"Studies on the effect of nitrogen, plant geometry and biofertilizers on growth, flowering and bulb production in tuberose (*Polianthes tuberosa* L.) cv. Double."

BY

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Dissertation submitted to the Chaudhary Charan Singh Haryana Agricultural University in the partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY
IN
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COLLEGE OF AGRICULTURE
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Dedicated

To My

Beloved Parents

CERTIFICATE - I

This is to certify that this dissertation entitled "**Studies on the effect of nitrogen, plant geometry and biofertilizers on growth, flowering and bulb production in tuberose (*Polianthes tuberosa* L.) cv. Double.**" submitted for the degree of **Doctor of Philosophy** in the subject of **Horticulture** of the CCS Haryana Agricultural University, Hisar, is a bonafide research work carried out by **Bijender Singh Yadav** under my supervision and that no part of this dissertation has been submitted for any other degree.

The assistance and help received during the course of investigation have been fully acknowledged.

31/4/03

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CERTIFICATE - II

This is to certify that this dissertation entitled **"Studies on the effect of nitrogen, plant geometry and biofertilizers on growth, flowering and bulb production in tuberose (*Polianthes tuberosa* L.) cv. Double."** submitted by **Bijender Singh Yadav** to the CCS Haryana Agricultural University, Hisar in partial fulfilment of the requirements for the degree of **Doctor of Philosophy** in the subject of **Horticulture,** has been approved by the Student's Advisory Committee after an oral examination on the same, in collaboration with an External Examiner.

MAJOR ADVISOR

EXTERNAL EXAMINER 12/06/03

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Place: Hisar
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BSyadav 4.4.03
(Bijender Singh Yadav)

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ABBREVIATIONS

%	:	per cent
@	:	at the rate of
°C	:	degree celsius
□l	:	microliter
CD	:	critical difference
cm	:	centimeter
cm^2	:	square centimeter
cv.	:	cultivar
et al.	:	et alli (and other)
FYM	:	farm yard manure
g	:	gram
GA_3	:	gibberellic acid
ha	:	hectare
i.e.	:	id. est (that is)
IAA	:	indole acetic acid
IBA	:	indole butyric acid
mm	:	millimeter
N	:	nitrogen
NAA	:	naphthalene acetic acid
NS	:	non-significant
P	:	phosphorus
pH	:	potential of hydrogen ions

ppm	:	parts per million
SADH	:	succinic acid dihydrazide
viz.	:	namely
kg	:	kilogram
BNF	:	biological nitrogen fixation
ATP	:	adenosine tri phosphate
GA	:	gibberellic acid
PSB	:	phosphate solubilizing bacteria
K	:	potassium
m	:	meter
msl	:	mean sea level
mg	:	milligram
dSm^{-1}	:	desi simon per meter
EC	:	electrical conductivity
□g	:	microgram

CHAPTER – I

Introduction

Among the commercially grown flowers in India, tuberose (*Polianthes tuberosa* Linn) occupy a prime position because of its potential for the cut flower trade as well as for the essential oil industry. Tuberose, commonly known as "*Rajnigandha*", is a bulbous, perennial, commercial plant and belongs to family Amaryllidaceae. Among the ornamental plants, tuberose is valued much higher by the aesthetic world for beauty and fragrance of their flowers. It is very popular among the flower growers due to its sweet fragrance and longer keeping quality of flower spikes (Banker and Mukhopadhyay, 1990). Tuberose is native of Mexico from where it spread to different parts of the world during 16th century. The name polianthes was given to the tuberose by Linnaeus in 1737 in his Genera Plantarum. The name tuberosa is derived from 'tuberose' as this plant being tuberous hyacinth as distinguished from bulbous hyacinth. The name therefore is tuber ose and not tuberose. Tuberose is not found wild any where in Mexico or in the Andes

region of South America. If it is considered as Mexican species, it is supposed to have originated from *Polianthes gracilis* Link and Otto.

Tuberose is cultivated on larger scale in many parts of tropical and subtropical countries such as France, Italy, South Africa, North Carolina, Southern State of America and India. In India, the commercial cultivation of tuberose is confined mainly to Karnataka, West Bengal, Tamil Nadu, Maharashtra and Andhra Pradesh. However, it is well adapted to the North Indian conditions and grows well in limited scale in Uttar Pradesh, Punjab, Rajasthan, Haryana and its cultivation is increasing in Haryana day by day. At present the total area under tuberose cultivation in the country is estimated to be about 20000 hectares (Yadav and Maiti, 1989), while in Haryana total area under tuberose is 150 hectares with production of 150 lacs spikes (Singh, 1997) and specially restricted to Ambala, Gurgaon, Faridabad and Hisar.

The tuberose has a great economic importance for cut flower trade and essential oil industry (Sadhu and Bose, 1973). Apart from out door cultivation as a successful economic crop with immense potentiality for export, it is also grown in pots, beds and borders for becautification and to enhance and modify the atmosphere of surrounding places like home, gardens, parks and public places with its sweet pleasant fragrance. Tuberose

spikes are useful as cut flowers for preparation of bouquets and for interior decoration particularly for table decoration in bowl and vases which are gaining popularity in our country due to urbanization and tourism. Its loose flowers are used for preparing artistic garlands, venis and ornaments for bridal make up and for other floral ornaments. The flower fragrance constitute the source of tuberose oil which remains as one of the expensive raw materials for the perfumes industry. The genus *Polianthes* is characterized by twin flowers, born on terminal spike and are arranged in pair at each node. There are 15 to 20 pairs in a spike. The flowers have a funnel shaped, waxy white perianth emitting a strong fragrance in air and transform the entire area into a nectarine and joyous one because of their lingering delightful fragrance. The leaves are long narrow, linear grass like and light green in colour. The crop is propagated by bulblets and bulbs which are made up of scales and leaf bases. The stem is condensed structure and concealed with in the scales. Roots are adventitious and shallow. There are several varieties in tuberose named on the basis of number of petals, type of variation in the leaves, coloration and size of flowers, etc.

The flowers are in high demand both in national and international market. To meet this continuous increasing demand the need of our is to increase the productivity of the

flowers with the improvement in growth, flowering and yield of spikes and bulbs either by adopting cultural practices.

Tuberose planting is made under various spacing depend upon region to region. On the other hand, the sowing of tuberose crop at different spacing has its own significance. So, there is need to work out spacing effect in tuberose.

The growth, flowering and yield depend upon fertilizer and other cultural practices. Due to high price of various fertilizers, its cultivation become unaffordable to use balanced fertilizers by growers. On the other hand, the unbalanced and continuous use of chemical fertilizers is making adverse effect on soil fertility, which will reduce flower yield, quality and vase life. Previous experiences clearly indicated that no single source of input can meet the twin challenge to maintain higher productivity with sustained environmental quality. At this stage, it is necessary to popularize 'Integrated Plant Nutrient Supply System (IPNS) which involve the combined use of different sources of nutrients such as chemical fertilizers, organic manures and biofertilizers, where biofertilizer can supplement the use of chemical fertilizers considerably.

In recent years biofertilizers alone and in combination with chemical fertilizers have been used and found effective in improving growth of various ornamental and fruit crops. So for no work has been conducted to ascertain the efficacy of

biofertilizers on tuberose hence, keeping in view the importance and scope, the present study on the effect of nitrogen, plant geometry and biofertilizers on growth, flowering and bulb production in tuberose cutlivar Double was planned with the following objectives:

1. To study the effect of nitrogen, plant geometry and biofertilizers on growth, flowering and bulb production of tuberose.
2. To study the effect on mineral composition of leaves.

CHAPTER – II

Review of Literature

Soil contains a variety of fungi and other micro organisms. Some of these are pathogens and harmful to plant growth, whereas others are beneficial to the plants. Such group of beneficial micro-organism includes *Azotobacter, Phosphorus Solubilizing Bacteria* (PSB) and *Azospirillum. Azotobacter* is a free living diazotroph, produces growth regulators, antifungal substances and fixes nitrogen. *Phosphorus Solubilizing Bacteria* (PSB) containing mainly Pseudomonas, Bacillus and Aspergillus etc. have ability to solubilize insoluble phosphorus to the soluble form by production of organic acids and then making it available to the plants, whereas *Azospirillum* is a free-living nitrogen fixer and occurs in association with roots of almost all plants of agricultural importance. This culture is prepared by using highly efficient nitrogen fixing strain of the organism.

Sukhda Mohandas (1999) suggested that biofertilizers are microorganisms which are capable of mobilizing nutritive elements from non-available form to usable form through

biological process. They are cost effective and inexpensive source of plant nutrients, do not require non-renewable source of energy during their production, improve crop growth and quality of the product by producing plant hormones, help in sustainable crop production through maintenance of soil productivity. They are useful, as biological agents, since they control many plant pathogen and harmful micro-organisms. The similar findings regarding biofertilizers have also been expressed by other workers (Gaur *et al.*, 1980; Tilak *et al.* 1982; Subba Rao *et al.* 1983; Hemandez and Hill, 1983; Bongale and Nadiger, 1989; Pactovsky *et al.* 1985 and Sardana, 1997).

The beneficial rate of bio-fertilizers were also highlighted by Bhattacharya and Mishra (1994). They have expressed that the bio-fertilizers can also be found beneficial in crops and ornamental plants like Rose, Jasmine, Chrysanthemum, Marigold, Dahlia, Aster, Poppy, Tuberose, Gladiolus and Lilies due to better root development, floral stalk production etc. When inoculated with biofertilizers. Several workers have worked on various crops of ornamental importance as Rhododendron (Moore and Englander, 1982), Tuberose (Ailincai, 1960; Wang *et al.*, 1995), Chrysanthemum (Johnson *et al.*, 1982), Arum (Wedding *et al.*, 1978), Easter lily (Ames and Linderman, 1977 and 1978), Marigold (Plenchette *et al.*, 1983; Bagyaraj and Powell, 1985), Petunia (Daft and Okusanya, 1973),

Poinsettias (Barrows and Roncadori, 1977), Magnolia and Junipers (Maronek *et al.*, 1980), Woody ornamental (Crew *et al.*, 1978), Aster (Kulkarni and Konde, 1990), Poppy (Chakraborti and Yadav, 1991) Gerbera and Syngonium (Wang *et al.*, 1993; Shashikala *et al.*, 1999).

The work done on *Azotobacter, Phosphorus Solubilizing Bacteria* (PSB), *Azospirillum*, Nutrients and Plant Geometry (Spacing) role in relation to plant growth, nutrient uptake etc. is being depicted separately.

2.1 *Azotobacter*, its role in plant growth and nutrition

Azotobacter is a free living organism on which extensive studies have been carried out. It not only fixes atmospheric nitrogen but also produces growth promoting substances and is known to suppress root pathogens (Tilak, 1993).

Effect of *Azotobacter*, application in crops can be enhanced by use of organic inputs like well decomposed FYM, compost, wormy compost, biogas slurry etc.

Brakel and Hilger (1965) found that an application of *Azotobacter* in plants produced IAA (Indole-3-acetic acid) in tryptophan added medium. A gibberellin like substance in old culture was detected (Margaret and Burlingham, 1968 and Azcon and Barea, 1975).

Brown (1974) suggested possible mechanism for action of *Azotobacter*, includes nitrogen fixation, defence of plant against pathogen and production of plant growth substance. Rao (1975) described the properties of *Azotobacter* to be considered responsible for their beneficial role:

(i) Produce vitamins and growth substance for enhancement of seed germination which was supported by various workers (Sundara Rao *et al.*, 1963; Shende *et al.*, 1973, 1977 and Narula *et al.*, 1981).

(ii) Production of IAA, auxins, gibberellins and cytokinins which enhance root growth and thereby help the plant in nutrient absorption (Lee *et al.*, 1970; Matimoud *et al.*, 1984; Martin *et al.*, 1988 and Martinez-Toledo *et al.*, 1988).

(iii) Inhibition of phytopathogenic fungi through antifungal substances (Sharma *et al.*, 1986).

(iv) Production of sidophores which solubilize Fe^{3+} and suppress plant pathogens through iron deprivation (Page, 1987 and Suneja and Lakshminarayan, 1993).

Verma and Bhattacharya (1990) explained the mode of nitrogen fixing by *Azotobacter* sp. These microorganisms contain 'nif' gene, which regulate the activity of nitrogenase enzyme, capable of combining elemental nitrogen with other elements like carbon, hydrogen and oxygen at ambient temperature and

pressure by using ATP as energy source. This combined nitrogen is further converted into assimiable form with respect to need of organisms which are subsequently utilized by plants. Biological nitrogen fixation being enzymatic biological process, there is low energy requirement which is met by nature.

Joi and Shinde (1976) observed significant increase in growth (plant height, number of leaves) of onion when inoculated by *Azotobacter*. Bagyaraj and Menge (1978) reported an increase in root and shoot dry weight in tomato inoculated with *Azotobacter* in sterilized and unsterilized soil than in uninoculated soil.

A significant increase in plant growth parameters have also been reported in rice, cabbage and brinjal with *Azotobacter* inoculation (Subba Rao, 1979). Similar positive crop response of *Azotobacter* inoculation has also been reported by other workers (Subba Rao, 1982; Narula and Yadav, 1989).

Tilak *et al.* (1982) found that the microbial inoculants prepared from *Azotobacter* etc. are well known to increase growth parameters (i.e. height, number of leaves, leaf area, number of branches etc.) of plants. Similar results have been reported by Gaur *et al.*, (1980); Hemandez and Hill, (1983) and Packovsky *et al.* (1985).

Kulkarni and Konde (1990) reported positive response of Aster to application of *Azotobacter* in relation to growth and

flowering. Chakraborti and Yadav (1991) also obtained increased plant growth and latex yield in poppy when inoculated with *Azotobacter.* Gangavar and Thangavelu (1992) inoculated mulberry with *Azotobacter* chroococcum and reported significant improvement in growth parameters viz., plant height, root length, number of roots/plants, number of leaves per plant, dry matter contents (shoot, root and leaves). Similar results were also found in various crops (Nagarajan *et al.*, 1986; Yadav and Kumar, 1984; Bangale and Dadvin, 1993; Balasubramaniam, 1995; Das *et al.*, 1990, 1993, 1994 and 1996). Siddiqui *et al.*, (1993) also recorded significant increase in plant growth, number of branches/plant, number of leaves/plant, leaf length and nitrogen fixation in mulberry inoculated with *Azotobacter.* Misra (1997) studied the effects of *Azotobacter* application and found significant increase in flower spike growth and variable changes in other growth parameters in gladiolus cv. Melody. Wang and Patil (1994) recorded significant increase in number of florets/spike, spike quality, number of bulb (rhizome) and flower yield by application of *Azotobacter* with nitrogen in tuberose (Palianthes tuberosa L.). A similar trend of results in tuberose have also been observed by (Wange, *et al.*, 1995). Mishustin and Naumova (1962) mentioned that *Azotobacter* has long been used in Soviet union to inoculate the crops to increase yields.

Joi and Shinde (1976) reported 18 per cent increase in bulb yield of onion when *Azotobacter* with nitrogen applied in comparison to the application of nitrogen alone. Similarly Subba Rao (1979) found a significant increase in yield in rice, cabbage, brinjal and other crops on *Azotobacter* application. A positive response of *Azotobacter* and similar results were summarized by various workers (Subba Rao, 1982, Narula and Yadav, 1989).

Lakshmanan and Kannan (1982) obtained high yield of cardamom on application of lignified based culture of *Azotobacter*. A higher yield of tea (young leaves) was obtained after inoculation with *Azotobacter* (Ahmed *et al.*, 1983).

Pandey and Kumar (1989) concluded that *Azotobacter* inoculation was beneficial to several crops and it increased the yield of wheat, rice, maize, pearlmillet and sorghum by 0 to 72% over uninoculated. In poppy the latex yield was increased by *Azotobacter* application as compare to control (Chakraborti and Yadav, 1991). Bhattacharya and Mishra (1994) suggested the use of *Azotobacter* biofertilizer, which can help in better root development and increase flower production in floricultural crops (i.e. Rose, Jasmine, Tuberose, Poppy, Dahlia, Aster, Gladiolus, Lilies etc.). Similarly significant increase in the flower yield (i.e. number of florets per spike) was reported by Mishra (1997) in Gladiolus when inoculated with Nafed superculture containing *Azotobacter* and micronutrietns. Wang *et al.*, (1995)

obtained increased yield of underground parts (bulbs) and number of spike per plant when tuberose plants were inoculated with *Azotobacter* sp. along with various levels of nitrogen. Similar results were obtained in tuberose on *Azotobacter*isation with nitrogen doses (Wang and Patil, 1994).

Ailincai (1960) reported the useful effect of micro-inoculants on number of flower or spike/plant in tuberose (*Polianthes tuberosa* L.). Kulkarni and Konde (1990) observed positive response of *Azotobacter* on flowering in Aster alone and in combination of 75 kg N/ha. Wang and Patil (1994) obtained significantly increased number of flowers/stalk and number of flower stems produced by tuberose when inoculated with *Azotobacter* and nitrogen.

Joi and Shinde (1976) reported that inoculation of onion with *Azotobacter* + Nitrogen resulted more beneficial than application of nitrogen alone.

Dart and Wani (1982) suggested that the inoculation of nitrogen fixer in cereal crops/monocots has responded benefically by increasing nitrogenase activities in rhizosphere. Similar results were also reported by (Wani *et al.*, 1983, 1984 and Kapuni K *et al.*, 1981). Ahmed *et al.* (1983) observed that *Azotobacter* had beneficial effects on growth and yield of young leaves in Tea, and enrichment of organic matter and nitrogen. Dosale and Konde (1984) revealed that the application of

increasing dose of nitrogen (i.e. 0, 33, 66 and 100 kg N/ha) with *Azotobacter* inoculation resulted in increased dry matter and yield. The inoculation of *Azotobacter* with 66 percent of recommended dose of nitrogen was found almost equal to the inoculation at 100% recommended nitrogen dose. This clearly shows that it is possible to save 33% N/ha. Mohandas (1987) reported that Aztobacter vinelandii significantly increased tomato leaf nitrogen content as compared to control. Kulkarni and Konde (1990) reported positive response of Aster to application of *Azotobacter* in combination of 75 kg N/ha. Wang *et al.* (1995) studied the effect of four levels of nitrogen with biofertilizers on the tuberose. The results of three year pooled data revealed that the nitrogen application @ 100 kg/ha should be supplemented with *Azotobacter*. Almost similar results were obtained with the application of different levels of nitrogen (100 kg and 150 kg/ha) with *Azotobacter* inoculation.

Conty *et al.*, (1974) inoculated cabbage seedlings with *Azotobacter* and application of 40 kg N/ha and 100 kg P_2O_5/ha where they observed 65.11% increase in yield in comparison to uninoculated. Gupta *et al.*, (1999) in marigold reported that in general, the growth and yield attributes exhibited maximum values in treatment of *Azotobacter* + *Phosphorus Solubilizing Bacteria* as soil and seedling treatment in combination with 75% and 100% nitrogen application.

2.2 *Phosphorus Solubilizing Bacteria* (PSB) and their role in plant growth and nutrition

Phosphorus is a very important nutrient required by plants in large quantities. But its availability is very less in most Indian soils, as most of the added phosphorus is converted to less available forms. Inorganic forms of this nutrient are compounds of Ca, Fe and Al, while organic forms are phytin, phospholipid and nucleic acid, which are added to the soil by the way of decaying vegetation. The soils containing high organic matter are rich in organic forms of phosphorus.

Several soil bacteria, (*Pseudomonas and Bacillus*) and fungi (*Penicillium* and *aspergillus*) have the ability to bring insoluble phoshphates in soil into soluble forms by secreting organic acids such as acetic, formic, propionic, lactic, glycolic, fumeric and succinic acids. These acids lower the pH and bring about dissolution of bound form of phosphate. Some of the hydroxy acids may chelate with Ca and Fe resulting in effective solubilization and utilization of phosphates by crops. Many attempts have been made to study the role of phosphate solubilizers in plants, however, very little work has been done in ornamental crops and other horticultural crops. The work done in past have been reviewed in relation to phosphate solubilizers.

Sundara Rao *et al.* (1963) reported that the beneficial effects of phosphate solubilizing micro-organisms in meeting

nutritional requirement and/or supplementing expensive inorganic fertilizers. Similar findings have also been reported by (Gaur and Ostwal, 1972 and Arora, 1975). Bhattacharya *et al.*, (1986) studied that phosphate solubilizer micro-organisms secrete different organic and inorganic acids including the production of phytase enzymes which act upon the residual phosphates for converting the insoluble fixed phosphates into orthophosphates in soil water solution very near to root surface and thus make it directly available to plants. The phosphate solubilizing power of these organisms increase positively under the influence of organic manures. Gaur, A.C. and Rana, J.P.S. (1990) suggested that the important phosphate solubilizing organisms are *Pseudomonas striata, Bacillus polymaxa, Aspergillus awamorii, Penicillium digitatum.* These microorganisms can grow on insoluble phosphatic sources such a tri-calcium phosphate, ferric aluminium and magnesium phosphate, rock phosphate and bone meal and then convert them into soluble forms. Tilak and Annapurna (1993) suggested that the phosphate solubilizing microorganisms are broad spectrum biofertilizers which may increase yield of crops (cereals, legume and vegetable etc.) by 10-30 per cent and supplement phosphorus needed by 30 kg P_2O_5/ha. Sukhda Mohandas (1999) described that several soil bacteria particularly *Pseudomonas* and *Bacillus* and fungi – *Penicillium* and

Aspergillus passes the ability to convert unavailable form of phosphate into available form by producing organic acids (formic, propionic, acetic, lactic, glycolic and fumaric acids) in rhizosphere and acidified the rhizosphere by lowering pH and bring about dissolution of bound form of phosphate.

Kandaswami *et al.*, (1985) recorded the per cent increase in height of seedlings (4.23%), seedling dry weight (66.88%) root length (19.35%), shoot N-concentration (8.7%) and shoot P-concentration (23.91%) in brinjal and per cent height of seedlings (21.77%), dry weight of seedling (7.76%), root length (33.93%) and shoot P-concentration in chilly over control when inoculated with phosphate Solubilizing Bacteria in nursery. Gaur and Rana (1990) mentioned that phosphobacterium by virtue of its capacity to elaborate certain growth promoting substances like IAA and GA (also reported by Ramamoorthy, 1982) might induce the growth of other associative organisms like VAM fungi so that for obtaining maximum growth and vigor of neem seedlings, a combined application of VAM and PSM was recommended. Tilak (1991) reported that significant increase in the yield of wheat, rice, potato and lentil when inoculated with microphos culture. Similar response of PSB has been observed in chickpea (Shinde, 1990). Algawadi and Gaur (1992) recorded increased grain yield, straw yield and dry matter content of sorghum, when inoculated with phosphate solubilizing bacteria

as compared to control with and without fertilizers. Sardana (1997) revealed that the PSB are known to produce certain growth promoting substances in the rhizosphere. As a result, their positive contribution in increasing availability of phosphorus and in improving growth and yield of different field crops have been observed.

Kandaswamy *et al.*, (1985) have found per cent increase in nitrogen and phosphorus in shoot of brinjal and chilly, by inoculation of phosphate solubilizing micro-organisms as compared to uninoculated control.

Algawadi and Gaur (1992) reported that the inoculation of sorghum with PSB increases N-uptake and P-uptake along with growth parameter and yield in comparison to non-inoculated control.

Sapatnekar *et al.* (2001a) concluded that use of phosphate solubilizers along with graded levels of single superphosphate is beneficial and necessary for better yield of green gram since it increased phosphate solubilization thereby increasing growth parameters. It was also revealed that 100% recommended dose of SSP and 75% of it with P-solubilizer recorded similar results in grain yield, (16.78 and 16.88 q per ha, respectively) and were statistically at par with each other, indicating saving of 25% SSP. The results are in conformity with

the finding of earlier workers (Bardiya and Gaur, 1990 and Wani *et al.* 1978).

Sapatnekar *et al.*, (2000b) reported that phosphorus sources in combination with PSM proved beneficial to wheat in respect of P-uptake and grain yield rather than their individual applications.

2.3 *Azospirillum*, its role in plant growth and nutrition

Azospirillum, an associative micro aerophilic nitrogen fixer, commonly found in association with roots of cereals and grasses has received great interest as a bio-fertilizer (Pandey and Kumar, 1989). Its useful characters include high nitrogen fixation capacity, low energy requirement and tolerance to high soil temperature for its suitability under tropical conditions. *Azospirillum* is a mesophyllic bacterium and is reported to occur in association with crops grown in acidic to alkaline pH range. Azospirilla are metabolically versatile and can grow vigorously in the presence of nitrogenous compounds present in the soil but as soon as the external N supply is exhausted the bacteria shift to diazotrophy. Use of *Azospirillum* inoculum under saline alkaline conditions is possible because strains adapted to these stress conditions maintained high nitrogen activity.

Jeeva *et al.* (1988) studied the effect of *Azospirillum sps.* on growth and development of banana cv. Poovan (AAB). The fertilizers in the form of urea, superphosphate and MOP

were applied in two split doses on the third and fifth months after planting. The *Azospirillum* culture was applied @ 2.5 kg/ha (in 3 splits) by mixing with FYM in the ratio of 1:20 on the third, 60th and 120th day after planting. The application of *Azospirillum* in combination with nitrogen fertilizer significantly improved the vegetative growth in terms of height and girth of pseudostem. *Azospirillum* with 75% of fertilizer had the same effect in increasing the plant height and girth as that of 100% nitrogenous fertilizer without inoculation. The other growth parameters such as total leaf urea, total number of leaves, number of suckers were also found to be enhanced with *Azospirillum*. Inoculation also reduced the time interval between the production of successive leaves. The bunch weight was increased due to *Azospirillum* inoculation. The increase in bunch weight due to *Azospirillum* inoculation was also found associated with a corresponding increase in length of bunch, number of hands and fingers, length, girth and weight of fingers. The increase in growth and yield parameters due to *Azospirillum* may be an account of its direct role in nitrogen fixation.

Rao and Das (1989) studied influence of nitrogen fixing bacteria on the growth of fruit plants. Soil inoculation with pure cell suspension of *Azospirillum* brasilense strains S-14, S-51 or S-54 and *Azotobacter* chroococcum increased plant height and dry weight in 6 months old budded plants of ber

(*Zizyphus mauritiana*) cv. Seb and Gola and in rooted cutting of pomegranate cv. Jalore seedless grown in pots. *A brasilense* strain S-14 had the best effect on plant dry weight in ber (*Z. mauritiana*) and S-54 had the best effect on pomegranate. In both cases, this was correlated with a marked increase in N uptake. It is suggested that growth enhancement could be due to the production of growth regulating plant hormones as well as to N fixation. The rhizosphere of inoculated plants carried higher population of A. brasilense than that of uninoculated controls.

Singh and Sharma (1993) studied leaf nutrient composition of sweet orange as affected by combined use of bio and chemical fertilizers. Three grams of *Azospirillum* per plant was applied to the root tip at the time of transplantation. In case of VAM, 50g of culture was placed at 15cm below soil near each plant. At 6 monthly intervals, 4-7 months old mature leaves were collected and analysed for macro and micro nutrients. *Azospirillum* application increased the N level to almost the same extet as full dose of N and P.

Kapulnik *et al.* (1979) in cereal crops reported that inoculation of wheat, panicum spp., maize and sorghum with N-fixing *Azospirillum* bacteria increased grain and dry matter yields.

Kapulnik *et al.* (1981) in wheat, sorghum and panicum revealed that the potential of the nitrogen fixing

bacterium *Azospirillum* brasilense to enhance development and increase growth of Panicum miliaceum, Triticum aestivum and Sorghum bicolor was investigated. In both sterilized and non-sterilized systems heading and flowering occurred earlier in the inoculated plants as compared to the non-inoculated ones. Total shoot and root weights, total N contents, plant height and leaf length were significantly increased by inoculation.

Neuer *et al.* (1985) in wheat observed that during the growth of the association, the bacteria lived exclusively from the carbon. Ram *et al.* (1986) in rice and chickpea found that 40 or 60 kg N/ha increased rice grain yield from 3.2 to 4.1 t/ha,; 10 kg BGA/ha increased yield to 3.9t. Chickpea yield increased from 1.5 t/ha with no-fertilizer to 2.1t with the residual fertility of 10kg BGA or *Azotobacter* applied to the rice crops. There were no residual effects on the other crops.

Shah and Joshi (1986) in cereal crops found that the use of inoculation with various strains of *Azotobacter* and *Azospirillum* to increase growth and yield of cereals is discussed, with data for maize, pearl millet (Pennisetum americanum), sorghum, wheat, paddy, ragi (Eleusine coracan) and sugarcane obtained by GSFC in Gujarat.

Pandey and Kumar (1989) in wheat, maize, sorghum, rice, millets, potatoes, cotton and sugarcane found that the beneficial effects of applying *Azotobacter* and *Azospirillum* to

non-legume crops on their yields are reviewed. Application of *Azotobacter* and *Azospirillum* to wheat, maize, sorghum, rice, millets, vegetables, potatoes, cotton and sugarcane grown under both irrigated and barani (rainfed) conditions, with and without application of NPK, increased yields of there crops. The beneficial effects of *Azotobacter* and *Azospirillum* are related that ony to their N-fixing proficiency but aso with their ability to produce antibacterial and antifungal compounds, growth regulators and side rophores.

Patra *et al.* (1989) in wheat and toria reported that the highest wheat grain yields were 3.74 and 3.68 t/ha with 60 kg N + *Azospirillum* and 40 kg N + *Azospirillum*, respectively. Yields were 2.90, 3.05 and 3.16t without N, with *Azotobacter* alone and with *Azospirillum* alone, respectively. Toria seed yields were 200, 300 and 273 kg/ha without N, with + *Azotobacter* alone and with *Azospirillum* alone, respectively., The highest toria yields were 560 and 550 kg/ha with 60 kg N + *Azotobacter* and 40 kg N + *Azotobacter*, respectively. It was concluded that 40 kg N + *Azotobacter* was the most economic fertilizer application for both crops.

Gamo (1991) in wheat, rice, sugarcane, sorghum and maize observed that no effect were observed in rice and wheat plants, but isolates from roots of sugarcane, sorghum, maize and C. ciliaris promoted root and shoot growth in maize. Growth

promotion was observed in spinach roots and shoots, and roots only in Chinese cabbage, cucumber and B. perviridis.

Wange and Patil (1994) in tuberose observed that applying 100 kg N/ha alone or inoculating with *Azotobacter* + *Azospirillum* mixtures significantly increased the number of flowers/stalk, bulb (rhizome) yield and the number of flower stems produced by polianthes tuberosa cv. Single in pot experiments.

Wange *et al.* (1995) in tuberose revealed that bulb yields were highest with 50 kg N/ha and inoculation with *Azospirillum*. Cut flower yields were highest with 150 kg N/ha and inoculation with *Azospirillum* (26288 dozen/ha) compared with the untreated control (15871 dozen/ha).

Mikhajiovskaya *et al.* (1997) in winter wheat and stubble oil radish found that a two year field study in Belarus with winter wheat and stubble oil radish, showed that the application of *Azospirillum* brasilense was effective for winter grain plants. Oil radish yield was positively influenced by diazotrophs.

Terry *et al.* (1998) in tomato observed that yields were highest in plants inoculated with *Azospirillum* brasilense (1 x 10^8 cfu/ml at 25 litres/ha applied 24h after sowing) + Glomus manihotis (applied to seeds at 100g/kg seed) + 90 kg N ha^{-1} (24.71 t/ha, compared with 23.26 t/ha in controls).

Bhavanisanker and Vanangamudi (1999) in gundumalli observed that the combined application of M1 and S1 gave the highest number of branches per plant, while the combined application of M6 and S5 gave the highest flower yield (1.56, 1.739 and 1.779 kg/plant) in the first, second and third years after treatment, respectively.

Bhavanisanker and Vanangamudi (1999) in crossandra revealed that the combined application of M_3 and S_2 gave the highest flower yield (1.106 and 1.474 kg/plant) at 3 and 17 months after planting, respectively, while the combined application of M_2 and S_2 have the highest flower yield (0.738 kg/plant) at 10 months after planting.

EL-Kased *et al.* (1999) in newly reciaimed sandy soil found that yield was highest in the bio-fertilizer treatment, while among N sources the best results were given by urea. All treatments at least doubled yield compared with controls. Net returns and benefit: cost ratio were highest with the bio-fertilizer treatments.

Jena *et al.* (1999) in turmeric observed that the rhizome yield and nutrient uptake by the crop were significantly higher following inoculation of either single or combined inoculants irrespective of fertilizer application. This increase was greater with 60 kg N. The percentage increase in yield due to inoculation integrated with fertilizer N ranged from 15.2 to

30.5%. The N-use efficiency was enhanced due to inoculation and showed higher values with 30 kg N than with 60 kg N/ha. The soil was left with a positive N-balance in the integrated treatments only, indicating a build up of soil fertility.

Nantha Kumar and Veeraragavathatham (1999) in brinjal reported that combined application of 12.5t FYM/ha, *Azospirillum* and Phosphobacteria (2kg each) + inorganic fertilizers at 75% of the recommended rate of N (75 kg/ha), P (37.5 kg/ha) and 100% of K (30 kg/ha) increased the keeping quality, lowered the CPLW, improved the general appearance and overall acceptance of the harvested fruits compared to the ones treated with inorganic fertilizers.

