetroot extract may have played a critical role in preserving the cellular integrity of floral tissues, ultimately enhancing the visual freshness and structural quality of the tuberose spikes. Additionally, beetroot pigments might have bind better to plant tissues or integrated into the epidermal and vascular areas, helping to maintain turgor pressure and offer color enhancement.

It was apparent from the data that the different dipping hours did not show any significant effect on the appearance and shape of tinted spike. However, the maximum score of 2.29 2.33 and 2.31 respectively was observed in B_3 (12 hour), while the least score was 2.25, 2.17 and 2.21, obtained from cut spikes in B_1(6 hour) during the year 2023 and 2024 and mean of both years.

The interaction effect between the natural extracted dyes and dipping hours did not showed any significant effect on the appearance and shape of tinted spike.

4.2.1.3 Freshness

Data depicted in Table 4.19 and graphically illustrated in Fig 2.24 revealed that the natural extracted dyes had a significant effect on the freshness of tinted spike. The cut spikes in treatment A_1 (beet root) showed the maximum freshness with score of 4.44, 4,33 and 4.39 respectively. While the minimum freshness was noticed in A_3 with 2.22, 244 and 2.33 score, during both the year (2022-23and 2023-24) and pooled data analysis.

The beetroot extract-tinted tuberose spikes exhibited higher freshness scores compared to those treated with other natural dyes. This observation may be attributed to the antioxidant and antimicrobial properties of beetroot, which likely supported more efficient water uptake through the xylem vessels, resulting in improved turgidity and prolonged freshness of the spikes. According to Reddy and Singh (1996) and Waithaka *et al.* (2001), efficient water absorption helps to maintain better water balance and flower freshness and saves from early wilting resulting in enhanced vase-life.

The various dipping hours did not depict any significant result on the freshness of tinted spike. However, the maximum freshness (3.33, 3.38 and 3.35) was recorded in B_3 (12 hours) and the minimum was observed in B_2 (6 hours) during both the year and pooled data analysis.

The interaction effect between extracted dyes and dipping hours failed to evoke any significant effect on the freshness of tinted tuberose spike.

4.2.1.4 Petal retention

Data recorded for petal retention have been presented in Table 4.21 and graphically illustrated in Fig 4.25.

Thorough scanning of the data revealed that the various natural extracted dyes had significant effect on the petal retention of tinted spike. A maximum petal retention with score of 4.56, 4.67 and 4.62 respectively, was recorded in beet root (A_1), while the spinach extract (A_3) showed the minimum petal retention with 2.44, 2.33 and 2.39 score, during both the year and pooled data analysis.

High water uptake maintained the turgidity and freshness of the spikes and thus increases the shelf life of the floret. The number of floret abscised was less in

Table 4.20 Effect of different natural extracted dyes and dipping hours on colour, appearance and shape and freshness of tinted tuberose spike.

Treatments	Effect of colour			Appearance and shape			Freshness		
	2023	2024	Pooled	2023	2024	Pooled	2023	2024	Pooled
A_1	4.22	4.11	4.17	4.22	4.44	4.33	4.44	4.33	4.39
A_2	3.11	3.11	3.11	3.22	3.33	3.28	3.33	3.44	3.39
A_3	2.22	2.44	2.33	2.33	2.11	2.22	2.22	2.44	2.33
A_4	3.00	2.89	2.94	2.78	2.44	2.61	2.89	2.78	2.83
A_5	4.00	4.11	4.06	3.78	4.00	3.89	3.67	4.00	3.83
A_6	2.89	2.89	2.89	3.11	3.22	3.17	3.00	3.11	3.06
A_7	3.22	3.33	3.28	4.11	4.33	4.22	4.11	4.00	4.06
A_8	2.89	2.56	2.72	2.44	2.22	2.33	2.78	2.56	2.67
Sem±	0.13	0.16	0.10	0.21	0.15	0.13	0.16	0.20	0.13
CD at 5%	0.37	0.46	0.29	0.59	0.43	0.36	0.46	0.57	0.36
B_1	3.04	2.96	3.00	3.25	3.17	3.21	3.29	3.29	3.29
B_2	3.17	3.25	3.21	3.21	3.29	3.25	3.29	3.33	3.31
B_3	3.38	3.33	3.35	3.29	3.33	3.31	3.33	3.38	3.35
Sem±	0.08	0.10	0.06	0.13	0.09	0.08	0.10	0.12	0.08
CD at 5%	0.23	0.28	0.18	NS	NS	NS	NS	NS	NS
(AxB) Interaction									
Sem±	0.23	0.28	0.18	0.36	0.26	0.22	0.28	0.35	0.22
CD at 5%	0.64	0.80	0.51	NS	NS	NS	NS	NS	NS

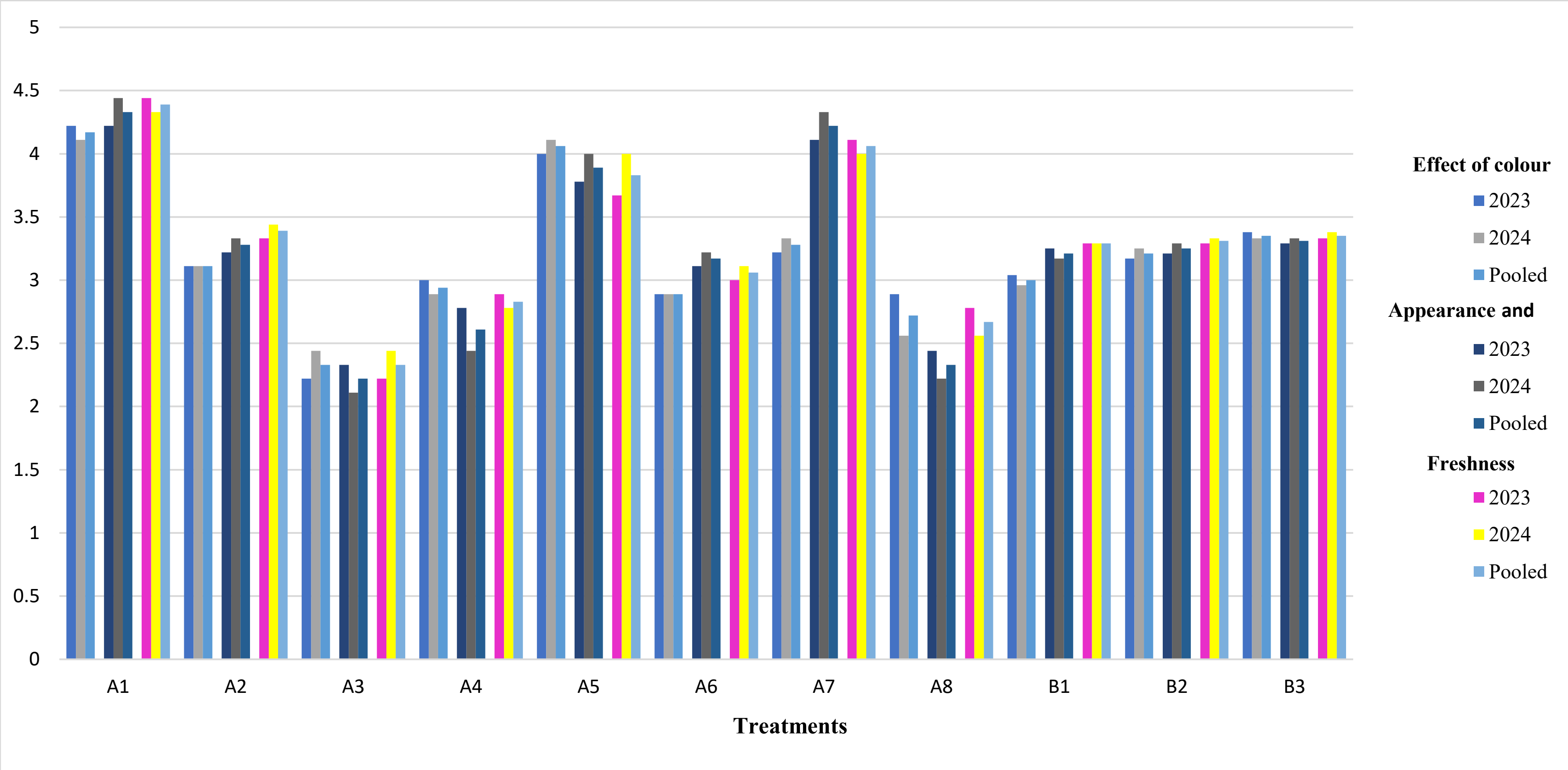

Fig. 4.26 Effect of different natural extracted dyes and dipping hours on colour, appearance and shape and freshness of tinted tuberose spike.

spikes tinted in beetroot extract which could be attributed to more opening of florets due to higher availability of respiratory substrate i.e. sucrose. Also, less floret dropping might be due to the interference of dye on osmotic pressure of the cells that altered the cell turgidity or blocked translocation in vascular vessels of the spikes (Chougala *et al.* 2016) which led to least score in spinach extract tinted spike.

Further perusal of the data showed that the various dipping hours had non-significant effect on the petal retention of tinted spike of tuberose. However, the cut spike dipped for 12 hours showed maximum petal retention (3.46, 3.50 and 3.48) while the spike dipped in 6 hours recorded minimum petal retention with 3.38, 3.42 and 3.40 score respectively, during both the year of experiment and pooled data analysis.

Ther was no significant effect of interaction between the natural extracted dyes and dipping hours on the petal retention of tinted spike of tuberose.

4.2.1.5 Over all acceptability

Over all acceptability of tinted spike of tuberose were significantly influenced by the different natural extracted dyes which is presented in Table 4.21 and Fig 4.25. Maximum score of 4.44, 4.67 and 4.56 respectively, was obtained in beet root (A_1), while the least score (2.44, 2.44 and 2.44) was recorded in spinach extract (A_3) during the year of 2022-23, 2023-24 and pooled data analysis.

The overall acceptability based on colour retention, freshness, appearance, petal retention of the flowers was found to be best in beetroot extract. This can be attributed to the fact that beetroot extract was non toxic to cell metabolism. As a result, no obstruction was created for movement of water and food materials. Hence osmotic pressure of the cell was unaffected and the cell turgidity was not altered (Safeena *et al.*, 2016).

Various dipping hours did not show any significant effect on the overall acceptability of tinted spike. However, the B_3 (12 hours) recorded maximum score of 3.63, 3.54 and 3.58 respectively, while minimum score (3,42, 3.46 and 3.44) was observed in B_1 (6 hours) during both the year of experiment and their means respectively.