Preethi *et al.* (1999) in Edward rose found that the treatment combination of nitrogen at 38.5 kg/ha, *Azospirillum* (@ 2kg/ha) application at sixth month after planting and foliar spray of ascorbic acid at 1000ppm, gave the highest number of total shoots, flowering shoots and the lowest number of blind shoots. The same treatment also recorded highest pedical length, flower weight, flower diameter, concrete recovery and ascorbic acid content in shoots.

Chokha *et al.* (2000) in sweet orange reported that the treatment combination of 3/4 P + vesicular arbuscular mycorrhizas (VAM) + N (T_{10}) was the best treatment for producing better growth and yield of high quality fruits in

Mosambi. Indicated the suitability of bio-fertilizers (*Azospirillum* brasilense culture and VAM) inoculation in combination with chemical fertilizers for better growth, yield and fruit quality. It will help bring down the cost of chemical fertilizers particularly nitrogen and phosphorus and help improve soil fertility by maintaining the physical conditions of the soil.

Panwar *et al.* (2000) in wheat revealed that both the bio-fertilizers increased leaf area, chlorophyll concentration, NR (nitrate reductase) activity, total biomass production and grain yield compared with untreated controls. DL153-2 had a greater response to inoculation than HD 2428. P and K uptake were increased by Bacillus subtilis, whereas N uptake was increased by *Azospirillum* brasilense.

Swaminathan and Sambandamurthi (2000) in crossandra found that the plant height, number of branches, number of leaves, leaf area per plant, number of spikes per plant, spike length, number of flowers per spike and flower yield per plant were the highest in N 120 kg + K_2O 70 kg/ha + *Azospirillum* 2 kg/ha + FYM 30t/ha. *Azospirillum* + N + K_2O proved to be more beneficial than *Azospirillum* or FYM alone.

Narasimha Raju and Haripriya (2001) in crossandra found that the present investigation on INM in crossandra cv. Dindigul local reveals that application of 100% NPK (75:50:125 kg/ha) + *Azospirillum* + Phosphobacteria each at 2 kg/ha gave

the highest flower yield of 41.72 g/plant with the maximum returns per rupee invested (1:3.50). Application of inorganic nutrients to a tune of 25% can be saved without any yield reduction of *Azospirillum* @ 2kg/ha is incorporated with 75% recommended dose of NPK.

Nanthakumar and Veeraragavathatham (2001) in brinjal observed that the study clearly indicated that the combined application of organic fertilizers through 12.5 t ha^{-1} of FYM, two kg in each of *Azospirillum* and phosphobacteria + inorganic fertilizers at 75 per cent of the recommended dose of N, P and 100 per cent of K favourably influenced the growth, yield (36.48 t ha^{-1}) and quality of brinjal cv. Palur 1.

Parthiban *et al.* (2001) in globe amaranth found that a maximum number of flowers of 292.56 in pink, 282.05 in white during kharif and 334.71 in pink and 308.35 in white type during summer were recorded in FYM + *Azospirillum* at N_{200}. The highest flower yield of 17736 kg/ha in pink, 17132 kg/ha in white during kharif and 20287 kg/ha in pink and 18958 kg/ha in white during summer were also recorded in FYM + *Azospirillum* at N_{200} level. However, N_{200} and N_{150} levels were statistically at par with each other for the flower yield characters.

Selvarajan and Chezhiyan (2001a) in turmeric found that the results of the influence of *Azospirillum* and different

levels of nitrogen on growth and yield of turmeric cv. BSR_2 have indicated that the treatment difference for the various characters studied was not consistent and significant. Yet, there was 16 per cent increased yield by the application of 25kg *Azospirillum* with the 50 per cent of the recommended doses of inorganic N_{25} kg and 5 t of FYM/ha over the recommended dose of fertilizer application, which is found beneficial considering the saving on the cost of 50 per cent of the inorganic nitrogen.

Selvarajan and Chezhiyan (2001b) in fenugreek reported that field experiments conducted to study the effect of *Azospirillum* and graded levels of fertilizer nitrogen on fenugreek cv. CO_2 indicated that seed inoculation of *Azospirillum* coupled with the recommended dose of inorganic fertilizer resulted in 42 per cent increased yield over the treatment with the recommended fertilizer dose without *Azospirillum*.

Subramanian and Vijayakumar (2001) in coriander reported that among the treatments, application of nitrogen @ 20 kg/ha along with *Azospirillum* given through seed treatment and soil application (N_2M_3) has increased the growth parameters such as germination percentage, vigour index, plant height and dry matter production besides various yield parameters and grain yield. However, the physiological parameters viz., the earliness in flowering (44.55 days), fruit set (50.25 days) were delayed in the same treatment.

Swedrzynska and Sawicka (2001) in winter wheat, oat and maize reported that the population of bacteria was estimated at different development stages of plants. Inoculation of cereals with *Azospirillum* brasilense bacteria contributed to the increase of their numbers in soil. No significant influence of fungicidal seed dressings on the numbers of *Azospirillum* bacteria was noted. The application of mineral nitrogen to the crops was favourable for the multiplication of *Azospirillum* bacteria under plants.

2.4 Inorganic Fertilizer (N) and their effect on growth and yield

The nutritional requirement of tuberose (*Polianthes tuberosa* Linn.) has been studied by many workers in relation to its plant growth and yield, however, very little work has been done in North India on fertilizer requirement and their role in relation to growth and yield in flower crops as compared to other Horticultural crops. The work done in the past has been reviewed for planning, execution and discussion of the present investigation.

Different levels of nitrogen, phosphorus and potash have variable effect on the initiation of growth. With the application of nitrogen, phosphorus and potash, improvement in growth was reported by Sadhu and Bose (1973) and Jana *et al.* (1974). Amongest three major nutrients, nitrogen played

comparatively more important role than phosphorus and potash in influencing growth in tuberose (Militiu *et al.*, 1970). They have noted that application of nitrogen (300 kg/ha) significantly reduced the number of days for sprouting as compared to lower dose in tuberose cv. 'Single'. They have also observed the increase in various growth parameters of the tuberose. Similar results were also obtained by Bankar and Mukhopadhayay (1990) in cv. Double. Mitra *et al.* (1979) conducted field trials, in which small and large bulbs were planted in late April. They have applied Phosphorus and potash dressing + nitrogen as ammonium sulphate at 70, 75 and 80 kg/ha in split doses at 2-3 leaf stage and flowering. The highest percentage of flowering plants, the earliest flowering and the highest number of florets per spike were obtained from plants raised from large bulbs receiving 75 kg/ha. Boon and Niers (1986) observed good results on plant growth with 300 kg/ha, nitrogen application in Lilium cv. Enchantment. In another experiment, it was seen that when nitrogen was applied at the time of corm planting it had no effect on subsequent plant growth but when applied 15-40 days after sprouting it had a beneficial effect (Fernandes *et al.*, 1974), Mukhopadhyay and Bankar (1986) and Bankar and Mukhopadhyay (1985) also reported in tuberose cv. Single that application of N ($20g/m^2$) have increased plant height and other growth parameters. Increased nitrogen significantly increased

the plant height in tuberose cv. Double (Gowda *et al.*, 1991). High level of nitrogen has significantly advanced the time taken for emergence of flower spikes as reported by Banker and Mukhopadhyay (1990). They have found that application of high dose of nitrogen (20 g/m^2) has reduced the number of days significantly (134.28) for spike emergence as compared to control which has taken 159.02 days. Similarly Mukhopadhyay (1981) in tuberose and Kosugi and Kondo (1961) in gladiolus reported early emergence of flower spikes due to N application. Ashok *et al.* (1995) found out the influence of different N fertilization on growth, flowering and water use of 'Single' tuberose on a well drained sandy loam soil. Irrigation equal to replenishing 120% of pan evaporation showed the maximum growth, flower yield (10.04 tonnes/ha), spike length (88.0cm), rachis length (22.2cm), florets/spike (38.8). The maximum growth, flower yield (10.23 tonnes/ha) were recorded with 400 kg N/ha. Hence the nitrogen fertilization significantly increased the plant height, number of leaves, leaf area and dry matter production. Nitrogen is one of the key elements which helps build up of vegetative parts. The results confirms the findings of Bankar (1988). Nitrogen @ 250 kg/ha in 'Shringar' tuberose gave better plant growth and economic flower yield, maximum number of leaves per clump, number of florets/spike and weight of individual floret. At 350 kg N/ha it increased the spike and rachis length

but delayed flowering. Application of 200, 250, 300 and 350 kg N/ha did not show significant difference in plant growth and flower parameters (Singh and Uma, 1996). N when applied at 0, 10, 20, 30 or 40 g/m^2, P at 0, 10 or 20g P_2O_5/m^2 and k at 0, 10 or 20 g K_2O/m^2. Bulb yields increased as N rate increased upto 30g/m^2. P and K rates had little effect on bulb yield and there was a significant interaction between N and P (Singh *et al.*, 1996). The influence of nitrogen and phosphorus nutrition on flowering, yield and quality of marigold (Anuradha *et al.*, 1990), N and P_2O_5 were found to cause earliness in flowering with maximum number of big sized flower and improved yield. The quality determining characters viz., flower size, stalk length and umber of ray florets per flower were also found to be improved with nutrition. The number of flowers per plant and individual weight of single flower both increased significantly with fertility level. The increased flower production under high levels of N and P_2O_5 (90 kg/ha each) might be attributed to increased branching and plant spread. The high N (300kg N/ha) and P (300 kg P_2O_5/ha) significantly increased the plant height and over all growth over control in tuberose cv. Single (Yadav *et al.*, 1985). The number of corms/per plant was also found significantly more by different levels of nitrogen and phosphorus as reported by Achal *et al.* (1984) in gladiolus cv. Vink's Glory. They have found that medium dose of nitrogen and low dose of phosphorus

resulted in higher number of corms/plot whereas the number of cormels/plot were recorded highest in low dose both N and P. Similar results were also reported by Armitage (1973) and Fernandes *et al.* (1974) in gladiolus. Parthiban and Abdul Khader (1991) studied the fertilizer requirement of tuberose (*Polianthes tuberosa* L.) cv. 'Single' have indicated that application of 100, 75 and 62.5 kg NPK/ha recorded the maximum growth of plants and number of spike/plant (1.72) maximum number of floret per spike (39.67) and maximum flower yield (3578.6 kg/ha). Sita Ram *et al.* (1997) conducted an experiment on tuberose (*Polianthes tuberosa* L.) cv. 'Single' and 'Double' and supplied with N at 0, 5, 10, 15 and 20 g/m^2. Half of N and a constant dose of P_2O_5 and K_2O (40 and 15 g/m^2) respectively were applied before plantation and the remaining N was applied 60 days after planting. N application significantly increased plant height, number of leaves per plant and other growth characters of both cultivars (i.e. Single and Double). Flowering was advanced by low N application rates (i.e. upto 10 g/m^2) but delayed by higher rates (15 or 20 g/m^2). Flower weight per spike and number of marketable spikes increased upto 20 g/m^2 in both cultivars. Leaf N content increased but P and K content decreased as N application rate increased. Correspondingly, leaf N content was positively correlated with

spike yield per unit area, while leaf P and K contents were negatively correlated with spike yield.

Bulb production is very important for propagation of tuberose. Increase in number of bulbs/plant has been reported by various workers. Bankar and Mukhopadhyay (1985) in cv. Single reported higher number of bulb per clump (22.12) when nitrogen was applied @ 20g/m^2 in two split doses i.e. half at 30 days and another half at 60 days after planting. Similar results were also obtained in gladiolus by Skalska (1970). In another trial, Mukhopadhyay and Bankar (1986) obtained a maximum number of bulblets/plant (12.13) with nitrogen application of 15 g/m^2 whereas without application of nitrogen gave 8.81 bulb/plant. They have further reported that higher dose of phosphorus did not influence the number of bulbs/plant as achieved with nitrogen. The number of corms/plot was also found significantly more by different levels of nitrogen and phosphorous as reported by Achal *et al.* (1984) in gladiolus cv. Vink's Glory. They have found that medium dose of nitrogen and low dose of phosphorous resulted in higher number of corm per plot whereas the number of cormels/plot was recorded highest in low dose of both nitrogen and phosphorous. Armitage (1973) also reported that different doses of N, P and K markedly influenced the number of corms. Potti and Arora (1986) obtained highest yield in terms of number of corms and cormels/plant in

cv. Sylvia of Gladiolus when 60g N/m^2 was applied. However, phosphorous and potassium application resulted in marginal increase in the number of corms and cormels. Similar results were also noted in gladiolus by Misra and Negi (1977). Deswal *et al.* (1983) reported that in gladiolus N and K application promoted number of corms/plant significantly while the effect of P was not significant.

2.5 Plant Geometry (Spacing) and their effect on growth and yield

Patil *et al.*, (1980) in tuberose found that in one year the highest number of tuberose flowers was obtained from bulbs spaced at 15 x 15cm planted singly/hill and in another year from bulbs spaced at 17 x 17cm and also planted singly/hill. Data are tabulated for other spacing and planting varieties.

Mukhopadhyay *et al.* (1986) in tuberose revealed that the number of flower spikes per plant increased with spacing and depth of planting. Bulb production increased with bulb size and spacing but decreased with depth of planting.

Patil *et al.* (1987) in tuberose observed that the highest yield of top quality flowers was obtained from the small rhizomes planted at 15 x 20cm.

Halepyati *et al.*, (1995) in tuberose revealed that plant densities had significant influence on the dry matter accumulation in reproductive parts only. Dry matter

accumulation of reproductive parts decreased, but cut flower yield increased with increase in plant density.

Mahanta and Paswan (1995) in tuberose reported that with regard to spacing, the number of leaves per plant decreased with plant density.

The time to flowering was shortest with S_3 (20 x 10cm) and longest with S_1 (20 x 20cm). The highest number of spikes/m^2 (58.55) and spike yield (169.18 q/ha) were obtained with the combination of D_1 (2.25-3.00cm) and S_3 (20 x 10cm).

Sharma *et al.* (1995) in tuberose observed that plants at the closer spacings grew taller than those at wider spacings, but the 3 closest spacings were detrimental to bulb production, flower spike length and numbers of florets per spike. The widest spacing gave the longest flower spike, and this and the next widest spacing gave the most florets/spike. It is suggested that the 2 closest spacings be used for growing tuberose for oil and loose flower production and that the 2 widest spacings be used for producing flowers for vase use and bulbs.

Khobragade *et al.* (1997) in tuberose found that plants at the widest spacing (20 x 30cm) produced more vegetative growth, the highest weight of bulbs and also exhibited improved flowering compared with plants at the narrower spacings of 20 x 10 and 20 x 20 cm.

Patel *et al.* (1997) in tuberose observed that neither plant height nor leaf width were affected by the different spacing or fertilizer treatments. Leaf number was highest with the widest spacing and highest NPK fertilizer rate. The yield of flower spikes/plant was similar in all treatments but the yield/ha was highest at the closest spacing (1 thin 047 thin 530 spikes/ha). Flower yield was highest with organic manure or the highest NPK fertilizer rate. Flower spike length and the number of florets/spike were highest at the closest spacing with the highest NPK rate. The highest cost: benefit ratios were obtained with the closest spacing (45cm x 15cm) and the highest NPK rate or organic manure.

Kumar *et al.* (1998) in tuberose revealed that bulb yields increased with increasing N rate and initial bulb size and with wider spacing.

Kumar and Singh (1998) in tuberose reported that scape emergence was earliest from the smallest bulbs planted at the widest spacing and given the highest N rate. Cut flower yield and quality and bulb production were greatest from the largest bulbs planted at the widest spacing and given the highest N rate.

Nagaraja *et al.* (1998) in tuberose found that the number of bulbs produced increased with increasing bulb size and spacing. Large bulbs planted in June at 30 x 30cm produced the highest bulb yield (109.78 g/plant).

Balak *et al.* (1999) in tuberose reported that application of 180 kg N/ha with a plant spacing of 45 x 30cm significantly influenced growth (plant height, leaf area,number of spikes and spike length), and was the best treatment for promoting flower yield.

Huang *et al.* (1999) in *Taxodium ascendens* observed that sowing density experiments were carried out with soyabeans and mung beans in year 3. The growth of T. ascendens was not significantly affected by wheat, rape, soyabeans and mung beans. When the trees were young (first 3 years), they did not depress crop yields, and a land equivalent ratio >1 was thus obtained together with a high yield of both components. The relative yields of the intercrops fell to >1 in the 4-yr-old stands at all spacings. The relative yield of wheat, soyabeans and rape was well >1 in the 5-yr-old stands. The realized productive coexistence suggested that rape had a higher ecological combining ability with T. ascendens than wheat and soyabeans.

Mohanty *et al.* (1999) found in tuberose that F_4 (325 kg N + 125 Kg P_2O_5 + 125 kg K_2O/ha), S_3 (30cm) and its combination resulted in the highest N, P and K uptake, both at50% flowering stage and harvesting stage.

Mosher and Turner (1999) in rose observed that the maximum number of basal shoots was formed at plant densities

of 4.20 and 3.32 plants/m^2 for Gabrielle and Kardinal, respectively. Within row spacing did not affect the number of flowering shoots per basal shoot. The single shoot planting system contained a mixed population of single stemmed R. hybrida (cvs. Gabrielle and Gerdo). Plants were grown in a field over a range of within row spacings to give 20-105 plants/m^2. Over 3 harvests, increasing the number of plants by 10 plants/m^2 reduced the proportion of flowering shoots by 4.4%. Expressed on a unit area basis, a 5-fold increase in plants/m^2 produced a 3-fold increase in stem production.

Nagaraja *et al.* (1999) in tuberose observed that plants at the wider spacing of 30 x 30cm recorded significantly higher plant height, increased numbers of leaves per clump and spikes per plant, and longer flowering duration. The wider spacing also resulted in better spike characters such as spike length, rachis length, number of florets per spike and fresh weight of spike.

Singh *et al.* (1999) in tuberose observed that the longest flower spikes and the highest numbers of spikes/clump resulted from June planting and the longest plant density. Shallow planting gave more spikes/clump. The number of bulbs/plant was highest for June planting, and this planting date also gave the largest bulbs. As plant density increased, the number of bulbs/plant decreased. Deep planting also gave more bulbs/plant than shallow planting.

Kartik *et al.* (2001) in rose reported that roses planted on flat ground, an in-row spacing of 20cm produced greater root dry weight and cliper than the 15cm spacing during both years. In 1997, shoot and total dry weight were greater when plants were grown at 20cm or 25cm in-row spacing versus 15cm spacing, while smaller differences between treatments were found in 1999.

CHAPTER – III

Materials and Methods

The present investigations entitled, "Studies on effect of nitrogen, plant geometry and biofertilizers on growth, flowering and bulb production in tuberose (*Polianthes tuberosa* L.) cv. Double" were carried out at the Experimental orchard and Laboratories, Department of Horticulture, CCS Haryana Agricultural University, Hisar, during 2001 and 2002. The materials and methodology used for carrying out these studies are described in this chapter under different sub heads.

3.1 Geographical location

The experimental orchards, Department of Horticulture, CCS Haryana Agricultural University, Hisar is situated in sub tropics at 29°10' North latitude and 75°46' East longitude with an elevation of 215.2 m above msl.

3.2 Climate

The climate of Hisar is very hot and dry during summer and very cold during winter season. The monsoon season remains warm and humid with average rainfall about

Studies on the effect of nitrogen, plant geometry and biofertilizers on growth, flowering and bulb production in tuberose (*Polianthes tuberosa* L.) Cv. Double

Plate 1 : Field area

425mm which is unevenly distributed in the year. The minimum and maximum temperature ranges between 7-11°C in winter and 40-46°C in summer. The observations recorded at meteorological observatory of the university are presented in Annexure-I.

3.3 Soil

The soil of experimental orchard field was sandy loam in texture with pH value 8.2. The physico-chemical analysis of the soil were carried out before start of experiment during both years as given in Table 1.

3.4 Land preparation

The land was brought to a fine tilth by repeated ploughing and leveled properly. Farm yard manure (FYM) was applied @ 30 tonnes per hectare and mixed well into the soil. Chemical fertilizer potassium was applied @ 100 kg per hectare by using murate of potash at the time of soil preparation.

3.5 Preparation of beds for experiment

The beds for planting of bulbs were prepared by maintaining bed size 1.00m x 1.00m. The total prepared beds were 144. In 48 beds planting was done at 20 x 20cm (having 25 plants/bed) apart from plant to plant and row to row. In other 48 beds planting was done at 20 x 25cm (having 20 plants/bed) apart from plant to plant and row to row. And in other 48 beds planting was done at 20 x 30cm (having 15 plants/bed) apart from plant to plant and row to row.

Table 1: Physico-chemical analysis of the experimental field soil.

Sr. No.	Character	Contents	Method used for analysis
1.	Texture	Sandy loam	International Pipette method (Piper, 1950)
2.	O.C. (%)	0.52	Walkley's and Black Rapid Titration method (Jackson, 1973)
3.	$CaCO_3$ (%)	2.66	Puri's method
4.	pH_2	8.2	Glass electrode pH meter, 1:2 soil water suspension (USDA Hand book No. 60, 1954)
5.	$E.C_2$ (dSm^{-1})	0.55	EC meter, 1:2 soil water suspension (USDA Hand book No. 60, 1954)
6.	Available Nitrogen (kg/ha)	187.5	Alkaline permanganate method
7.	Available phosphorus (kg/ha)	22.8	Olsen's method of extraction with $NaHCO_3$ at pH 8.5 (Olsen *et al.*, 1954)
8.	Available potassium (kg/ha)	408.5	Flame Photometer method (USDA Hand book No. 60, 1954)
9.	DTPA extractable zinc (ppm)	1.02	DTPA method (Lindsay and Norwel, 1965)

3.6 Planting Materials and Planting

The bulbs of tuberose cv. 'Double' used in the experiment, were obtained from the Department of Horticulture, CCS HAU, Hisar. The bulbs of uniform size (2 to 2.5cm in diameter) were selected and planted at a depth of 5.0cm from the tip of the bulb. The planting was done on 21st May in the year 2001 and on 3rd May in the year 2002.

3.7 Cultural practices

All the plants in whole of the experiment have received uniform cultural practices except various treatments of nitrogen and biofertilizers applications. An assured irrigation once in 5-10 days, depending upon the weather conditions was provided regularly. In order to make the field weed free and to conserve the moisture, hoeing was done as and when was needed.

3.8 Experiment

Studies on the effect of nitrogen, plant geometry and biofertilizers on growth, flowering and bulb production in tuberose (*Polianthes tuberosa* L.) cv. 'Double'.

3.8.1 Treatments

a) Main plot treatments:

i) Levels of nitrogen : 4 (0, 100, 200, 300 kg/ha)

Or 4 (0, 10, 20, 30 g/m^2)

ii) Plant population per square meter :

3 (20 x 20cm, 20 x 25cm, 20 x 30cm)

(25 plants) (20 plants) (15 plants) per plot

b) Sub plot treatments:

4 (0, *Azotobacter* (Mac-68),

Phosphorus solubilizing bact. (PSB),

Azospirillum)

In addition to above a basal dose of 6 g/m^2 P_2O_5 was also applied

Source of fertilizers

i. CAN

ii. Single super phosphate

Time of Application

Application of ½ nitrogen + full P_2O_5 was done at the time of field preparation and other ½ (half) nitrogen at spike emergence stage.

Replication : 3

Design : Split plot design

Size of plot/plot size : 1 x 1 m^2

Total no. of treatment combinations:

4 (nitrogen) x 3 (spacing) x 4 (Biofertilizers) = 48

Total number of plots (48 x 3) = 144

Total no. of bulbs for one year

48 x 25 = 1200

48 x 20 = 960

48 x 15 = 720

Total = 1200 + 960 + 720 = 2880

Plant to plant and row to row distance for all the (144) Plots:

48 plots have = 20 x 20cm (25 plants per plot)

48 plots have = 20 x 25cm (20 plants per plot)

48 plots have = 20 x 30cm (15 plants per plot)

Cultivar : Double

Date of planting : 21st May in the year 2001

3rd May in the year 2002

3.8.2 Treatments description

a) Main plot treatments

i) There are four levels of nitrogen (N) by using CAN with 25% N:

N_0 = No application of nitrogen

N_1 = 100kg/ha (i.e. 10g/m^2)

N_2 = 200kg/ha (i.e. 20g/m^2)

N_3 = 300kg/ha (i.e. 30g/m^2)

ii) Three levels of plant geometry (spacing):

S_1 = 20 x 20cm (i.e. 25 plants/plot)

S_2 = 20 x 25cm (i.e. 20 plants/plot)

S_3 = 20 x 30cm (i.e. 15 plants/plot)

All the 12 combinations of nitrogen and spacing were taken as main plot treatments:

1.	N_0S_1	7.	N_2S_1
2.	N_0S_2	8.	N_2S_2
3.	N_0S_3	9.	N_2S_3
4.	N_1S_1	10.	N_3S_1
5.	N_1S_2	11.	N_3S_2
6.	N_1S_3	12.	N_3S_3

b) Four types of biofertilizers were taken as sub plot treatments:

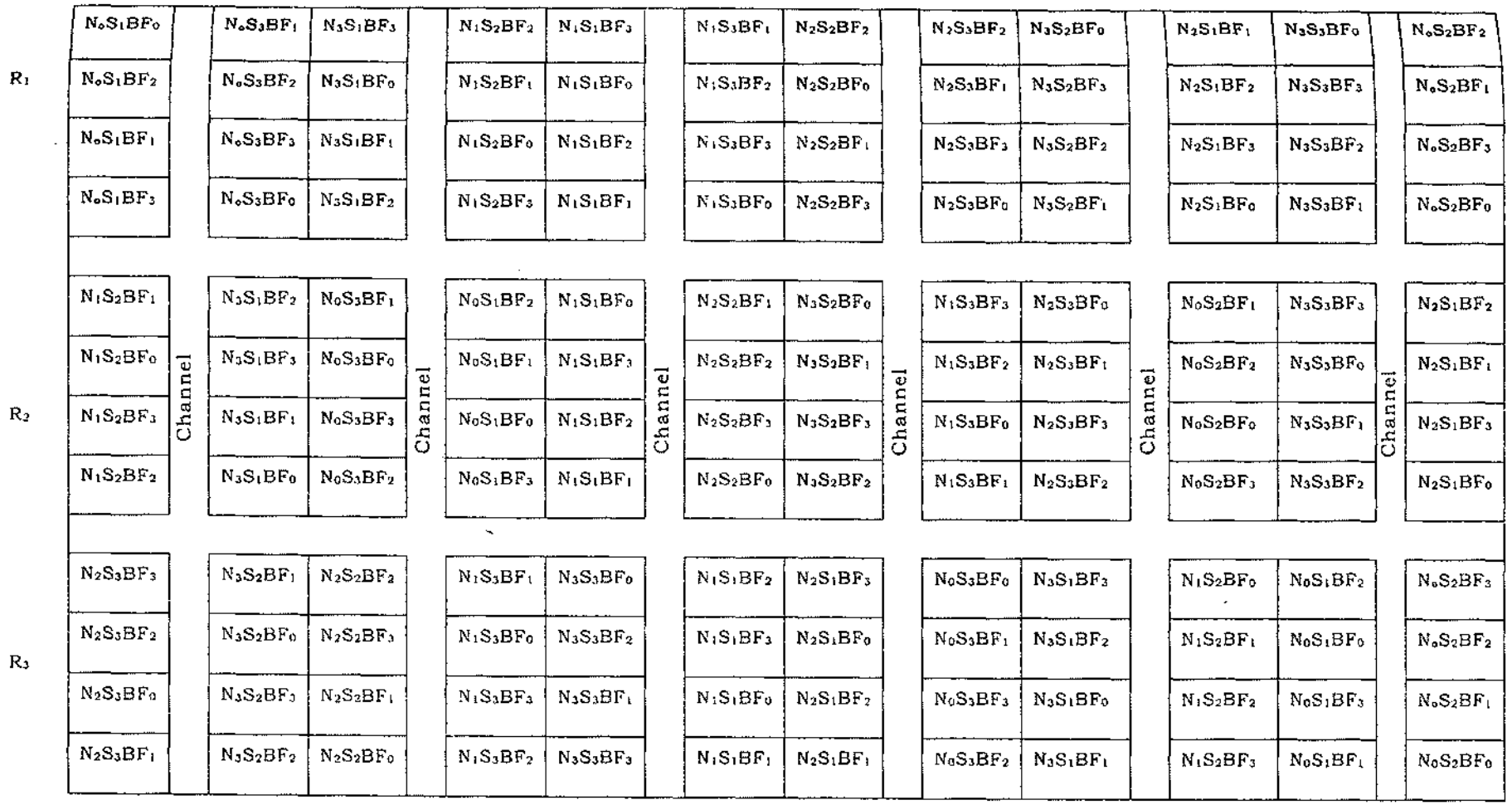
BF_0 = No application of biofertilizer.

BF_1 = *Azotobacter* application (Mac – 68).

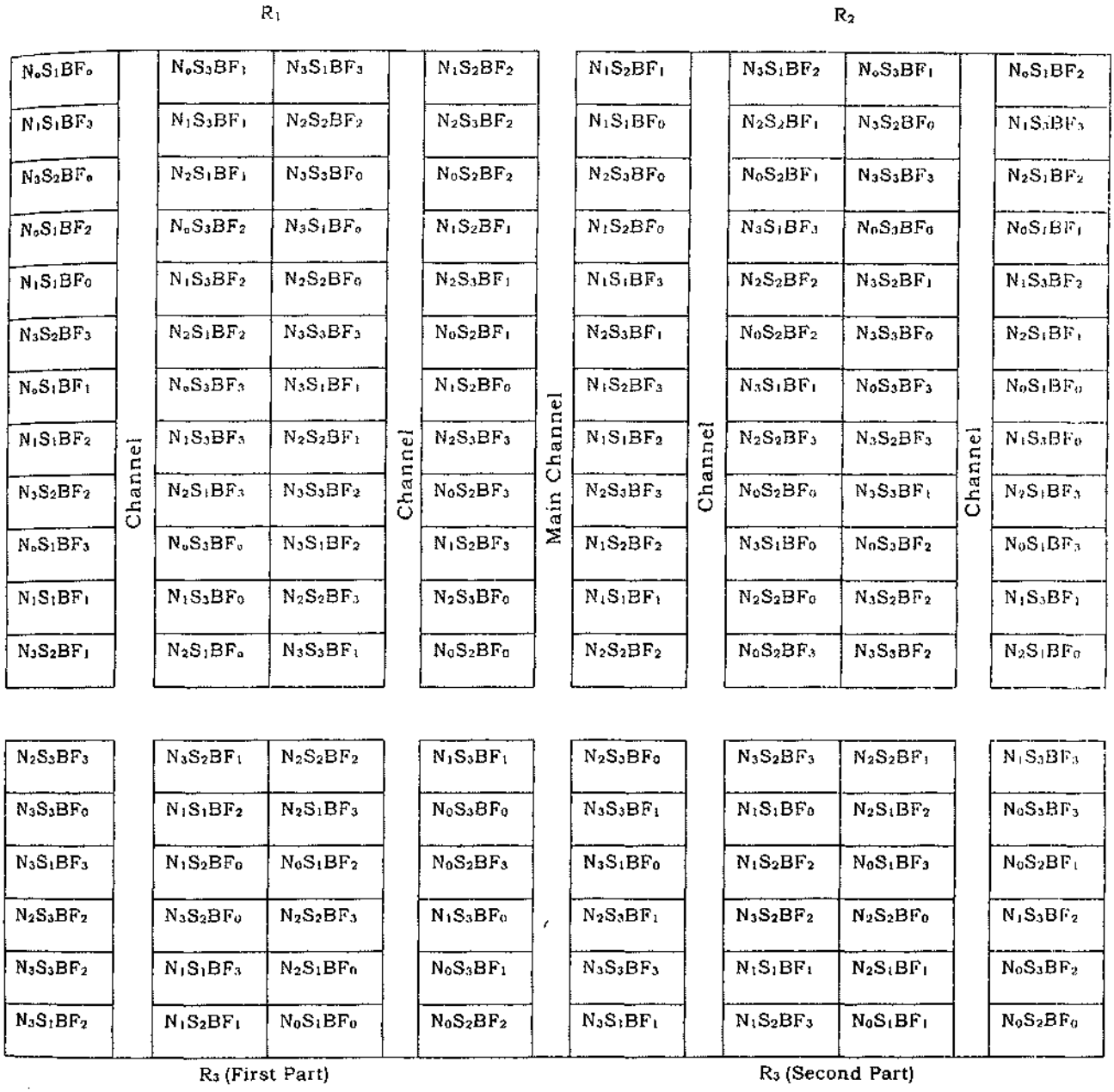
BF_2 = *Phosphorus Solubilizing Bacteria* (PSB) application.

BF_3 = *Azospirillum* application.

There were 48 treatments combinations adopting split plot design. In each replication the levels of nitrogen, spacing and biofertilizers types were randomized, one plot was kept as one unit for each treatment and set was replicated thrice in both the years. Field layout of both the years given below.



Field Layout of year 2001



Field Layout of year 2002

3.8.3 Methods of application of treatments.

a) Chemical fertilizer

i) Nitrogen

Half dose of nitrogen was applied as basal dose, just before planting of bulbs while remaining half dose of the nitrogen was applied at the time of spike emergence (after 100 days of planting) by top dressing method in both the years. Calcium ammonium nitrate (CAN) was the source of N used.

b) Plant geometry (spacing)

There were three plant geometry (spacing) used; Total plots were 144. Plot size was 1 x $1m^2$. Three replications were used. One replication have 48 plots. In 48 plots we used plant geometry (spacing) randomized, 16 plots have spacing 20 x 20cm (25 plants/plot), 16 plots have plant geometry (spacing) 20 x 25cm (20 plants/plot) and 16 plots have plant geometry (spacing) 20 x 30cm (15 plants/plot). And same pattern was repeated in replication two and three.

c) Biofertilizers

Biofertilizers are microbial inoculants consisting of living cells of micro-organisms like bacteria, algae and fungi alone or in combination, increasing crop productivity by way of helping in the biological nitrogen fixation, solubilization of insoluble fertilizer materials, stimulating plant growth or

decomposition of plant residues. The present study included three biofertilizers as mentioned in the treatments.

i) *Azotobacter*

Azotobacter is free living heterotrophic nitrogen fixing bacteria present in soil and fixes 20-30 kg N/ha per year. *Azotobacter* is multipurpose bioinoculant because it also produce growth promoting substances antibiotics, stimulants along with biological nitrogen fixation.

Inoculation method

A culture suspension was prepared by mixing one packet (200g) of *Azotobacter* culture in 10 litre of water. The bulbs of tuberose required for 48m^2 (i.e. 960 bulbs) were immersed in the suspension for 15-20 minutes, taken out and dried in shade for 15-20 minutes, before planting. The commercial culture of *Azotobacter* was supplied by Biofertilizer Production Technology Section Department of Microbiology CCS HAU, Hisar.

ii) *Phosphorus Solubilizing Bacteria* (PSB)

Phosphorus solubilizing biofertilizers are the micro-organisms (bacteria and fungi) which help in solubilization of fixed phosphorus that is these organisms change unavailable form of phosphorus to available form of phosphorus by liberating organic acids which mineralize organic phosphorus to a soluble form.

Inoculation method

One packet of commercial PSB inoculum was suspended in 10 litres of water and the bulbs of tuberose were immersed for 15-20 minutes. After that bulb were allowed to dry in shade and then planted in the plots. The source of commercial culture of phosphate solubilizing bacteria was same as in the case of *Azotobacter* culture.

iii) *Azospirillum*

Azospirillum is a free living nitrogen fixer and occurs in association with roots of almost all plants of agricultural importance. This culture is prepared by using highly efficient nitrogen fixing strain of the organism.

Among various crops tested for their response to *Azospirillum* cultures under different soil and agro-climatic conditions of our country, Jowar, Bajra, Ragi and millets. Barley, Oats and several forage grasses and fodder crops responded favourably to bacterial inoculation. The response of these crops to inoculation with *Azospirillum* on grain/fodder yield is almost equivalent to that attainable due to the application of 15-20 kg N/ha.

Inoculation method

A culture suspension was prepared by mixing one packet (150-200g) of *Azospirillum* culture in 10 litres of water. The bulbs of tuberose required for 48 m^2 (i.e. 960 bulbs) were immersed in the suspension for 15-20 minutes, taken out and dried in shade for 15-20 minutes before planting. The source of commercial culture of *Azospirillum* was same as in the case of *Azotobacter* culture.

3.8.4 Observations recorded

Observations were recorded from five randomly selected plants from each treatment (Plot) leaving the border plants. The data for following parameters were collected in both the years.

3.8.4.1 Growth parameters

i) Number of days taken for sprouting of bulbs

Time taken for sprouting of bulb was recorded from date of planting to the date of appearance of cotyledonary leaves. Average for all bulbs per plots was worked out.

ii) Percent sprouting of bulbs

Sprouting percentage was calculated on the basis of number of bulbs sprouted out of the total number of bulbs planted.

iii) Plant height

Plant height was measured from the base of plant to the tip of spike at the time of full bloom stage with the help of meter rod and the average plant height was worked out.

iv) No. of leaves per plant

Number of leaves per plant were counted on 90th day after planting of bulbs. The average number of leaves per plant were worked out.

v) Length of leaves

Length of leaves were measured with the help of meter rod at the time of full bloom stage and averaged.

vi) Leaf area

The five leaves (fully expanded and recently matured) were taken from each plant at the time of full bloom stage and leaf area was worked out with the help of leaf area meter.

3.8.4.2 Flowering parameters

i) Number of days taken for spike emergence

Number of days taken for appearance of spike from date of planting of bulbs were recorded and average number of days were worked out.

ii) Number of days taken for opening of basal floret

Time taken in basal floret opening was recorded from the date of planting of bulbs to the date of basal floret opening and average time in days was calculated per plant.

iii) Length of spike

Length of spike per plant was measured with the help of meter rod from the point of emergence to the tip of spike at the time of opening of first floret.

iv) No. of florets/spike

The number of florets produced in a spike were counted and average was worked out.

v) Spike girth

It was noted at a level below the Ist floret.

vi) Rachis length

From portion of flower spike bearing floret to the top of floret was measured to measure the length of rachis.

vii) Duration of flowering

The period between opening of first floret and last floret of a spike per plant of same plot was noted and the average was worked out for expressing duration of flowering.

3.8.4.3 Bulb production

i) Number of bulbs produced/plant

After harvesting or digging of the bulb, the number of bulbs and bulblets per plant were counted and their average number was worked out accordingly.

ii) Weight of bulbs/plant

The weight of bulbs and bulblets per plant were recorded on physical balance after harvesting the bulbs from the plot and their average weight was calculated.

iii) Diameter of bulb

Diameter of bulb recorded with the help of digital verneer calliper.

3.8.4.4 Root characters

Five plants per plot were carefully uprooted without damaging roots. The heavy irrigation was applied for two days continuously, water allowed to stagnate in plots and then plants were carefully uprooted.

i) Number of roots developed per plant

Total number of roots were counted individually. Finally the average number of roots were recorded.

ii) Average length of root per plant

The length of roots were measured and average root length of each plant were recorded.

iii) Total root biomass

The uprooted plants were collected from the experimental field to determine the total root biomass. These were Ist dried in sunlight and then in oven at 60°C till constant weight was obtained. Finally the total root biomass were recorded with the help of electrical balance.

3.8.4.5 Leaf and soil analysis

i) Leaf analysis

The fully developed and recently matured (i.e. 3rd whirl of leaves from outside) leaves were randomly sampled from each plot at full bloom stage for estimation of N, P, K and Zn.

a) Estimation of nitrogen

Nitrogen was estimated by Nessler's reagent method as per standard procedure (Jackson, 1967).

b) Estimation of phosphorus

The total phosphorus content was determined according to vandomolybdate phosphate yellow colour method (Jackson, 1967).

c) Estimation of potassium

Potassium was estimated by flame photometer method as described by Pier (1966).

d) Estimation of zinc

Zinc was estimated by inductively coupled plasma 400 spectrophotometer.

ii) Soil analysis

Available nitrogen was determined by alkaline permanganate method and organic carbon by Walkley's and Black Rapid Titration method. Phosphorus was estimated by Olsen's method as described by Jackson (1973). Available potash was determined by flame photometer (ammonium acetate

solution) method (USDA Hand book No. 60, 1954). Available Zn was determined by DTPA method given by Lindsay and Norwel, 1965. Soil pH was determined by glass electrode pH meter, 1:2 soil water suspension (by USDA Hand book No. 60, 1954). Soil EC (dSm^{-1}) was determined by EC meter, 1:2 soil water suspension (by USDA Hand book No. 60, 1954).

CHAPTER – IV

Results

In the present investigation, interaction effect of biofretilizers with nitrogen and plant geometry (spacing) on growth, flowering, bulb production, root characters and N, P, K an Zn contents in tuberose were studied. Th results are presented under different headings in this chapter as given below:

4.1 Growth Parameters

4.1.1 Number of days taken for sprouting of bulbs

The perusal of data presented in Table 2 and 3 showed that application of nitrogen had significantly advanced the sprouting of bulbs over the control during both the years. The N_2 level (200 Kg N ha^{-1}) was found to be at par with N_3 level (300 Kg N ha^{-1}) and these both were significantly advanced the sprouting of bulbs as compared to N_1 level (100 Kg N ha^{-1}) during 2001 and 2002, respectively. The bulbs sprouted in 12.20 and 12.15 days at N_3 level, which was at par with N_2 level during 2001 and 2002, respectively whereas, in control bulbs

Table 2 : ***Effect of nitrogen, plant geometry and biofertilizers on number of days taken for sprouting of bulbs in tuberose.***

Treatments		2001							
		BF_0	BF_1	BF_2	BF_3	Mean (N x S)	Mean (S x BF)	Overall mean (N)	Overall Mean (S)
	S_1	20.30	16.58	17.92	18.45	18.31	13.23		14.44
N_0	S_2	19.20	15.50	16.80	17.37	17.22	11.91		
	S_3	18.28	14.64	15.87	16.45	16.31	14.62	17.28	
	Mean	19.26	15.57	16.86	17.42		13.66		
	S_1	17.60	14.76	15.98	16.51	16.21	13.00		
N_1	S_2	16.51	13.70	14.95	15.42	15.15	15.72		13.97
	S_3	15.40	12.62	13.90	14.33	14.06		15.14	
	Mean	16.50	13.69	14.94	15.42		14.32		
	S_1	14.50	12.28	13.55	13.98	13.58	14.73		
N_2	S_2	13.40	11.15	12.43	12.92	12.48			
	S_3	12.46	10.30	11.55	11.97	11.57	15.25	12.54	
	Mean	13.45	11.24	12.51	12.96		12.56		
	S_1	13.64	11.52	12.90	13.08	12.79	13.83		
N_3	S_2	12.58	10.45	11.87	12.06	11.74	14.25		
	S_3	11.47	9.35	10.78	11.02	10.66		12.20	13.35
	Mean	12.56	10.44	11.88	12.05				
Overall Mean (BF)		15.20	12.49	13.79	14.21				

C.D. at 5%

N	=	0.44	N x S	=	0.89
S	=	0.38	N x BF	=	1.03
BF	=	0.51	S x BF	=	NS
			N x S x BF	=	NS

Table 3 : **Effect of nitrogen, plant geometry and biofertilizers on number of days taken for sprouting of bulbs in tuberose.**

Treatments		2002							
		BF_0	BF_1	BF_2	BF_3	Mean (N x S)	Mean (S x BF)	Overall mean (N)	Overall Mean (S)
	S_1	20.00	16.38	17.67	18.16	18.05	14.88		15.23
N_0	S_2	19.52	15.91	17.07	17.73	17.56	12.17		
	S_3	19.42	15.77	17.01	17.63	17.46	13.46	17.69	
	Mean	19.65	16.02	17.25	17.84		13.92		
	S_1	18.85	15.97	17.26	17.73	17.45			
N_1	S_2	16.27	13.42	14.72	15.12	14.88	15.46		14.22
	S_3	15.64	12.91	14.13	14.60	14.32	12.78	15.55	
	Mean	16.92	14.10	15.37	15.82		14.07		
	S_1	14.24	12.05	13.25	13.77	13.33	14.47		
N_2	S_2	13.70	11.56	12.83	13.22	12.83			
	S_3	13.69	11.40	12.69	13.13	12.73	16.48	12.96	
	Mean	13.88	11.67	12.92	13.38		13.81		
	S_1	14.84	12.79	14.14	14.35	14.03	15.08		
N_3	S_2	12.32	10.25	11.63	11.82	11.51	15.51		
	S_3	11.75	9.59	11.01	11.31	10.92		12.15	13.59
	Mean	12.97	10.88	12.26	12.49				
Overall Mean (BF)		15.60	12.92	14.20	14.63				

C.D. at 5%

N	=	0.90	N x S	=	1.93
S	=	0.58	N x BF	=	2.22
BF	=	1.11	S x BF	=	NS
			N x S x BF	=	NS

sprouted in 17.28 and 17.69 days during 2001 and 2002, respectively. It is further clear from the data that days taken for sprouting of bulbs were also significantly advanced with the increasing levels of plant geometry (spacing) over S_1 (20 x 20cm) and S_2 (20 x 25 cm) levels of plant geometry (spacing) during both the years. The bulbs sprouted in 13.35 and 13.59 days at S_3 (20 x 30 cm)level during 2001 and 2002, respectively whereas, in S_1 level bulbs sprouted in 14.44 and 15.23 days during 2001 and 2002, respectively. It is also clear from the data that application of only BF_1 (*Azotobacter*) biofertilizer had significantly shortened the sprouting period over control during both the years. The minimum days for sprouting of buls i.e. 12.49 and 12.92 were recorded with the application of BF_1 (*Azotobacter*) level of biofertilizer whereas, maximum days for sprouting of bulbs i.e. 15.20 and 15.60 were recorded in control in 2001 and 2002, respectively. The interactions of N x S and N x BF were also found significant as in both the treatments the sprouting period was reduced. The interactions of SxBF and NxSxBF were found to be non-significant during both the years.

4.1.2 Per cent sprouting of bulbs

A significant increase in per cent sprouting of bulbs was observed with the increasing levels of nitrogen over the control during both the years. The N_2 level was found to be at par with N_3 level & these both were significantly higher as

compared to N_1 level in both the years (Table 4 & 5). Maximum per cent sprouting (89.90% and 92.77%) were recorded under treatment N_3, which was at par with treatment N_2 whereas, minimum per cent sprouting (81.96% and 84.73%) were recorded without application of nitrogen, during 2001 and 2002, respectively. It is further clear from the data that per cent sprouting of bulbs was also increased significantly with the increasing levels of plant geometry (spacing) over S_1 and S_2 levels of plant geometry (spacing) during both the years. Maximum per cent sprouting i.e. 88.04% and 90.06% were recorded under S_3 level of plant geometry (spacing), whereas minimum per cent sprouting i.e 86.51% and 88.00% were recorded under S_1 level of plant geometry (spacing) during 2001 and 2002, respectively. It is also clear from the data that application of different biofertilizers had also increased the per cent sprouting of bulbs significantly over the control, with maximum per cent sprouting in case of BF_2 (*Phosphorus Solubilizing Bacteria*) i.e. 87.90% and 90.23% during 2001 and 2002, respectively. The interaction of NxS and NxBF had also increased the per cent sprouting of bulbs significantly in both the years. The interaction of SxBF and NxSxBF were found to be non-significant in both the years.

Table 4 : Effect of nitrogen, plant geometry and biofertilizers on percent sprouting in tuberose.

Treatments		2001							
		BF_0	BF_1	BF_2	BF_3	Mean (N x S)	Mean (S x BF)	Overall mean (N)	Overall Mean (S)
	S_1	79.20	81.53	81.40	81.68	80.96	85.17		86.51
N_0	S_2	80.15	82.40	82.35	82.62	81.88	87.57		
	S_3	81.28	83.50	83.62	83.78	83.05	87.65	81.96	
Mean		80.21	82.48	82.46	82.69		87.51		
	S_1	83.30	85.52	85.64	85.45	84.98			
N_1	S_2	84.48	86.60	86.75	85.60	85.86	86.30		87.11
	S_3	85.55	87.74	87.90	86.75	86.99	88.62	85.94	
Mean		84.44	86.62	86.76	85.93		88.73		
	S_1	85.95	88.44	88.50	88.71		88.51		
N_2	S_2	86.80	89.30	89.49	89.62	87.90			
	S_3	87.92	90.40	90.65	90.70	88.81	85.07	88.88	
Mean		86.89	89.38	89.55	89.68	89.92	87.37		
	S_1	87.55	89.88	89.84	89.95		87.41		
N_3	S_2	88.42	90.81	90.79	90.90	89.31	87.28		
	S_3	89.50	91.95	91.88	91.96	90.23		89.90	88.04
Mean		88.49	90.88	90.84	90.94	91.32			
Overall Mean (BF)		85.51	87.84	87.90	87.81				

C.D. at 5%

N	=	1.01	N x S	=	2.24
S	=	0.54	N x BF	=	2.58
BF	=	1.29	S x BF	=	NS
			N x S x BF	=	NS

Table 5 : Effect of nitrogen, plant geometry and biofertilizers on percent sprouting of bulbs in tuberose.

Treatments		2002							
		BF_0	BF_1	BF_2	BF_3	Mean (N x S)	Mean (S x BF)	Overall mean (N)	Overall Mean (S)
	S_1	82.17	84.81	84.60	85.24	84.21	87.18		88.00
N_0	S_2	83.10	85.53	85.35	85.65	84.91	89.60		
	S_3	82.80	85.65	85.81	85.99	85.07	89.83	84.73	
Mean		82.69	85.33	85.26	85.63		89.58		
	S_1	85.89	88.20	88.33	88.12	87.64			
N_1	S_2	86.97	88.95	89.12	87.97	88.26	87.79		89.10
	S_3	89.40	91.58	91.80	90.74	90.88	90.24	88.93	
Mean		87.42	89.58	89.75	88.95		90.40		
	S_1	89.86	92.19	92.41	92.60	91.77	90.23		
N_2	S_2	89.93	92.30	92.44	92.68	91.84			
	S_3	90.11	92.57	92.96	93.14	92.20	88.31	91.94	
Mean		89.97	92.36	92.61	92.81		90.65		
	S_1	90.77	93.10	93.05	93.36	92.57	90.69		
N_3	S_2	90.80	93.18	93.14	93.25	92.60	90.58		
	S_3	91.28	93.79	93.70	93.81	93.15		92.77	90.06
Mean		90.95	93.36	93.30	93.48				
Overall Mean (BF)		87.76	90.17	90.23	90.15				

C.D. at 5%

N	=	1.19	N x S	=	2.37
S	=	0.51	N x BF	=	2.74
BF	=	1.37	S x BF	=	NS
			N x S x BF	=	NS

4.1.3 Plant height

The observations recorded on plant height are presented in Table 6 & 7. It is clear from the data that plant height increased significantly with increasing levels of nitrogen over the control in both the years. The N_3 treatment was significantly higher over N_2 and N_1 treatments during both the years. The increasing plant geometry (spacing) signifincatly decreased the plant height over the S_1 and S_2 levels of plant geometry (spacing) in both the years. It is further clear that the treatment N_3 has produced longest plant height i.e. 70.01cm and 72.01cm, whereas the shortest plant height i.e. 56.14cm and 58.23cm were obtained without application of nitrogen in 2001 and 2002, respectively. But in case of plant geometry (spacing) plant height decreased with the increasing plant geometry (spacing). The longest plant height i.e. 67.01cm and 68.00cm were recorded under the S_1 during both the years respectively. Similarly in case of different biofertilizers plant height was increased significantly over control by all the biofertilizers except BF_3 (*Azospirillum*) in 2001, with maximum plant height in case of BF_1 (*Azotobacter*) biofertilizer i.e. 67.08 cm and 68.09cm during 2001 & 2002, respectively. The interaction of NxS and SxBF showed significant increase in the plant height, in both the years. The interaction of NxBF and NxSxBF showed significant

Table 6 : Effect of nitrogen, plant geometry and biofertilizers on plant height (cm) in tuberose.

Treatments		2001							
		BF_0	BF_1	BF_2	BF_3	Mean (N x S)	Mean (S x BF)	Overall mean (N)	Overall Mean (S)
	S_1	56.01	59.70	57.87	56.45	57.51	66.00		67.01
N_0	S_2	54.72	57.15	56.30	55.50	55.92	68.92		
	S_3	53.03	56.63	55.40	54.90	54.99	67.14	56.14	
	Mean	54.59	57.83	56.52	55.62		65.99		
	S_1	63.70	66.84	64.60	63.35	64.62			
N_1	S_2	61.15	64.43	63.60	62.71	62.97	63.95		65.40
	S_3	59.10	63.20	62.64	61.38	61.58	66.70	63.06	
	Mean	61.32	64.82	63.61	62.48		65.84		
	S_1	69.50	71.62	70.30	69.80	70.31	65.10		
N_2	S_2	67.41	70.10	69.42	68.60	68.88			
	S_3	65.20	68.31	67.62	66.40	66.88	61.92	68.69	
	Mean	67.37	70.01	69.11	68.27		65.64		
	S_1	70.80	73.50	71.80	70.38	71.62	64.84		
N_3	S_2	68.52	71.10	70.05	69.60	69.82	63.65		
	S_3	66.33	70.41	69.70	67.90	68.59		70.01	64.01
	Mean	68.55	71.67	70.52	69.29				
Overall Mean (BF)		63.96	67.08	65.94	64.92				

C.D. at 5%

N	=	0.49	N x S	=	1.76
S	=	0.43	N x BF	=	2.03
BF	=	1.01	S x BF	=	1.76
			N x S x BF	=	3.51

Table 7 : ***Effect of nitrogen, plant geometry and biofertilizers on plant height (cm) in tuberose.***

Treatments		2002							
		BF_0	**BF_1**	**BF_2**	**BF_3**	**Mean (N x S)**	**Mean (S x BF)**	**Overall mean (N)**	**Overall Mean (S)**
	S_1	57.83	61.65	59.91	58.63	59.51	66.74		68.00
N_0	S_2	56.71	59.45	58.70	57.91	58.20	69.83		
	S_3	54.90	58.62	57.45	56.90	56.97	68.10	58.23	
	Mean	56.48	59.91	58.69	57.82		67.33		
	S_1	65.40	68.69	66.41	65.93	66.61			
N_1	S_2	62.99	66.30	65.59	64.72	64.90	64.82		66.44
	S_3	60.93	65.25	64.53	63.34	63.51	67.73	65.01	
	Mean	63.11	66.75	65.51	64.66		66.95		
	S_1	71.33	73.54	72.27	71.81	72.24	66.24		
N_2	S_2	69.20	72.10	71.46	70.75	70.88			
	S_3	67.50	70.40	69.79	68.58	69.07	62.90	70.73	
	Mean	69.34	72.01	71.17	70.38		66.70		
	S_1	72.40	75.44	73.80	72.93	73.64	65.88		
N_3	S_2	70.38	73.07	72.05	71.57	71.77	64.69		
	S_3	68.28	72.52	71.73	69.95	70.62		72.01	65.04
	Mean	70.35	73.68	72.53	71.48				
Overall Mean (BF)		64.82	68.09	66.98	66.09				

C.D. at 5%

N	=	0.40	N x S	=	2.11
S	=	0.35	N x BF	=	NS
BF	=	1.22	S x BF	=	2.11
			N x S x BF	=	**NS**

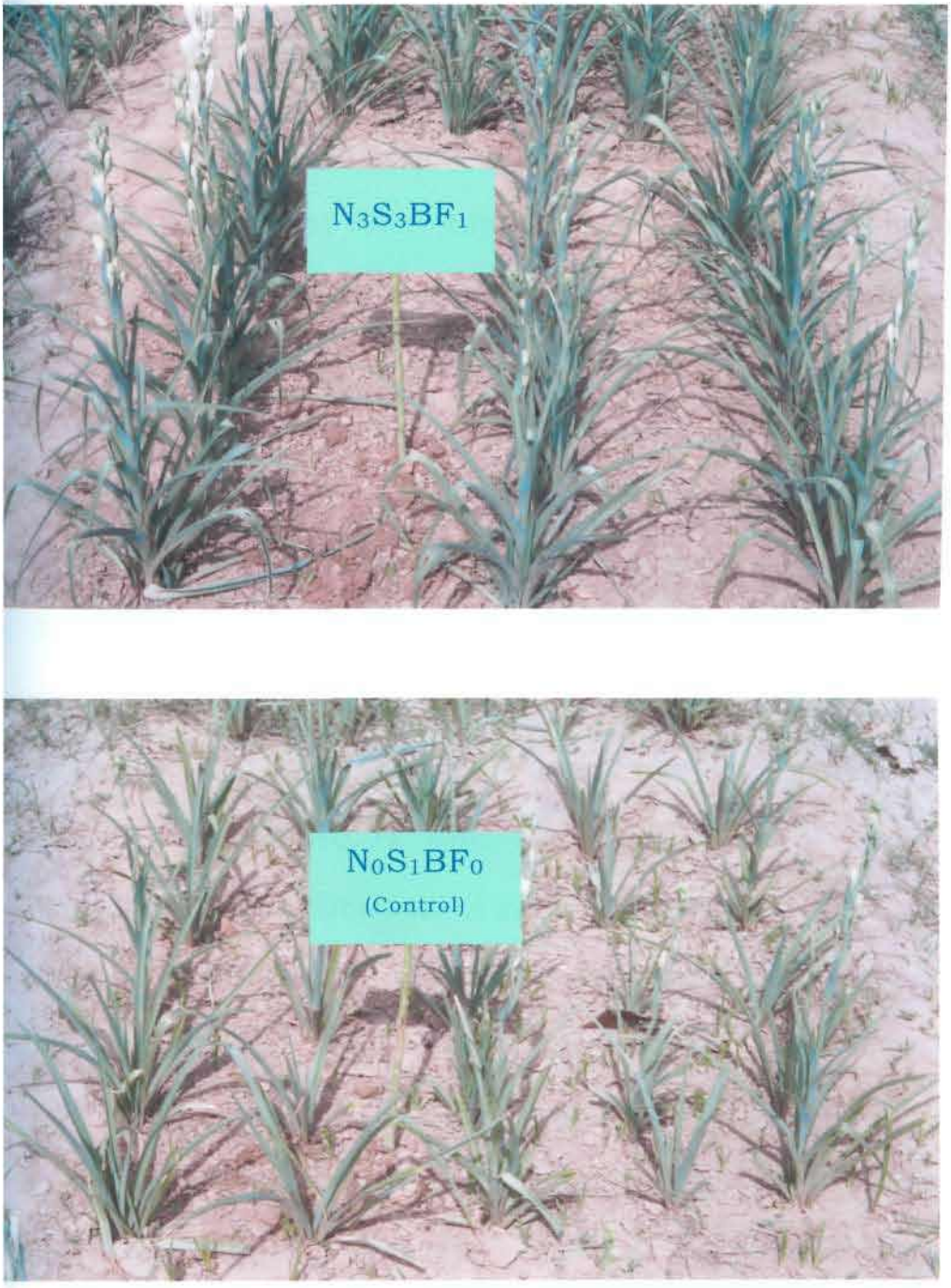


Plate 2: Effect of nitrogen, plant geometry and biofertilizers on plant height

increase in plant height in the year 2001, but showed non-significant increase in plant height in the year 2002.

4.1.4 Number of leaves per plant

It is evident from the Table 8 & 9 that application of nitrogen, plant geometry (spacing) at their increasing levels and different biofertilizers had increased significantly the number of leaves in both the years. It is further clear from the data that the increasing levels of nitrogen had increased significantly the number of leaves per plant over the control in both the years. The N_3 treatment was significantly higher over the N_2 and N_1 treatments during both the years. Maximum number of leaves (59.02 and 62.07) per plant were recorded under treatment N_3, whereas, minimum (40.77 and 43.78) number of leaves were produced without application of nitrogen during 2001 and 2002, respectively. Perusal of the data has further revealed that number of leaves per plant were also increased significantly with the increasing levels of plant geometry (spacing) over S_1 and S_2 levels of plant geometry (spacing) during both the years. Maximum number of leaves per plant i.e. 55.94 and 57.62 were obtained with the S_3 level of plant geometry (spacing) whereas, minimum number of leaves (49.83 and 51.72) were observed with S_1 level of plant geometry (spacing) in 2001 and 2002, respectively. Perusal of the data also revealed that application of different biofertilizers had increased significantly the number of

Table 8 : Effect of nitrogen, plant geometry and biofertilizers on number of leaves per plant in tuberose

Treatments		2001							
		BF_0	BF_1	BF_2	BF_3	Mean (N x S)	Mean (S x BF)	Overall mean (N)	Overall Mean (S)
	S_1	35.10	40.34	38.43	35.15	37.26	47.46		49.83
N_0	S_2	38.62	43.52	41.70	40.51	41.09	52.27		
	S_3	41.20	46.87	44.47	43.27	43.95	50.69	40.77	
	Mean	38.31	43.58	41.53	39.64		48.92		
	S_1	43.70	48.07	46.80	45.53	46.03			
N_1	S_2	46.73	51.40	49.90	48.61	49.16	50.65		53.06
	S_3	49.35	54.15	52.55	51.30	51.84	55.29	49.01	
	Mean	46.59	51.21	49.75	48.48		53.70		
	S_1	52.40	57.15	55.67	54.45	54.92	52.61		
N_2	S_2	55.80	60.10	58.52	57.40	57.96			
	S_3	58.65	63.35	61.60	60.72	61.08	53.35	57.99	
	Mean	55.62	60.20	58.60	57.52		58.39		
	S_1	53.62	58.50	56.87	55.53	56.13	56.49		
N_3	S_2	56.43	61.15	59.68	58.90	59.04	55.52		
	S_3	59.20	64.18	62.35	61.80	61.88		59.02	55.94
	Mean	56.42	61.28	59.63	58.74				
Overall Mean (BF)		50.48	55.32	53.63	52.35				

C.D. at 5%

N	=	0.51	N x S	=	1.53
S	=	0.44	N x BF	=	1.77
BF	=	0.89	S x BF	=	1.53
			N x S x BF	=	3.07

Table 9 : Effect of nitrogen, plant geometry and biofertilizers on number of leaves per plant in tuberose.

Treatments		2002							
		BF_0	BF_1	BF_2	BF_3	Mean (N x S)	Mean (S x BF)	Overall mean (N)	Overall Mean (S)
	S_1	37.62	43.14	41.32	40.13	40.55	49.14		51.72
N_0	S_2	41.44	46.38	44.64	43.50	43.99	54.11		
	S_3	44.17	49.46	47.27	46.24	46.79	52.43	43.78	
	Mean	41.08	46.33	44.41	43.29		51.19		
	S_1	47.00	51.48	49.95	48.54	49.24			
N_1	S_2	49.80	54.37	52.91	51.66	52.19	52.52		54.81
	S_3	52.33	57.71	55.97	54.49	55.13	57.12	52.19	
	Mean	49.71	54.52	52.94	51.56		55.35		
	S_1	55.60	60.10	58.57	57.46	57.93	54.26		
N_2	S_2	58.94	63.60	61.15	60.00	60.92			
	S_3	61.25	66.10	64.42	63.67	63.86	54.98	60.91	
	Mean	58.60	63.27	61.38	60.38		60.12		
	S_1	56.33	61.71	59.87	58.62	59.13	58.27		
N_3	S_2	59.90	64.14	62.70	61.87	62.15	57.31		
	S_3	62.17	67.19	65.42	64.85	64.91		62.07	57.67
	Mean	59.47	64.35	62.66	61.78				
Overall Mean (BF)		52.21	57.12	55.35	54.25				

C.D. at 5%

N	=	0.26	N x S	=	NS
S	=	0.22	N x BF	=	NS
BF	=	1.38	S x BF	=	NS
			N x S x BF	=	NS

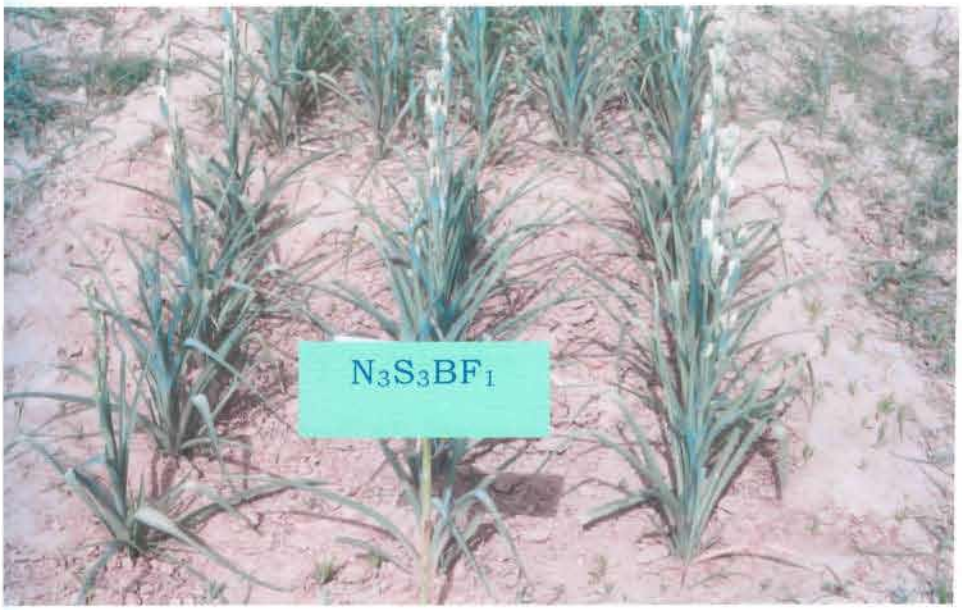


Plate 3: Effect of nitrogen, plant geometry and biofertilizers on number of leaves per plant

leaves per plant over the control during both the years. The maximum number of leaves per plant i.e. 55.32 and 57.12 were obtained with the application of BF_1 (*Azotobacter*) level of biofertilizer, whereas, minimum number of leaves (50.48 and 52.21) were observed without application of biofertilizers in 2001 and 2002, respectively. All the interactions had increased significantly the number of leaves in first year but they were non-significant in second year.

4.1.5 Length of leaves (cm)

It is clear from the Table 10 & 11 that application of nitrogen, plant geometry (spacing) at their increasing levels and different biofertilizers had increased significantly the length of leaves in both the years. It is further clear from the data that the increasing levels of nitrogen had increased significantly the length of leaves over the control but N_2 and N_3 treatments were found to be at par and these both were significantly higher as compared to N_1 treatment in both the years. Maximum length of leaves (39.24cm and 40.62cm) were recorded under treatment N_3 which was at par with treatment N_2, whereas, minimum length of leaves i.e. 32.95cm and 34.50cm were produced without application of nitrogen during 2001 and 2002, respectively. Perusal of the data has further revealed that length of leaves were also increased significantly with the increasing levels of plant geometry (spacing) over S_1 and S_2 levels of plant geometry

Table 10 : Effect of nitrogen, plant geometry and biofertilizers on length of leaves (cm) in tuberose.