Table 2.21 Effect of different natural extracted dyes and dipping hours on petal retention and overall acceptability of tinted tuberose spike

Treatments	Petel retention			Over all acceptability		
	2023	2024	Pooled	2023	2024	Pooled
A_1	4.56	4.67	4.61	4.44	4.67	4.56
A_2	3.44	3.33	3.39	3.67	3.78	3.72
A_3	2.44	2.33	2.39	2.44	2.44	2.44
A_4	2.89	2.78	2.83	3.22	3.00	3.11
A_5	4.11	4.22	4.17	4.11	4.33	4.22
A_6	3.00	3.22	3.11	3.33	3.00	3.17
A_7	4.33	4.33	4.33	4.22	4.22	4.22
A_8	2.56	2.67	2.61	2.67	2.56	2.61
Sem±	0.19	0.19	0.13	0.15	0.16	0.11
CD at 5%	0.54	0.55	0.38	0.42	0.46	0.31
B_1	3.38	3.42	3.40	3.42	3.46	3.44
B_2	3.42	3.42	3.42	3.50	3.50	3.50
B_3	3.46	3.50	3.48	3.63	3.54	3.58
SEm±	0.12	0.12	0.08	0.09	0.10	0.07
CD at 5%	NS	NS	NS	NS	NS	NS
(AxB) Interaction						
SEm±	0.33	0.33	0.23	0.25	0.28	0.19
CD at 5%	NS	NS	NS	0.72	0.80	0.53

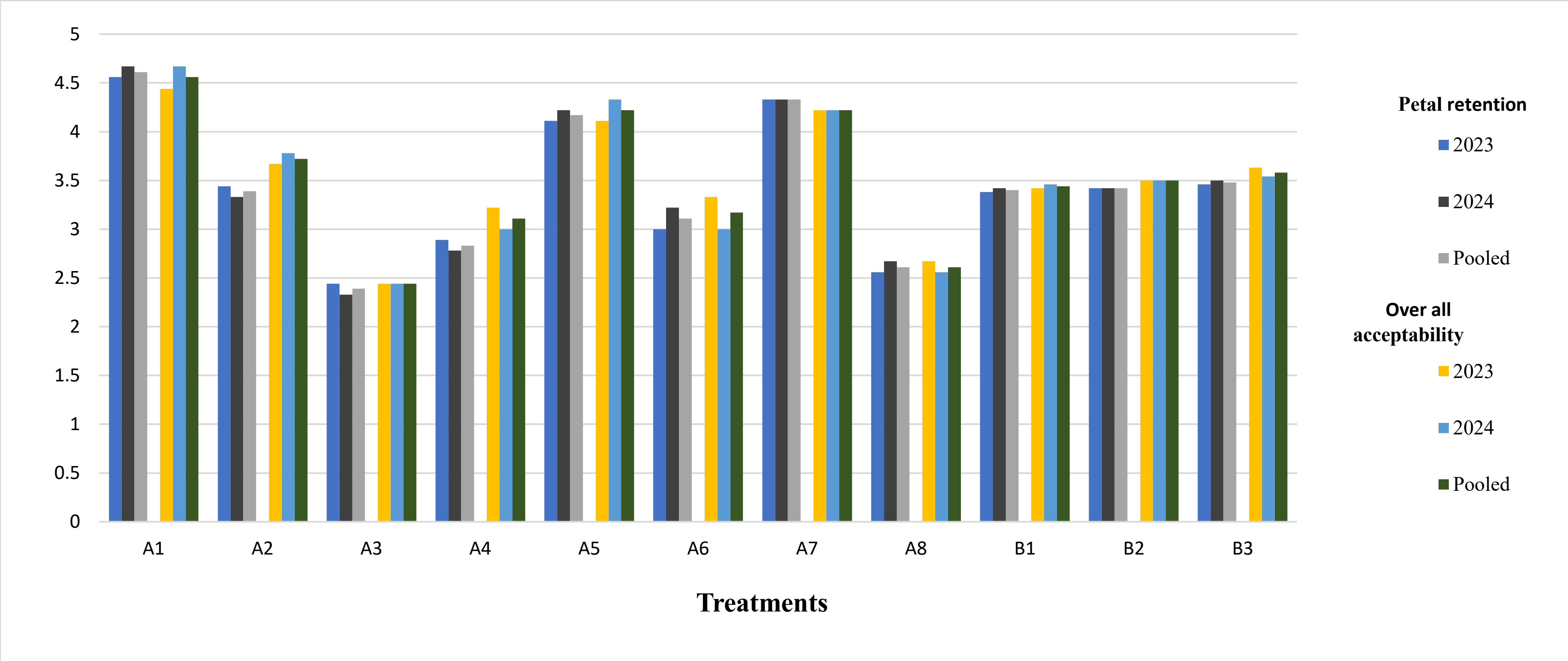

Fig. 4.27 Effect of different natural extracted dyes and dipping hours on petal retention and overall acceptability of tinted tuberose spike.

The data depicted from the table revealed that the interaction between natural extracted dyes and dipping hours had significant effect on the overall acceptability of tinted spike. Maximum score (4.67, 5 and 4.83) was recorded in treatment combination A_1B_3, while the least score 2, 2 and 2 respectively, was obtained in the A_3B_3 during both the years and pooled data analysis.

In the present study, there was no adverse effect of natural extracted dyes, time of immersion and combination of both factors on the vase life and quality and overall acceptability of the tuberose. Higher time of immersion allowed more dye to be translocated up to the terminal buds of the tuberose flower spike. Sudha and Dhaduk (2008) reported that there was no adverse effect of dye, time of immersion and combination of both factors on the vase life and quality of lady's lace. Similar result was quoted by Safeena *et al*. (2016) in tuberose.

4.2.2 Quantitative evaluations

The data recorded under quantitative evaluation *viz*. changes in fresh weight (g), days to 50% floret opening, diameter of floret (cm), floret length (cm), spike elongation (cm), rachis elongation (cm), water uptake(g), water loss (g), water balance and vase life as effected by natural extracted dyes and different dipping hours are discussed below.

4.2.2.1 Changes in fresh weight

Data depicted in Table 4.22 and 4.23 and Fig 4.26 clearly indicates that the changes in fresh weight of tinted tuberose spikes on 2^{nd}, 4^{th}, 6^{th} and 8^{th} day were significantly affected by the different natural extracted dyes during both year of the experiment and their pooled data analysis.

The weight of tinted spikes of tuberose before keeping in distilled water for vase life studies were recorded as initial weight (g). It was observed that fresh weight of tinted spik increased till the 3^{rd} day and decrease gradually from 4^{th} day in all the treatments. Maximum gain in fresh weight of spike (7.56, 7.67 and 7.61 g) was observed with treatment A_1 (Beet root extract) followed by (6.44, 7.33 and 6.89 g) under the treatment A_7 (Hibiscus extract) on 2^{nd} day, whereas minimum gain in fresh

Table 2.22 Effect of natural extracted dyes and dipping hours on the changes in fresh weight (g) in tinted spikes during the vase life

Treatments	Day 2			Day 4		
	2023	2024	Pooled	2023	2024	Pooled
A_1	58.22	57.11	57.67	55.11	54.11	54.61
	7.56	7.67	7.61	-3.11	-3.00	-3.06
A_2	53.67	53.22	53.44	49.89	49.33	49.61
	5.78	5.33	5.56	-3.78	-3.89	-3.83
A_3	54.11	54.89	54.50	49.56	50.33	49.94
	4.67	4.56	4.61	-4.56	-4.56	-4.56
A_4	51.00	51.33	51.17	47.00	47.22	47.11
	4.89	5.00	4.94	-4.00	-4.11	-4.06
A_5	56.78	52.89	54.83	53.22	49.11	51.17
	6.11	7.00	6.56	-3.56	-3.78	-3.67
A_6	51.56	55.89	53.72	47.67	51.89	49.78
	5.56	5.22	5.39	-3.89	-4.00	-3.94
A_7	54.78	57.11	55.94	51.44	53.78	52.61
	6.44	7.33	6.89	-3.33	-3.33	-3.33
A_8	52.78	54.67	53.72	48.67	50.67	49.67
	5.22	5.00	5.11	-4.11	-4.00	-4.06
SEm±	1.44	1.36	0.99	1.38	1.43	0.99
CD at 5%	4.08	3.88	2.78	3.91	4.07	2.79
B_1	53.75	54.83	54.29	49.88	50.92	50.40
	5.54	5.42	5.48	-3.88	-3.92	-3.90
B_2	54.88	54.13	54.50	51.08	50.29	50.69
	5.63	6.04	5.83	-3.79	-3.83	-3.81
B_3	53.71	54.96	54.33	50.00	51.21	50.60
	6.17	6.21	6.19	-3.71	-3.75	-3.73
SEm±	0.88	0.84	0.61	0.84	0.88	0.61
CD at 5%	NS	NS	NS	NS	NS	NS
(AxB) Interaction						
SEm±	2.49	2.36	1.71	2.38	2.48	1.72
CD at 5%	NS	NS	NS	NS	NS	NS

Table 2.23 Effect of natural extracted dyes and dipping hours on the changes in fresh weight (g) at 6th and 8th day of tinted spike.

Treatments	Day 6			Day 8		
	2023	2024	Pooled	2023	2024	Pooled
A_1	51.56	50.00	50.78	46.89	45.78	46.33
	-3.00	-4.00	-3.50	-4.67	-4.33	-4.50
A_2	45.67	44.67	45.17	40.67	39.67	40.17
	-4.22	-4.56	-4.39	-5.00	-5.11	-5.06
A_3	44.44	45.11	44.78	38.33	39.11	38.72
	-5.11	-5.22	-5.17	-6.11	-6.00	-6.06
A_4	42.44	42.11	42.28	36.56	36.78	36.67
	-4.56	-5.00	-4.78	-5.89	-5.44	-5.67
A_5	49.22	44.67	46.94	44.33	40.11	42.22
	-4.00	-4.22	-4.11	-4.89	-4.78	-4.83
A_6	43.22	47.00	45.11	37.89	42.00	39.94
	-4.44	-4.67	-4.56	-5.33	-5.22	-5.28
A_7	47.33	49.56	48.44	42.56	45.11	43.83
	-4.11	-4.11	-4.11	-4.78	-4.56	-4.67
A_8	43.89	45.67	44.78	37.89	39.89	38.89
	-4.78	-5.11	-4.94	-6.00	-5.67	-5.83
SEm±	1.37	1.44	1.00	1.18	1.35	0.90
CD at 5%	3.91	4.10	2.80	3.36	3.84	2.52
B_1	45.25	46.17	45.71	39.83	41.00	40.42
	-4.42	-4.71	-4.56	-5.42	-5.21	-5.31
B_2	46.88	45.58	46.23	41.54	40.58	41.06
	-4.21	-4.58	-4.40	-5.33	-5.13	-5.23
B_3	45.79	46.54	46.17	40.54	41.58	41.06
	-4.21	-4.54	-4.38	-5.25	-5.08	-5.17
SEm±	0.84	0.88	0.61	0.72	0.83	0.55
CD at 5%	NS	NS	NS	NS	NS	NS
(AxB) Interaction						
SEm±	2.38	2.50	1.73	2.04	2.34	1.55
CD at 5%	NS	NS	NS	NS	NS	NS