Treatments		2001							
		BF_0	BF_1	BF_2	BF_3	Mean (N x S)	Mean (S x BF)	Overall mean (N)	Overall Mean (S)
	S_1	30.45	32.90	32.10	31.80	31.81	34.57		35.97
N_0	S_2	31.60	34.17	33.19	32.69	32.91	37.07		
	S_3	32.75	35.50	34.40	33.86	34.13	36.29	32.95	
	Mean	31.60	34.19	33.23	32.78		35.96		
	S_1	33.34	35.74	35.12	34.88	34.77			
N_1	S_2	34.85	37.30	36.50	36.20	36.21	35.94		37.33
	S_3	36.04	38.94	37.79	37.09	37.47	38.43	36.15	
	Mean	34.74	37.33	36.47	36.06		37.64		
	S_1	36.25	38.85	37.85	37.30	37.56	37.33		
N_2	S_2	37.70	40.05	39.34	39.15	39.06			
	S_3	38.85	41.30	40.51	40.20	40.22	37.05	38.95	
	Mean	37.60	40.07	39.23	38.88		39.62		
	S_1	36.56	39.09	38.39	38.18	38.06	38.72		
N_3	S_2	37.92	40.51	39.82	39.60	39.46	38.31		
	S_3	38.87	41.05	40.50	40.40	40.21		39.24	38.42
	Mean	37.78	40.22	39.57	39.39				
Overall Mean (BF)		35.85	38.37	37.55	37.20				

C.D. at 5%

N	=	0.32	N x S	=	1.12
S	=	0.28	N x BF	=	1.29
BF	=	0.65	S x BF	=	NS
			N x S x BF	=	NS

Table 11 : Effect of nitrogen, plant geometry and biofertilizers on length of leaves (cm) in tuberose.

Treatments		2002							
		BF_0	BF_1	BF_2	BF_3	Mean (N x S)	Mean (S x BF)	Overall mean (N)	Overall Mean (S)
	S_1	31.58	34.61	34.00	33.48	33.42	35.62		37.12
N_0	S_2	33.19	35.93	34.81	33.98	34.48	38.35		
	S_3	34.20	37.30	35.94	35.02	35.62	37.49	34.50	
	Mean	32.99	35.95	34.92	34.16		37.02		
	S_1	34.85	36.86	36.14	35.70	35.89			
N_1	S_2	35.66	39.10	38.23	37.81	37.70	36.96		38.50
	S_3	37.38	40.04	39.07	38.46	38.74	39.95	37.44	
	Mean	35.96	38.67	37.81	37.32		38.81		
	S_1	37.65	40.40	39.33	38.91	39.07	38.30		
N_2	S_2	39.26	41.78	40.34	40.04	40.36			
	S_3	39.64	42.67	41.96	41.62	41.48	38.01	40.30	
	Mean	38.85	41.62	40.55	40.19		40.85		
	S_1	37.71	40.85	39.82	39.33	39.43	39.90		
N_3	S_2	39.05	42.30	41.17	40.71	40.81	39.35		
	S_3	40.16	42.73	41.95	41.64	41.62		40.62	39.53
	Mean	38.97	41.96	40.95	40.56				
Overall Mean (BF)		36.86	39.72	38.73	38.23				

C.D. at 5%

N	=	0.38	N x S	=	1.92
S	=	0.33	N x BF	=	NS
BF	=	1.11	S x BF	=	NS
			N x S x BF	=	3.84

(spacing) during both the years. Maximum length of leaves i.e. 38.42cm and 39.53cm were obtained with the S_3 level of plant geometry (spacing) whereas, minimum length of leaves (35.97cm and 37.12cm) were observed with S_1 level of plant geometry (spacing) in 2001 and 2002, respectively. Perusal of the data also revealed that application of different biofertilizers had increased significantly the length of leaves over the control. The maximum length of leaves i.e. 38.37cm and 39.72cm were obtained with the application of BF_1 (*Azotobacter*) level of biofertilizer whereas, minimum length of leaves (35.85cm and 36.86cm) were observed without application of biofertilizers in 2001 and 2002, respectively. The interaction of NxS showed significant increase in length of leaves in both the years. The interaction of NxBF showed significant increase in length of leaves in the first year, but non-significant in second year. The interaction of SxBF was found to ,be non-significant in both the years. The interaction of NxSxBF were found to be non-significant in the first year, whereas, showed significant increase in length of leaves in the second year.

4.1.6 Leaf area (cm^2)

It is evident from the Table 12 & 13 that application of nitrogen, plant geometry (spacing) at their increasing levels and different biofertilizers had increased the leaf area significantly in both the years. It is further clear from the data that the increasing

Table 12 : Effect of nitrogen, plant geometry and biofertilizers on leaf area (cm^2) in tuberose.

Treatments		2001							
		BF_0	BF_1	BF_2	BF_3	Mean (N x S)	Mean (S x BF)	Overall mean (N)	Overall Mean (S)
	S_1	198.05	208.21	205.40	203.78	203.86	220.52		226.42
N_0	S_2	204.07	213.86	211.29	209.87	209.77	231.06		
	S_3	209.18	218.80	216.40	215.19	214.89	227.93	209.51	
	Mean	203.77	213.62	211.03	209.61		226.17		
	S_1	216.12	226.37	223.53	221.87	221.97			
N_1	S_2	221.28	231.24	228.70	227.40	227.16	225.87		231.68
	S_3	225.97	236.38	233.48	231.73	231.89	235.78	227.01	
	Mean	221.12	231.33	228.57	227.00		233.22		
	S_1	229.25	239.75	236.75	234.83	235.15	231.86		
N_2	S_2	234.43	244.42	241.78	240.24	240.22			
	S_3	239.67	249.55	247.04	245.64	245.48	230.74	240.28	
	Mean	234.45	244.57	241.86	240.24		240.76		
	S_1	230.25	241.52	237.66	235.82	236.31	238.10		
N_3	S_2	235.31	245.21	242.72	241.52	241.19	236.60		
	S_3	239.73	249.91	247.08	245.44	245.54		241.02	236.55
	Mean	235.10	245.55	242.49	240.93				
Overall Mean (BF)		225.71	235.87	233.08	231.54				

C.D. at 5%

N	=	0.79	N x S	=	2.41
S	=	0.69	N x BF	=	NS
BF	=	1.39	S x BF	=	2.41
			N x S x BF	=	NS

Table 13 : Effect of nitrogen, plant geometry and biofertilizers on leaf area (cm^2) in tuberose.

Treatments		2002							
		BF_0	BF_1	BF_2	BF_3	Mean (N x S)	Mean (S x BF)	Overall mean (N)	Overall Mean (S)
	S_1	205.57	217.23	214.48	212.76	212.51	227.55		234.12
N_0	S_2	213.48	221.76	219.32	217.91	218.12	239.07		
	S_3	217.29	228.30	225.41	223.98	223.75	235.72	218.12	
	Mean	212.11	222.43	219.74	218.22		234.15		
	S_1	225.12	235.28	232.53	231.37	231.08			
N_1	S_2	231.02	240.92	238.32	236.44	236.68	233.69		239.48
	S_3	235.10	246.00	242.90	240.75	241.19	243.76	236.31	
	Mean	230.41	240.73	237.92	236.19		240.97		
	S_1	237.22	249.00	245.78	244.17	244.04	239.53		
N_2	S_2	243.48	254.10	250.77	249.33	249.42			
	S_3	248.44	259.34	257.60	254.52	254.98	238.10	249.48	
	Mean	243.05	254.15	251.39	259.34		249.20		
	S_1	239.02	251.51	246.82	245.03	245.60	246.48		
N_3	S_2	243.52	254.98	252.19	251.16	250.46	244.28		
	S_3	248.29	259.91	256.73	254.59	254.88		250.31	244.51
	Mean	243.61	255.47	251.91	250.26				
Overall Mean (BF)		233.11	244.01	241.05	239.32				

C.D. at 5%

N	=	0.93	N x S	=	3.05
S	=	0.81	N x BF	=	3.52
BF	=	1.76	S x BF	=	3.05
			N x S x BF	=	**6.10**

levels of nitrogen had increased significantly the leaf area over the control but N_2 and N_3 treatments were found to be at par and these both were significantly higher as compared to N_1 treatment in both the years. Maximum leaf area (241.02cm^2 and 250.31cm^2) were recorded under treatment N_3, which was at par with treatment N_2, whereas, minimum leaf area i.e. 209.51cm^2 and 218.12cm^2 were produced without application of nitrogen during 2001 and 2002, respectively. Perusal of the data has further revealed that the leaf area was also increased significantly with the increasing levels of plant geometry (spacing) over S_1 and S_2 levels of plant geometry (spacing) during both the years. Maximum leaf area i.e. 236.55cm^2 and 244.51cm^2 were obtained with the S_3 level of plant geometry (spacing) whereas, minimum leaf area i.e. 226.42cm^2 and 234.12cm^2 were observed with S_1 level of plant geometry (spacing) in 2001 and 2002, respectively. Perusal of the data also revealed that application of different biofertilizers had increased the leaf area significantly over the control. The maximum leaf area i.e. 235.87cm^2 and 244.01cm^2 were obtained with the application of BF_1 (*Azotobacter*) level of biofertilizers whereas, minimum leaf area i.e. 225.71cm^2 and 233.11cm^2 were observed without application of biofertilizers in 2001 and 2002, respectively. The interaction of NxS and SxBF showed significant increase in leaf area in both the years. The

interaction of NxBF and NxSxBF were found to non-significant in the first year, whereas, showed significant increase in leaf area during the second year.

4.2 Flowering Parameters

4.2.1 Number of days taken for initiation of spike

The data recorded on number of days taken for spike emergence is presented in Table 14 & 15. It is apparent from the data that the spike emergence was significantly affected by the application of nitrogen, plant geometry (spacing) and biofertilizers during both the years. It is further clear from the data that the increasing levels of nitrogen had significantly delayed the spike emergence over the control but N_2 and N_3 treatments were found to be at par and these both were significantly delayed the spike emergence as compared to N_1 treatment in both the years. The days taken for spike emergence were minimum at N_0 level (75.76 days and 76.80 days) whereas, maximum (87.10 days and 88.20 days) at N_3 level, which was at par with N_2 level in 2001 and 2002, respectively. Perusal of the data has further revealed that spike emergence was also significantly delayed with the increasing levels of plant geometry (spacing) over S_1 and S_2 levels of plant geometry (spacing) during both the years. Highest level of plant geometry (spacing) i.e. S3 also took maximum (85.14 and 85.61) days for spike emergence while minimum (82.05 and 82.50) days were recorded at the

Table 14 : Effect of nitrogen, plant geometry and biofertilizers on number of days taken for initiation of spike in tuberose.

Treatments		2001							
		BF_0	BF_1	BF_2	BF_3	Mean (N x S)	Mean (S x BF)	Overall mean (N)	Overall Mean (S)
	S_1	76.00	72.60	72.20	74.48	73.82	84.34		82.05
N_0	S_2	78.72	74.80	74.61	76.78	76.23	80.74		
	S_3	79.93	75.98	75.45	77.60	77.24	80.49	75.76	
	Mean	78.22	74.46	74.09	76.29		82.63		
	S_1	82.31	78.71	78.50	80.58	80.03			
N_1	S_2	84.50	80.75	80.60	82.70	82.14	86.39		84.04
	S_3	85.85	81.92	81.68	83.76	83.30	82.67	81.82	
	Mean	84.22	80.46	80.26	82.35		82.44		
	S_1	87.65	83.73	83.58	85.70	85.17	84.65		
N_2	S_2	89.25	85.65	85.30	87.52	86.93			
	S_3	90.49	86.73	86.55	88.70	88.12	87.63	86.74	
	Mean	89.13	85.37	85.14	87.31		83.78		
	S_1	87.86	84.36	84.14	86.20	85.64	83.50		
N_3	S_2	89.56	85.94	85.70	88.06	87.32	85.65		
	S_3	90.71	86.94	86.76	88.99	88.35		87.10	85.14
	Mean	89.38	85.75	85.53	87.75				
Overall Mean (BF)		86.12	82.39	82.14	84.31				

C.D. at 5%

N	=	0.39	N x S	=	2.13
S	=	0.33	N x BF	=	NS
BF	=	1.23	S x BF	=	NS
			N x S x BF	=	NS

Table 15: Effect of nitrogen, plant geometry and biofertilizers on number of days taken for initiation of spike in tuberose.

Treatments		2002							
		BF_0	BF_1	BF_2	BF_3	Mean (N x S)	Mean (S x BF)	Overall mean (N)	Overall Mean (S)
	S_1	76.86	73.63	73.27	75.58	74.84	84.64		82.50
N_0	S_2	79.61	75.79	75.60	77.84	77.21	81.25		
	S_3	80.80	77.18	76.82	78.64	78.36	80.96	76.80	
Mean		79.09	75.53	75.23	77.35		83.18		
	S_1	83.19	79.79	79.56	81.71	81.06			
N_1	S_2	85.52	81.99	81.76	84.00	83.32	86.72		84.53
	S_3	86.82	83.08	82.85	85.03	84.45	83.24	82.94	
Mean		85.18	81.62	81.39	83.58		82.95		
	S_1	88.54	85.02	84.80	86.92	86.32	85.22		
N_2	S_2	90.28	86.92	86.49	88.68	88.09			
	S_3	91.44	87.67	87.38	89.61	89.03	87.98	87.81	
Mean		90.09	86.54	86.22	88.40		84.29		
	S_1	88.85	85.44	85.09	87.39	86.69	84.02		
N_3	S_2	90.36	87.15	86.83	89.27	88.40	86.14		
	S_3	91.75	88.12	87.93	90.18	89.50		88.20	85.61
Mean		90.32	86.90	86.62	88.95				
Overall Mean (BF)		86.44	82.92	82.64	84.85				

C.D. at 5%

N	=	0.44	N x S	=	NS
S	=	0.38	N x BF	=	NS
BF	=	1.72	S x BF	=	NS
			N x S x BF	=	NS

lowest level of plant geometry (spacing) i.e. S_1, in 2001 and 2002, respectively. It is clear from the table that plant geometry (spacing) had taken less number of days for spike emergence as compared to nitrogen. It is also clear from the data that application of biofertilizers had significantly advanced the spike emergence over the control except BF_3 (*Azospirillum*) in year 2002. In case of inoculation of BF_2 (*Phosphorus Solubilizing Bacteria*), spike emergence took minimum days (82.14 and 82.64) followed by BF_1 (*Azotobacter*) and BF_3 (*Azosprillum*) in both the years. The interaction of NxS had also significantly enhanced the spike emergence in 2001, whereas, this interaction was found non-significant in 2002. The interactions of NxBF, SxBF and NxSxBF were found non-significant in both the years.

4.2.2 Number of days taken for opening of basal floret

Perusal of the data presented in Table 16 & 17 indicate that the basal floret opening was significantly affected by the application of nitrogen, plant geometry (spacing) and biofertilizers during both the years. It is further clear from the data that the increasing levels of nitrogen had significantly delayed the basal floret opening over the control but N_2 and N_3 treatments were found to be at par and these both were significantly delayed the basal floret opening as compared to N_1 treatment in both the years. The days taken for basal floret opening were minimum at N_0 level (90.77 days and 92.87 days)

Table 16 : Effect of nitrogen, plant geometry and biofertilizers on number of days taken for opening of basal floret in tuberose.

Treatments		2001							
		BF_0	BF_1	BF_2	BF_3	Mean (N x S)	Mean (S x BF)	Overall mean (N)	Overall Mean (S)
	S_1	91.25	87.80	87.35	89.60	89.00	100.04		97.74
N_0	S_2	93.40	89.75	89.53	91.70	91.10	96.43		
	S_3	94.65	90.90	90.58	92.75	92.22	96.17	90.77	
	Mean	93.10	89.48	89.15	91.35		98.32		
	S_1	97.45	93.80	93.62	95.74	95.15			
N_1	S_2	99.68	95.95	95.64	97.80	97.27	102.54		100.16
	S_3	100.75	96.90	96.68	98.76	98.27	98.82	96.90	
	Mean	99.29	95.55	95.31	97.43		98.59		
	S_1	103.30	99.65	99.42	101.50	100.97	100.68		
N_2	S_2	106.77	102.92	102.70	104.58	104.24			
	S_3	107.60	103.85	103.71	105.60	105.19	103.70	103.47	
	Mean	105.89	102.14	101.94	103.89		99.90		
	S_1	104.44	100.74	100.59	102.71	102.12	99.64		
N_3	S_2	106.60	102.94	102.79	104.91	104.31	101.72		
	S_3	108.09	104.25	103.89	106.04	105.57		104.00	101.24
	Mean	106.38	102.64	102.42	104.55				
Overall Mean (BF)		102.09	98.38	98.14	100.24				

C.D. at 5%

N	=	0.63	N x S	=	1.94
S	=	0.55	N x BF	=	NS
BF	=	1.12	S x BF	=	NS
			N x S x BF	=	NS

Table 17: Effect of nitrogen, plant geometry and biofertilizers on number of days taken for opening of basal floret in tuberose.

Treatments		2002							
		BF_0	BF_1	BF_2	BF_3	Mean (N x S)	Mean (S x BF)	Overall mean (N)	Overall Mean (S)
	S_1	93.10	89.67	89.24	91.59	90.90	101.08		99.02
N_0	S_2	95.41	92.07	91.85	94.09	93.36	97.79		
	S_3	96.45	93.04	92.81	95.10	94.35	97.55	92.87	
	Mean	94.99	91.59	91.30	93.59		99.68		
	S_1	99.40	96.24	96.05	98.07	97.44			
N_1	S_2	101.55	98.14	97.77	100.01	99.37	103.57		101.41
	S_3	102.78	99.27	99.06	101.12	100.56	100.14	99.12	
	Mean	101.24	97.88	97.63	99.73		99.91		
	S_1	105.19	101.88	101.66	103.85	103.15	102.04		
N_2	S_2	108.58	105.01	104.84	106.76	106.30			
	S_3	109.89	106.07	105.96	107.83	107.44	104.84	105.63	
	Mean	107.89	104.32	104.15	106.15		101.33		
	S_1	106.41	103.13	103.00	104.99	104.38	101.11		
N_3	S_2	108.50	105.09	104.95	107.08	106.41	103.18		
	S_3	110.02	106.70	106.37	108.45	107.89		106.22	102.62
	Mean	108.31	104.97	104.77	106.84				
Overall Mean (BF)		103.16	99.75	99.52	101.64				

C.D. at 5%

N	=	0.63	N x S	=	2.23
S	=	0.55	N x BF	=	NS
BF	=	1.29	S x BF	=	NS
			N x S x BF	=	NS

whereas, maximum (104.00 days and 106.22 days) at N_3 level, which was at par with N_2 level in 2001 and 2002, respectively. Perusal of the data has further revealed that basal floret opening was also significantly delayed with the increasing levels of plant geometry (spacing) over S_1 and S_2 levels of plant geometry (spacing) during both the years. Highest level of plant geometry (spacing) i.e. S_3 also took maximum (101.24 and 102.62) days for basal floret opening while minimum (97.74 and 99.02) days were recorded at the lowest level of plant geometry (spacing) i.e. S_1, in 2001 and 2002, respectively. It is also clear from the data that application of biofertilizers had significantly advanced the basal floret opening over the control during both the years. In case of inoculation of BF_2 (*Phosphorus Solubilizing Bacteria*), basal floret opening took minimum days (98.14 and 99.52) followed by BF_1 (*Azotobacter*) and BF_3 (*Azospirillum*) in both the years. The application of nitrogen along with spacing had also significantly enhanced the basal floret opening in both the years whereas, all other interaction were found to be non-significant.

4.2.3 Length of spike (cm)

It is evident from the data recorded on spike length presented in Table 18 & 19 that spike length was increased significantly with the increasing levels of nitrogen and plant geometry (spacing) during both the years. It is further clear from the data that the increasing levels of nitrogen had increased

Table 18 : Effect of nitrogen, plant geometry and biofertilizers on length of spike (cm) in tuberose.

Treatments		2001							
		BF_0	BF_1	BF_2	BF_3	Mean (N x S)	Mean (S x BF)	Overall mean (N)	Overall Mean (S)
	S_1	46.40	49.70	48.54	47.61	48.06	56.00		57.62
N_0	S_2	48.02	51.18	50.14	49.20	49.64	59.21		
	S_3	49.90	53.10	52.05	51.08	51.54	58.10	49.75	
	Mean	48.11	51.33	50.24	49.30		57.17		
	S_1	53.15	56.40	55.32	54.38	54.81			
N_1	S_2	54.95	57.15	56.10	55.13	55.83	57.42		58.86
	S_3	56.41	59.72	58.53	57.64	58.08	60.38	56.24	
	Mean	54.84	57.76	56.65	55.72		59.29		
	S_1	59.75	62.90	61.81	60.87	61.33	58.34		
N_2	S_2	60.40	63.73	62.55	61.61	62.07			
	S_3	62.05	65.20	64.15	63.18	63.65	59.08	62.35	
	Mean	60.73	63.94	62.84	61.89		62.29		
	S_1	59.70	62.84	61.73	60.80	61.27	61.20		
N_3	S_2	61.32	64.44	63.38	62.40	62.89	60.25		
	S_3	62.96	66.12	65.06	64.10	64.56		62.90	60.71
	Mean	61.33	64.47	63.39	62.43				
Overall Mean (BF)		57.50	60.62	59.53	58.58				

C.D. at 5%

N	=	0.60	N x S	=	1.89
S	=	0.52	N x BF	=	NS
BF	=	1.09	S x BF	=	NS
			N x S x BF	=	NS

Table 19: Effect of nitrogen, plant geometry and biofertilizers on length of spike (cm) in tuberose.

Treatments		2002							
		BF_0	BF_1	BF_2	BF_3	Mean (N x S)	Mean (S x BF)	Overall mean (N)	Overall Mean (S)
	S_1	47.42	51.11	49.87	48.80	49.30	56.21		58.02
N_0	S_2	49.12	52.65	51.50	50.47	50.94	59.75		
	S_3	50.90	54.41	53.27	52.30	52.72	58.59	50.99	
	Mean	49.15	52.73	51.55	50.53		57.54		
	S_1	54.22	57.83	56.68	55.63	56.09			
N_1	S_2	55.97	58.64	57.42	56.33	57.09	57.69		59.27
	S_3	57.50	61.16	59.92	58.81	59.35	60.95	57.51	
	Mean	55.90	59.21	58.01	56.92		59.75		
	S_1	60.81	64.25	63.23	62.09	62.60	58.71		
N_2	S_2	61.52	65.15	63.86	62.84	63.34			
	S_3	63.19	66.60	65.48	64.44	64.93	59.30	63.62	
	Mean	61.84	65.33	64.19	63.12		62.79		
	S_1	60.83	64.25	63.03	62.08	62.55	61.65		
N_3	S_2	62.59	65.82	64.66	63.63	64.18	60.60		
	S_3	64.07	67.45	66.37	65.28	65.79		64.17	61.09
	Mean	62.50	65.84	64. 69	63.66				
Overall Mean (BF)		57.73	61.17	60.00	58.95				

C.D. at 5%

N	=	0.60	N x S	=	2.37
S	=	0.52	N x BF	=	NS
BF	=	1.37	S x BF	=	NS
			N x S x BF	=	NS

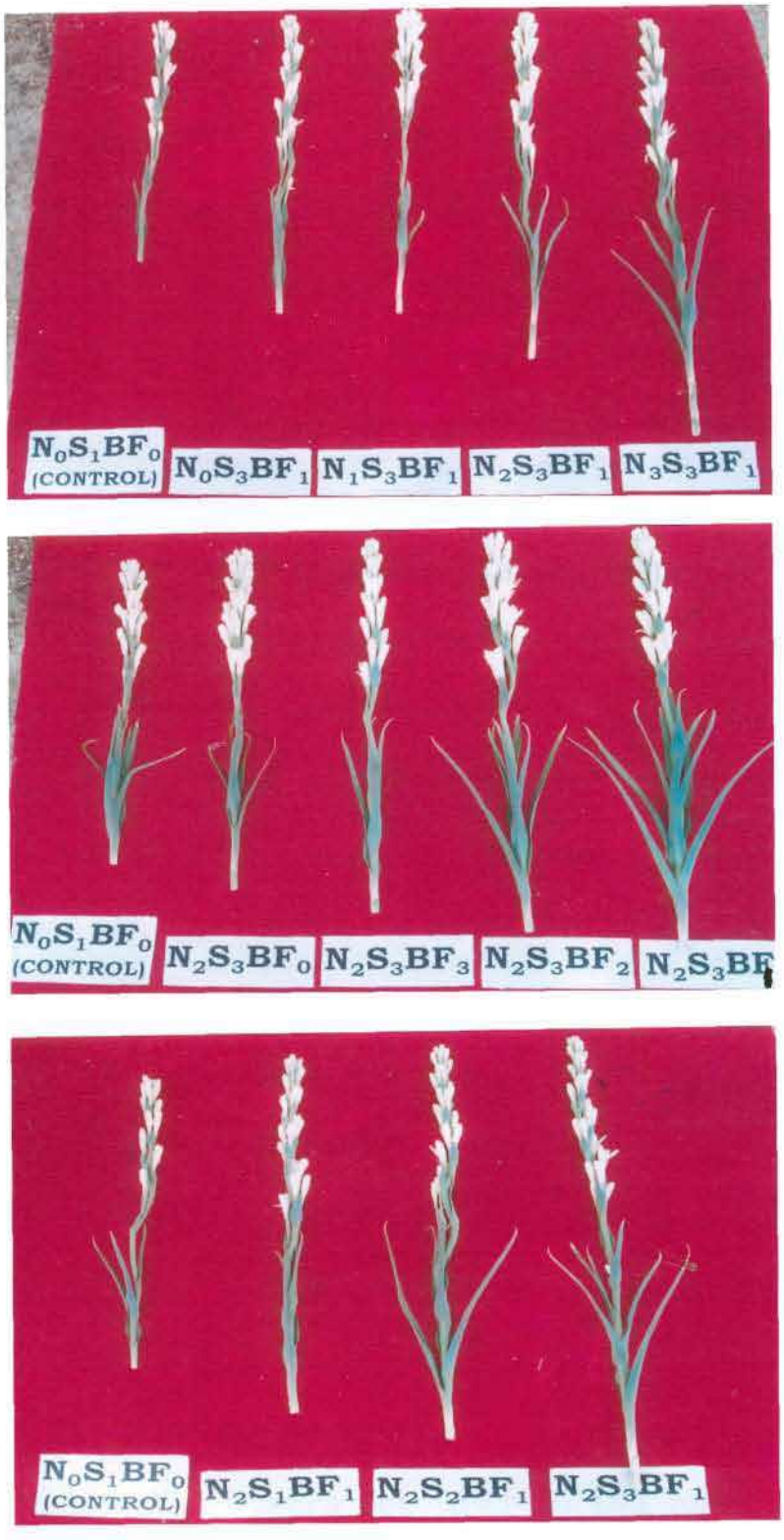


Plate 5: Effect of nitrogen, plant geometry and biofertilizers on spike length

significantly the length of spike over the control but N_2 and N_3 treatments were found to be at par and these both were significantly higher as compared to N_1 treatment in both the years. The maximum spike length was observed at N_3 level (62.90cm and 64.17cm), which was at par with N_2 level during 2001 and 2002, respectively. Perusal of the data has further revealed that spike length was also increased significantly with the increasing levels of plant geometry (spacing) over S_1 and S_2 levels of plant geometry (spacing) during both the years. The maximum spike length was observed at S_3 plant geometry (spacing) i.e. 60.71 cm and 14.91cm during 2001 and 2002, respectively. It is also clear from the data that all the biofertilizers except BF_3 (*Azospirillum*) increased significantly the spike length over the control in both the years. The maximum spike length was recorded i.e. 60.62cm and 61.17cm when bulbs were inoculated with BF_1 (*Azotobacter*) in 2001 and 2002, respectively. The interaction of NxS, showed a significant increased in spike length during both the years. The interactions of NxBF, SxBF and NxSxBF had shown non-significant effect during both the years.

4.2.4 Number of florets/spike

Observations were recorded on the number of florets per spike and these were given in Table 20 & 21. It is evident from the table that nitrogen, plant geometry (spacing) and biofertilizers

Table 20 : Effect of nitrogen, plant geometry and biofertilizers on number of florets per spike in tuberose.

Treatments		2001							
		BF_0	BF_1	BF_2	BF_3	Mean (N x S)	Mean (S x BF)	Overall mean (N)	Overall Mean (S)
	S_1	20.05	24.60	23.45	22.20	22.58	27.23		29.61
N_0	S_2	22.80	26.93	25.85	24.64	25.06	31.50		
	S_3	25.30	29.48	28.40	27.34	27.63	30.42	25.09	
	Mean	22.72	27.00	25.90	24.73		29.30		
	S_1	25.42	29.75	28.70	27.62	27.87			
N_1	S_2	27.95	31.98	30.91	29.80	30.16	29.46		31.73
	S_3	30.10	34.38	33.33	32.25	32.52	33.58	30.18	
	Mean	27.82	32.04	30.98	29.89		32.51		
	S_1	29.63	33.76	32.68	31.55	31.91	31.37		
N_2	S_2	31.35	35.50	34.46	33.32	33.66			
	S_3	33.56	37.48	36.44	35.31	35.70	31.51	33.75	
	Mean	31.51	35.58	34.53	33.39		35.65		
	S_1	30.42	34.50	33.47	32.44	32.71	34.60		
N_3	S_2	32.37	36.52	35.45	34.33	34.67	33.52		
	S_3	33.70	37.89	36.86	35.80	36.06		34.48	33.82
	Mean	32.16	36.30	35.26	34.19				
Overall Mean (BF)		29.40	33.58	32.51	31.40				

C.D. at 5%

N	=	0.80	N x S	=	0.82
S	=	0.70	N x BF	=	NS
BF	=	0.47	S x BF	=	NS
			N x S x BF	=	NS

Table 21: ***Effect of nitrogen, plant geometry and biofertilizers on number of florets per spike in tuberose.***

Treatments		2002							
		BF_0	**BF_1**	**BF_2**	**BF_3**	**Mean (N x S)**	**Mean (S x BF)**	**Overall mean (N)**	**Overall Mean (S)**
	S_1	21.90	26.70	25.43	24.06	24.52	28.27		30.65
N_0	S_2	24.67	28.92	27.73	26.39	26.93	32.60		
	S_3	27.19	31.30	30.41	29.20	29.53	31.47	26.99	
	Mean	24.59	28.97	27.86	26.55		30.28		
	S_1	27.34	31.69	30.73	29.66	29.86			
N_1	S_2	29.92	34.18	32.99	31.62	32.18	30.44		32.84
	S_3	31.96	36.45	35.49	34.08	34.50	34.87	32.18	
	Mean	29.74	34.11	33.07	31.79		33.69		
	S_1	31.51	35.45	34.32	33.13	33.60	32.37		
N_2	S_2	33.00	37.69	36.47	35.21	35.59			
	S_3	35.68	39.47	38.25	37.10	37.63	32.59	35.61	
	Mean	33.40	37.54	36.35	35.15		36.81		
	S_1	32.13	36.33	35.18	34.05	34.42	35.78		
N_3	S_2	33.94	38.48	37.36	36.04	36.46	34.56		
	S_3	35.31	39.80	38.75	37.63	37.87		36.25	34.93
	Mean	33.79	38.20	37.10	35.91				
Overall Mean (BF)		30.43	34.76	33.65	32.40				

C.D. at 5%

N	=	0.71	N x S	=	1.61
S	=	0.62	N x BF	=	NS
BF	=	0.93	S x BF	=	NS
			N x S x BF	=	NS

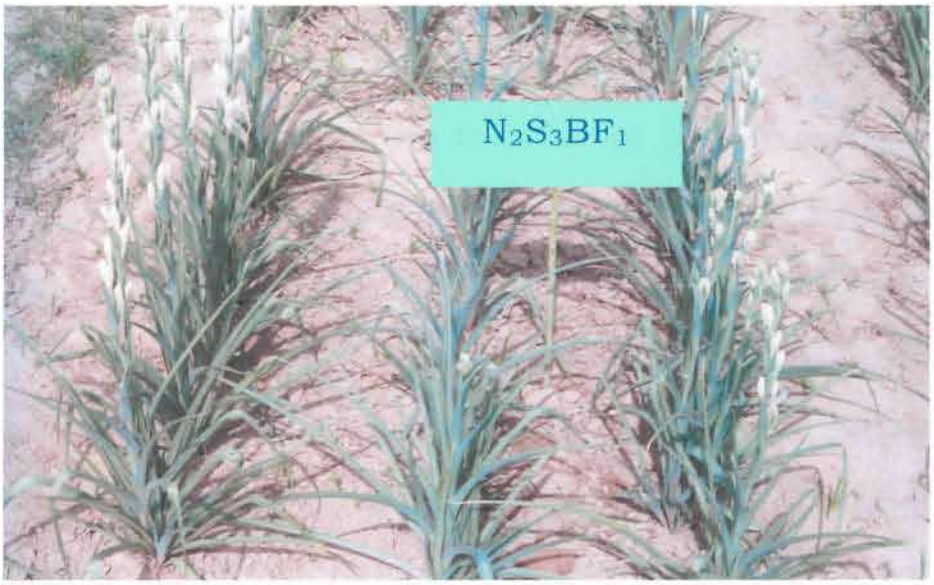


Plate 4: Effect of nitrogen, plant geometry and biofertilizers on number of florets per spike

had increased significantly the number of florets per spike during first as well as in second year of the experiment. It is further clear from the data that the increasing levels of nitrogen had increased significantly the number of florets per spike over the control but N_2 and N_3 treatments were found to be at par and these both were significantly higher as compared to N_1 treatment in both the years. Maximum florets per spike (34.48 and 36.25) were recorded under treatment N_3, which was at par with N_2 treatment whereas, minimum florets per spike (25.09 and 26.99) were produced without application of nitrogen during 2001 and 2002, respectively. Perusal of the data has further revealed that number of florets per spike were also increased significantly with the increasing levels of plant geometry (spacing) over S_1 and S_2 levels of plant geometry (spacing) during both the years. Maximum number of florets per spike i.e. 33.82 and 34.93 were obtained with the S_3 level of plant geometry (spacing) whereas, minimum number of florets per spike i.e. 29.61 and 30.65 were observed with S_1 level of plant geometry (spacing) in 2001 and 2002, respectively. Perusal of the data also revealed that application of different biofertilizers had increased significantly the number of florets per spike over the control during both the years. The maximum number of florets per spike i.e. 33.58 and 34.76 were obtained with the application of BF_1 (*Azotobacter*) level of biofertilizer whereas, minimum number of florets per

spike i.e. 29.40 and 30.43 were observed without application of biofertilizers in 2001 and 2002, respectively. The interaction of NxS, showed a significant increase in number of florets per spike during both the years. All other interactions were found to be non-significant in both the years.

4.2.5 Spike girth (mm)

It is clear from the data recorded on spike girth (mm) and presented in Table 22 & 23 that spike girth was increased significantly with the increasing level of nitrogen and plant geometry (spacing) during both the years. It is further clear from the data that the increasing levels of nitrogen had increased significantly the spike girth over the control but N_2 and N_3 treatments were found to be at par and these both were significantly higher as compared to N1 treatment in both the years. Maximum spike girth (7.98mm and 8.14mm) was observed at N_3 level, which was at par with N_2 level whereas, minimum spike girth (6.36mm and 6.50mm) was observed without application of nitrogen during 2001 and 2002, respectively. Perusal of the data has further revealed that spike girth was also increased significantly with the increasing levels of plant geometry (spacing) over S_1 and S_2 levels of plant geometry (spacing) during both the years. Maximum spike girth i.e. 7.59mm and 7.62mm was obtained with the S_3 level of plant geometry (spacing) whereas, minimum spike girth i.e. 7.51mm

Table 22 : Effect of nitrogen, plant geometry and biofertilizers on spike girth (mm) in tuberose.

Treatments		2001							
		BF_0	BF_1	BF_2	BF_3	Mean (N x S)	Mean (S x BF)	Overall mean (N)	Overall Mean (S)
	S_1	6.20	6.41	6.35	6.28	6.31	7.39		7.51
N_0	S_2	6.25	6.47	6.41	6.33	6.37	7.62		
	S_3	6.29	6.49	6.44	6.38	6.40	7.56	6.36	
	Mean	6.25	6.46	6.40	6.33		7.48		
	S_1	7.10	7.32	7.26	7.19	7.22			
N_1	S_2	7.16	7.39	7.33	7.26	7.29	7.44		7.55
	S_3	7.21	7.40	7.32	7.24	7.29	7.65	7.27	
	Mean	7.16	7.37	7.30	7.23		7.59		
	S_1	7.80	8.04	7.99	7.93	7.94	7.51		
N_2	S_2	7.85	8.03	7.96	7.85	7.93			
	S_3	7.88	8.11	8.03	7.94	7.99	7.48	7.95	
	Mean	7.84	8.06	7.99	7.91		7.69		
	S_1	7.81	8.06	7.98	7.88	7.93	7.62		
N_3	S_2	7.87	8.09	8.02	7.94	7.98	7.55		
	S_3	7.91	8.12	8.06	7.99	8.02		7.98	7.59
	Mean	7.86	8.09	8.02	7.94				
Overall Mean (BF)		7.44	7.67	7.59	7.51				

C.D. at 5%

N	=	0.04	N x S	=	NS
S	=	0.03	N x BF	=	NS
BF	=	0.22	S x BF	=	NS
			N x S x BF	=	NS

Table 23: ***Effect of nitrogen, plant geometry and biofertilizers on spike girth (mm) in tuberose.***

Treatments		2002							
		BF_0	**BF_1**	**BF_2**	**BF_3**	**Mean (N x S)**	**Mean (S x BF)**	**Overall mean (N)**	**Overall Mean (S)**
	S_1	6.33	6.59	6.50	6.41	6.46	7.38		7.52
N_0	S_2	6.38	6.64	6.57	6.46	6.51	7.65		
	S_3	6.40	6.66	6.59	6.50	6.54	7.57	6.50	
	Mean	6.37	6.63	6.55	6.46		7.47		
	S_1	7.20	7.48	7.42	7.31	7.35			
N_1	S_2	7.27	7.56	7.49	7.40	7.43	7.44		7.57
	S_3	7.34	7.60	7.51	7.42	7.47	7.70	7.42	
	Mean	7.27	7.55	7.47	7.38		7.62		
	S_1	7.94	8.21	8.13	8.05	8.08	7.52		
N_2	S_2	8.01	8.20	8.11	7.99	8.08			
	S_3	8.05	8.30	8.20	8.09	8.16	7.49	8.11	
	Mean	8.00	8.24	8.15	8.05		7.75		
	S_1	7.94	8.22	8.13	8.02	8.08	7.66		
N_3	S_2	8.00	8.29	8.20	8.11	8.15	7.56		
	S_3	8.08	8.33	8.23	8.14	8.20		8.14	7.62
	Mean	8.01	8.28	8.19	8.09				
Overall Mean (BF)		7.44	7.72	7.62	7.52				

C.D. at 5%

N	=	0.04	N x S	=	NS
S	=	0.03	N x BF	=	NS
BF	=	0.26	S x BF	=	NS
			N x S x BF	=	NS

and 7.52 mm was observed with the S_1 level of plant geometry (spacing) in 2001 and 2002, respectively. Perusal of the data also revealed that application of only BF_1 (*Azotobacter*) biofertilizer had increased significantly the spike girth over the control during both the years. The maximum spike girth i.e. 7.67mm and 7.72mm was obtained with the application of BF_1 (*Azotobacter*) level of biofertilizer, whereas, minimum spike girth i.e. 7.44mm and 7.44mm was observed without application of biofertilizers in 2001 and 2002, respectively. All interactions were found to be non-significant during both the years.

4.2.6 Rachis length (cm)

It is evident from the data recorded on rachis length (cm) and presented in Table 24 & 25 that rachis length was increased significantly with the increasing levels of nitrogen and plant geometry (spacing) during both the years. It is further clear from the data that the increasing levels of nitrogen had increased significantly the rachis length over the control but N_2 and N_3 treatments were found to be at par and these both were significantly higher as compared to N_1 treatment in both the years. Maximum rachis length (32.49cm and 33.60cm) was observed at N_3 level, which was at par with N_2 level whereas, minimum rachis length (28.29cm and 29.31cm) was observed without application of nitrogen during 2001 and 2002, respectively. Perusal of the data has further revealed that rachis

Table 24 : Effect of nitrogen, plant geometry and biofertilizers on rachis length (cm) in tuberose.

Treatments		2001							
		BF_0	BF_1	BF_2	BF_3	Mean (N x S)	Mean (S x BF)	Overall mean (N)	Overall Mean (S)
	S_1	26.25	28.80	27.95	27.45	27.62	29.09		30.29
N_0	S_2	27.40	29.78	28.85	27.50	28.38	31.36		
	S_3	27.96	29.98	28.95	28.60	28.87	30.48	28.29	
	Mean	27.20	29. 52	28.58	27.85		30.21		
	S_1	28.35	30.56	29.68	29.60	29.55			
N_1	S_2	29.56	31.70	30.78	30.63	30.67	30.29		31.36
	S_3	30.10	32.34	31.41	31.27	31.28	32.49	30.50	
	Mean	29.34	31.53	30.62	30.50		31.56		
	S_1	30.15	32.30	31.45	31.25	31.29	31.10		
N_2	S_2	31.40	33.62	32.70	31.54	32.57			
	S_3	31.98	33.90	32.95	32.72	32.89	30.85	32.25	
	Mean	31.18	33.27	32.37	32.17		32.93		
	S_1	30.45	32.61	31.68	31.38	31.53	31.99		
N_3	S_2	31.63	33.68	32.75	32.54	32.65	31.72		
	S_3	32.18	34.33	33.46	33.13	33.28		32.49	31.87
	Mean	31.42	33.54	32.63	32.35				
Overall Mean (BF)		30.08	32.26	31.34	31.01				

C.D. at 5%

N	=	0.28	N x S	=	NS
S	=	0.24	N x BF	=	NS
BF	=	1.36	S x BF	=	NS
			N x S x BF	=	NS

Table 25: ***Effect of nitrogen, plant geometry and biofertilizers on rachis length (cm) in tuberose.***

Treatments		2002							
		BF_0	**BF_1**	**BF_2**	**BF_3**	**Mean (N x S)**	**Mean (S x BF)**	**Overall mean (N)**	**Overall Mean (S)**
	S_1	27.05	29.79	28.81	28.23	28.47	29.71		31.10
N_0	S_2	28.17	31.08	30.06	28.84	29.54	32.32		
	S_3	28.99	31.22	29.95	29.52	29.92	31.37	29.31	
	Mean	28.07	30.70	29.61	28.87		31.02		
	S_1	29.25	31.87	30.90	30.74	30.69			
N_1	S_2	30.42	33.07	32.04	31.00	31.63	30.99		32.26
	S_3	30.56	33.62	32.70	32.38	32.32	33.58	31.55	
	Mean	30.08	32.85	31.88	31.38		32.59		
	S_1	31.01	33.53	32.65	32.40	32.40	31.87		
N_2	S_2	32.59	34.93	33.97	33.71	33.80			
	S_3	32.85	35.18	34.23	33.98	34.06	31.44	33.42	
	Mean	32.15	34.55	33.62	33.36		33.96		
	S_1	31.29	33.83	32.87	32.44	32.61	32.94		
N_3	S_2	32.53	34.97	34.03	33.67	33.80	32.58		
	S_3	33.09	35.58	34.64	34.20	34.38		33.60	32.73
	Mean	32.30	34.79	33.85	33.44				
Overall Mean (BF)		30.71	33.29	32.30	31.82				

C.D. at 5%

N	=	0.25	N x S	=	NS
S	=	0.21	N x BF	=	NS
BF	=	1.38	S x BF	=	NS
			N x S x BF	=	**NS**

length was also increased significantly with the increasing levels of plant geometry (spacing) over S_1 and S_2 levels of plant geometry (spacing) during both the years. Maximum rachis length i.e. 31.87cm and 32.73cm was obtained with the S3 level of plant geometry (spacing) whereas, minimum rachis length i.e. 30.29 cm and 31.10cm was observed with the S_1 level of plant geometry (spacing) in 2001 and 2002, respectively. Perusal of the data also revealed that application of only BF_1 (*Azotobacter*) biofertilizer had increased significantly the rachis length over the control while other biofertilizers were at par with control in year 2001. All the biofertilizers had increased significantly the rachis length over the control except BF_3 (*Azospirillum*) in year 2002. The maximum rachis length i.e. 32.26cm and 33.29cm was obtained with the application of BF_1 (*Azotobacter*) level of biofertilizer, whereas, minimum rachis length i.e. 30.08cm and 30.71cm was observed without application of biofertilizers in 2001 and 2002, respectively. The interactions were found to be non- significant during both the years.

4.2.7 Duration of flowering (days)

It is evident from the data recorded on duration of flowering (days) and presented in Table 26 & 27 that duration of flowering was increased significantly with the increasing level of nitrogen and plant geometry (spacing) during both the years. It is further clear from the data that the increasing levels of nitrogen

Table 26 : Effect of nitrogen, plant geometry and biofertilizers on duration of flowering (days) in tuberose.

Treatments		2001							
		BF_0	BF_1	BF_2	BF_3	Mean (N x S)	Mean (S x BF)	Overall mean (N)	Overall Mean (S)
	S_1	12.05	12.60	12.50	12.35	12.38	14.61		14.94
N_0	S_2	12.70	13.22	13.13	13.00	13.02	15.16		
	S_3	13.10	13.67	13.54	13.35	13.42	15.06	12.94	
	Mean	12.62	13.16	13.06	12.90		14.92		
	S_1	14.00	14.55	14.45	14.30	14.33			
N_1	S_2	14.60	15.10	15.02	14.89	14.90	15.21		15.52
	S_3	15.05	15.61	15.50	15.34	15.38	15.73	14.87	
	Mean	14.55	15.09	14.99	14.84		15.64		
	S_1	15.65	16.18	16.10	15.97	15.98	15.51		
N_2	S_2	16.32	16.90	16.77	16.59	16.65			
	S_3	16.65	17.16	17.10	16.99	16.98	15.55	16.53	
	Mean	16.21	16.75	16.66	16.52		16.08		
	S_1	16.02	16.57	16.47	16.32	16.35	15.99		
N_3	S_2	16.47	16.97	16.92	16.82	16.80	15.84		
	S_3	16.67	17.16	17.07	16.94	16.96		16.70	15.86
	Mean	16.39	16.90	16.82	16.69				
Overall Mean (BF)		15.12	15.66	15.56	15.42				

C.D. at 5%

N	=	0.21	N x S	=	0.67
S	=	0.19	N x BF	=	NS
BF	=	0.39	S x BF	=	NS
			N x S x BF	=	NS

Table 27: Effect of nitrogen, plant geometry and biofertilizers on duration of flowering (days) in tuberose.

Treatments		2002							
		BF_0	BF_1	BF_2	BF_3	Mean (N x S)	Mean (S x BF)	Overall mean (N)	Overall Mean (S)
	S_1	12.96	13.78	13.66	13.47	13.47	15.50		15.97
N_0	S_2	13.71	14.61	14.45	14.26	14.26	16.32		
	S_3	14.39	15.19	15.00	14.71	14.82	16.14	14.18	
	Mean	13.69	14.53	14.37	14.15		15.94		
	S_1	15.21	15.98	15.78	15.59	15.64			
N_1	S_2	15.85	16.67	16.46	16.24	16.31	16.17		16.63
	S_3	16.52	17.10	16.84	16.60	16.77	16.98	16.24	
	Mean	15.86	16.58	16.36	16.14		16.79		
	S_1	17.05	17.77	17.58	17.41	17.45	16.58		
N_2	S_2	17.62	18.23	18.06	17.85	17.94			
	S_3	17.67	18.45	18.27	17.98	18.10	16.65	17.83	
	Mean	17.45	18.15	17.97	17.75		17.34		
	S_1	16.77	17.73	17.52	17.30	17.33	17.16		
N_3	S_2	17.49	18.41	18.19	17.95	18.01	16.90		
	S_3	18.02	18.63	18.51	18.30	18.37		17.90	17.01
	Mean	17.43	18.26	18.07	17.85				
Overall Mean (BF)		16.11	16.88	16.69	16.47				

C.D. at 5%

N	=	0.30	N x S	=	1.01
S	=	0.26	N x BF	=	NS
BF	=	0.58	S x BF	=	NS
			N x S x BF	=	**NS**

had increased significantly the duration of flowering over the control but N_2 and N_3 treatments were found to be at par and these both were significantly higher as compared to N_1 treatment in both the years. Maximum duration of flowering (16.70 days and 17.90 days) was observed at N_3 level, which was at par with N_2 level whereas, minimum duration of flowering (12.94 days and 14.18 days) was observed without application of nitrogen during 2001 and 2002, respectively. Perusal of the data has further revealed that duration of flowering was also increased significantly with the increasing levels of plant geometry (spacing) over S_1 and S_2 levels of plant geometry (spacing) during both the years. Maximum duration of flowering i.e. 15.86 days and 17.01 days was obtained with the S_3 level of plant geometry (spacing) whereas, minimum duration of flowering i.e. 14.94 days and 15.97 days was observed with the S_1 level of plant geometry (spacing) in 2001 and, 2002, respectively. Perusal of the data also revealed that applications of all the biofertilizers increased significantly the duration of flowering over the control except BF_3 (*Azospirillum*) biofertilizer in the year 2001. And only BF_1 (*Azotobacter*) biofertilizer had increased significantly the duration of flowering over the control, while other biofertilizers were at par with control in the year 2002. Maximum duration of flowering was recorded (15.66 days and 16.88 days) when bulbs were inoculated with BF_1 (*Azotobacter*) biofertilizer whereas,

minimum duration of flowering i.e. 15.12 days and 16.11 days was observed without application of biofertilizers in 2001 and 2002, respectively. The interaction of NxS, showed a significant increase in duration of flowering during both the years. Whereas, all other interactions had shown non-significant effect during both the years.

4.3 Bulb Production

4.3.1 Number of bulbs produced per plant

The number of bulbs produced per plant were counted and presented in Table 28 & 29. A significant increase in the number of bulbs produced per plant were observed with biofertilizers and increasing levels of nitrogen and plant geometry (spacing) during both the years. It is further clear from the data that the increasing levels of nitrogen had increased significantly the number of bulbs per plant over the control but N_2 and N_3 treatments were found to be at par and these both were significantly higher as compared to N_1 treatment in both the years. At N_3 level maximum bulbs (14.89 and 15.32) were produced, which was at par with the N_2 level whereas at N_0 level minimum bulbs (11.44 and 11.81) were produced during 2001 and 2002, respectively. Perusal of the data has further revealed that number of bulbs per plant were also increased significantly with the increasing levels of plant geometry (spacing) over S_1 and S_2 levels of plant geometry (spacing) during both the years.

Table 28: Effect of nitrogen, plant geometry and biofertilizers on number of bulbs per plant in tuberose.

Treatments		2001							
		BF_0	BF_1	BF_2	BF_3	Mean (N x S)	Mean (S x BF)	Overall mean (N)	Overall Mean (S)
	S_1	8.50	10.05	10.70	9.58	9.71	10.85		12.21
N_0	S_2	10.03	12.54	12.98	11.65	11.80	12.88		
	S_3	11.10	13.70	13.89	12.58	12.82	13.13	11.44	
	Mean	9.88	12.10	12.52	11.27		12.00		
	S_1	10.18	12.40	12.53	11.38	11.62			
N_1	S_2	11.70	13.82	13.90	12.75	13.04	12.20		13.65
	S_3	12.41	14.68	14.93	13.70	13.93	14.44	12.87	
	Mean	11.43	13.63	13.79	12.61		14.60		
	S_1	12.10	14.30	14.48	13.36	13.56	13.38		
N_2	S_2	13.35	15.55	15.60	14.41	14.73			
	S_3	14.20	16.32	16.40	15.35	15.57	13.01	14.62	
	Mean	13.22	15.39	15.49	14.37		15.28		
	S_1	12.60	14.75	14.81	13.68	13.96	15.44		
N_3	S_2	13.70	15.85	15.90	14.70	15.04	14.28	14.89	14.50
	S_3	14.30	16.40	16.55	15.48	15.68			
	Mean	13.53	15.67	15.75	14.62				
Overall Mean (BF)		12.02	14.20	14.39	13.22				

C.D. at 5%

N	=	0.63	N x S	=	1.05
S	=	0.54	N x BF	=	NS
BF	=	0.61	S x BF	=	NS
			N x S x BF	=	NS

Table 29: **Effect of nitrogen, plant geometry and biofertilizers on number of bulbs per plant in tuberose.**

Treatments		2002							
		BF_0	**BF_1**	**BF_2**	**BF_3**	**Mean (N x S)**	**Mean (S x BF)**	**Overall mean (N)**	**Overall Mean (S)**
	S_1	8.72	10.52	11.20	9.97	10.10	11.11		12.59
N_0	S_2	10.27	12.86	13.47	11.92	12.13	13.32		
	S_3	11.36	14.17	14.32	12.88	13.19	13.59	11.81	
	Mean	10.12	12.52	13.00	11.59		12.34		
	S_1	10.45	12.80	12.96	11.68	11.97			
N_1	S_2	11.99	14.32	14.39	13.21	13.48	12.50		14.07
	S_3	12.86	15.12	15.36	14.10	14.36	14.87	13.27	
	Mean	11.77	14.08	14.24	13.00		15.10		
	S_1	12.37	14.76	14.89	13.71	13.94	13.81		
N_2	S_2	13.68	15.99	16.08	14.91	15.17			
	S_3	14.49	16.78	16.89	15.82	16.00	13.34	15.03	
	Mean	13.52	15.84	15.95	14.82		15.73		
	S_1	12.90	15.20	15.29	14.01	14.35	15.91		
N_3	S_2	14.04	16.30	16.45	15.21	15.50	14.68		
	S_3	14.64	16.85	17.05	15.90	16.11		15.32	14.91
	Mean	13.86	16.12	16.26	15.04				
Overall Mean (BF)		12.32	14.64	14.86	13.61				

C.D. at 5%

N	=	0.58	N x S	=	1.11
S	=	0.51	N x BF	=	1.29
BF	=	0.64	S x BF	=	NS
			N x S x BF	=	**NS**

Maximum number of bulbs per plant i.e. 14.50 and 14.91 were obtained with the S_3 level of plant geometry (spacing) whereas, minimum number of bulbs per plant i.e. 12.21 and 12.59 were observed with the S_1 level of plant geometry (spacing) in 2001 and 2002, respectively. Perusal of the data also revealed that all the biofertilizers had increased the bulbs production significantly over the control during both the years. Maximum number of bulbs per plant in case of BF_2 (*Phosphorus Solubilizing Bacteria*) i.e. 14.39 and 14.86 whereas, minimum number of bulbs per plant i.e. 12.02 and 12.32 were observed without application of biofertilizers in 2001 and 2002, respectively. The interaction of nitrogen with plant geometry (spacing) had increased significantly the number of bulbs produced per plant with maximum bulbs in case of N_3S_3 which was at par with N_2S_3 in 2001 and 2002, respectively. The interaction of nitrogen with biofertilizers was found to be non-significant in the year 2001, and had produced significantly more bulbs at N_2BF_2 level which was at par with N_3BF_2 level in the year 2002. Other interactions were found to be non-significant during both the years.

4.3.2 Weight of bulbs per plant (g)

The weight of bulbs produced per plant were weighed and presented in Table 30 & 31. A significant increase in the weight of bulbs produced per plant were observed with biofertilizers

Table 30: ***Effect of nitrogen, plant geometry and biofertilizers on weight of bulbs per plant (g) in tuberose.***

Treatments		2001							
		BF_0	BF_1	BF_2	BF_3	Mean (N x S)	Mean (S x BF)	Overall mean (N)	Overall Mean (S)
	S_1	161.35	196.00	208.64	183.45	187.36	206.24		233.03
N_0	S_2	195.80	230.69	243.55	218.15	222.05	241.69		
	S_3	212.08	245.77	257.75	233.78	237.35	255.06	215.59	
	Mean	189.74	224.15	236.65	211.79		229.14		
	S_1	198.35	233.56	245.56	221.54	224.76			
N_1	S_2	220.89	252.97	263.21	240.14	244.31	230.12		254.43
	S_3	235.44	265.72	273.85	251.61	256.66	262.87	241.91	
	Mean	218.23	250.75	260.87	237.76		274.37		
	S_1	226.46	261.18	274.05	248.14	252.46	250.35		
N_2	S_2	242.34	274.39	287.47	261.35	266.39			
	S_3	266.87	301.52	314.16	288.97	292.88	246.24	270.58	
	Mean	245.22	279.03	291.89	266.15		279.39		
	S_1	238.77	276.01	291.96	263.43	267.55	290.55		
N_3	S_2	261.43	293.41	303.25	281.73	284.96	266.57		
	S_3	270.56	304.55	316.42	291.93	295.87		282.79	270.69
	Mean	256.92	291.32	303.88	279.03				
Overall Mean (BF)		227.53	261.32	273.33	248.69				

C.D. at 5%

N	=	12.29	N x S	=	20.33
S	=	10.64	N x BF	=	27.33
BF	=	10.92	S x BF	=	24.85
			N x S x BF	=	32.66

Table 31: ***Effect of nitrogen, plant geometry and biofertilizers on weight of bulbs per plant (g) in tuberose.***

Treatments		2002							
		BF_0	BF_1	BF_2	BF_3	Mean (N x S)	Mean (S x BF)	Overall mean (N)	Overall Mean (S)
	S_1	165.40	201.69	217.72	191.44	194.06	211.87		240.66
N_0	S_2	200.95	240.09	252.96	226.22	230.06	249.13		
	S_3	219.59	253.98	266.74	241.36	245.42	264.27	223.18	
	Mean	195.32	231.92	245.81	219.68		237.38		
	S_1	204.95	241.91	254.87	229.83	232.89			
N_1	S_2	227.76	261.15	272.26	249.38	252.64	236.71		262.37
	S_3	243.39	275.06	283.34	260.68	265.62	271.45	250.38	
	Mean	225.37	259.38	270.16	246.63		283.55		
	S_1	233.16	269.64	283.33	256.21	260.59	257.78		
N_2	S_2	248.90	282.75	296.26	267.02	273.74			
	S_3	271.96	308.90	322.51	295.47	299.71	252.89	278.01	
	Mean	251.34	287.10	300.70	272.90		287.79		
	S_1	243.20	282.51	300.38	271.26	274.34	300.00		
N_3	S_2	268.48	301.03	311.96	287.73	292.30	274.53		
	S_3	275.84	312.47	326.64	299.87	303.71		290.12	278.80
	Mean	262.51	298.67	312.99	286.29				
Overall Mean (BF)		233.82	269.46	282.60	256.56				

C.D. at 5%

N	=	12.52	N x S	=	21.66
S	=	10.84	N x BF	=	28.23
BF	=	12.12	S x BF	=	24.68
			N x S x BF	=	34.33

and increasing levels of nitrogen and plant geometry (spacing) during both the years. It is further clear from the data that the increasing levels of nitrogen had increased significantly the weight of bulbs per plant over the control but N_2 and N_3 treatments were found to be at par and these both were significantly higher as compared to N_1 treatment in both the years. At N_3 level maximum weight (282.79 g and 290.12g) was recorded, which was at par with the N_2 level whereas at N_0 level minimum weight (215.59g and 223.18g) was recorded during 2001 and 2002, respectively. Perusal of the data has further revealed that weight of bulbs per plant was also increased significantly with the increasing levels of plant geometry (spacing) over S_1 and S_2 levels of plant geometry (spacing) during both the years. Maximum weight of bulbs per plant i.e. 270.69g and 278.80g was obtained with the S_3 level of plant geometry (spacing) whereas, minimum weight of bulbs per plant i.e. 233.03g and 240.66g was observed with the S_1 level of plant geometry (spacing) in 2001 and 2002, respectively. Perusal of the data also revealed that all the biofertilizers had increased the weight of bulbs per plant significantly over the control during both the years. Maximum weight of bulbs per plant in case of BF2 (*Phosphorus Solubilizing Bacteria*) i.e. 273.33g and 282.60g whereas, minimum weight of bulbs per plant i.e. 227.53g and 233.82g was observed without application of

biofertilizers in 2001 and 2002, respectively. The interaction of nitrogen with spacing had increased significantly the weight of bulbs per plant with maximum weights in case of N_3S_3 which was at par with N_2S_3 in 2001 and 2002, respectively. The interaction of nitrogen with biofertilizers had increased significantly the weight of bulbs per plant with maximum weight in case of N_3BF_2 which was found to be at par with N_2BF_2 in 2001 & 2002, respectively. The interaction of spacing with biofertilizers had increased significantly the weight of bulbs per plant with maximum weight in case of S_2BF_2 in 2001 and 2002, respectively. The interaction of NxSxBF had increased significantly the weight of bulbs per plant with maximum weight in case of $N_3S_3BF_2$ which was at par with $N_2S_3BF_2$ in 2001 and 2002, respectively.

4.3.3 Diameter of bulb (mm)

The diameter of bulbs is presented in Table 32 & 33. A significant increase in the diameter of bulbs was observed with biofertilizers and increasing levels of nitrogen and plant geometry (spacing) during both the years. It is further clear from the data that the increasing levels of nitrogen had increased significantly the diameter of bulbs over the control but N_2 and N_3 treatments were found to be at par and these both were significantly higher as compared to N_1 treatment in both the years.

Table 32 : Effect of nitrogen, plant geometry and biofertilizers on diameter of bulbs (mm) in tuberose.

Treatments		2001							
		BF_0	BF_1	BF_2	BF_3	Mean (N x S)	Mean (S x BF)	Overall mean (N)	Overall Mean (S)
	S_1	21.10	22.75	23.28	22.05	22.30	23.36		24.57
N_0	S_2	21.70	23.41	24.03	22.69	22.96	25.02		
	S_3	22.15	23.75	24.29	23.09	23.32	25.56	22.86	
	Mean	21.65	23.30	23.87	22.61		24.34		
	S_1	22.90	24.55	25.08	23.85	24.10			
N_1	S_2	23.45	24.97	25.37	24.18	24.49	23.88		24.94
	S_3	23.87	25.63	26.24	24.97	25.18	25.41	24.59	
	Mean	23.41	25.05	25.56	24.33		25.85		
	S_1	24.15	25.92	25.56	25.28	25.48	24.63		
N_2	S_2	24.72	26.21	26.59	25.42	25.74			
	S_3	25.08	26.72	27.26	26.02	26.27	24.24	25.83	
	Mean	24.65	26.28	26.80	25.57		25.81		
	S_1	24.89	26.47	26.94	25.77	26.02	26.33		
N_3	S_2	25.26	26.66	27.03	25.85	26.20	25.10		
	S_3	25.45	26.74	27.12	25.93	26.31		26.18	25.37
	Mean	25.20	26.62	27.03	25.85				
Overall Mean (BF)		23.83	25.41	25.91	24.69				

C.D. at 5%

N	=	0.40	N x S	=	0.50
S	=	0.34	N x BF	=	0.58
BF	=	0.29	S x BF	=	0.50
			N x S x BF	=	1.01

Table 33: Effect of nitrogen, plant geometry and biofertilizers on diameter of bulb (mm) in tuberose.