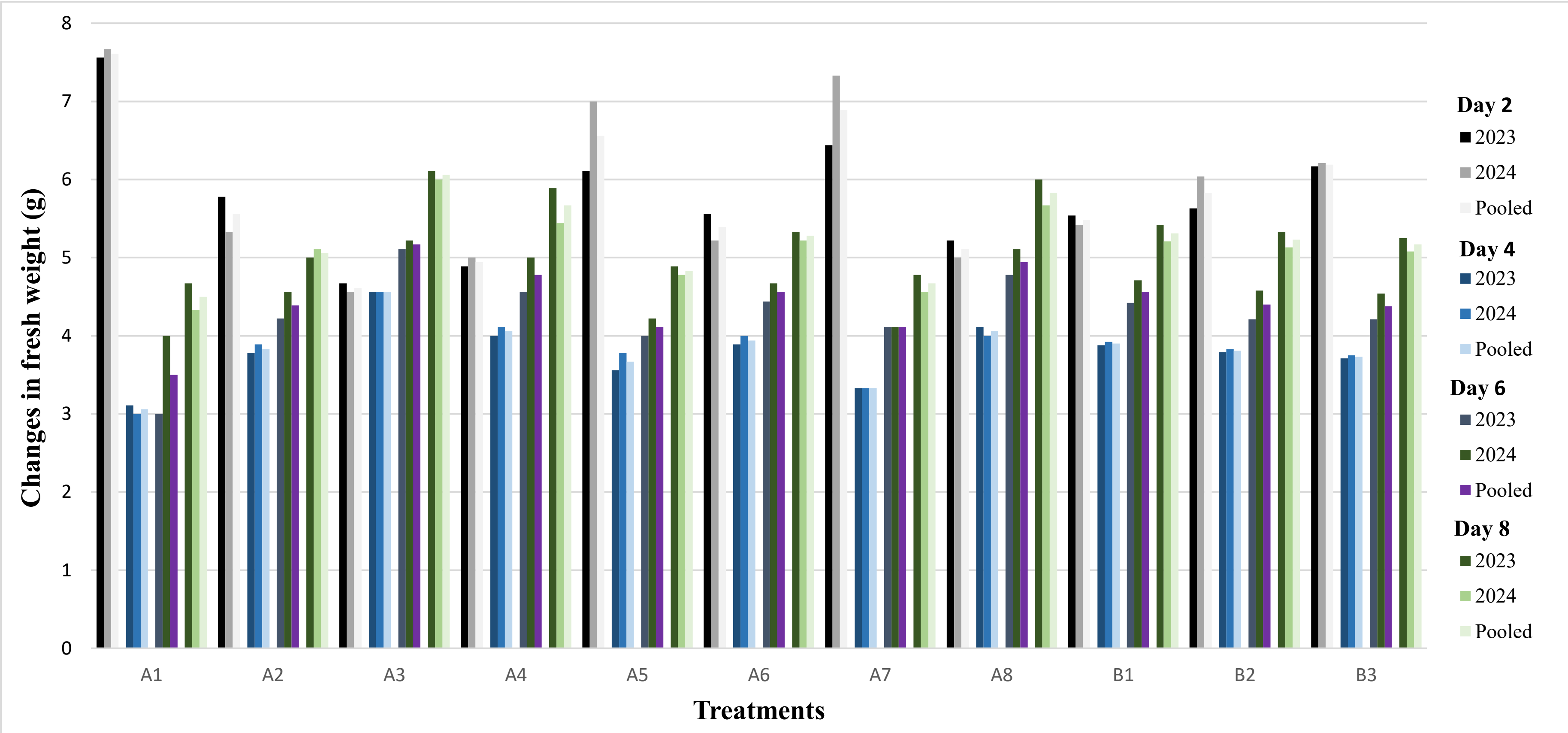

Fig. 4. 28 Effect of natural extracted dyes and dipping hours on changes in fresh weight (g) on 2nd, 4th , 6th and 8th day of tinted spike.

weight of spike (4.67, 4.56 and 4.61 g) was observed in A_3 (Spinach extract). The maximum loss in fresh weight was recorded on 8th day in all the treatment and it was observed in A_3 (Spinach extract) on an average of -6.11, -6 and -6.06 g respectively. The minimum loss in weight (-4.67, -4.33 and -4.50 g) was observed with treatment A_1 (Beet root extract) which was at par with the treatment A_7 (Hibiscus) (-4.78, -4.56 and -4.67 g) during both the year of experiment and pooled data analysis.

The spike treated with beetroot extract showed maximum water uptake which might have attributed to the maximum gain in fresh weight. Beetroot contains bioactive compounds such as betalains and natural sugars (Kale *et al.,* 2018). These components may play a significant role in enhancing vascular flow by maintaining xylem conductivity and reducing microbial contamination and allowing the flower tissues to absorb and retain more water. Ushasri *et al*. (2023) also observed in tuberose that fresh weight of spike increases with beetroot. Similar results have been recorded by Kumari and Deb (2018), where they observed that the weight of the cut spike increases for 3 days and later decrease during vase life period.

Further perusal of the data revealed that the various dipping hours and interaction between natural extracted dyes and dipping hours had a non-significant effect on the fresh weight of the tinted spike during both the year of experiment and pooled data analysis.

4.2.2.2 Days to 50% floret opening

Data enumerated in Table 4.24 and Fig 4.26 indicate that the days to 50% floret opening was significantly influenced by various natural extracted dyes, dipping hour and their interaction during both the year (2022-23 and 2023-24) and pooled data analysis.

The data depicted in Table 4.23 revealed that A_1 (Beet root extract) took minimum days (4.11, 4.44 and 4.28 days) to 50% floret open, which was at par with A_5 (Dragon fruit extract) the 4.67, 4.56 and 4.61 respectively, while the maximum days (5.89, 5.56 and 5.72 days) to 50% floret opening was observed in A_3 (Spinach extract), during both the year 2023 and 2024 and pooled analysis.

Tuberose spikes treated with beetroot extract improved floret opening compared to other natural dye treatments. It might be due to enhanced water uptake and positive water balance promoted tissue hydration, while natural sugars in the extract likely served as an immediate energy source for petal expansion and bud development. Furthermore, the antioxidant activity of betalains delayed cellular degradation, enabling sustained floret opening even during mid-to-late vase life.

However, different dipping hours markedly influenced the 50% floret opening. The minimum days (4.83, 4.75 and 4.79 days) taken to 50% floret opening was noted in B_3(12 hour) and maximum (5.29, 5.21 and 5.25 days) was recorded in B_1(6 hours). This may be due to availability of considerable quantity of respiratory substrate (sucrose) that ensures opening of immature florets and further with increase in immersion time more solutes could be located through xylem (Singh and Kumar 2008). Similar finding a line with result of Gupta and Jhanji (2020) in tuberose they stated that immersion time significantly increased the per cent opening of florets.

The interaction between natural extracted dyes and dipping hours reached the level of significance where treatment combination A_1B_3 recorded least days (3.33, 3.33 and 3.33) to 50% floret opening while A_3B_3 took maximum days 6.67, 6.33 and 6.50 to 505 florets opening during the both year of experiment and pooled data. The long time for submerged condition in natural extracted dyes specially beetroot extract is responsible for early floret opening, as it allows for greater water circulation and water balance.

4.2.2.3 Diameter of floret

Diameter of floret was influenced by various natural extracted dyes and dipping hours and their interaction during the year 2022-23, 2023-24 and means of the two year which has been presented in Table 4.24 and graphically illustrated in Fig4.26.

The various in diameter of floret significant influenced by the various natural extracted dyes. The maximum diameter of floret (3.71, 3.70 ad 3.71 cm) was recorded in beet root extract (A_1) whereas, the minimum diameter of floret (3.18,3.17 and 3.17 cm) was observed in Spinach extract (A_3), during both the year and pooled data analysis.

The highest diameter of floret in beetroot extract might be due to a sufficient supply of sucrose which might have speed up respiration rate required for cell division, cell elongation, and production of cell constituents, all of which would have contributed to large size of floret (Bhatt *et al.* 2010)

The different dipping hours did not show any significant effect on the diameter of floret of tinted spike. However, the maximum diameter (3.50, 3.48 and 3.39 cm) was noted in B_3 (12 hour), and B_2 (9 hours) recorded minimum diameter of floret (3.48, 3.38 and 3.43 cm) during both the year of experiment and pooled data.

The interaction between the different natural dyes and dipping hours had no significant influence on the floret diameter of tined spike of tuberose during the years of 2022-23, 2023-24 and their pooled data analysis.

4.2.2.4 Floret length

Table 4.24 and Fig 4.26 represent the floret length (cm) as influenced by natural extracted dyes, dipping hours and their interaction. The effect of natural extracted dyes on floret length was recorded significantly maximum (5.68, 5.79 and 5.73 cm) in A_1 (Beet root) which was found to be at par with A_5 (Dragon fruit) with 5.44. 5.20 and 5.32 cm respectively, while the shortest floret length (4.09, 4.20 and 4.14 cm) obtained in A_8 (Rhoeo) during the year 2022-23, 2023-24 and mean of two years. The osmotic balance established by the presence of natural sugars and phenolic compounds in beetroot extract might also have contributed to greater turgidity in the floral tissues, indirectly supporting increased water intake to maintain cellular functions and petal expansion.

Further perusal of the data showed that the different dipping hours had non-significant effect on the floret length of tinted spike of tuberose. However the maximum floret length (4.65, 4.89 and 4.77 cm) was found in B_3 during both the years and pooled data analysis. While the minimum floret length, 4.46 cm was observed in the 1st year (2023) and the 4.87 and 4,74 cm floret length was recorded in the 2nd year (2024) and pooled data analysis.

Table 2.24 Effect of various natural extracted dyes and dipping hours on days to 50% floret opening, diameter of floret (cm) and length of floret (cm) on tinted tuberose spike

Treatments	Days to 50% floret opening			Diameter of floret (cm)			Length of floret (cm)		
	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
A_1	4.11	4.44	4.28	3.71	3.70	3.71	5.68	5.79	5.73
A_2	5.22	5.00	5.11	3.51	3.42	3.47	4.29	4.66	4.47
A_3	5.89	5.56	5.72	3.18	3.17	3.17	4.14	4.24	4.19
A_4	5.22	5.22	5.22	3.40	3.31	3.36	4.18	4.60	4.39
A_5	4.67	4.56	4.61	3.60	3.69	3.64	5.44	5.20	5.32
A_6	5.00	5.11	5.06	3.43	3.38	3.41	4.24	4.62	4.43
A_7	4.78	4.89	4.83	3.68	3.60	3.64	4.53	5.71	5.12
A_8	5.44	5.33	5.39	3.42	3.20	3.31	4.09	4.20	4.14
SEm±	0.21	0.21	0.15	0.11	0.14	0.09	0.16	0.16	0.11
CD at 5%	0.59	0.60	0.42	0.30	0.39	0.24	0.47	0.45	0.32
B_1	5.29	5.21	5.25	3.49	3.45	3.47	4.61	4.87	4.74
B_2	5.00	5.08	5.04	3.48	3.38	3.43	4.46	4.88	4.67
B_3	4.83	4.75	4.79	3.50	3.48	3.49	4.65	4.89	4.77
SEm±	0.13	0.13	0.09	0.06	0.08	0.05	0.10	0.10	0.07
CD at 5%	0.36	0.37	0.25	NS	NS	NS	NS	NS	NS
(AxB) Interaction									
SEm±	0.36	0.37	0.26	0.18	0.24	0.15	0.29	0.28	0.20
CD at 5%	1.02	1.04	0.72	NS	NS	NS	0.81	0.78	0.56

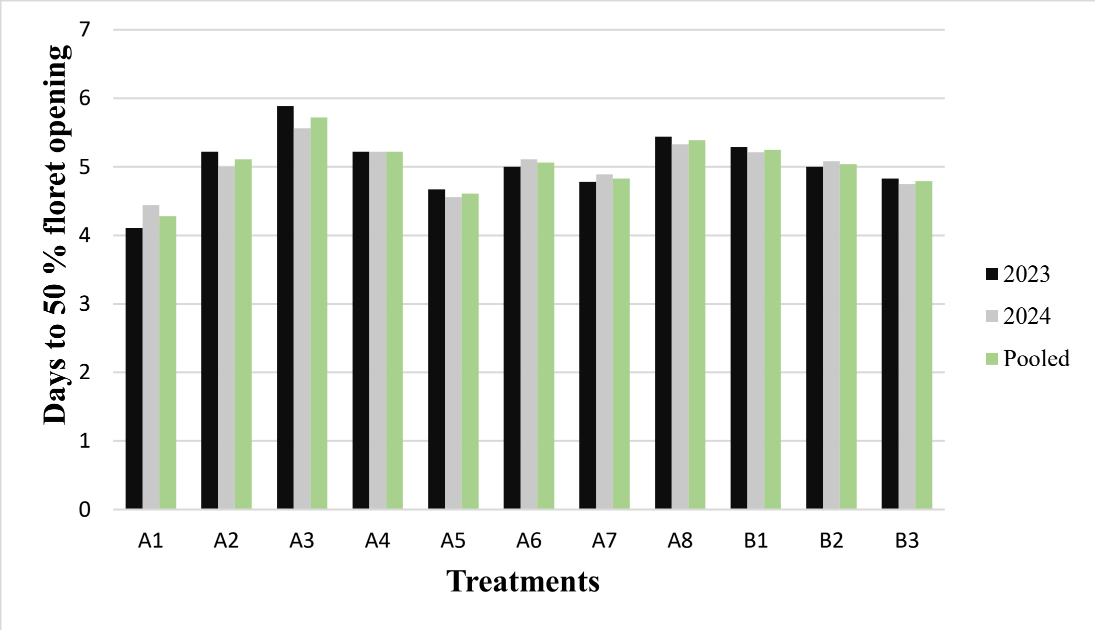

Fig.4.29 Effect of various natural extracted dyes and dipping hours on days to 50% floret opening on tinted tuberose spike.

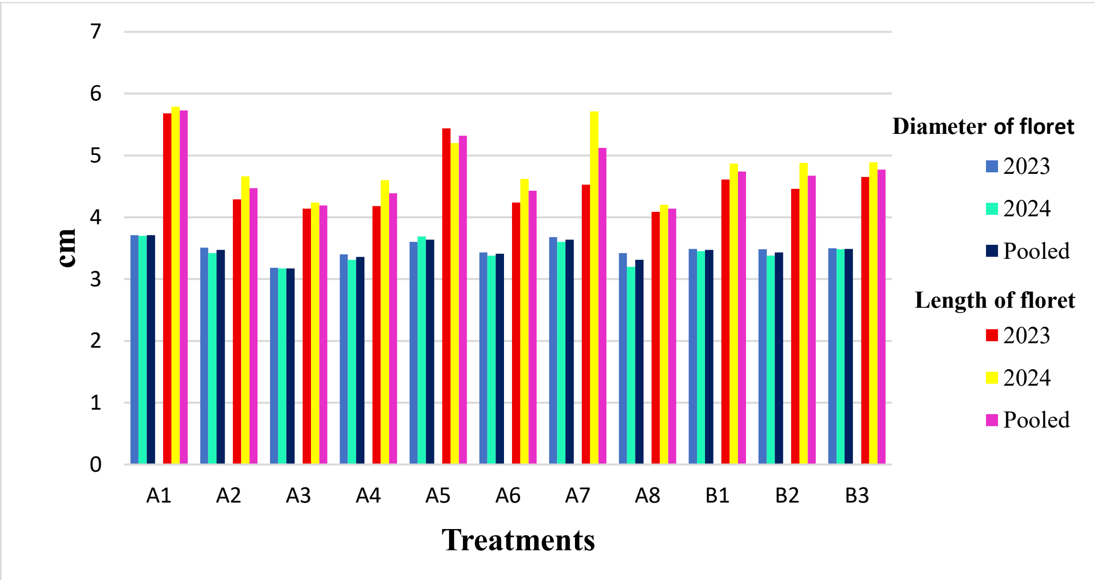

Fig. 4.30 Effect of various natural extracted dyes and dipping hours on diameter of floret and length of floret on tinted tuberose spik

The interaction between natural extracted dyes and dipping hours showed a significant effect on the floret length where the treatment combination, A_1B_3 recorded maximum floret length (6.33, 6.20 and 6.27 cm) and minimum (3.70, 3.53 and 3.62 cm) was observed in A_8B_3 during both the years and their pooled data analysis.

4.2.2.5 Spike elongation

The data pertaining to spike elongation as influenced by natural extracted dyes, dipping hours and their interaction are presented in Table 4.25 and Fig 4.26.

It is evident from the data that natural extracted dyes had significant effect on the spike elongation. The maximum spike elongation (47.23, 47.42 and 47.33 cm) was found in A_1 (Beet root), which was found to be at par with A_7 (Dragon fruit) with values of 47.22, 47.41 and 47.32 cm respectively, while the minimum spike elongation (46.61, 46.49 and 46.55 cm) was noted in A_3 (spinach) during the year 2022-23, 2023-24 and mean of both years. It might be due to natural sugars present in beetroot and dragon fruit as readily available carbohydrate source, fuelling cell metabolism and elongation.

Further examination of the data revealed that various dipping hours did not have any significant effect on the spike elongation. However, the maximum spike elongation (46.98, 46.93 and 46.95 cm) was observed in B_3 during both the years and pooled data analysis. While the minimum spike length 46.83cm in 2023 and 46.83 and 46.84 cm was recorded in 2024 and pooled data analysis.

The interaction effect between natural extracted dyes and dipping hours failed to evoke any significant effect on the spike elongation.

4.2.2.6 Rachis elongation

The data presented in Table 4.25 and Fig 4.27, showed that the various natural extracted dyes had a significant result on the rachis elongation of tinted spike. The highest rachis elongation (2.24, 2.42 and 2.33 cm) was recorded in beet root extract (A_1), which found to be at par with hibiscus extract (A_7) recording values of 2.22, 2.41 and 2.32 cm respectively, while the minimum (1.61, 1.49 and 1.55 cm) was in spinach extract (A_3) during both the years and their means. Maximum rachis elongation with beetroot extract might be due to its betalain content and antioxidant capacity, also contains sugars, minerals, and nitrate compounds (Kale *et al.,* 2018), which may play a supportive role in cell expansion and elongation. Enhanced water uptake due to reduced microbial clogging and improved xylem conductivity can lead to more effective hydration of elongating tissues, especially in the rachis

The data enumerated in Table 4.24 revealed that the various dipping hours had no significant effect on the rachis elongation. However, the maximum rachis elongation (1.98, 1.93 and 1.95 cm) was observed in B_3 while the minimum rachis length 1.83cm in 2023 and 1.83 and 1.84 cm was recorded in during 2024 and pooled data analysis.

Further perusal of the data revealed that the interaction between natural extracted dyes and dipping hours was found to be non-significant on rachis elongation.

4.2.2.7 Water uptake

The data on water uptake by the tinted spike represented in Table 2.26 and Fig 2.28 revealed water uptake by tinted spike till 3rd day and decreases gradually thereafter in all the treatments.

It was evident from the analysis of the data that the natural extracted dyes had a significant effect on the water uptake. The maximum water uptake on 3rd (11.37, 11.25 and 11.31g) and 6th (6.33, 6.26 and 6.29 g) days was observed in beetroot extract (A_1) while the minimum water uptake on 3rd (7.48, 7.61 and 7.54 g) and 6th (3.51, 3.74 and 3.63 g) days war recorded in rhoeo extract (A_8) during both the year as well as in pooled data analysis.

Maximum water uptake was recorded in beetroot extract which might be due its richness in bioactive, antioxidant, sugars, and minerals compounds (Kale *et al.,* 2018) that may have contributed to the reduction of microbial growth at the stem ends, thereby maintaining xylem integrity and removing vascular blockage during the postharvest period. The variation in water uptake among the dyes may depend on the number of open florets and number of buds on the spike (Kumar, 2014). Similar result was recorded by Ushasri *et al.* (2023) in tuberose.

Table 2.25 Effect on natural extracted dyes on the spike elongation (cm) and rachis elongation (cm) in tinted tuberose spike.

Treatments	Spike elongation (cm)			Rachis elongation (cm)		
	2023	2024	Pooled	2023	2024	Pooled
A_1	47.23	47.42	47.33	2.23	2.42	2.33
A_2	46.79	46.76	46.77	1.79	1.76	1.77
A_3	46.61	46.49	46.55	1.61	1.49	1.55
A_4	46.73	46.59	46.66	1.73	1.59	1.66
A_5	47.08	47.19	47.13	2.08	2.19	2.13
A_6	46.77	46.62	46.69	1.77	1.62	1.69
A_7	47.22	47.41	47.32	2.22	2.41	2.32
A_8	46.64	46.66	46.65	1.64	1.66	1.65
SEm±	0.12	0.12	0.08	0.12	0.12	0.08
CD at 5%	0.34	0.34	0.24	0.34	0.34	0.24
B_1	46.83	46.92	46.87	1.83	1.92	1.87
B_2	46.85	46.83	46.84	1.85	1.83	1.84
B_3	46.98	46.93	46.95	1.98	1.93	1.95
SEm±	0.07	0.07	0.05	0.07	0.07	0.05
CD at 5%	NS	NS	NS	NS	NS	NS
(AxB) Interaction						
SEm±	0.21	0.20	0.15	0.21	0.20	0.15
CD at 5%	NS	NS	NS	NS	NS	NS