Treatments		2002							
		BF_0	BF_1	BF_2	BF_3	Mean (N x S)	Mean (S x BF)	Overall mean (N)	Overall Mean (S)
	S_1	21.31	23.14	23.76	22.39	22.65	23.60		24.94
N_0	S_2	21.93	23.81	24.53	23.06	23.33	25.43		
	S_3	22.50	24.14	24.76	23.42	23.71	26.04	23.23	
	Mean	21.91	23.70	24.35	22.96		24.70		
	S_1	23.15	25.00	25.55	24.23	24.48			
N_1	S_2	23.69	25.37	25.83	24.50	24.85	24.16		25.32
	S_3	24.08	26.07	26.71	25.33	25.55	25.81	24.96	
	Mean	23.64	25.48	26.03	24.69		26.32		
	S_1	24.40	26.28	27.04	25.65	25.84	24.98		
N_2	S_2	25.11	26.62	27.08	25.77	26.15			
	S_3	25.34	27.16	27.76	26.39	26.66	24.50	26.22	
	Mean	24.95	26.69	27.29	25.94		26.23		
	S_1	25.15	26.90	27.42	26.13	26.40	26.81		
N_3	S_2	25.53	27.05	27.44	26.18	26.55	25.46		
	S_3	25.70	27.16	27.61	26.32	26.70		26.55	25.75
	Mean	25.46	27.04	27.49	26.21				
Overall Mean (BF)		24.09	25.82	26.39	25.05				

C.D. at 5%

N	=	0.40	N x S	=	1.35
S	=	0.34	N x BF	=	NS
BF	=	0.78	S x BF	=	NS
			N x S x BF	=	NS

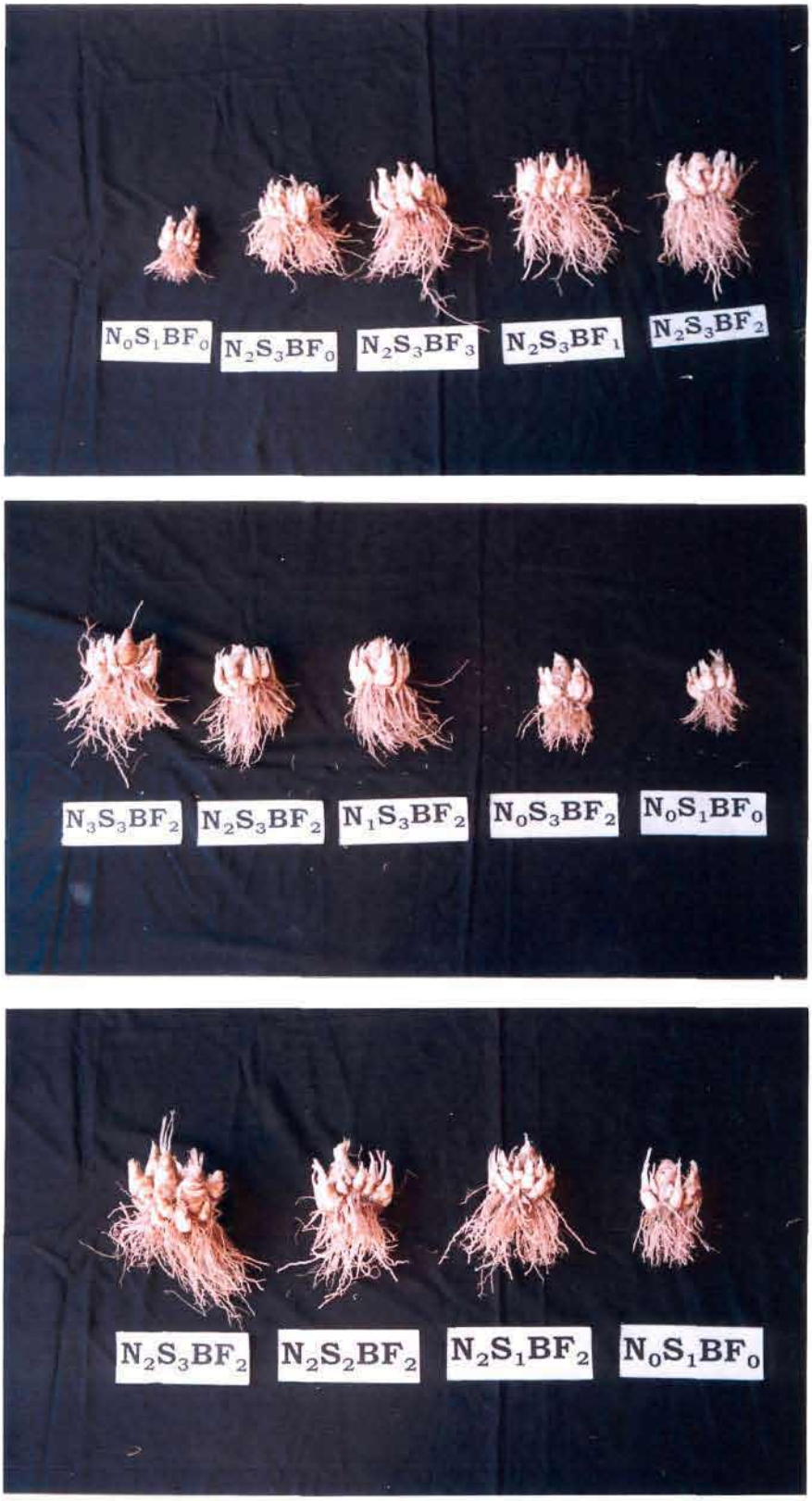


Plate 6: Effect of nitrogen, plant geometry and biofertilizers on bulb production and root characters

At N_3 level maximum diameter of bulbs (26.18mm and 26.55mm) was produced, which was at par with the N_2 level whereas at N_0 level minimum diameter of bulbs (22.86mm and 23.23mm) was produced during 2001 and 2002, respectively. Perusal of the data has further revealed that diameter of bulbs was also increased significantly with the increasing levels of plant geometry (spacing) over S_1 and S_2 levels of plant geometry (spacing) during both the years. Maximum diameter of bulbs i.e. 25.37mm and 25.75mm was obtained with the S_3 level of plant geometry (spacing) whereas, minimum diameter of bulbs i.e. 24.57mm and 24.94mm was observed with the S_1 level of plant geometry (spacing) in 2001 and 2002, respectively. Perusal of the data also revealed that all the biofertilizers had increased the diameter of bulbs significantly over the control during both the years. Maximum diameter of bulbs in case of BF_2 (*Phosphorus Solubilizing Bacteria*) i.e. 25.91mm and 26.39mm whereas, minimum diameter of bulbs i.e. 23.83mm and 24.09mm was observed without application of biofertilizers in 2001 and 2002, respectively. The interaction of nitrogen with spacing had increased significantly the diameter of bulbs with maximum diameter in case of N_3S_3 which was at par with N_2S_3 in 2001 and 2002, respectively. The interaction of nitrogen with biofertilizers had produced significantly were diameter of bulbs

at N_2BF_2 level which was at par with N_3BF_2 level in 2001, and was found to be non- significant in the year 2002. The interaction of spacing with biofertilizers had produced significantly more diameter of bulbs at S_3BF_2 in the year 2001 and was found to be non- significant in the year 2002. The interactions of NxSxBF had increased significantly the diameter of bulbs with more diameter of bulbs in case of $N_3S_3BF_2$ which was at par with $N_2S_3BF_2$ in the year 2001, and was found to be non-significant in the year 2002.

4.4 Root characters

4.4.1 Number of roots developed per plant

Number of roots per plant were counted at the end of the growing season in both the years and the data is presented in Table 34 & 35. Number of roots per plant were increased significantly with the increasing levels of nitrogen and plant geometry (spacing) in both the years. It is further clear from the data that the increasing levels of nitrogen had increased significantly the number of roots per plant over the control but N_2 and N_3 treatments were found to be at par and these both were significantly higher as compared to N_1 treatment in both the years. At N_3 level maximum number of roots (96.65 and 98.83) were recorded, which was at par with the N_2 level whereas, at N_0 level minimum number of roots (81.53 and 83.55) were recorded during 2001 and 2002, respectively. Perusal of

Table 34 : ***Effect of nitrogen, plant geometry and biofertilizers on number of roots developed per plant in tuberose.***

Treatments		2001							
		BF_0	**BF_1**	**BF_2**	**BF_3**	**Mean (N x S)**	**Mean (S x BF)**	**Overall mean (N)**	**Overall Mean (S)**
	S_1	76.00	78.80	82.20	77.60	78.65	86.03		88.30
N_0	S_2	79.25	82.14	83.66	80.93	81.50	88.83		
	S_3	82.40	85.08	86.38	83.89	84.44	90.73	81.53	
	Mean	79.22	82.01	84.08	80.81		87.62		
	S_1	83.45	86.30	87.76	85.09	85.65			
N_1	S_2	86.60	89.25	90.54	88.06	88.61	89.01		91.15
	S_3	89.85	92.65	94.05	91.45	92.00	91.80	88.75	
	Mean	86.63	89.40	90.78	88.20		93.20		
	S_1	90.78	93.68	95.18	92.48	93.03	90.60		
N_2	S_2	93.56	96.23	97.51	95.05	95.59			
	S_3	96.40	99.27	100.73	98.04	98.61	91.65	95.74	
	Mean	93.58	96.39	97.81	95.19		94.39		
	S_1	92.31	94.95	96.18	93.73	94.29	95.75		
N_3	S_2	95.03	97.97	99.48	96.75	97.31	93.19		
	S_3	96.36	98.98	100.23	97.78	98.34		96.65	93.74
	Mean	94.57	97.30	98.63	96.09				
Overall Mean (BF)		88.90	91.67	93.22	90.47				

C.D. at 5%

N	=	1.19	N x S	=	4.35
S	=	1.03	N x BF	=	NS
BF	=	2.51	S x BF	=	NS
			N x S x BF	=	NS

Table 35: Effect of nitrogen, plant geometry and biofertilizers on number of roots developed per plant in tuberose.

Treatments		2002							
		BF_0	BF_1	BF_2	BF_3	Mean (N x S)	Mean (S x BF)	Overall mean (N)	Overall Mean (S)
	S_1	77.51	80.82	82.55	79.49	80.09	87.48		90.07
N_0	S_2	80.97	84.24	86.15	83.35	83.68	90.84		
	S_3	84.78	87.54	88.95	86.27	86.89	92.39	83.55	
	Mean	81.09	84.20	85.88	83.04		89.55		
	S_1	85.43	88.81	90.40	87.64	88.07			
N_1	S_2	88.63	91.89	93.23	90.67	91.11	90.49		93.12
	S_3	91.96	95.31	96.86	94.03	94.54	93.88	91.24	
	Mean	88.67	92.00	93.50	90.78		95.42		
	S_1	92.92	96.42	98.01	95.13	95.62	92.69		
N_2	S_2	95.60	99.02	100.37	97.71	98.18			
	S_3	98.56	101.88	103.43	100.62	101.12	93.34		
	Mean	95.69	99.11	100.60	97.82		96.51	98.31	
	S_1	94.07	97.31	98.59	95.93	96.48	97.96		
N_3	S_2	96.75	100.35	101.91	99.03	99.51	95.23		
	S_3	98.04	101.31	102.61	100.00	100.49		98.83	95.76
	Mean	96.29	99.66	101.04	98.32				
Overall Mean (BF)		90.44	93.74	95.26	92.49				

C.D. at 5%

N	=	1.41	N x S	=	3.40
S	=	1.22	N x BF	=	NS
BF	=	1.96	S x BF	=	NS
			N x S x BF	=	NS

the data has further revealed that number of roots per plant were also increased significantly with the increasing levels of plant geometry (spacing) over S_1 and S_2 levels of plant geometry (spacing) during both the years. Maximum number of roots per plant i.e. 93.74 and 95.76 were produced with the S_3 level of plant geometry (spacing) whereas, minimum number of roots per plant i.e. 88.30 and 90.07 were produced with the S_1 level of plant geometry (spacing) in 2001 and 2002, respectively. Perusal of the data also revealed that all the biofertilizers had increased the number of roots per plant significantly over the control except BF_3 (*Azospirillum*) in the year 2001, with maximum number of roots per plant in case of BF_2 (*Phosphorus Solubilizing Bacteria*) i.e. 93.22 and 95.26 whereas, minimum number of roots per plant i.e. 88.90 and 90.44 were observed without application of biofertilizers in 2001 and 2002, respectively. The interaction of nitrogen with spacing had increased significantly the number of roots per plant with maximum number of roots per plant in case of N_3S_3 which was at par with N_2S_3 in 2001 and 2002, respectively. Other interactions were found to be non-significant during both the years.

4.4.2 Average length of roots per plant (cm)

Average length of roots were measured at the end of growing season in both the years and the data is given in Table 36 & 37. Average length of roots per plant were increased significantly

Table 36 : ***Effect of nitrogen, plant geometry and biofertilizers on average length of root (cm) in tuberose.***

Treatments		2001							
		BF_0	**BF_1**	**BF_2**	**BF_3**	**Mean (N x S)**	**Mean (S x BF)**	**Overall mean (N)**	**Overall Mean (S)**
	S_1	5.25	5.70	6.05	5.45	5.61	7.05		7.42
N_0	S_2	5.62	6.17	6.62	5.92	6.08	7.50		
	S_3	5.93	6.35	6.72	6.14	6.29	7.87	5.99	
	Mean	5.60	6.07	6.46	5.84		7.27		
	S_1	6.60	6.98	7.31	6.77	6.92			
N_1	S_2	7.00	7.50	7.88	7.22	7.40	7.46		7.89
	S_3	7.35	7.75	8.04	7.47	7.65	7.98	7.32	
	Mean	6.98	7.41	7.74	7.15		8.39		
	S_1	7.95	8.56	9.06	8.35	8.48	7.72		
N_2	S_2	8.33	8.78	9.13	8.53	8.69			
	S_3	8.65	9.14	9.55	8.88	9.06	7.80	8.74	
	Mean	8.31	8.83	9.25	8.59		8.24		
	S_1	8.08	8.45	8.74	8.17	8.36	8.59		
N_3	S_2	8.56	9.15	9.60	8.89	9.05	7.98		
	S_3	8.93	9.38	9.74	9.12	9.29		8.90	8.15
	Mean	8.52	8.99	9.36	8.73				
Overall Mean (BF)		7.43	7.91	8.28	7.66				

C.D. at 5%

N	=	0.21	N x S	=	0.35
S	=	0.18	N x BF	=	NS
BF	=	0.20	S x BF	=	0.35
			N x S x BF	=	0.71

Table 37: ***Effect of nitrogen, plant geometry and biofertilizers on average length of root (cm) in tuberose.***

Treatments		2002							
		BF_0	**BF_1**	**BF_2**	**BF_3**	**Mean (N x S)**	**Mean (S x BF)**	**Overall mean (N)**	**Overall Mean (S)**
	S_1	5.30	5.78	6.14	5.51	5.68	7.11		7.50
N_0	S_2	5.68	6.24	6.71	5.97	6.15	7.59		
	S_3	6.00	6.43	6.82	6.21	6.37	7.97	6.07	
	Mean	5.66	6.15	6.56	5.90		7.33		
	S_1	6.68	7.07	7.41	6.83	7.00			
N_1	S_2	7.05	7.55	7.97	7.32	7.47	7.52		7.96
	S_3	7.42	7.83	8.13	7.58	7.74	8.05	7.40	
	Mean	7.05	7.48	7.84	7.24		8.47		
	S_1	8.01	8.64	9.16	8.42	8.56	7.79		
N_2	S_2	8.39	8.87	9.21	8.61	8.77			
	S_3	8.72	9.22	9.65	8.95	9.14	7.86		
	Mean	8.37	8.91	9.34	8.66		8.32	8.82	
	S_1	8.16	8.56	8.86	8.26	8.46	8.69		
N_3	S_2	8.65	9.25	9.69	8.97	9.14	8.06		
	S_3	9.00	9.49	9.86	9.21	9.39		9.00	8.23
	Mean	8.60	9.10	9.47	8.81				
Overall Mean (BF)		7.50	7.99	8.38	7.73				

C.D. at 5%

N	=	0.20	N x S	=	0.76
S	=	0.18	N x BF	=	NS
BF	=	0.44	S x BF	=	NS
			N x S x BF	=	NS

with increasing levels of nitrogen and plant geometry (spacing) in both the years. It is further clear from the data that the increasing levels of nitrogen had increased significantly the average length of roots per plant over the control but N_2 and N_3 treatments were found to be at par and these both were significantly higher as compared to N_1 treatment in both the years. At N_3 level maximum length of roots (8.90cm and 9.00cm) were recorded, which was at par with the N_2 level whereas, at N_0 level minimum length of roots (5.99cm and 6.07cm) were recorded during 2001 and 2002, respectively. Perusal of the data has further revealed that average length of roots per plant were also increased significantly with the increasing levels of plant geometry (spacing) over S_1 and S_2 levels of plant geometry (spacing) during both the years. Maximum length of roots per plant i.e. 8.15 cm and 8.23cm were produced with the S_3 level of plant geometry (spacing) whereas, minimum length of roots per plant i.e. 7.42cm and 7.50cm were produced with the S_1 level of plant geometry (spacing) in 2001 and 2002, respectively. Perusal of the data also revealed that all the biofertilizers had increased the average length of roots per plant significantly over the control except BF_3 (*Azospirillum*) in year 2002, with maximum root length in case of BF_2 (*Phosphorus Solubilizing Bacteria*) i.e. 8.28cm and 8.38cm whereas minimum root length i.e. 7.43cm and 7.50cm were observed without application of biofertilizers in

2001 and 2002, respectively. The interaction of nitrogen with spacing had increased significantly the average length of roots per plant with maximum root length per plant in case of N_3S_3 level, which was at par with N_2S_3 level in 2001 and 2002, respectively. The interaction of nitrogen with biofertilizers were found to be non-significant in both the years. The interaction of spacing with biofertilizers had increased significantly the average length of roots with maximum length of roots per plant in case of S_3BF_2 in the year 2001, and was found to non-significant in the year 2002. The interactions of NxSxBF had increased significantly the average length of roots per plant with maximum length of roots per plant in case of $N_3S_3BF_2$ level, which was found to be at par with the $N_2S_3BF_2$ level, in the year 2001, and was found to be non-significant in the year 2002.

4.4.3 Total root biomass (g)

Total root biomass was noted at the end of the growing season in both the years and the data is given in Table 38 & 39. Total root biomass were increased significantly with the increasing levels of nitrogen and plant geometry (spacing) during both the years. It is further clear from the data that the increasing levels of nitrogen had increased significantly the total root biomass over the control but N_2 and N_3 treatments were found to be at par and these both were significantly higher as compared to N_1 treatment in both the years. At N_3 level maximum

Table 38 : Effect of nitrogen, plant geometry and biofertilizers on total root biomass (g) in tuberose.

Treatments		2001							
		BF_0	BF_1	BF_2	BF_3	Mean (N x S)	Mean (S x BF)	Overall mean (N)	Overall Mean (S)
	S_1	1.45	1.49	1.52	1.47	1.48	2.41		2.44
N_0	S_2	1.87	1.94	1.99	1.91	1.93	2.46		
	S_3	2.12	2.21	2.29	2.19	2.20	2.50	1.87	
	Mean	1.81	1.88	1.93	1.86		2.44		
	S_1	2.10	2.14	2.17	2.12	2.13			
N_1	S_2	2.45	2.47	2.49	2.46	2.47	2.77		2.81
	S_3	2.78	2.83	2.89	2.82	2.83	2.84		
	Mean	2.44	2.48	2.52	2.47		2.89	2.48	
	S_1	2.80	2.87	2.93	2.86	2.87	2.81		
N_2	S_2	3.14	3.24	3.32	3.22	3.23			
	S_3	3.35	3.38	3.42	3.36	3.38	3.04	3.16	
	Mean	3.10	3.16	3.22	3.15		3.09		
	S_1	2.90	2.94	2.97	2.92	2.93	3.14		
N_3	S_2	3.22	3.29	3.34	3.26	3.28	3.07		
	S_3	3.50	3.53	3.55	3.51	3.52			
	Mean	3.21	3.25	3.29	3.23			3.24	3.07
Overall Mean (BF)		2.71	2.78	2.84	2.76				

C.D. at 5%

N	=	0.11	N x S	=	0.06
S	=	0.10	N x BF	=	0.07
BF	=	0.05	S x BF	=	0.06
			N x S x BF	=	0.13

Effect of nitrogen, plant geometry and biofertilizers on total root biomass (g) in tuberose.

Treatments		2002							
		BF_0	BF_1	BF_2	BF_3	Mean (N x S)	Mean (S x BF)	Overall mean (N)	Overall Mean (S)
	S_1	1.48	1.53	1.59	1.51	1.53	2.38		2.45
N_0	S_2	1.91	2.00	2.06	1.96	1.98	2.45		
	S_3	2.17	2.28	2.37	2.25	2.27	2.50	1.93	
	Mean	1.85	1.94	2.01	1.91		2.42		
	S_1	2.14	2.20	2.24	2.17	2.19			
N_1	S_2	2.50	2.53	2.57	2.52	2.53	2.74		2.83
	S_3	2.83	2.89	2.94	2.87	2.88	2.83	2.53	
	Mean	2.49	2.54	2.58	2.52		2.89		
	S_1	2.85	2.94	3.00	2.93	2.93	2.80		
N_2	S_2	3.18	3.32	3.40	3.28	3.30			
	S_3	3.38	3.44	3.50	3.41	3.43	3.00	3.22	
	Mean	3.14	3.23	3.30	3.21		3.08		
	S_1	2.93	3.00	3.04	2.97	2.99	3.14		
N_3	S_2	3.26	3.35	3.41	3.31	3.33	3.05		
	S_3	3.53	3.59	3.62	3.56	3.58		3.30	3.08
	Mean	3.24	3.31	3.36	3.28				
	Mean (BF)	2.74	2.79	2.84	2.78				

=	0.12	N x S	=	0.43
=	0.11	N x BF	=	NS
=	0.04	S x BF	=	NS
		N x S x BF	=	**NS**

total root biomass (3.24g and 3.30g) were recorded, which was at par with the N_2 level whereas, at N_0 level minimum total root biomass (1.87 g and 1.93g) were recorded during 2001 and 2002, respectively. Perusal of the data has further revealed that total root biomass were also increased significantly with the increasing levels of plant geometry (spacing) over S_1 and S_2 levels of plant gometry (spacing) during both the years. Maximum total root biomass i.e. 3.07g and 3.08g were produced with the S_3 level of plant geometry (spacing) whereas, minimum total root biomass i.e. 2.44g and 2.45g were produced with the S_1 level of plant geometry (spacing) in 2001 and 2002, respectively. Perusal of the data also revealed that all the biofertilizers had increased significantly the total root biomass over the control except BF_3 (*Azospirillum*) in both the years. Maximum total root biomass in case of BF_2 (*Phosphorus Solubilizing Bacteria*) i.e. 2.84g and 2.84g whereas, minimum total root biomass i.e. 2.71 and 2.74g were observed without application of biofertilizers in 2001 and 2002, respectively. The interaction of nitrogen with spacing had increased significantly the total root biomass in both the years. The interaction of nitrogen with biofertilizers had increased significantly the total root biomass in the year 2001, and was found to be non-significant in the year 2002. The interaction of spacing with biofetilizers had increased significantly the total root biomass in

the year 2001, and was found to be non-significant in the year 2002. The interactions of NxSxBF had significant effect on the total root biomass in the year 2001, and was found to be non-significant in the year 2002.

4.5 Nutrient contents

4.5.1 Nitrogen content in leaves (%)

The perusal of data presented in Table 40 & 41 showed that nitrogen content in leaves were increased significantly with increasing levels of nitrogen and plant geometry (spacing) during both the years. It is further clear from the data that the increasing levels of nitrogen had increased significantly the nitrogen content in leaves over the control in both the years. The N_3 treatment was significantly higher over N_2 and N_1 treatment during both the years. At N_3 level maximum nitrogen content in leaves (2.08% and 2.17%) was recorded whereas, at N_0 levels minimum nitrogen content in leaves (1.59% and 1.69%) was recorded during 2001 and 2002, respectively.

Perusal of the data has further revealed that nitrogen content in leaves were also increased significantly with the increasing levels of plant geometry (spacing) over S_1 and S_2 levels of plant geometry (spacing) during the both the years. Maximum nitrogen content in leaves i.e. 1.92% and 2.02% was recorded with the S_3 level of plant geometry (spacing) whereas,

Table 40 : ***Effect of nitrogen, plant geometry and biofertilizers on nitrogen content in leaves (%) in tuberose.***

Treatments		2001							
		BF_0	**BF_1**	**BF_2**	**BF_3**	**Mean (N x S)**	**Mean (S x BF)**	**Overall mean (N)**	**Overall Mean (S)**
	S_1	1.46	1.60	1.53	1.56	1.54	1.76		1.81
N_0	S_2	1.55	1.64	1.57	1.61	1.59	1.86		
	S_3	1.60	1.69	1.63	1.65	1.64	1.80	1.59	
	Mean	1.54	1.64	1.58	1.61		1.83		
	S_1	1.69	1.79	1.72	1.76	1.74			
N_1	S_2	1.74	1.83	1.76	1.79	1.78	1.82		1.85
	S_3	1.80	1.88	1.81	1.84	1.83	1.90	1.78	
	Mean	1.74	1.83	1.76	1.80		1.83		
	S_1	1.90	1.98	1.92	1.95	1.94	1.87		
N_2	S_2	1.94	2.02	1.95	1.99	1.98			
	S_3	2.00	2.12	2.05	2.08	2.06	1.87	1.99	
	Mean	1.95	2.04	1.97	2.01		1.97		
	S_1	2.00	2.08	2.01	2.04	2.03	1.91		
N_3	S_2	2.03	2.11	2.04	2.08	2.07	1.93		
	S_3	2.09	2.18	2.13	2.15	2.14		2.08	1.92
	Mean	2.04	2.12	2.06	2.09				
Overall Mean (BF)		1.82	1.92	1.84	1.88				

C.D. at 5%

N	=	0.02	N x S	=	NS
S	=	0.02	N x BF	=	NS
BF	=	0.09	S x BF	=	NS
			N x S x BF	=	NS

Table 41: ***Effect of nitrogen, plant geometry and biofertilizers on nitrogen content in leaves (%)in tuberose.***

Treatments		2002							
		BF_0	**BF_1**	**BF_2**	**BF_3**	**Mean (N x S)**	**Mean (S x BF)**	**Overall mean (N)**	**Overall Mean (S)**
	S_1	1.56	1.69	1.63	1.66	1.64	1.86		1.91
N_0	S_2	1.65	1.73	1.66	1.70	1.69	1.96		
	S_3	1.71	1.79	1.73	1.74	1.74	1.89	1.69	
	Mean	1.64	1.74	1.67	1.70		1.92		
	S_1	1.78	1.89	1.82	1.85	1.84			
N_1	S_2	1.83	1.93	1.87	1.89	1.88	1.91		1.95
	S_3	1.89	1.97	1.91	1.93	1.93	1.99	1.88	
	Mean	1.83	1.93	1.87	1.89		1.93		
	S_1	1.99	2.08	2.02	2.04	2.03	1.97		
N_2	S_2	2.03	2.11	2.05	2.09	2.07			
	S_3	2.09	2.21	2.15	2.18	2.16	1.97	2.09	
	Mean	2.04	2.13	2.07	2.10		2.06		
	S_1	2.09	2.16	2.10	2.13	2.12	2.01		
N_3	S_2	2.12	2.19	2.13	2.18	2.16	2.02		
	S_3	2.19	2.28	2.23	2.24	2.24		2.17	2.02
	Mean	2.13	2.21	2.15	2.18				
Overall Mean (BF)		1.91	2.00	1.94	1.97				

C.D. at 5%

N	=	0.02	N x S	=	0.13
S	=	0.02	N x BF	=	NS
BF	=	0.07	S x BF	=	NS
			N x S x BF	=	**NS**

minimum nitrogen content in leaves i.e. 1.81% and 1.91% was recorded with the S_1 level of plant geometry (spacing) in 2001 and 2002, respectively. Perusal of the data also revealed that only BF_1 (*Azotobacter*) biofertilizer had increased significantly the nitrogen content in leaves over the control during both the years. Maximum nitrogen content in leaves i.e. 1.92% and 2.00% was recorded in case of BF_1 (*Azotobacter*) biofertilizer whereas, minimum nitrogen content in leaves i.e. 1.82% and 1.91% were observed without application of biofertilizers in 2001 and 2002, respectively. The interaction of nitrogen with spacing was found to be non-significant in the year 2001, and had increased significantly the nitrogen content in case of N_3S_3 in the year 2002. Other interactions were found to be non-significant in both the years.

4.5.2 Phosphorus content in leaves (%)

The perusal of data presented in Table 42 & 43 showed that phosphorus content in leaves was increased significantly with the increasing levels of nitrogen and plant geometry (spacing) during both the years. It is further clear from the data that the increasing levels of nitrogen had increased significantly the phosphorus content in leaves over the control but N_2 and N_3 treatment was found to be at par and N_3 treatment was significantly higher as compared to N_1 treatment but N_2 treatment was found to be at par with N_1 treatment in

Table 42: ***Effect of nitrogen, plant geometry and biofertilizers on phosphorus content in leaves (%) in tuberose.***

Treatments		2001							
		BF_0	**BF_1**	**BF_2**	**BF_3**	**Mean (N x S)**	**Mean (S x BF)**	**Overall mean (N)**	**Overall Mean (S)**
	S_1	0.25	0.28	0.34	0.27	0.29	0.29		0.32
N_0	S_2	0.30	0.33	0.37	0.32	0.33	0.32		
	S_3	0.32	0.34	0.38	0.33	0.34	0.38	0.32	
	Mean	0.29	0.32	0.36	0.31		0.31		
	S_1	0.28	0.32	0.38	0.30	0.32			
N_1	S_2	0.33	0.37	0.41	0.35	0.37	0.34		0.37
	S_3	0.36	0.37	0.42	0.36	0.38	0.37	0.36	
	Mean	0.32	0.35	0.40	0.34		0.41		
	S_1	0.30	0.32	0.39	0.31	0.33	0.35		
N_2	S_2	0.35	0.37	0.41	0.36	0.37			
	S_3	0.37	0.38	0.43	0.38	0.39	0.36	0.37	
	Mean	0.34	0.36	0.41	0.35		0.38		
	S_1	0.31	0.34	0.40	0.34	0.35	0.42		
N_3	S_2	0.35	0.39	0.44	0.37	0.39	0.37		
	S_3	0.38	0.39	0.44	0.38	0.40		0.38	0.38
	Mean	0.35	0.37	0.43	0.36				
Overall Mean (BF)		0.33	0.35	0.41	0.34				

C.D. at 5%

N	=	0.01	N x S	=	NS
S	=	0.01	N x BF	=	NS
BF	=	0.04	S x BF	=	0.06
			N x S x BF	=	NS

Table 43: ***Effect of nitrogen, plant geometry and biofertilizers on phosphorus content in leaves (%)in tuberose.***

Treatments		2002							
		BF_0	**BF_1**	**BF_2**	**BF_3**	**Mean (N x S)**	**Mean (S x BF)**	**Overall mean (N)**	**Overall Mean (S)**
	S_1	0.28	0.32	0.38	0.31	0.32	0.32		0.37
N_0	S_2	0.34	0.37	0.42	0.36	0.37	0.36		
	S_3	0.35	0.38	0.43	0.37	0.39	0.42	0.36	
	Mean	0.32	0.36	0.41	0.35		0.35		
	S_1	0.33	0.36	0.42	0.35	0.37			
N_1	S_2	0.37	0.41	0.44	0.39	0.40	0.37		0.41
	S_3	0.39	0.41	0.47	0.40	0.42	0.41	0.40	
	Mean	0.37	0.40	0.45	0.38		0.45		
	S_1	0.33	0.36	0.43	0.35	0.37	0.39		
N_2	S_2	0.38	0.41	0.46	0.40	0.41			
	S_3	0.41	0.43	0.48	0.42	0.44	0.39	0.41	
	Mean	0.37	0.40	0.46	0.39		0.42		
	S_1	0.34	0.38	0.45	0.39	0.39	0.47		
N_3	S_2	0.39	0.43	0.48	0.40	0.43	0.40		
	S_3	0.41	0.44	0.48	0.41	0.44		0.42	0.42
	Mean	0.38	0.42	0.47	0.40				
Overall Mean (BF)		0.36	0.40	0.45	0.38				

C.D. at 5%

N	=	0.01	N x S	=	0.07
S	=	0.01	N x BF	=	NS
BF	=	0.04	S x BF	=	0.07
			N x S x BF	=	**NS**

both the years. At N_3 levels maximum phosphorus content in leaves (0.38% and 0.42%) was recorded, which was found to be at par with N_2 level whereas, minimum phosphorus content in leaves (0.32% and 0.36%) was recorded at N_0 level during 2001 and 2002, respectively. Perusal of the data has further revealed that phosphorus content in leaves was also increased significantly with the increasing levels of plant geometry (spacing) over S_1 level of plant geometry (spacing) but S_3 level of plant geometry (spacing) was found to be at par with S_2 level of plant geometry (spacing) during both the years. Maximum phosphorus content in leaves (0.38% and 0.42%) was produced at S_3 level of plant geometry (spacing), which was found to be at par with S_2 level of plant geometry (spacing) whereas, minimum phosphorus content in leaves (0.32% and 0.37%) was recorded at S_1 level of plant geometry (spacing) during 2001 and 2002, respectively. Perusal of the data also revealed that only BF_2 (*Phosphorus solulbilizing bacteria*) biofertilizer had increased significantly the phosphorus content in leaves over the control during both the years. Maximum phosphorus content in leaves (0.41% and 0.45%) was recorded in case of BF_2 (*Phosphorus Solubilizing Bacteria*) whereas, minimum phosphorus content in leaves i.e. 0.33% and 0.36% was recorded without application of biofertilizer in 2001 and 2002, respectively. The interaction of nitrogen with spacing was found to be non-significant in the

year 2001 and had increased significantly the phosphorus content in leaves in the year 2002 . The interaction of nitrogen with biofertilizers was found to be non-significant in both the years. The interaction of spacing with biofertilizers had increased significantly the phosphorus content in leaves in both the years. The interactions of NxSxBF were found to be non-significant in both the years.

4.5.3 Potassium content in leaves (%)

The perusal of data presented in Table 44 & 45 showed that potassium content in leaves was significantly reduced with the increasing levels of nitrogen over the control in both the year. The N_3 treatment was significantly reduced the potassium content in leaves over N_2 and N_1 treatments during both the years. At N_0 level maximum potassium content in leaves (5.29% and 5.44%) was recorded during 2001 and 2002, respectively. At N_3 level maximum potassium content in leaves (4.25% and 4.40%) was recorded during 2001 and 2002, respectively. Perusal of data has further revealed that the potassium content in leaves was increased significantly with the increasing levels of plant geometry (spacing) over S_1 and S_2 levels of plant geometry (spacing) during both the years. Maximum potassium content in leaves (4.87% and 5.01%) was recorded at S_3 level of plant geometry (spacing) whereas, minimum potassium content in leaves (4.75% and 4.90%) was

Table 44 : ***Effect of nitrogen, plant geometry and biofertilizers on potassium content in leaves (%) in tuberose.***

Treatments		2001							
		BF_0	**BF_1**	**BF_2**	**BF_3**	**Mean (N x S)**	**Mean (S x BF)**	**Overall mean (N)**	**Overall Mean (S)**
	S_1	5.18	5.23	5.27	5.25	5.23	4.69		4.75
N_0	S_2	5.24	5.28	5.35	5.32	5.30	4.75		
	S_3	5.30	5.35	5.38	5.35	5.35	4.80	5.29	
	Mean	5.24	5.29	5.33	5.31		4.77		
	S_1	4.98	5.04	5.08	5.05	5.04			
N_1	S_2	5.05	5.09	5.14	5.11	5.10	4.77		4.82
	S_3	5.11	5.14	5.17	5.15	5.14	4.81	5.09	
	Mean	5.05	5.09	5.13	5.10		4.87		
	S_1	4.50	4.56	4.60	4.58	4.56	4.84		
N_2	S_2	4.57	4.62	4.67	4.64	4.63			
	S_3	4.63	4.66	4.70	4.67	4.67	4.83	4.62	
	Mean	4.57	4.61	4.66	4.63		4.87		
	S_1	4.10	4.18	4.23	4.20	4.18	4.90		
N_3	S_2	4.22	4.26	4.31	4.27	4.27	4.87		
	S_3	4.27	4.31	4.35	4.32	4.31		4.25	4.87
	Mean	4.20	4.25	4.30	4.26				
Overall Mean (BF)		4.76	4.81	4.85	4.83				

C.D. at 5%

N	=	0.02	N x S	=	NS
S	=	0.01	N x BF	=	NS
BF	=	0.07	S x BF	=	NS
			N x S x BF	=	NS

Table 45: ***Effect of nitrogen, plant geometry and biofertilizers on potassium content in leaves (%)in tuberose.***

Treatments		2002							
		BF_0	**BF_1**	**BF_2**	**BF_3**	**Mean (N x S)**	**Mean (S x BF)**	**Overall mean (N)**	**Overall Mean (S)**
	S_1	5.31	5.37	5.43	5.39	5.38	4.82		4.90
N_0	S_2	5.36	5.43	5.52	5.46	5.44	4.89		
	S_3	5.43	5.50	5.52	5.51	5.49	4.95	5.44	
	Mean	5.37	5.43	5.49	5.45		4.92		
	S_1	5.12	5.20	5.25	5.18	5.19			
N_1	S_2	5.20	5.25	5.27	5.25	5.24	4.91		4.97
	S_3	5.23	5.28	5.32	5.28	5.28	4.97	5.24	
	Mean	5.18	5.24	5.28	5.24		5.02		
	S_1	4.62	4.70	4.75	4.74	4.70	4.99		
N_2	S_2	4.70	4.77	4.81	4.80	4.77			
	S_3	4.77	4.81	4.87	4.81	4.82	4.96	4.76	
	Mean	4.70	4.76	4.81	4.78		5.02		
	S_1	4.23	4.30	4.38	4.36	4.32	5.05		
N_3	S_2	4.36	4.41	4.47	4.44	4.42	5.02		
	S_3	4.40	4.48	4.49	4.47	4.46		4.40	5.01
	Mean	4.33	4.40	4.45	4.42				
Overall Mean (BF)		4.89	4.96	5.01	4.97				

C.D. at 5%

N	=	0.02	N x S	=	NS
S	=	0.02	N x BF	=	NS
BF	=	0.08	S x BF	=	NS
			N x S x BF	=	**NS**

recorded at S_1 level of plant geometry (spacing) during 2001 and 2002, respectively. Perusal of the data also revealed that only BF_2 (*Phosphorus Solubilizing Bacteria*) biofertilizer had increased significantly the potassium content in leaves during both the years. Maximum potassium content in leaves i.e. 4.85% and 5.01% was recorded in case of BF_2 (*Phosphorus Solubilizing Bacteria*) biofertilizer whereas, minimum potassium content in leaves i.e. 4.76% and 4.89% was recorded without application of biofertilizer in 2001 & 2002, respectively. The interactions were found to be non-significant in both the years.

4.5.4 Zinc content in leaves (ppm)

The perusal of data presented in Table 46 & 47 showed that zinc content in leaves was increased significantly with the increasing levels of nitrogen and plant geometry (spacing) during both the years. It is further clear from the data that the increasing levels of nitrogen had increased significantly the zinc content in leaves over the control but N_2 and N_3 treatments were found to be at par and these both were significantly higher as compared to N_1 treatment in both the years. At N_3 level maximum zinc content in leaves (53.01 ppm and 58.11 ppm) was recorded, which was found to be at par with N_2 level whereas, minimum zinc content in leaves (40.47 ppm and 42.94 ppm) was recorded at N_0 during 2001 and 2002, respectively. Perusal of the data has further revealed that zinc

Table 46 : Effect of nitrogen, plant geometry and biofertilizers on Zinc content in leaves (ppm) in tuberose.

Treatments		2001							
		BF_0	BF_1	BF_2	BF_3	Mean (N x S)	Mean (S x BF)	Overall mean (N)	Overall Mean (S)
	S_1	40.15	40.19	40.28	40.34	40.24	48.71		48.80
N_0	S_2	40.38	40.43	40.53	40.60	40.49	48.75		
	S_3	40.58	40.64	40.73	40.82	40.69	48.83	40.47	
	Mean	40.37	40.42	40.51	40.59		48.90		
	S_1	46.25	46.30	46.38	46.45	46.35			
N_1	S_2	46.47	46.53	46.64	46.70	46.59	48.94		49.04
	S_3	46.67	46.74	46.82	46.91	46.79	48.99	46.57	
	Mean	46.46	46.52	46.61	46.69		49.08		
	S_1	52.60	52.63	52.72	52.79	52.69	49.16		
N_2	S_2	52.84	52.89	52.98	53.06	52.94			
	S_3	53.04	53.11	53.19	53.27	53.15	49.14	52.93	
	Mean	52.83	52.88	52.96	53.04		49.20		
	S_1	52.69	52.74	52.82	52.88	52.78	49.28		
N_3	S_2	52.93	52.97	53.05	53.15	53.03	49.38		
	S_3	53.12	53.17	53.25	53.37	53.23		53.01	49.25
	Mean	52.91	52.96	53.04	53.13				
Overall Mean (BF)		48.93	48.98	49.07	49.14				

C.D. at 5%

N	=	0.10	N x S	=	NS
S	=	0.07	N x BF	=	NS
BF	=	NS	S x BF	=	NS
			N x S x BF	=	NS

Table 47: ***Effect of nitrogen, plant geometry and biofertilizers on zinc content in leaves (ppm) in tuberose.***

Treatments		2002							
		BF_0	BF_1	BF_2	BF_3	Mean (N x S)	Mean (S x BF)	Overall mean (N)	Overall Mean (S)
	S_1	42.18	42.54	42.78	42.98	42.62	51.98		52.25
N_0	S_2	42.82	42.90	43.00	43.10	42.96	52.23		
	S_3	43.07	43.15	43.30	43.40	43.23	52.34	42.94	
	Mean	42.69	42.86	43.03	43.16		52.46		
	S_1	50.37	50.45	50.53	50.62	50.49			
N_1	S_2	50.65	50.73	50.88	50.92	50.80	52.46		52.60
	S_3	50.87	50.95	51.00	51.12	50.99	52.54	50.76	
	Mean	50.62	50.71	50.80	50.89		52.66		
	S_1	57.40	57.67	57.75	57.85	57.67	52.74		
N_2	S_2	57.95	58.03	58.15	58.27	58.10			
	S_3	58.24	58.29	58.38	58.50	58.35	52.71	58.04	
	Mean	57.86	58.00	58.09	58.21		52.78		
	S_1	57.60	57.85	57.90	57.98	57.83	52.86		
N_3	S_2	58.03	58.10	58.21	58.28	58.16	52.98		
	S_3	58.25	58.31	58.37	58.48	58.35		58.11	52.83
	Mean	57.96	58.09	58.16	58.25				
Overall Mean (BF)		52.38	52.51	52.62	52.73				

C.D. at 5%

N	=	0.09	N x S	=	NS
S	=	0.08	N x BF	=	NS
BF	=	NS	S x BF	=	NS
			N x S x BF	=	NS

content in leaves was also increased significantly with the increasing levels of plant geometry (spacing) over S_1 and S_2 levels of plant geometry (spacing) during the both the years. Maximum zinc content in leaves i.e. 49.25 ppm and 52.83 ppm was recorded with the S_3 level of plant geometry (spacing) whereas, minimum zinc content in leaves i.e. 48.80 ppm and 52.25 ppm was recorded with the S_1 level of plant geometry (spacing) in 2001 and 2002, respectively. Perusal of the data also revealed that biofertilizers had no effect on zinc content of leaves during both the years. The interactions were found to be non-significant in both the years.

CHAPTER – V

Discussion

Tuberose (*Polianthes tuberosa* L.) popularly known as 'Rajnigandha', is an important cut flower due to its prettiness, elegance and pleasant fragrance. It has great role in economy as the cut flowers are exported to other countries, spikes as cut flower are used in vase decoration, bouquet and for other purposes. Application of nitrogen, phosphorus and potassium has shown improvement in the growth and floral quality of this crop. A lot of information is available regarding this aspect. With almost twice the quantity of plant nutrients are removed from soil than what were added through fertilizers i.e. the growing nutrients imbalance, poses a major threat to sustain soil, health and crop productivity. The recent fall in the fertilizer consumption due to unprecedented hike in the prices of P and K fertilizers has further aggregated the problem and has underlined the need for adoption of integrated nutrient supply system which involves the combined use of different nutrient

sources such as chemical fertilizers, organic manures and biofertilizers etc.

Biofertilizers are the products conferring living cells of different types of micro-organisms which have the ability to mobilise nutritionally important elements from non-usable. So the present investigation was planned to generate information on the effects of biofertilizers alone and in combination with different levels of nitrogen and plant geometry (spacing) on different growth and quality parameters and N,P,K and Zn content in the leaves of tuberose. The results of the present investigation are discussed as under:

5.1 Growth parameters

5.1.1 Number of days taken for sprouting of bulbs

The sprouting period of tuberose was significantly shortened with the increasing doses of nitrogen over the control (N_0) but N_2 (200 kg N ha^{-1})and N_3 (300 kg N ha^{-1}) treatments were found to be at par and these both were significantly shortened the sprouting period as compared to N_1 (100 kg N ha^{-1}) treatment during both the years. The sprouting period of tuberose were also significantly shortened with the increasing levels of plant geometry (spacing) over S_1 (20 x 20cm) and S_2 (20 x 25cm) levels of plant geometry (spacing) during both the years. In case of biofertilizers only BF_1 (*Azotobacter*) biofertilizer had significantly shortened the sprouting period over control during

both the years. The interactions of N x S and N x BF were also found significant as in both the treatments the sprouting was earlier. The interactions of S x BF and N x S x BF were found to be non-significant during both the years. Shortening of sprouting period may be due to early absorption of nitrogen through the surface of the bulbs or by primary roots which might have stimulated early sprouting. Biofertilizers also reduced the sprouting period as they supply nitrogen and phosphorus which is helpful in sprouting and in combination with nitrogen and phosphorus, biofertilizers increased the availability of the macro as well as micro-nutrients due to which the sprouting period was reduced. Mukhopadhyay and Bankar (1986). Singh *et al.*, (1996) also reported similar results when they applied nitrogen alone and in combination.

5.1.2 Per cent sprouting of bulbs

The per cent sprouting as shown in Table 4 and 5, was increased significantly with the increasing levels of nitrogen over the control but N_2 and N_3 treatments were found to be at par and these both were significantly higher as compared to N_1 treatment in both the years. The per cent sprouting was also increased significantly with the increasing levels of plant geometry (spacing) over S_1 and S_2 levels of plant geometry (spacing) during both the years. The all the biofertilizers had also increased the per cent sprouting of bulbs significantly over

the control. The interaction of N x S and N x BF had also increased the per cent sprouting of bulbs significantly in both the years. The interaction of S x BF and N x S x BF were found non-significant in both the years. As biofertilizers improve availability of the nutrients to the bulbs which activates the physiological processes which helps in germination of bulbs. Sukhda Mohan Das (1999) had also similar views. Kumar *et al.*, (2001) also reported increased germination in cowpea with the application of *Azotobacter* and VAM.

5.1.3 Plant height

The plant height data revealed that plant height was increased significantly with the increasing levels of nitrogen in both the years. The increasing plant geometry (spacing) significantly decreased the plant height in both the years. Similarly in case of different biofertilizers plant height was increased significantly over control by all the biofertilizers except BF_3 (*Azospirillum*) biofertilizer in 2001. The interaction of N x S and S x BF showed significant increase in the plant height, in both the years. The interaction of N x BF and N x S x BF showed significant increase in the plant height in the year 2001, but showed non-significant increase in plant height in the year 2002.

The increase in plant height due to nitrogen might be due to the fact that nitrogen is a constituent of protein which is

essential for the formation of protoplasm thus affecting the cell division and cell enlargement and ultimately better vegetative growth. Mukhopadhyay and Bankar (1986) and Gowda *et al.*, (1991) also reported that plant height increased with the application of nitrogen. It is quite natural that when more plants per unit area are retained, mutual shading will be more which tends to grow the plants taller. The increase in plant height under closer spacing was also due to competition for light under inadequate spacing. The results are in conformity with the finding of Bhatnagar (1976). Crew *et al.*, (1978) reported that biofertilizers had increased the plant height in three woody ornamentals. They have concluded that the increase in plant height was due to the increased availability of nitrogen and biofertilizers.

5.1.4 Number of leaves per plant

It is evident from the Table 8 and 9 that the number of leaves per plant were increased significantly with the increasing levels of nitrogen and plant geometry (spacing) in both the years. In case of biofertilizers all the biofertilizers had increased the number of leaves per plant significantly over the control during both the years. All the interactions had increased significantly the number of leaves in first year but they were non-significant in second year. The increase in number of leaves as a result of nitrogen application is due to the beneficial effect

of nitrogen in promoting growth due to enhanced synthesis and accumulation of protein, aminoacids and enzymes, which are responsible for cell division and cell elongation. With the application of nitrogen the increased uptake of other nutrients might have lead to increase in rate of various photosynthetic and metabolic processes in the plant system (Wadleigh, 1957). Increasing levels of nitrogen had been reported to increase the number of leaves by Jana *et al.*, (1974). Bankar and Mukhopadhyay (1990) earlier found that medium level of nitrogen i.e. $20gm^{-2}$ was found better in comparison to higher doses. However Rahman and Mitra (1974) obtained maximum number of leaves in dahlia with high doses of nitrogen. The number of leaves per plant recorded highest with widest plant geometry (spacing). This finding get support from Rudolaha and Rudolah (1988) suggesting that it may be due to higher nutrients, sufficient moisture and light available from widest spacing. Siddiqui *et al.*, (1993) reported increased number of leaves in mulberry when they used *Azotobacter* alone and in combination with urea.

5.1.5 Length and area of leaf

Size of leaf with respect to length and area (Table 10, 11, 12 and 13) were increased significantly with the increasing levels of nitrogen upto N_2 level and plant geometry (spacing) upto S_3 level (20 x 30cm) in both the years. In case of biofertilizers

allthe biofertilizers had increased the length and area of leaf significantly over the control during both the years. Length of leaf and leaf area are the main photosynthetic apparatus in plant system to synthesize various metabolites required for plant growth and development. Nitrogen is a constituent part of protein which is essential for the formation of protoplasm thus affecting the cell division and cell enlargement and ultimately better the leaf length and leaf area. Sadhu *et al.*, (1978) also reported that increasing nitrogen stimulated the vegetative growth and increased the length of leaf and leaf area. Under wider row spacing (S_2) there was less competition for moisture, nutrients and light and the lateral spread of plants was more which resulted in significantly increased the length of leaf and leaf area per plant under this spacing as compared to close spacing. Tilak *et al.*, (1982) found that the microbial inoculants prepared from *Azotobacter* etc. are well known to increase growth parameter (i.e. height, number of leaves, leaf area, leaf length, number of branches etc.) of plants. Similar results have been reported by Gaur *et al.*, (1980), Hemandez and Hill, (1983) and Packovsky *et al.*, (1985).

5.2 Flowering parameters

5.2.1 Number of days taken for initiation of spike

Perusal of the data presented in Table 14 and 15 revealed that the spike emergence was significantly delayed with

the increasing levels of nitrogen upto N_2 level and plant geometry (spacing) upto S_3 level in both the years. In case of biofertilizers all the biofertilizer had significantly advanced the spike emergence over the control except BF_3 (*Azospirillum*) in year 2002. The interaction of N x S had also significantly enhanced the spike emergence in 2001, whereas, this interaction was found non-significant in 2002. The interactions of N x BF, S x BF and N x S x BF were found non-significant in both the years. Amarjeet Singh (1992) had recorded the delayed spike emergence in tuberose with the applications of nitrogen and described that delay in spike emergence was due to prolonged vegetative phase because nitrogen had synergistic effect. Similar results were also reported by Potti and Arora (1996), Gowda *et al.*, (1991) and Daft and Okusanya (1973) confirms the results as they also reported early flower initiation in mycorhizal inoculated petunia. They said that flower induction can be controlled by leaves which in the site of auxin production and other hormones which is responsible for flower induction trusses that would be taken place in prior infection with mycorrhiza so that the flower initiation is early in Petunia.

5.2.2 Number of days taken for opening of basal floret

The basal floret opening was significantly delayed with the increasing levels of nitrogen upto N_2 level and plant geometry (spacing) upto S_3 level in both the years. In case of

biofertilizers all the biofertilizers had significantly advanced the basal floret opening over the control during both the years (Table 16 and 17). The application of nitrogen along with plant geometry (spacing) had also significantly enhanced the basal floret opening in both the years. Whereas, all other interactions were found to be non-significant. The basal floret opening was delayed with the increased doses of nitrogen as they had prolonged the vegetative phase and due to which basal floret opening was delayed. The biofertilizers had advanced the basal floret opening.

5.2.3 Length and girth of spike

The data revealed that quality of spike with respect to length and girth are presented in Table 18, 19, 22 and 23 that spike length and girth were increased significantly with the increasing levels of nitrogen upto N_2 level and plant geometry (spacing) upto S_3 level in both the years. In case of biofertilizers all the biofertilizers had increased significantly the spike length over the control except BF_3 (*Azospirillum*) during both the years. In case of spike girth only BF_1 (*Azotobacter*) biofertilizer had increased significantly the spike girth over the control during both the years. The increase in spike length and girth might be due to the fact that nitrogen helped in increasing the more amount of assimilates that are needed for improvement in length of spike. Similar results were obtained by Deswal *et al.*, (1983);

Afity (1985); Yadav *et al.*, (1985) and Mukhopadhyay and Bankar (1986). The maximum spike length and girth were obtained under wider spacing. Similar trend due to various planting densities has also been obtained by Bhattacharjee *et al.*, (1979) and Bhaskaraiah *et al.*, (1991) in tuberose cv. Single. Mukhopadhyay and Yadav (1984) have also observed similar trend in gladiolus due to different planting densities. Khatri and Bhide (1976) had reported that when *Azotobacter* was applied with nitrogen it produced growth promoting substances such as IAA and or gibberellin like substances, viz. thiamine and riboflavin (B_2) etc. which might have helped to increase the flower stalks in tuberose.

5.2.4 Number of florets per spike and rachis length

The number of florets per spike and rachis length were increased significantly with the increasing levels of nitrogen upto N_2 level and plant geometry, (spacing) upto S_3 level in both the years (Table 20, 21, 24 and 25). In case of biofertilizers all the biofetilizers had increased significantly the number of florets per spike over control during both the years. In case of rachis length only BF_1 (*Azotobacter*) biofertilizer had increased significantly the rachis length over the control in the year 2001. All the biofertilizers had increased significantly the rachis length over the control except BF_3 (*Azospirillum*) biofertilizer in year 2002. The number of florets were increased due to higher level of

nitrogen which had increased synthesis of amino acids and chlorophyll formation and better carbohydrates transformation which in turn resulted into better growth and better length of rachis which had ultimately produced more florets per spike. The results obtained by Achal *et al.*, (1984), Afity (1985) and Gowda *et al.*, (1988 and 1991) confirms these results. Bankar and Mukhopadhyay (1980) reported that at closer spacing less number of florets were obtained per spike. Mishra (1997) had reported increased number of florets per spike in Gladiolus with the application of *Azotobacter*.

5.2.5 Duration of flowering (days)

Duration of flowering was increased significantly with the increasing levels of nitrogen upto N_2 level and plant geometry (spacing) upto S_3 level in both the years (Table 26 and 27). In case of biofertilizers all the biofertilizers had increased significantly the duration of flowering over the control except BF_3 (*Azospirillum*) biofertilizer in the year 2001. And only BF1 (*Azotobacter*) biofertilizer had increased significantly the duration of flowering over the control in the year 2002. The interaction of N x S, showed a significant increased in duration of flowering during both the years. Whereas all other interactions had shown non-significant effect during both the years. Increase in the period of flowering might be due to abundant supply of nitrogen which prolonged the vegetative

growth and thus, increased the flower bearing portion with number of florets on the spike and hence, increased the flowering period. Similar, results were also obtained by Garibaldi (1964) in gladiolus and Bankar and Mukhopadhyay (1985 and 1990) in tuberose. Bankar and Mukhopadhyay (1980) have reported that close spacing reduced flowering duration of gladiolus spikes under field conditions.

5.3 Bulb Production

5.3.1 Number of bulbs per plant, Weight of bulbs per plant and Diameter of bulbs

Significant increase in the number of bulbs produced per plant, weight of bulbs per plant and diameter of bulbs were observed with biofertilizers and increasing levels of nitrogen up to N_2 level and plant geometry (spacing) upto S_3 level during both the years (Table 28, 29, 30, 31, 32 & 33). Better supply of nitrogen has already been reported to influence the bulb production by Bankar and Mukhopadhyay (1985) in tuberose and Potti and Arora (1986) in gladiolus. Skalska (1970) and Mugge *et al.* (1987) studied the effect of nitrogen application on bulb production in gladiolus and tulip and they found that application of nitrogen beyond 180 kg ha^{-1} decreased bulb production. The other possibility of decreasing bulb production as a result of heavy application of nitrogen might be due to the diversion of metabolites for vegetative growth. Several workers

like Armitage (1973), Rahman and Mitra (1974) and Misra and Negi (1977) also agreed with these results. The production of daughter corms decreased in colser spacings during both the years of trails. This decrease in corm production in closed spacing might be due to lesser spacing available and lesser nutrients available per corm as compared to wider spacing. Similar trend has also been reported by Fernandes *et al.* (1975). Lesser weight in corms in closer spacing might be due to more competition of nutrients and shadowing effect of plants on each other which might have affected photosynthesis ultimately accumulation of dry matter. Similarly wider spacing enhanced flower quality, corm weight as reported by El-gamassy *et al.*, (1977). Wang and Patil (1994) and Wang *et al.*, (1995) had also reported increased number of bulbs per plant when tuberose was inoculated with *Azotobacter* alone and with graded nitrogen. This may be due to the ability of biofertilizers to produc growth promoting substances such as IAA and gibberellin like substances viz., vitamins and riboflavin etc. which might have helped to increase bulb production.

5.4 Root characters

5.4.1 Number of roots per plant

Number of roots per plant were increased significantly with the increasing levels of nitrogen upto N_2 level and plant geometry (spacing) upto S_3 level during both the years (Table 34

& 35). In case of biofertilizers all the biofertilizers had increased the number of roots per plant significantly over the control except BF_3 (*Azospirillum*) biofertilizer in the year 2001. The interaction of nitrogen with spacing had significantly increased the number of roots per plant during both the years. other interactions were found to be non-significant during both the years. the increase in root length might be due to sufficient amount of essential elements supplied by nitrogen. In case of wider spacing there were more roots produced because in case of wider spacing more space available, more nutrients available, there is no shadowing effect of plants on each other and there is no competition for light. Carolina Gallegvillos *et al.*, (2000) had obtained increased root length in lettuce when inoculated with VAM. The VA-Mycorhizae facilitates the accumulation of the phosphorus needed by plants, through mycelial net work. The fungus spread to a limited extent in the roots of the tuberose plants and improved the absorption of nitrogen and phosphorus as the phosphorus is important for root development, ultimately resulted in increased number of roots.

5.4.2 Average length of roots per plant

Average length of roots per plant were increased significantly with the increasing levels of nitrogen upto N_2 level and plant geometry (spacing) upto S_3 level during both the years (Table 36 & 37). In case of biofertilizers all the biofertilizers had

increased the average length of roots per plant significantly over the control except BF_3 (*Azospirillum*) biofertilizer in year 2002. The interactions of NxSxBF had significantly increase the length of roots in the year 2001, and was found to be non- significant in the year 2002. The increase in length of roots might be due to sufficient amount of essential elements supplied by nitrogen. In case of wider spacing there were more length of roots because of more space, more nutrients available, there is no shadowing effect of plants on each other and there is no competition for light. The biofertilizers increased the length of roots due to the ability of biofertilizers to produce growth promoting substances such IAA and gibberellin like substances viz., vitamins and riboflavin etc. which might have helped to increase the length of roots.

5.4.3 Total root biomass

Total root biomass were increased significantly with the increasing levels of nitrogen upto N_2 level and plant geometry (spacing) upto S_3 level in both the years (Table 38 & 39). In case of biofertilizers all the biofertilizers had increased significantly the total root biomass over the control except BF_3 (*Azospirillum*) biofertilizer during both the years. The interactions of NxSxBF had significant effect on the total root biomass in the year 2001, and was found to be non-significant in the year 2002. The increase in total root biomass might be

due to sufficient amount of essential elements supplied by nitrogen. In case of wider spacing there were more total root biomass because of more space, more nutrients available, there is no shadowing effect of plants on each other and there is no competition for light. The biofertilizers increased the total root biomass due to the ability of biofertilizers to produce growth promoting substances such IAA and gibberellin like substaces viz., vitamins and riboflavin etc. which might have helped to increase the total root biomass.

5.5. Nutrient content

5.5.1 Nitrogen content in leaves (%)

Nitrogen content in leaves was increased significantly with the increasing levels of nitrogen and plantgeometry (spacing) in both the years (Table 40 & 41). In case of biofertilizers only BF_1 (*Azotobacter*) biofertilizer had increased significantly the nitrogen content in leaves over the control during both the years. The interaction of nitrogen with spacing was found to be non-significant in the year 2001, and had increased significantly the nitrogen content in leaves in the year 2002. Other interactions were found to be non-significant in both the years. The increase in concentration of nitrogen in the leaves is due to the uptake of nitrogen by the plants. The findings of Bankar and Mukhopadhyay (1990) also revealed that nitrogen content in of leaves increased significantly with the application of nitrogen.

Reddy (1993) analysed tuberose leaves and found that the concentration of nitrogen in leaves ranged from 1.6- 1.8%. These values were much below the nitrogen concentration (2.66%) reported by Bankar and Mukhopadhyay (1990), which might be due to different agroclimatic conditions. Nitrogen content in leaves was highest under S_3 (20 x 30 cm) spacing because more area was available to individual plant for foraging the nutrients at wider spacing (20 x 30cm) followed by S_2 (20 x 25 cm) and S_1 (20 x 20cm). Moreover with the decrease in intra row spacing from 30cm to 25cm to 20cm, number of plants per unit area increased which resulted in competition for absorption of nitrogen by plants there by affecting there availability to plants.

The biofertilizers had increased the availability of the nutrients by changing the insoluble form to soluble form as *Azotobacter* and *Azospirillum* converts the atmospheric nitrogen in to available form. Whereas, PSB (*Phosphorus Solubilizing Bacteria*) converts phosphate into available soluble form of phosphorus by secreting several organic acids. The biofertilizers are more active in low fertile soils. Kandasawamy *et al.*, (1985) observed increased nitrogen and phosphorus content in brinjal and chillies when inoculated with VAM, *Phosphorus Solubilizing Bacteria* individually and in combination. The increase was due to enhancement in the nitrate reductase activity of mycorrhizal roots. Ames and Linderman (1978) and Algawadi and Gaur

(1992) obtained higher macro-nutrients in the tissues of lily and sorghum, respectively by using VAM in first case and PSB in second case. Several workers namely Haider *et al.*, (1981); Boon *et al.*, (1983); Sidhu and Arora (1989) and Bankar and Mukhopadhyay (1990) were in agreement with the results of the present study that nitrogen and phosphorus had increased the macro-nutrients.

5.5.2 Phosphorus content in leaves (%)

Phosphorus content in leaves was increased significantly with increasing levels of nitrogen upto N_2 level and plant geometry (spacing) up to S_2 level during both the years (Table 42 & 43). In case of biofertilizers only BF_2 (*Phosphorus Solubilizing Bacteria*) biofertilizer had increased significantly the phosphorus control in leaves over the control in both the years. The interactions of NxSxBF were found to be non-significant in both the years. Yoshiba *et al.*, (1981) also observed that P content of plants decreased with the increased application of nitrogen levels. Bankar and Mukhopadhyay (1990) found that P content decreased with the increase in nitrogen concentration. Phosphorus content is leaves was highest under S_3 (20 x 30cm) spacing because more area was available to individual plant for foraging the nutrients at wider spacing (20 x 30cm) followed by S_2 (20 x 25 cm) and S_1 (20 x 20 cm). Moreover with the decrease in intra row spacing from 30 cm to 25 cm to 20 cm, number of

plants per unit area increased which resulted in competition for absorption of phosphorus by plants thereby affecting their availability to plants.

5.5.3 Potassium content in leaves (%)

Potassium content in leaves was significantly reduced with the increasing levels of nitrogen in both the years (Table 44 & 45). The potassium content in leaves was increased significantly with the increasing levels of plant geometry (spacing) in both the years. In case of biofertilizers only BF_2 (*Phosphorus Solubilizing Bacteria*) biofertilizer had increased significantly the potassium content in leaves over the control in both the years. The interactions were found to be non-significant in both the years. However, Bankar and Mukhopadhyay (1990) found that K content decreased with the increase in nitrogen level and K content ranged from 2.7 to 2.8 percent. Potassium content in leaves was highest under S_3 (20 x 30 cm) spacing because more area was available to individual plant for foraging the nutrients at wider spacing (20 x 30cm) followed by S_2 (20 x 25cm) and S_1 (20 x 20cm). Moreover with the decrease in intra row spacing from 30cm to 25cm to 20cm, number of plants per unit area increased which resulted in competition for absorption of potassium by plants there by affecting their availability to plants.

5.5.4 Zinc content in leaves (ppm)

Zinc content in leaves was increased significantly with the increasing levels of nitrogen upto N_2 level and plant geometry (spacing) upto S_3 level in both the years (Table 46 and 47). In case of biofertilizers the effect of biofertilizers were found to be non-significant in both the years. The all the interactions were found to be non-significant during both the years. The positive interaction between nitrogen and zinc was reported by Awada and Long (1978) in papaya. It was found that nitrogen increased the uptake of zinc. Zinc content in leaves was highest under S_3 (20 x 30cm) spacing because more area was available to individual plant for foraging the nutrients at wider spacing (20 x 30cm) followed by S_2 (20 x 25cm) and S_1 (20 x 20cm). Moreover with the decrease in intra row spacing from 30cm to 25cm to 20cm, number of plants per unit area increased which resulted in competition for absorption of zinc by plants. The possible reason for this is that the root colonization is increased with the simultaneous application of biofertilizers and nitrogen which had increased the surface area for absorption and it was possible that the biofertilizers converts the insoluble nutrients content from the rhizosphere soil to soluble form so that it was easily available resulting in increased content of micronutrients i.e. Zinc. Sander and Tinker (1973) hypothesized that uptake of any element would be enhanced by mycorrhizae if it is slolwly

available and its soil diffusion rate is the limiting factor in its uptake. Similar results were also obtained by Pinochet *et al.*, (1995) in cherry root stocks. Bagyaraj and Menge (1978) also reported increased zinc content in tomato when *Azotobacter* and VAM were applied alone and in combination. These results are in agreement with the findings of Gilmore (1971); La Rue *et al.*, (1975) and El Maksound *et al.*, (1988).

CHAPTER – VI

Summary and Conclusion

The present investigation was carried out to study the effect of nitrogen, plant geometry (spacing) and biofertilizers alone and in combinations on growth, flowering, bulb production, root characters and N, P, K and Zn contents in tuberose. The experiment was conducted at Research Area, Deptt. of Horticulture, CCS Haryana Agricultural University, Hisar in split plot design with three replications. Nutrient analysis was done in laboratory of the Department of Horticulture. The results of the present investigation are summarized and concluded as below:

(i) The sprouting period of bulb was significantly shortened with increasing levels of nitrogen up to N_2 level (200 kg N ha^{-1}) and highest plant geometry /spacing (S_3-20x30cm) in both the years. In case of biofertilizers only BF_1 (*Azotobacter*) biofertilizer had significantly shortened the sprouting period by 2.71 days in year 2001 and 2.68 days in year 2002 over the control. Interactions among

$N_3S_1BF_1$ had taken minimum days to sprouting of bulbs in 2001 and also in 2002.

(ii) The per cent sprouting of bulbs were increased significantly with the increasing levels of nitrogen upto N_2 level and plant geometry (spacing) upto S_3 level during both the years. In case of biofertilizers all biofertilizers had increased the per cent sprouting of bulbs significantly over the control during both the yeas. Maximum per cent sprouting of bulbs was found at $N_3S_3BF_2$ in 2001 and also in 2002.

(iii) The plant height was increased significantly with the increasing levels of nitrogen in both the years. The increasing plant geometry (spacing) significantly decreased the plant height in both the years. All biofertilizers increased the plant height significantly over control except BF_3 (*Azospirillum*) in 2001. The maximum plant height was recorded at $N_3S_1BF_1$ in 2001 and 2002.

(iv) The number of leaves per plant were increased significantly with the increasing levels of nitrogen and plant geometry (spacing) in both the years. In case of biofertilizers all the biofertilizers had increased the number of leaves per plant significantly over the control during both the years. The maximum leaves per plant were found at $N_3S_3BF_1$ during both the years.

(v) Length of leaves were increased significantly with the increasing levels of nitrogen upto N_2 level and plant geometry (spacing) upto S_3 level in both the years. In case of biofertilizers all the biofertilizers had increased the length of leaves significantly over the control during both the years. The maximum length of leaves was found at $N_2S_3BF_1$ which was at par with $N_3S_3BF_1$ in 2001 and 2002.