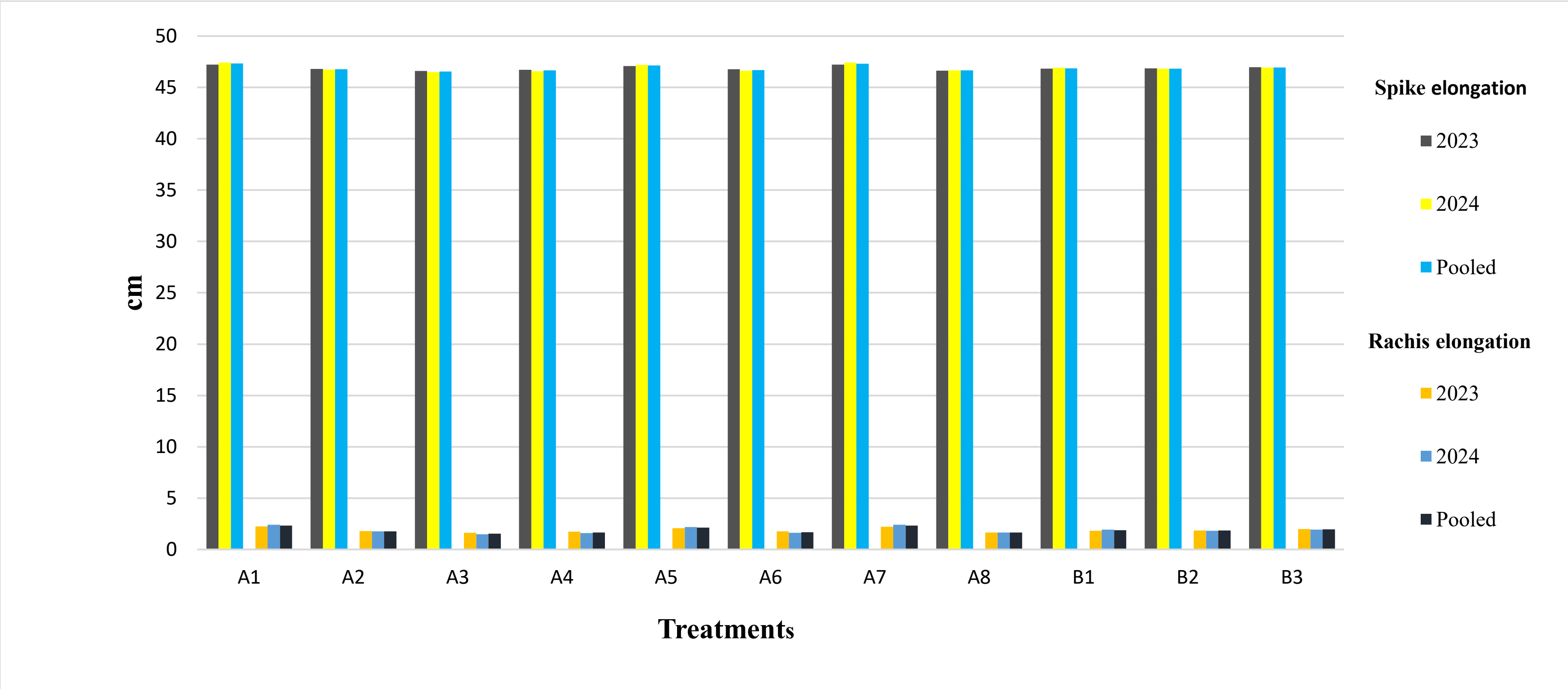

Fig. 4.31 Effect on natural extracted dyes on the spike elongation (cm) and rachis elongation (cm) of tinted tuberose spike

Table 2.26 Effect of natural extracted dyes and dipping hours on water uptake (g) by tinted spike.

Treatments	Day 3			Day 6		
	2023	2024	Pooled	2023	2024	Pooled
A_1	11.37	11.25	11.31	6.33	6.26	6.29
A_2	9.14	9.89	9.52	4.84	5.19	5.02
A_3	7.92	7.58	7.75	3.74	3.72	3.73
A_4	8.44	9.18	8.81	3.96	4.11	4.04
A_5	10.80	10.57	10.68	6.21	6.12	6.17
A_6	8.70	9.51	9.11	4.06	4.37	4.22
A_7	11.10	10.98	11.04	5.88	5.93	5.90
A_8	7.48	8.03	7.75	3.51	3.74	3.63
SEm±	0.18	0.21	0.14	0.18	0.15	0.12
CD at 5%	0.51	0.61	0.39	0.51	0.43	0.33
B_1	9.24	9.53	9.38	4.64	4.78	4.71
B_2	9.39	9.55	9.47	4.88	4.91	4.90
B_3	9.47	9.79	9.63	4.93	5.10	5.01
SEm±	0.11	0.13	0.09	0.11	0.09	0.07
CD at 5%	NS	NS	NS	NS	NS	NS
(AxB) Interaction						
SEm±	0.31	0.37	0.24	0.31	0.26	0.20
CD at 5%	0.89	1.06	0.68	0.88	0.74	0.57

The different dipping hours did not show any significant effect on the water uptake of tinted spike. However, the highest water uptake on 3rd (9.47, 9.65 and 9.56 g) and 6th (4.93, 5.08 and 5.01 g) days was observed in B_3 (12 hours) and minimum on 3rd (9.24, 9.55 and 9.39 g) and 6th (4.64, 4.81 and 4.72 g) days was recorded in B_1 (6 hours).

The interaction between natural extracted dyes and dipping hours had significant effect on the water uptake. Maximum water uptake was noted in treatment combination A_1B_3 on 3rd (12.17, 12.48 and 12.32 g) and 6th (7.21, 6.81 and 7.01 g) days, while A_8B_3 recorded minimum water uptake on 3rd (7.22, 6.48 and 6.85 g) and 6th (3.03, 3.43 and 3.23 g) days during both the year of experiment and their pooled data. The spikes immersed in beetroot extract for 12 hours, absorbed more water. This might be due to antimicrobial properties of beetroot (Kale *et al.,* 2018) which preventing vascular blockage leading to more translocation of the water.

4.2.2.8 Water loss

The data presented in Table 4.27 and Fig 2.29 revealed that the various natural extracted dyes showed significant effect on the water loss on all dates of observation. where the highest water loss (10.57, 11.01 and 10.79 g) on 3rd day and (8.36, 8.78 and 8.57 g) 6th day was noted in beetroot extract (A_1), whereas the minimum water loss on 3rd day (9.24g and 9.08 g) during 1st year and pooled data was observed in rhoeo extract (A_8) and 8.82 g recorded during 2024 in A_3 (spinach extract), while on 6th day minimum water loss (3.51, 3.74 and 3.63 g) was noted in rhoeo extract (A_8) during the year 2023, 2024 and pooled data.

A higher water loss is corelated to the higher water uptake by the cut flower (Debbarma, 2016), where increased water absorption supported transpiration and turgidity. In the present study, a general trend of low water loss during the early postharvest period with accelerated loss during later stages reflects the dual influence of initial physiological health and progressive senescence in cut tuberose spikes. The least transpirational loss of water from the spikes may be due to the fact that most of the water absorbed by the spikes utilized by the cells in order to put the cells in turgid condition enhancing greater vase life in tuberose (Kumar *et al.,* 2015)

Table 2.27 Effect of natural extracted dyes and dipping hours on the water loss (g) in tinted spike.

Treatments	Day 3			Day 6		
	2023	2024	Pooled	2023	2024	Pooled
A_1	10.57	11.01	10.79	8.36	8.78	8.57
A_2	10.17	10.28	10.22	6.99	7.42	7.21
A_3	9.43	8.82	9.12	5.98	6.28	6.13
A_4	9.54	10.22	9.88	6.21	6.30	6.26
A_5	10.44	10.54	10.49	8.18	8.55	8.36
A_6	9.97	10.30	10.14	6.06	6.60	6.33
A_7	10.50	10.97	10.74	8.10	8.25	8.18
A_8	9.24	8.93	9.08	5.71	6.07	5.89
SEm±	0.26	0.18	0.16	0.26	0.28	0.19
CD at 5%	0.75	0.52	0.45	0.74	0.78	0.53
B_1	10.15	10.10	10.13	6.86	7.17	7.01
B_2	9.88	10.06	9.97	6.96	7.27	7.11
B_3	9.92	10.24	10.08	7.03	7.41	7.22
SEm±	0.16	0.11	0.10	0.16	0.17	0.12
CD at 5%	NS	NS	NS	NS	NS	NS
(AxB) Interaction						
SEm±	0.46	0.32	0.28	0.45	0.48	0.33
CD at 5%	NS	NS	NS	NS	NS	NS

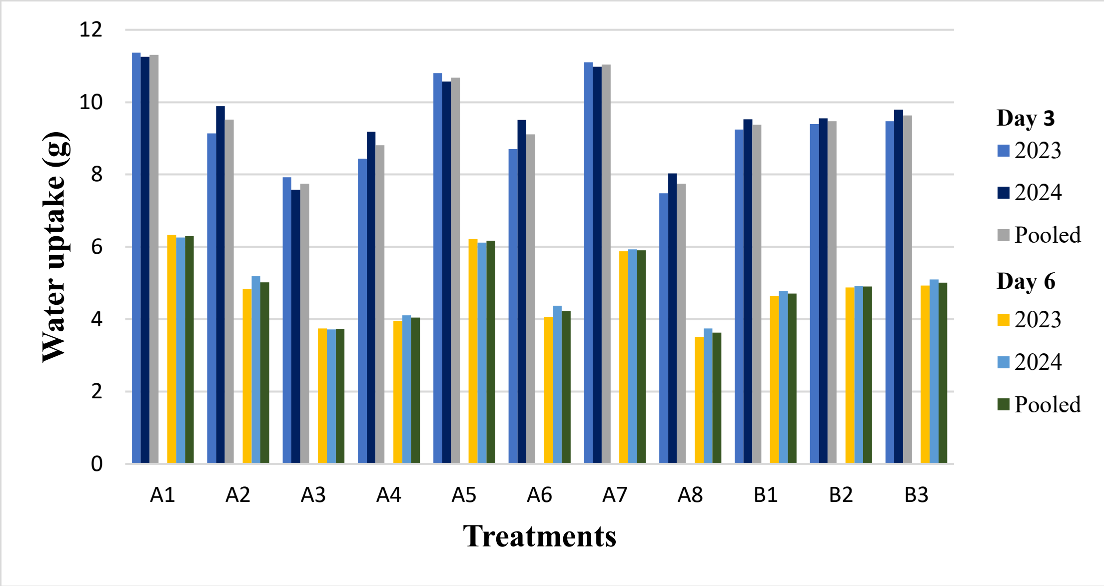

Fig. 4.32 Effect of natural extracted dyes and dipping hours on the water uptake (g) of tinted spike.

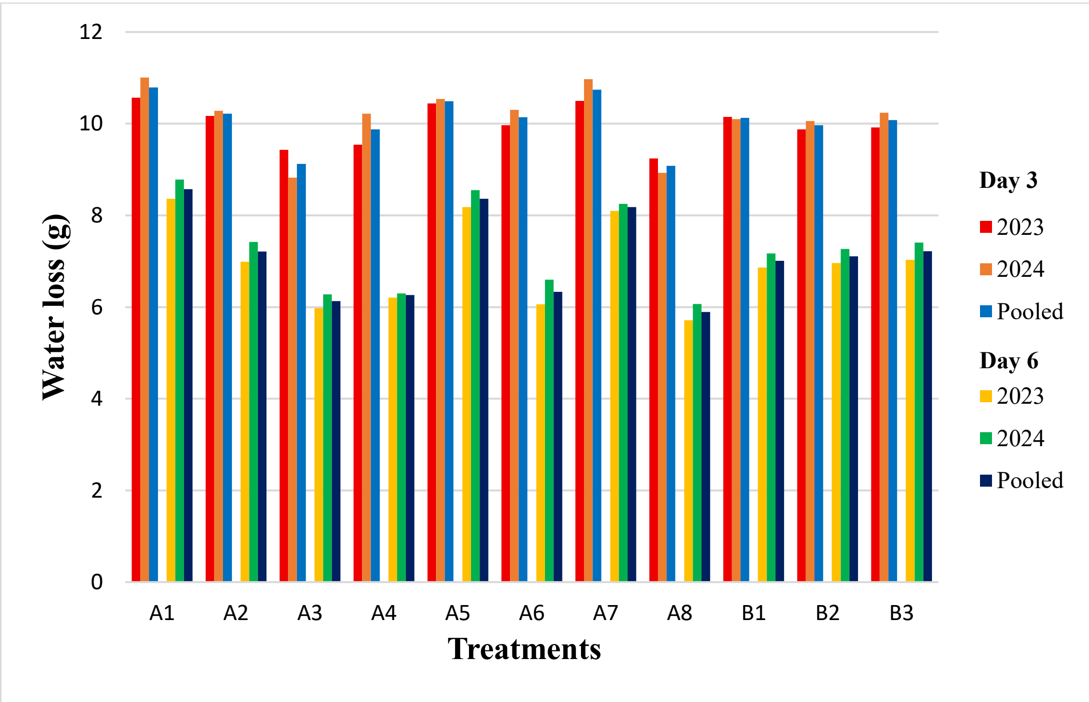

Fig. 4.33 Effect of natural extracted dyes and dipping hours on the water loss (g) of tinted spike.

As the vase life proceeds there was gradual decrease in the percent of relative water content, this decreasing trend in the relative water content was noticed due to loss in the membrane integrity of the florets which in turn results in the wilting of the tinted flowers such symptoms have been reported by Hossain *et al*. (2006) in gladiolus

The different dipping hours did not showed any significant effect on the water loss of tinted spike. However, the highest water loss on 3rd day (10.15 g and 10.13g) was recorded in B_1 during 2023 and pooled data, while 10.24g water loss observed in B_3 during 2024 was observed and on 6th days (7.03, 7.42 and 7.22 g) was noted in B_3, while the minimum water loss (9.88, 10.06 and 9.97 g) was noted on 3rd day in B_2 and on 6th day recording values 6.86g, 7.17g and 7.07 respectively in B_1.

The interaction between natural extracted dyes and dipping hours had non-significant effect on the water loss of the tinted spike of tuberose during both the year and pooled data analysis.

4.2.2.9 Water balance

The data on water balance ratio of tinted spike on 3rd and 6th of both the year and their pooled analysis are presented in Table 2.28 and Fig 2.28.

From the analysis of the data, it was found that the natural extracted dyes had a significant effect on the water balance ratio. The maximum water balance ratio (1.07, 1.02 and 1.05) on 3rd and (0.74, 0.74 and 0.75) 6th days was observed in beetroot extract (A_1) while the minimum water balance ratio (0.82, 0.86 and 0.84) on 3rd and (0.62, 0.61 and 0.61) 6th day was recorded in rhoeo extract (A_8) during both the years and pooled data analysis.

Beetroot extract-treated tuberose spikes demonstrated the highest water balance, which might be due to a combination of high osmotic potential from natural sugars, antioxidant protection from betalains, and moderate antimicrobial effects. These factors synergistically improved water uptake while minimizing water loss, resulting

Table 2.28 Effect of natural extracted dyes and dipping hours on water balance of tinted spike.

Treatments	Day 3			Day 6		
	2023	2024	Pooled	2023	2024	Pooled
A_1	1.07	1.02	1.05	0.76	0.74	0.75
A_2	0.90	0.96	0.93	0.70	0.70	0.70
A_3	0.86	0.87	0.86	0.63	0.62	0.62
A_4	0.88	0.90	0.89	0.64	0.65	0.65
A_5	1.04	1.00	1.02	0.76	0.72	0.74
A_6	0.87	0.93	0.90	0.68	0.67	0.67
A_7	1.06	1.00	1.03	0.73	0.72	0.73
A_8	0.82	0.86	0.84	0.62	0.61	0.61
SEm±	0.02	0.02	0.01	0.03	0.03	0.02
CD at 5%	0.06	0.06	0.04	0.09	0.09	0.06
B_1	0.93	0.93	0.93	0.68	0.67	0.67
B_2	0.94	0.94	0.94	0.69	0.68	0.68
B_3	0.95	0.95	0.95	0.70	0.69	0.69
SEm±	0.01	0.01	0.01	0.02	0.02	0.01
CD at 5%	NS	NS	NS	NS	NS	NS
(AxB) Interaction						
SEm±	0.04	0.03	0.03	0.06	0.06	0.04
CD at 5%	NS	NS	NS	NS	NS	NS

in sustained tissue hydration and delayed senescence compared to other natural dye treatments.

The different dipping hours did not showed any significant effect on the water balance ratio of tinted spike. The highest water balance ratio (0.93, 0.93 and 0.93) on 3rd and (0.70, 0.69 and 0.69) 6th days was observed in B_3 (12 hours) and minimum (0.95, 0.95 and 0.95) on 3rd and (0.68, 0.67 and 0.67) 6th was recorded in B_1(6 hours).

The interaction between natural extracted dyes and dipping hours on water balance ratio found to be non-significant on all the dates of observation.

4.2.2.10 Vase life

The data depicted in Table 4.26 and graphically illustrated in Fig 2.29 revealed that the natural extracted dyes had significant effecton vase life of tined spike during both the year (2022-23 and 2023-24) and pooled data analysis. The maximum vase life (9.11, 9.22 and 9.17 day) was recorded in A_1 (Beetroot) whereas the minimum vase life (7.33, 7.33 and 7.33 day) was observed in A_3 (spinach) during both years as well as pooled data analysis.

The application of natural colorants for tinting of cut flowers not only enhances their ornamental value but also has the potential to influence postharvest longevity through various biochemical and physiological mechanisms. In the present study, maximum vase life in beetroot extract might be due to its high betalain content, providing strong antioxidant protection, reducing oxidative stress and delaying floral senescence. Additionally, its mild antimicrobial activity helps in maintaining stem conductivity. Safeena *et al*. (2016), stated that dyes did not alter the cell metabolism. Hence no barrier was formed for movement of water and food materials in tuberose.

Further investigation of the data exhibited that the different dipping hours significantly influenced the vase life of tinted spike of tuberose. Maximum vase life (8.42, 8.38 and 8.40 days) was noted in B_3 (12 hours), while the B_1 recorded minimum vase life of 7.79, 7.88 and 7.83 days respectively, during 2022-23 and 2023-24 and pooled data analysis.

Table 2.27 Effect of different natural extracted dyes and dipping hours on the vase life of tinted spike

Treatments	2023	2024	Pooled
A_1	9.11	9.22	9.17
A_2	7.89	7.78	7.83
A_3	7.33	7.33	7.33
A_4	7.44	7.56	7.50
A_5	8.78	8.89	8.83
A_6	7.56	7.78	7.67
A_7	8.89	9.00	8.94
A_8	7.56	7.44	7.50
Sem±	**0.22**	**0.23**	**0.16**
CD at 5%	**0.62**	**0.64**	**0.44**
B_1	7.79	7.88	7.83
B_2	8.00	8.13	8.06
B_3	8.42	8.38	8.40
Sem±	**0.13**	**0.14**	**0.10**
CD at 5%	**0.38**	**0.39**	**0.27**
(AxB)Interaction			
Sem±	**0.38**	**0.39**	**0.27**
CD at 5%	**1.08**	**1.11**	**0.76**

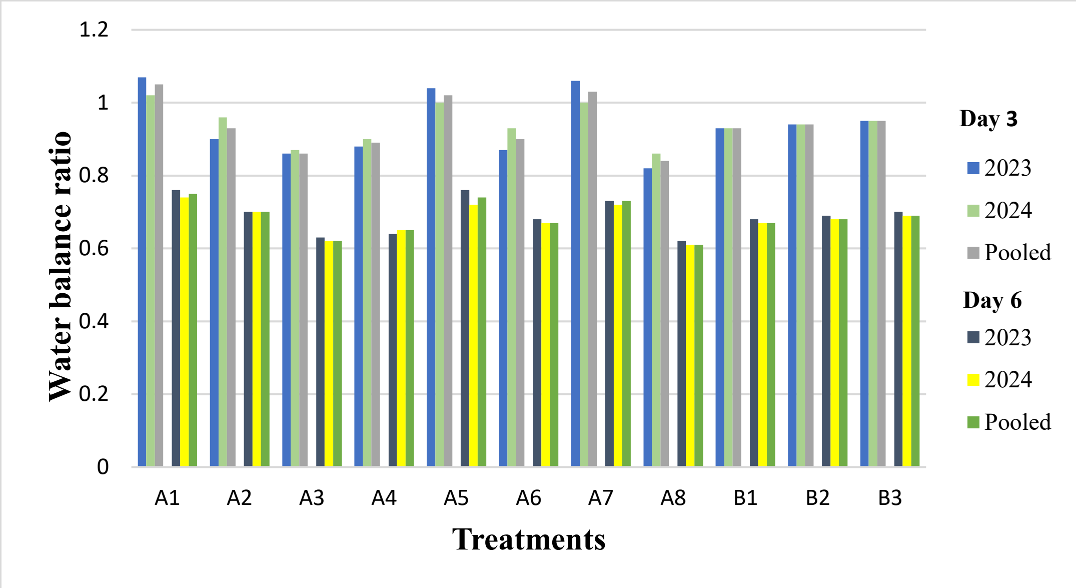

Fig. 4.34 Effect of natural extracted dyes and dipping hours on the water balance of tinted spike.

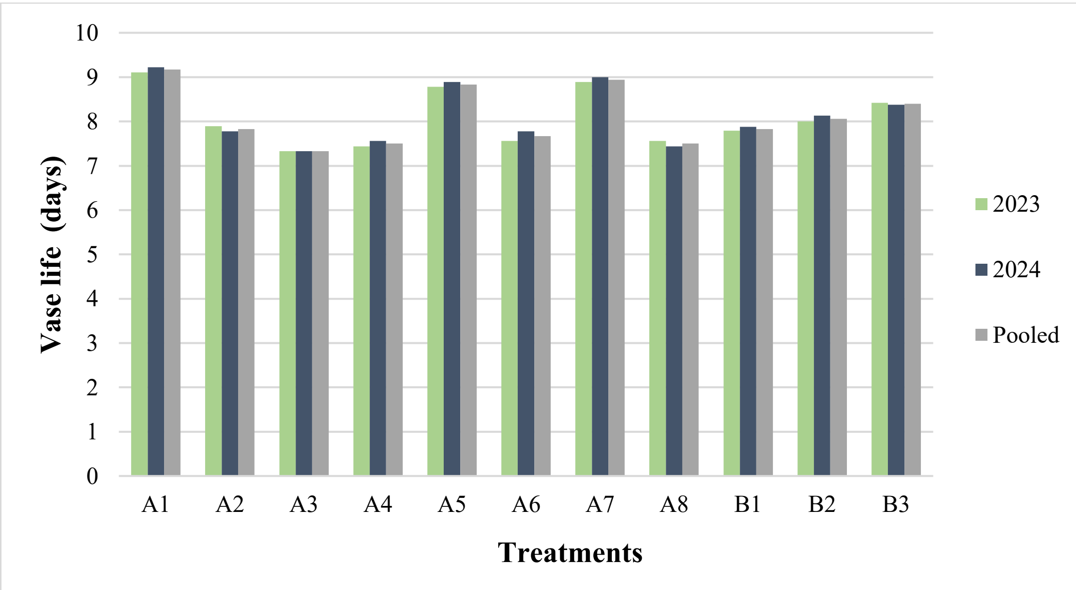

Fig. 4.35 Vase life of tinted spike as effect by different natural extracted dyes and dipping hours.

The interaction between natural extracted dyes and dipping hours caused significant increase in the vase life of the tinted spike. Longest vase life with 10.33, 10.67 and 10.50 days respectively, was noticed in the treatment combination of A_1B_3 and shortest vase life (7, 7 and 7 day) observed in A_3B_3 during the year and their mean respectively. The maximum vase life was noticed in A_1B_3. This may be due to more absorption of dye to the petals through the vasculatory system along with water or dye uptake Mekala *et al*. (2012) in tuberose.

4.2.3 Economics of tinted spike

In the present experiment, among all the treatments, only beetroot and dragon fruit extract imparted colour while the rest of the natural extract did not impart any colour to tuberose spike throughout its vase life. The colour shade obtained by beetroot and dragon fruit extracted dye looks beautiful and very attractive. The economics of colouring tuberose spikes was highly effective for beetroot extracted dye. The highest B:C ratio (1.2 and 1.3) was obtained from beetroot extracted dye with the spike immersed for 12 hours in dyes during both year of experiment. Though the B:C ratio of tinted spikes did not varied much with the dipping hours of food dyes.

In addition to physiological benefits, tinting tuberose with beetroot extract enhances its ornamental appeal, transforming its typically white florets with subtle hues of pink to purple. This coloration not only increases visual novelty and consumer attractiveness but also augments the commercial value of the spikes, particularly in decorative floral arrangements and event-based floristry.

Beetroot extract

6 hours

9 hours

12 hours

Dragon fruit extract

6 hours

9 hours

12 hours

Plate No. 20 Tinting of tuberose

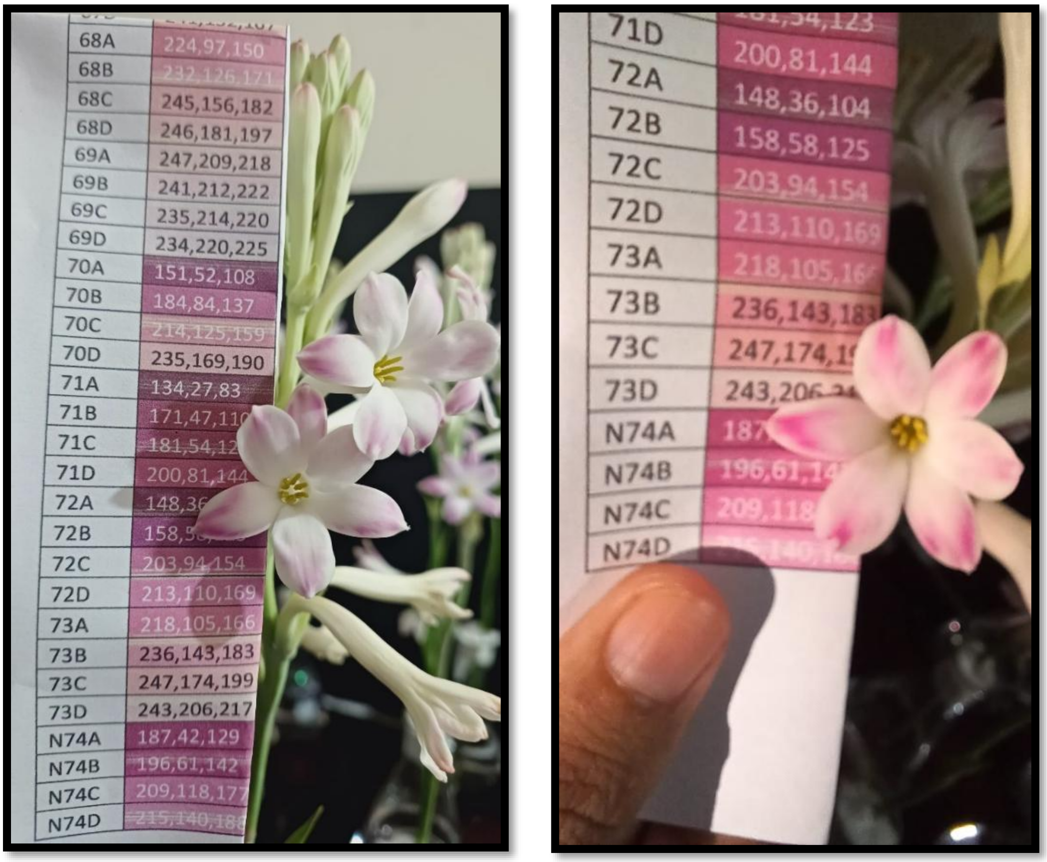

Plate No. 21 Coloure intensity of tinted tuberose

Plate No. 22 Diameter of tinted floret

CHAPTER - V

SUMMARY AND CONCLUSIONS

SUMMARY AND CONCLUSIONS

The present investigation entitled "Effect of INM on the performance of tuberose (*Polianthes tuberosa* L.) and tinting of cut tuberose with natural extracted dyes" was carried out in the experimental farm and post-harvest laboratory, Department of Horticulture, School of Agricultural Sciences (SAS), Nagaland University, Medziphema Campus, Nagaland during the year of 2022-23 and 2023-24. The investigation was undertaken with the following objectives.

i. To study the effect of INM on the performance of tuberose.
ii. To find out the suitable INM practices for extending flower durability of tuberose.
iii. To study the influence of different natural dyes on the post-harvest life of cut tuberose.
iv. To work out benefit cost ratio of INM and tinting in tuberose.

In this chapter salient results obtained from the above studies are summarized below.

5.1 Experiment I-Effect of INM on the performance of tuberose (*Polianthes tuberosa* L.)

5.1.1 Growth parameters

The results of vegetative parameters *viz*. minimum days to sprouting, maximum, number of leaves per plant, length of leaves (cm), plant height (cm) and number of side shoots per plant at flowering stage were observed under T_4 (75% RDF + Vermicompost at 5 t/ha) followed by T_6 (75% RDF + Poultry manure at 2 t /ha), while the minimum result was recorded in control.

5.1.2 Flowering parameters

It was revealed that different treatments of organic manures and inorganic fertilizers had significant effect on flowering parameters. Among different treatments, T_4 (75% RDF + Vermicompost at 5 t/ha) was recorded the minimum days to spike emergence, first floret opening and 50% floret opening, while minimum days to 50%

flowering was noticed in by T_6 (75% RDF + Poultry manure at 2 t/ha), whereas control took maximum days. Length of the spike (cm), rachis length (cm), number of florets per spike, diameter of floret (cm), weight of individual floret (g) and flower durability was found maximum in T_4 (75% RDF + Vermicompost at 5 t/ha) followed by T_6 (75% RDF + Poultry manure at 2 t/ha), while minimum was recorded in control.

5.1.3 Bulb parameters

Regarding the bulb attributes, the number of bulb and bulblets per plant, bulb diameter (cm), weight of bulb (g) and bulblets (g), bulb yield (ton) was obtained maximum with the application of T_4 (75% RDF + Vermicompost at 5 t/ha), which was mostly followed by T_2 (75% RDF + FYM at 10 t/ha) and T_6 (75% RDF + Poultry manure at 2 t/ha), while the lowest bulb parameters was noted in control.

5.1.4 Post harvest studies

There is a significant difference between the treatments with respect to post harvest parameters. The maximum fresh weight (g), minimum days to 50% floret opening, maximum water uptake (g) and longest vase life (days) was exhibited in T_4 (75% RDF + Vermicompost at 5 t/ha), followed by T_6 (75% RDF + Poultry manure at 2 t/ha) and T_2 (75% RDF + FYM at 10 t/ha), while maximum days to 50 % floret opening, minimum, fresh weight (g), water uptake (g) and vase life (days) was recorded in control.

5.1.5 Biochemical parameters

Among the biochemical factors, total chlorophyll, nitrogen, phosphorus and potassium content in leaves and bulb of tuberose were resulted highest under T_4 (75% RDF + Vermicompost at 5 t/ha), mostly followed by T_6 (75% RDF + Poultry manure at 2 t/ha) and T_2 (75% RDF + FYM at 10 t/ha), while lowest results of the biochemical observations were noted with the control plants.

5.1.6 Physio-Chemical properties of soil

The results showed significant variation among different treatments on physio-Chemical properties of soil. The maximum available, nitrogen, phosphorus and potassium (kg/ha) was obtained in T_4 (75% RDF + Vermicompost at 5 t/ha), followed by T_2 (75% RDF + FYM at 10 t/ha) and T_6 (75% RDF + Poultry manure at 2 t/ha), whereas soil organic carbon was maximum in T_{12} (FYM at10 t/ha + Vermicompost at 5 t/ha + Poultry manure at 2 t/ha + forest soil at 10 t /ha+ Humic Acid t/ha). On the other hand, minimum was found in control. There was no significant difference noticed among the treatments in soil pH and EC.

5.1.7 Economic analysis

The economical observations revealed the highest net return in T_4 (75% RDF + Vermicompost at 5 t/ha), however the B:C ratio was obtained highest in T_6 (75% RDF + Poultry manure at 2 t/ha). The lowest net return and B:C ratio was recorded in T_{11} (50%RDF +Humic Acid at 2 t/ha).

5.2 Experiment II- Tinting of cut tuberose with natural extracted dyes

5.2.1 Sensory evaluation

Tuberose spikes were treated with different natural extracted dyes i.e. beetroot, turmeric, spinach, pomegranate, dragon fruit, marigold, hibiscus and rhoeo extract and various dipping hours i.e. 6 hours, 9 hours and 12 hours. It was observed that the spikes treated with beetroot extract for 12 hours recorded maximum score irrespective of colour, appearance and shape, freshness, petal retention and overall acceptability, while minimum score was obtained in spike treated with spinach extract for 12 hours.

5.2.2 Quantitative Evaluation

There is a significant difference between the treatments with respect to quantitative parameters of the tinted spikes. Minimum days to 50% floret opening, and gain in fresh weight (g), diameter of floret (cm), floret length (cm), spike elongation (cm), rachis elongation (cm), water uptake(g), water loss (g), water balance and vase life was exhibited maximum in beetroot extract (A_1). The various dipping hours had a significant effect only in colour intensity, days to 50% floret opening and vase life maximum was recorded in 12 hours (B_3) dipping duration. The treatment combination of natural extracted dyes and dipping hours showed significant effect only on overall acceptability. days to 50% floret opening, length of floret, water uptake and vase life. The maximum was recorded when she spikes was immersed in beetroot extract for 12 hours (A_1B_3). There was no significant difference noticed among the treatment's combination in, changes in fresh weight (g), diameter of floret (cm), spike elongation (cm), rachis elongation (cm), water loss (g) and water balance.

5.2.3 Economics of tinted spike

The B:C ratio revealed that, most of the treatments were not economically viable. The highest B:C ratio was obtained from beetroot extracted dye, when the spike emerged for 12 hours.

Conclusion

- From the present investigation it may be concluded that among the different treatment T_4 (75% RDF + Vermicompost at 5 t/ha) gave best results for the growth, flowering, bulb, post-harvest characters and nitrogen, phosphorus & potassium content in plant and soil. Followed by T_6 (75% RDF + Poultry manure at 2 t/ha) and T_2 (75% RDF + FYM at 10 t/ha).

- Similarly for flower durability, treatment T_4 (75% RDF + Vermicompost at 5 t /ha) was significantly better in improving the flower durability of tuberose.

- In terms of economics of the tuberose T_6 (75% RDF + Poultry manure at 2 t /ha) was best treatment for benefit: cost analysis followed by T_4 (75% RDF + Vermicompost at 5 t /ha) and T_2 (75% RDF + FYM at 10 t/ha)

- For tinting study concluded that naturally available dyes extracted from various plant sources exhibit the potential to enhance the color of tuberose flowers. Among the tested extracts, T_1 (beetroot) and T_5 (dragon fruit) were particularly effective, imparting greater color intensity to the flower spikes when immersed 12 hours in extract solution. These findings highlight the feasibility of using eco-friendly, plant-based dyes as natural colorants in floricultural applications, offering a sustainable alternative to synthetic dyes.

- For the economics of the tinted tuberose spike, highest B:C ratio was obtained from beetroot extracted dye when the spike immerged for 12 hours in dyes.

Suggestions for future work

1. The present study can be repeated with different doses of organic and inorganic fertilizers.
2. Similar study can be conducted at different locations.
3. The same studies can be carried out for different types as well as varieties of tuberose.
4. Tinting of cut tuberose can be carried out with different natural extracted dyes and preservative.

APPENDICES

APPENDIX - I

Table 3.1(a) Average weekly meteorological data recorded during the cropping system (2022-2023)

Week no.	Temperature		Relative Humidity		Rainfall (mm)	Wind speed (km hr^{-1})	Sunshine hour
	Max. °C	Min. °C	Max. %	Min. %			
20	29.1	21.9	93	81	110.6	0.989	2.2
21	30.8	22.3	93	72	10.9	1.116	3.4
22	33.3	23.3	93	65	22.5	1.214	4.8
23	33.0	24.0	94	74	51.1	1.196	2.9
24	30.3	23.3	95	74	46.7	0.872	1.3
25	31.2	23.4	95	75	34.8	0.824	1.8
26	33.3	24.9	93	68	9.9	1.313	4.5
27	34.2	24.7	91	66	77.1	1.569	7.2
28	34.1	24.5	90	69	22.9	1.464	6.9
29	33.9	24.5	92	75	135.3	1.357	3.4
30	31.8	23.2	96	70	135.3	1.024	3.6
31	33.6	23.9	93	68	48.8	1.259	3.1
32	33.3	23.9	96	71	114.7	1.205	5.1
33	33.6	24.2	91	72	27.5	1.286	6.1
34	34.1	24.5	94	68	64.2	1.039	4.1
35	32.7	24.3	93	68	9.0	0.945	4.6
36	33.4	24.4	89	67	21.7	1.423	4.9
37	31.9	23.5	91	72	42.8	1.042	4.1
38	33.5	24.0	91	65	15.3	0.964	5.6
39	32.8	23.2	91	70	81.2	1.024	6.3
40	31.9	23.5	95	74	31.0	0.672	4.4
41	31.8	22.7	91	71	2.9	0.810	5.0
42	30.9	20.6	94	65	19.7	1.010	5.9
43	28.1	19.9	95	71	41.0	1.127	4.7
44	29.8	17.1	96	60	0.0	0.963	8.0
45	29.3	16.7	96	57	0.0	0.867	8.2

46	27.9	14.6	98	56	0.0	0.971	8.2
47	27.7	12.8	96	52	0.0	0.913	8.0
48	27.8	14.3	96	67	0.0	0.932	7.4
49	27.6	12.0	95	49	0.0	0.944	8.0
50	26.4	11.3	96	50	0.0	0.843	7.0
51	25.7	11.0	96	51	0.2	0.704	6.4
52	22.7	11.2	97	60	15.2	0.595	3.9
1	23.2	9.2	97	50	0.0	0.782	6.9
2	25.4	8.8	96	55	0.0	0.114	6.9
3	22.8	7.0	94	45	0.0	0.791	5.7
4	24.9	6.9	93	45	0.0	0.804	6.0
5	27.0	10.4	93	46	0.0	0.868	6.2
6	25.6	10.2	94	53	0.0	1.156	3.7
7	26.9	11.0	91	43	0.0	1.337	5.3
8	29.0	15.1	93	51	0.0	1.513	3.4
9	29.1	11.2	89	39	0.0	1.995	7.0

Source: ICAR Research Complex for NEH Region, Jharnapani, Nagaland

Table 3.2. (b) Average weekly metrological data during the cropping system (2023-2024)

Week no.	Temperature		Relative Humidity		Rainfall (mm)	Wind speed (km hr^{-1})	Sunshine hour
	Max. °C	Min. °C	Max. %	Min %			
20	30.4	20.8	92	63	24.5	0.271	3.6
21	33.4	21.8	80	58	35.2	0.976	5.0
22	35.8	22.8	85	49	2.5	0.392	9.2
23	36.9	24.1	84	61	77.1	0.561	5.1
24	30.3	23.3	95	74	46.7	0.872	1.3
25	31.2	23.4	95	75	34.8	0.824	1.8
26	33.3	24.9	93	68	9.9	1.313	4.5
27	34.2	24.7	91	66	77.1	1.569	7.2
28	34.1	24.5	90	69	22.9	1.464	6.9
29	33.9	24.5	92	75	135.3	1.357	3.4
30	31.8	23.2	96	70	135.3	1.024	3.6
31	33.6	23.9	93	68	48.8	1.259	3.1
32	33.3	23.9	96	71	114.7	1.205	5.1
33	33.6	24.2	91	72	27.5	1.286	6.1
34	34.1	24.5	94	68	64.2	1.039	4.1
35	32.7	24.3	93	68	9.0	0.945	4.6
36	33.4	24.4	89	67	21.7	1.423	4.9
37	31.9	23.5	91	72	42.8	1.042	4.1
38	33.5	24.0	91	65	15.3	0.964	5.6
39	32.8	23.2	91	70	81.2	1.024	6.3
40	31.9	23.5	95	74	31.0	0.672	4.4
41	31.8	22.7	91	71	2.9	0.810	5.0
42	30.9	20.6	94	65	19.7	1.010	5.9
43	28.1	19.9	95	71	41.0	1.127	4.7
44	29.8	17.1	96	60	0.0	0.963	8.0
45	29.3	16.7	96	57	0.0	0.867	8.2
46	27.9	14.6	98	56	0.0	0.971	8.2
47	27.7	12.8	96	52	0.0	0.913	8.0
48	27.8	14.3	96	67	0.0	0.932	7.4
49	27.6	12.0	95	49	0.0	0.944	8.0
50	26.4	11.3	96	50	0.0	0.843	7.0
51	25.7	11.0	96	51	0.2	0.704	6.4

52	22.7	11.2	97	60	15.2	0.595	3.9
1	23.2	9.2	97	50	0.0	0.782	6.9
2	25.4	8.8	96	55	0.0	0.114	6.9
3	22.8	7.0	94	45	0.0	0.791	5.7
4	24.9	6.9	93	45	0.0	0.804	6.0
5	27.0	10.4	93	46	0.0	0.868	6.2
6	25.6	10.2	94	53	0.0	1.156	3.7
7	26.9	11.0	91	43	0.0	1.337	5.3
8	29.0	15.1	93	51	0.0	1.513	3.4
9	25.4	11.7	93	45	0.7	0.547	7.0
30	34.9	25.5	88	67	17.3	30	34.9
31	33.7	25.1	91	71	114.7	31	33.7
32	33.1	25.0	91	71	37.7	32	33.1
33	33.3	25.3	91	77	14.8	33	33.3
34	31.4	24.4	90	76	62.9	34	31.4
35	33.9	25.2	90	72	10.3	35	33.9
36	33.7	24.9	91	68	49.2	36	33.7
37	33.9	25.0	87	68	2.4	37	33.9
38	30	25.2	93	69	7.3	38	30

Source: ICAR Research Complex for NEH Region, Jharnapani, Nagaland

APPENDIX - II

1. Cost of cultivation per ha of tuberose under INM (both year)

A. Fixed cost

S. No.	**Material/work**	**Cost**	
		2022-23	**2023-24**
1	Planting material @ ₹ 2.4/ bulb	₹ 277750	₹ 277750
2	Land preparation		
	Ploughing Tractor rent @ ₹ 800/hrs	₹ 2400	₹ 2700
	Bed preparation by 15 men @ ₹ 450/men	₹ 6750	₹ 7500
	Manure and fertilizer application by 5 men@ ₹ 450/men	₹ 2250	₹ 2500
3	Planting		
	Fungicide treatment	₹ 2000	₹ 2500
	Planting of bulb by 22 men @ ₹ 450/men	₹ 9900	₹ 11000
4	Interculture operation 4 time by 12 men @ ₹ 450/men	₹ 21600	₹24000
5	Irrigation	₹ 4000	₹ 4500
6	Harvesting, Grading		
	Flower spike by 30 men@ ₹ 450	₹ 13500	₹ 15000
	Lifting of bulb by 30 men @ ₹ 450	₹ 13500	₹ 15000
7	Miscellanies	₹ 2300	₹ 2300
	Total	**₹ 3,55,950**	**3,64,750**

B. Treatment cost

	Treatments	Cost	
		2022-23	**2023-24**
T_1	Control (RDF $N_{200}P_{200}K_{150}$kg/ha)		
	Urea @ ₹ 7/ kg (435kg) 75-2283.75, 50-1522.5	3045	3045
	SSP @ 8.5 /kg (1250) 75- 7968.75, 50-5312.5	10625	10625
	MOP @ 19.6/kg (250) 75-3675, 50-2450	4900	4900
	Total	**18570**	**18570**
T_2	75% RDF + FYM at 10 t /ha @ 2	33927.5	33927.5
T_3	50% RDF + FYM at 20 t /ha @ 2	49285.0	49285.0
T_4	75% RDF + Vermicompost at 5 t /ha @ 15	88927.5	113927.5
T_5	50% RDF + Vermicompost at 10t /ha @ 15	159285.0	209285.0
T_6	75% RDF + Poultry manure at 2 t /ha@ 3	19927.5	19927.5
T_7	50% RDF + Poultry manure at 4 t /ha @ 3	21285.0	10485.0
T_8	75% RDF + forest soil at 10 t /ha @ 2	33927.5	33927.5
T_9	50% RDF + forest soil at 20 t /ha @ 2	49285.0	49285.0
T_{10}	75% RDF + Humic Acid at 1t /ha @ 250	263927.5	269927.5
T_{11}	50% RDF +Humic Acid at 2 t /ha @ 250	509285.0	521285.0
T_{12}	FYM at10 t /ha + Vermicompost at 5 t /ha + Poultry manure at 2 t /ha+ forest soil at 10 t /ha+ Humic Acid at 1t /ha	371000	402000.0
yield	Sell price		
	Spike	₹ 3	₹ 3
	Bulb	₹ 3	₹ 3.5

2. **Cost of cultivation of tuberose in tinting**

	Particular	**Juice content/ kg**	**Price /kg**		**Quantity Use**	**Cost**	
			2023	**2024**		**2023**	**2024**
1	Flower spike				1	₹ 3	₹3
2.	Distilled water @ ₹ 10/L				100 ml	₹ 1	₹ 1
3	Beet root /kg,	750 ml	₹40	₹ 45	100 ml	₹ 5.00	₹ 6.00
4	Turmeric	400 ml	₹70	₹73	100 ml	17.50	₹18.25
5	Spinach	600 ml	₹40	₹45	100 ml	₹6.60	₹7.50
6	Pomegranate peel	400 ml	₹5	₹6	100 ml	₹1.50	₹1.50
7	Daigon fruit	700 ml	₹200	₹200	100 ml	₹28.00	₹28.57
8	Marigold	300 ml	₹20	₹20	100 ml	₹ 6.60	₹ 6.60
9	Hibiscus	500 ml	₹10	₹12	100 ml	₹2.00	₹2.40
10	Rhoeo	600 ml	₹5	₹5	100 ml	₹0.83	₹0.83

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