(vi) Leaf area was increased significantly with the increasing levels of nitrogen upto N_2 level and plant geometry (spacing) upto S_3 level in both the years. In case of biofertilizers all the biofertilizers had increased the leaf area significantly over control in both the years. The maximum leaf area (249.91 cm^2 and 259.91 cm^2) was found at treatment $N_3S_3BF_1$ which was at par with treatment $N_2S_3BF_1$ during 2001 and 2002, respectively.

(vii) The spike emergence was significantly delayed with the increasing levels of nitrogen upto N_2 level and plant geometry (spacing) upto S_3 level in both the years. In case of biofertilizers all the biofertilizers had significantly advanced the spike emergence over the control except BF_3 (*Azospirillum*) in year 2002. The spike emergence delayed maximum at $N_3S_3BF_0$ which was found to be at par with $N_2S_3BF_0$ during both the years.

(viii) The basal floret opening was significantly delayed with the increasing levels of nitrogen upto N_2 level and plant geometry (spacing) upto S_3 level in both the years. In case of biofertilizers all the biofertilizer had significantly advanced the basal floret opening over the control during both the years. Maximum number of days taken by basal floret opening at $N_3S_3BF_0$ which was found to be at par with $N_2S_3BF_0$ during both the years.

(ix) The spike length was increased significantly with the increasing levels of nitrogen upto N_2 level and plant geometry (spacing) upto S_3 level in both the years. In case of biofertilizers all the biofertilizers had increased significantly the spike length over the control except BF_3 (*Azospirillum*) in both he years. The longest spike length was found at $N_3S_3BF_1$.

(x) The number of florets per spike were increased significantly with the increasing levels of nitrogen upto N_2 level and plant geometry (spacing) upto S_3 level in both the years. In case of biofertilizers all the biofertilizers had increased significantly the number of florets per spike over the control in both the years. The maximum number of florets per spike were found at $N_3S_3BF_1$ which was found to be at par with $N_2S_3BF_1$ during both the years.

(xi) The spike girth was increased significantly with the increasing levels of nitrogen upto N_2 level and plant geometry (spacing) upto S_3 level in both the years. In case of biofertilizers only BF_1 (*Azotobacter*) biofertilizer had increased significantly the spike girth over the control during both the years. The maximum spike girth was found at $N_3S_3BF_1$ which was found to be at par with $N_2S_3BF_1$ during both the years.

(xii) The rachis length was increased significantly with the increasing levels of nitrogen upto N_2 level and plant geometry (spacing) upto S_3 level in both the years. In case of biofertilizers only BF_1 (*Azotobacter*) biofertilizer had increased significantly the rachis length over the control in the year 2001. All the biofertilizers had increased significantly the rachis length over the control except BF_3 (*Azospirillum*) biofertilizer in year 2002. The maximum rachis length was found at $N_3S_3BF_1$ which was found to be at par with $N_2S_3BF_1$ during both the years.

(xiii) Duration of flowering was increased significantly with the increasing levels of nitrogen upto N_2 level and plant geometry (spacing) upto S_3 level in both the years. In case of biofertilizers all the biofertilizers had increased significantly the duration of flowering over the control except BF_3 (*Azospirillum*) biofertilizer in the year 2001.

And only BF_1 (*Azotobacter*) biofertilizer had increased significantly the duration of flowering over the control in the year 2002. The maximum duration of flowering was found at $N_3S_3BF_1$ which was found to be at par with $N_2S_3BF_1$ during both the years.

(xiv) A significant increase in the number of bulbs produced per plant, weight of bulbs per plant and diameter of bulbs were observed with biofertilizers and increasing levels of nitrogen upto N_2 level and plant geometry (spacing) upto S_3 level during both the years. The maximum number of bulbs per plant, weight of bulbs per plant and diameter of bulbs were produced at $N_3S_3BF_2$ which was found to be at par with $N_2S_3BF_2$ during both the years.

(xv) Number of roots per plant were increased significantly with the increasing levels of nitrogen upto N_2 level and plant geometry (spacing) upto S_3 level during both the years. In case of biofertilizers all the biofertilizers had increased the number of roots per plant significantly over the control except BF_3 (*Azospirillum*) biofertilizer in the year 2001. The maximum number of roots per plant were found at $N_2S_3BF_2$ which was found to be at par with $N_3S_3BF_2$ during both the years.

(xvi) Average length of roots per plant were increased significantly with the increasing levels of nitrogen upto N_2 level and plant geometry (spacing) upto S_3 level during both the years. In case of biofertilizers, all the biofertilizers had increased the average length of roots per plant significantly over control except BF_3 (*Azospirillum*) biofertilizer in year 2002. The longest root was observed at $N_3S_3BF_2$ which was found to be at par with $N_2S_3BF_2$ during both the year.

(xvii) Total root biomass were increased significantly with the increasing levels of nitrogen upto N_2 level and plant geometry (spacing) upto S_3 level in both the years. All the biofertilizers had increased the total root biomass significantly over the control except BF_3 (*Azospirillum*) biofertilizer during both the years. The maximum total root biomass were found at $N_3S_3BF_2$ which was found to be at par with $N_2S_3BF_2$ during both the years.

(xviii) Nitrogen content in leaves was increased significantly with the increasing levels of nitrogen and plant geometry (spacing) in both the years. In case of biofertilizers only BF_1 (*Azotobacter*) biofertilizer had increased significantly the nitrogen content in leaves over the control during both the years. Maximum nitrogen content was found at $N_3S_3BF_1$ in both the years.

(xix) Phosphorus content in leaves was increased significantly with increasing levels of nitrogen upto N_2 level and plant geometry (spacing) upto S_2 level during both the years. In case of biofertilizers only BF_2 (*Phosphorus Solubilizing Bacteria*) biofertilizer had increased significantly the phosphorus content in leaves over the control in both the years. Maximum phosphorus content in leaves was found at $N_3S_3BF_2$ which was at par with $N_2S_3BF_2$ during both the years.

(xx) Potassium content in leaves was significantly reduced with the increasing levels of nitrogen in both the years. The potassium content in leaves was increased significantly with the increasing levels of plant geometry (spacing) in both the years. In case of biofertilizers only BF_2 (*Phosphorus Solubilizing Bacteria*) biofertilizer had increased significantly the potassium content in leaves over the control in both the years. The maximum potassium content in leaves was found at $N_0S_3BF_2$ during both the years.

(xxi) Zinc content in leaves was increased significantly with the increasing levels of nitrogen upto N_2 level and plant geometry (spacing) up to S_3 level in both the years. In case of biofertilizers the effect of biofertilizers were found to be non-significant in both the years. The maximum

zinc content was found at $N_3S_3BF_3$ which was found to be at par with $N_2S_3BF_3$ during both the years.

Conclusion

From the present investigation it may be concluded that application of 200 kg N ha^{-1} at 20 x 30 cm spacing resulted in good performance of tuberose in terms of growth, flowering and bulb production. Among different biofertilizers, *Azotobacter* was found more effective in increasing growth and other parameters whereas bulb production was found better with PSB (*Phosphorus Solubilizing Bacteria*).

Bibliography

Achal, S., Lal, S.D. and Seth, J.N. 1984. Effect of different levels of nitrogen and phosphorus on growth, flowering and corm yield of gladiolus cv. Vink's Glory. *Prog. Hort.* **16**(3-4): 304-307.

Afity, M.M. 1985. Effect of high fertilizer rates on the growth, flowering and flower quality of three gladiolus cvs. (Preliminary communication. *K. E.K.* **47**(15): 75-82.

Ahmed, M.V., Uddin, F. and Rashid, A. 1983. Effect of bacterial fertilizer and chemical fertilizer on the growth of young tea and soil properties. *Proc. of the 8th Bangladesh Sci. Conf.*, Dhaka, p.44.

Ailincai, N. 1960. Influence of some fertilizers on flowering of *Polianthes tuberosa.* Lucr. *Sti. Inst. Agron.* pp. 355-360.

Algawadi, A.R. and Gaur, A.C. 1988a. Associative effect of *Rhizobium* and phosphate solubilizing bacteria on the yield and nutrient uptake of chickpea. *Plant Soil.* **105**: 241-246.

Algawadi, A.R. and Gaur, A.C. 1992. Inoculation of *Azospirillum* brasilanse and phosphate solubilizing bacteria on yield of

sorghum (*Sorghum bicolor* (L) Moench) in dry land. *Tropi: Agric. (Trinidad)* **69**(4): 347-350.

Amarjeet Singh 1992. Studies on the nutritional requirement and vase life of tuberose (*Polianthes tuberosa* Linn.) cv. Single, Ph.D. thesis submitted to CCS HAU, Hisar.

Ames, R.N. and Linderman, R.G. 1978. The growth of Easter lily (*Lilium longiflorum*) as influenced by VAM fungi, *Fusarium oxysporum* and fertility level. *Can. J. Bot.* **56**: 2773-2780.

Ames, R.N., and Linderman, R.G. 1977. Vesicular-arbuscular mycorrhizae of Easter lily in north western united states. *Can. J. Microbial.* **23**: 1663-1668.

Anuradha, K., Pampapathy, K. and Narayana, N. 1990. Effect of nitrogen and phosphorus on flowering, yield and quality of marigold. *Ind. J. Hort.* **47**(3): 353-357.

Armitage, M.S. 1973. The fertilizing of gladiolus in swaziland. A preliminary report. *Misc. Rept. Malkerns. Res. Stn. Swaziland.* 19-21.

Arora, D. 1975. Ph.D. thesis, post Graduate School, Indian Agricultural Research Institute, New Delhi.

Ashok, S.H., Sujatha, K. and Prabhakar, M. 1995. Growth, yield, water relation and its use in tuberose (*Polianthes tuberosa* L.) as influenced by irrigation regime and nitrogen level. *Indian J. of Agril. Sci.* **65**(12): 866-869.

Awada, M. and Long, C. 1978. Relation of nitrogen and phosphorus fertilization to fruiting and petiole

composition of 'Solo' papaya. *J. Amer. Soc. Hort. Sci.* **103**: 217-219.

Azcon, R. and Barea, J.M. 1975. Synthesis of *auxins, gibberellins* and *cytokinins* by *Azotobacter* vinelandii and *A. beijerinckii* related to effect produced on tomato plant. *Plant and Soil.* **43**: 609-619.

Bagyaraj, D.J. and Menge, J.A. 1978. Interaction between a VA-mycorrhiza and *Azotobacter* and their effects on rhizosphere microflora and plant growth. *New phytol.* **80**: 567-573.

Bagyaraj, D.J. and Powell, C.L.I. 1985. Effect of vesicular-arbuscular mycorrhizal inoculation and fertilizer application on the growth of marigold. New Zealand. *J. Agril. Research.* **28**: 169-173.

Balak, Ram; Katiyar, R.S.; Tewari, S.K.; Singh, C.P and Ram, B. 1999. Effect of nitrogen and plant spacings on the growth and flower yield of tuberose (*Polianthes tuberosa*) cv. Single on sodic soils. *J. Medicinal and Aromatic Plant Sci.*, **21** (4): 959-962.

Balasubramanian, A. 1995. Developing *Azospirillum* and *Azotobacter* biofertilizer for mulberry project report. Tamil Nadu Agricultural University, Coimbatore.

Bangale, U.D. and Dandin, S.B. 1993. Nitrogen fixing bacterial biofertilizers. *Ind. Silk.* **32** (2): 28-33. 677.41 Ban

Bankar, G.J. 1988. Nutritional studies in tuberose cv. *Double. Progressive Horticulture* **20**: 49-52.

Bankar, G.J. and Mukhopadhyay, A. 1980. Effects of corm size, depth of planting and spacing on the production of flowers and corms in gladiolus. *Indian J. Hort.* **37** (4): 403-408.

Bankar, G.J. and Mukhopadhyay, A. 1980. Varietal trial on tuberose (*Polianthes tuberosa* L.) *South Indian Hort.*, **28** (4): 150-151.

Bankar, G.J. and Mukhopadhyay, A. 1985. Response of *Polianthes tuberosa* L. cv. 'Single' to high dose of NPK. *South Indian Hort.* **33** (2): 214-216.

Bankar, G.J. and Mukhopadhyay, A. 1990. Effect of NPK on growth and flowering in tuberose cv. Double. *Indian J. Hort.* **47**(1): 120-126.

Bardiya, M.C. and Gaur, A.C. 1990. Effect of inoculation of phosphate solubilizing micro organisms on yield of green-gram (*Vigna radiata.* Phosphate salubilizing microorganisms as biofertilizers. *Omega Scientific Publisher,* New Delhi. pp. 77-78.

Barrows, J.B. and Roncadori. R.W. 1977. Endomycorrhizal synthesis by Gigaspora margarita in Poinsettia. *Mycologia.* **69**: 1173-1184.

Bhaskaraiah, M.D.V., Raghava Rao, K., Hari Babu and Ramavatharam, 1991. Effect of different levels of spacings

and nitrogen on tuberose (*Polianthes tuberosa* L.) cv. Single. *Advances Hort.* **2**: 151-155.

Bhatnagar, D.K. 1976. Effect of nitrogen, phosphorus and plant population of vegetative growth, yield and fruit quality of tomato cv. HS-102. M.Sc. Thesis submitted to Haryana Agricultural University, Hisar, Haryana (India.

Bhattacharjee, S.K., Yadav, L.P. and Mukhopadhyay, 1979. Effect of bulb size, planting depth and spacing on tuberose (*Polianthes tuberosa* L.) *Lal Baugh,* **24**: 24-29.

Bhattacharya, P. Dey, B.K., Banik, S. and Neth, S.Z. 1986. *Mikrobiol.* **141**: 357-365.

Bhattacyharya, P. and Mishra, U.C. 1994. Biofertilizers for flowers and ornamental plants. In: A book on biofertilizer to extension worker (ed.) T. Singh, *National Biofertlizer Development Centre, Gbd.* UP. pp. 102.

Bhavani Sanker, K. and Vanagamudi, K. 1999. Integrated nutrient management in croşsandra (*Crossandra infundi-buliformis* L.).*South Indian Hort.* **47** (1-6): 125-129.

Bhavani Sanker, K. and Vanangamudi, K. 1999. Integrated nutrient management in gundumalli (*Jasminum sambac* L.).*South Indian Hort.* **47** (1-6): 111-114.

Bongale, U.D. and Nadiger, G.S. 1989. The role of biofertilizers in mulberry cultivation. *Indian Silk.* **28** (1): 34-39.

Boon, J. Der, V., Niers, H. and Kruyer, C.J. 1983. The lily cv. Enchanment: Nitrogen manuring in sandy soil and uptake of nutrients. *Bedrijtsontwikkeling.* **14** (1): 77-80.

Boon, J.V. and Niers, H. 1986. Effect of nitrogen on bulb production, forcing quality of the bulb and vase life of flower of Lilium 'Enchantment'. *Acta Horticulture.* **177**: 249-254.

Brakel, J. and Hilger, F. 1965. Etude qualitative et quantitative de la synthase de substances de nature auxinique par *Azotobacter chroococcum in vitro. Bull. Inst. Agron. Stns. Rech. Gembloux* **33**: 469.

Brown, M.E. 1974. Seed and root bacterisation. *Annu. Rev. Phytopathol.* **12**:181.

Carolina, G., Cesar, A., Jose, M.B. and Azcon, R. (2000. Growth promoting effect of two *Sinorhizobium meliloti* strains (a wild type and its genetically modified derivative) on a non-legume plant species in specific interaction with two arbuscular mycorrhizal fungi. *Plant Science.* **159**: 57-63.

Chakraborti, D.K. and yadav, A.L. 1991. Effect of *Azotobacter* sp. on incidence of downy mildew (*Paronospora arborscens*) and growth and yield of opium poppy (*Papaver somniferum*). *Ind. J. Agric. Sci.* **61**: 287-288.

Chokha, Singh, Saxena, S.K.; Goswami, A.M.; Sharma, R.R. and Singh, C. (2000). Effect of fertilizers on growth, yield and quality of sweet orange (*Citrus sinensis*) cv. Mosambi. *Ind. J. Hort.* **57** (2): 114-117.

Conty, A., Gonzales, C.I. and Iswarn, V. 1974. Effect of coating cabbage seedlings with *Azotobacter chroococcum* and di-calcium phosphate on their yield. *Philippine J. Pl. Indust.* **30**: 159-162.

Crew, C.E., Johnson, C.R. and Joiner, J.N. 1978. Benefit of mycorrhizae on growth and development of three woody ornamentals. *Hort. Science.* **13** (4): 429-430.

Daft, M.J. and Okusanya, B.O. 1973. Effect of endogone mycorrhiza on plant growth. VI. Influence of infection on anatomy and reproductive development of four hosts. *New Phytologist.* **72**: 1333-1339.

Dart, P.J. and Wani, S.P. 1982. Non-symbiotic nitrogen fixation and soil fertility. In: Non symbiotic nitrogen fixation and organic matter in the tropics. *Transaction of the 12th International congress of soil Science*, New Delhi, India, 8-16 February, 1982. Symposia paper 1: 3-27.

Das, P.K., Chaudhury, P.C., Ghosh, A., Katiyar, R.S., Madhav Rao, V.R., Mathur, V.B. and Majumdar, M.K. 1994. Studies on the effect of bacterial biofertilizers in irrigated mulberry (*M. alba* L.).*Ind. J. Seri.* **33**(2): 170-173.

Das, P.K., Chaudhury, P.C., Ghosh, A., Katiyar, R.S., Mathur, V.B. and Datta, R.K. 1993. Use of *Azotobacter* biofertilizer in Mulberry cultivation. *Ind. Silk* **31**(10): 43-45.

Das, P.K., Chaudhury, P.C., Ghosh, A., Katiyar, R.S., Suryanarayana, N. and Sengupta, K. 1990. Search of

nitrogen fixing bacteria on biofertilizers for Mulberry. CSRTI, News Letter, 55-5.

Das, P.K., Hanumantha Gowda, M., Katiyar, R.S, Ghosh, A. and Chaudhury, P.C. 1996. Response of different mulberry cultivars to *Azotobacter* biofertilizer under irrigated conditions. *Ind. J. Seri.* **35**(1): 35-38.

Deswal, K.S., Patil, V.K. and Anserwadekar, K.W. 1983. Nutritional and plant population studies in gladiolus. *Indian J. Hort.* **40**(3/4): 254-259.

Donarie, J. and Blachere, H. 1966. Inoculation de graines de vegetaux cutives ai aide de sauches bacterienns. *Annl. Enst. Pasteur,* Paris III, Suppl. to No. **3**: 57.

Dosale, A.G. and Konde, B.K. 1984. Response of sorghum to seed bacterization with nitrogen levels. *J. Maharastra Agric. Univ.* **9**(2): 169-170.

El-Gamassy, A., . . El-Borkooky, and . Hashem, 1977. Effect of the position of planting in the furrows and flowering of gladiolus cv. Lovely Melody. *Technical Bulletin, Qubby Botanic gardens.* **1**: 1-17.

El-Kased, F.A.; Kamn, R.N. and Abd-El-Ghany, B.F. 1999. Wheat response to bio and mineral nitrogen fertigated in newly reclaimed sandy soil. *Desert Institute Bulletin, Egypt,* **46** (2): 373-386.

El-Maksoud, H.K.A., Boutros, B.N. and Lotfy, A.A. 1988. Growth response of sour oranage to mycorrhizal

inoculation and super phosphate fertilization in sandy and calcareous soils. *Egyptio J. Soil Sci.* **28**: 385-395.

Fernandes, P.D., A.J.J. Eysink, A.C. Bissoni, J.J. De, Oliverira Fillo. 1975. Studies on spacing gladiolus corms. I. Variation in spacing within the row. *Cientifica.* **3** (1): 42-47.

Fernandes, P.D., Haag, H.P. and Oliveira, G.D. 1974. Mineral nutrition of ornamental plants. V. Studies on fertilization with nitrogen of Gladiolus grandiflorus cv. "Perusi" Anals da Escola superior de Agricultura "Luiz de Queiroz" **31**: 621-634.

Gamo, T. 1991. *Azospirillum* spp. from crop roots: a promoter of plant growth. JARQ, Japan *Agri. Res. Quarterly,* **24** (4): 253-259.

Gangavar, S.K. and Thangavelu, K. 1992. Evaluation of biofertilizer for establishment of mulberry (*M. alba. Sericologia* **32**(2): 173-181.

Garibaldi, A.E. 1964. Preliminary results of a fertilizer trial on gladioli. *Riv. Ortofloro. Fruttic.* **48**: 535-540.

Gaur, A.C. and ostwal, K.P. 1972. *J. Experimental Biology* **10**(5): 393-394.

Gaur, A.C. and Rana, J.P.S. 1990. Role of mycorrhizae, phosphate solubilizing bacteria and their interaction on growth and uptake of nutrients by wheat crop. Trends in mycorrhizal research. Proc. of Nat. Conference of

mycorrhizae, (Eds., B.L. Jalali and H. chand. *Har. Agril. Univ.*, Hisar, India. p. 157-159.

Gaur, A.C., Ostwal, K.P. and Mathur, R.S. 1980. Save super phosphate by using phosphate solubilizing cultures and rock phosphate. *Kheti* **32**: 23-25.

Gilmore, A.E. 1971. The influence of endotrophic mycorrhiae on the growth of peach seedlings. *J. Amer. Soc. Hort. Sci.* **96**: 35-37.

Gowda, J.V.N., Jacob, S. and Hudder, A.G. 1991. Effect of N, P and K on growth and flowering of tuberose (*Polianthes tuberosa* L.) cv. 'Double'. *Indian Perfumer* **35**(2): 100-101.

Gowda, J.V.N., Jayanthi, R. and Raju, B. 1988. Studies on the effect of nitrogen and phosphorus on flowering in gladiolus cv. Debonair. *Curr. Res. Univ. Agril. Sci.* Bangalore **17**(6): 80-81.

Gupta, N.S.; Sadavarte, K.T.; Mahorkar, V.K.; Jadhao, B.J. and Dorak, S.V. 1999. Effect of graded levels of nitrogen and bioinoculants on growth and yield of marigold (*Tagetes erecta*). *J. Soils and Crops.* **9**(1): 80-83.

Haider, M.M., Rao, M.V. and Murthy, A.S. 1981. Effect of nitrogen on growth and development of gladiolus. *Indian J. Hort.* **38**(3/4): 241-245.

Halepyati, A.S., Sujatha, K. and Prabhakar, M. 1995. Effects of moisture stress and population densities on tuberose. *J Maharashtra Agri. Univ.*, **20** (2): 205-208.

Hemnandez, L.P. and Hill, G.D. 1983. Effect of plant population and inoculation on yield and yield components of chickpea (*Cicer arietinum* L.). *Proc. Agron. Soc.* NZ. **13**: 175-179.

Huang, Wen Ding, Xu, Qifen; Huang, W.D. and Xu, QF. 1999. Over yield of Taxodium ascendens inter crop systems. *Forest Eco. Manage.*, **116** (1-3): 33-38.

Jackson, M.L. 1967. Soil chemical analysis. Asia Publishing house, Bombay.

Jackson, M.L. 1973. Soil Chemical analysis. *Prentice Hall of India Pvt. Ltd.* New Delhi, India.

Jana, B.K., Roy, S.S. and Bose, T.K. 1974. Studies on the nutrition of ornamental plants. Effects of nutrition on growth and flowering of Dahlia and tuberose. *Indian J. Hort.* **31**: 182-185.

Jeeva, S.; Kulase Karan, M. and Shanmugavelu, K.G. 1988. Studies the effect of *Azospirillum* sps. on growth and development of banana cv. Poovan (AAB). *South Indian Horticulture,* **36**(1-2): 1-4. 633 05 So62

Jena, M.K.; Das, P.K. and Pattanaik, A.K. 1999. Integrated effect of microbial inoculants and fertilizer nitrogen on N-use efficiency and rhizome yield of turmeric (*Curcuma longa* L.. *Orissa J. Hort.* **27** (2): 10-16.

Johnson, C.R., Graham, J.H., Leonard, R.T. and Menge, J.A. 1982. Effect of flower bud development in chrysanthemum of VAM formation. *New Phytol.* **90**: 671-675.

A

Joi, M.B. and Shinde, P.A. 1976. Response on onion crop to *Azotobacterization*. *J. Maharastra Agril. Universities.* **1**(2-6): 161-162.

Kalavathi, B.P., Santhanakrishnan, P. and Divya, M.P. (2000. Effect of VA-Mycorrhizal fungus and phosphorus solubilizing bacterium in neem. *Indian Forester.* **126**(1): 67-70.

Kandashamy, D., Mohanraj Samuel, G. and Oblisami, G. 1985. Influence of VA-mycorrhizae and phosphobacteria on growth of brinjal and chillies in nursery. *South Indian Hort.* **33**: 172-176.

Kapulnik, Y. Kigel, J., Okon, Y.; Nur, I. and Henis, Y. 1981. Effect of *Azospirillum* inoculation on some growth parameters and N-content of wheat, sorghum and panicum. *Plant and Soil,* **61**: 1-2, 65-70.

Kapulnik, Y., Sarig, S., Nur, I., Okon, Y., Kigel, J. and Henis, Y. 1981. Yield increase in summer cereal crops of Israel in field inoculated with *Azospirillum. Experimental Agriculture.* **17**: 171-178.

Kartik, J.F; Schuch, U.K.; Becker, J.O.; Zieslin, N. and Agbaria, H. (2001. Bare root rose production with under ground drip irrigation. *Acta Horticulturae, No.* **547**, 221-226.

Khatri, A.A. and Bhide, V.P. 1976. Seed germination on studies in *Polianthes tuberosa.* Lucr. *Sti. Inst. Agron. Lassi.* pp. 355-360.

Khobragade, R.I., Damke, M. M. Jadhao, B.J. and Hedav, C.V. 1997. Effect of planting time and spacing on growth, flowering and bulb production of tuberose cv. 'Single'. *PKV Res. J.*, **21**:1, 44-47.

Kosugi, K. and Kondo, M. 1961. Studies on blindness in Gladiolus VIII. Effects of nutritional treatments on flowering and blindness on gladiolus grown from cormels J. *Jap. Soc. Hort. Sci.* 30: 89-92.

Kulkarni, R.G. and Konde, B.K. 1990. Studies on the effect of *Azotobacter* and *Azospirillum* alone and in combination under graded levels of nitrogen on growth and yield of Aster. In Proc. VIIIth Southern Regional Conference on Microbial inoculent 5-6 Feb., 1990, held at College of Agriculture, Pune-5 pp. 44-45.

Kumar, R., Gupta, P.P. and Jalali, B.L. (2001. Impact of VA-mycorrhiza, *Azotobacter* and *Rhizobium* on growth and nutrition of cowpea. *J. Myco. Pl. Pathology.* 31 (1): 38-41.

Kumar, Sunil and Singh, R.P. 1998. Effect of nitrogen, bulb size and plant density on growth, flowering and yield of tuberose (*Polianthes tuberosa* L.). *J. Ornamental Hort. New Series*, **1**: 1, 6-10.

Kumar, Sunil, Singh, R.P. and Kumar, S. 1998. Effect of nitrogen, bulb size and spacing on bulb and bulblet production of tuberose (*Polianthes tuberosa* L.). *South Indian Hort.*, **46**: 3-6, 294-298.

Lakshmanan, M. and Kannan, N. 1982. Effect of biofertilizer on cardamom. *Proc. 5th Annual Symp. on plantation crops. (PLACROSYM-5)* pp. 429-433.

La-rue, J.R., Mc Cpellan, W.D. and Peacock, W.L. 1975. Mycorrhizal fungi and peach nursery nutrition. *Calif Agric.* **29**: 6-7.

Lee, M., Breckenridge, C. and Knowles, R. 1970. Effects of some cultural conditions on the production of indole-3-acetic acid and gibberellins like substances by *Azotobacter* vinelandii. *Can. J. Microbial.* **16**: 1325-1329.

Mahanta, P. and Paswan, L. 1995. Effect of bulb size and spacing on growth, flowering and bulb production of tuberose (*Polianthes tuberosa* L.. cv. Single). *Hort. J.*, **8**:1, 75-83.

Margaret, E.B. and Burlingham, S.K. 1968. Production of plant growth substances by *Azotobacter chroococcum. J. Gen. Microbiology.* **53**: 135-144.

Maronek, D.M., Hendrix, J.W. and Kiernan, J. 1981. Mycorrhizal fungi and their importance in horticultural crop production. *Hort. Reviews.* **3**: 172-213.

Martin, T.M., Rubia Tde La., Moreno, J. and Gonzalez-Lopez, J.J. 1988. Root exudates of zea mays and production of auxin, gibberellins and cytokinin by *Azotobacter chroococcum. Plant and Soil.* **110**: 149-152.

Martinez-Toledo, M.V., De La Rubia, T., Moreno, J. and Gonzalez Lopez, J. 1988. Root exudates of Zea mays and production of auxins, gibberellins and cytokinins by *Azotobacter chroococcum*. *Plant Soil.* **110**: 149-152.

Matimoud, S.H.Z., Ramadan, E.M., Thabet, F.M. and Khater, T. 1984. Production of plant growth promoting substances by rhizosphere microorganisms. *Zantralbl. Mikrobiol.* **139**: 227-232.

Mikhajiovskaya, N.A.; Buiavin, L.A.; Moroz. G.V.; Khankevich, V.A.; Gedrovich, S.V.; Pal -Ko, T.P. and Mikhailovskaya, N.A. 1997. Influence of a associative bacteria *Azospirillum* on the yield of winter wheat and stubble oil radish. *Soil research and the use of fertilizers*, 165-169, 206.

Militiu, A., Vierasu, E. and Lliescu, A.F. 1970. The influence of chemical fertilizers on flower qualtiy and bulb production in tuberose growing. *Lucrari Stiinntifice Institutal Agronomic N. Balcesu.* **13**: 115-120.

Mishustin, E.N. and Naumova, A.N. 1962. Bacterial fertilizers, their effectiveness and mechanism of action. *Microbiologia.* **31**: 543.

Misra, A.K. and Negi, S.S. 1977. Effect of nitrogen and pinching of main shoot and tuberization in gladiolus. *South Indian Hort.* **25** (2): 88-89.

Misra, R.L. 1997. Nafed superculture and the growth and corm production in Gladiolus var. *Melodie Recent Horticulture.* **4**: 76.

Mitra, S.N., Munshi, P.S. and Roy, S. 1979. Effects of different levels of nitrogen and bulb size on growth and flowering of tuberose (*Polianthes tuberosa* L.). *Indian Agriculturist.* **23** (3): 185-188.

Mohandas, S. 1987. Field response of tomato to inoculation with VAM fungus *Glomus fusciculatum* and with *Azotobacter vinelandii. Plant and Soil.* **98**: 295-297.

Mohanty, B.K.; Sankar, C.R. and Dayanand, T. 1999. Effect of NPK and spacing on nutrient content of leaves and uptake in tuberose (*Polianthes tuberosa* L.). *South Indian Hort.*, **47** (1-6): 327-330.

Moore-Parkhurst, S. and Englander, L. 1982. Mycorrhizal status of Rhododendron spp. in commercial nurseries in Rhode Island. *Can. J. Bot.* **60**: 2342-2344.

Mosher, J.M. and Turner, D.W. 1999. The impact of within row spacing on the productivity of glasshouse roses grown in two planting systems. *J. Hort. Sci. Biotech.*, **74** (6): 721-728.

Mugge, A., Benkenstein, H., Richter, P. and Alex, H. 1987. Effect of increasing nitrogen applications to tulips on cut flower yield and bulb reproduction during forcing. *Archiv fur Gartenban.* **35** (6): 249-253.

Mukahopadhyay, A.; Bankar, G.J. and Sadh, M.K. 1986. Influence of bulb size, spacing and depth of planting on growth, flowering and bulb production in tuberose. *Haryana J. Hort. Sci.*, **15** (1-2): 18-24.

Mukhopadhyay, A. 1981. Standardization agrotechnqiue in tuberose (*Polianthes tuberosa* L.) and Carnation (Dianthus caryophyllus L.). Ph.D. thesis, Calcutta University, pp. 154.

Mukhopadhyay, A. and Bankar, G.J. 1986. Studies on nutritional requirement of tuberose. *South Indian Hort.* **34** (3): 167-172.

Mukhopadhyay, A. and Yadav, L.A. 1984. Effect of corm size and spacing on growth, flowering and corm production in gladiolus. *Haryana J. Hort. Sci.* **13**: 95-99.

Nagaraja, G.S., Gowda, J.V.N. and Farooqui, A.A. 1998. Influence of season, bulb size and spacing on bulb production of tuberose cv. Single. *Karnataka J. Agri. Sci.*, **11** (4): 1145-1147.

Nagaraja, G.S.; Narayanagowda, J.V. and Farooqui, A.A. 1999. Effect of planting densities on growth and flowering in thuerose (*Polianthes tuberosa* L.) cultivar 'Single'. Mysore *J. Agri. Sci.*, **33** (2): 206-209.

Nagarajan, P., Radha, N.B. and Oblisami, G. 1986. Influence of biofertilizer application in the mulberry field on economic characters of silkworm. (*B. mori* L.) *Proc. Natl. Sem.* On Prospects and problem of Seri in India, March 27-30, Bangalore, pp. 9.

Nantha Kumar, S. and Veeraragavathatham, D. 1999. Effect of integrated nutrient management on yield and yield

attributes of brinjal (*Solanum melongena*) cv. plr. 1. *South Indian Hort.* **47** (1-6): 42-48.

NanthaKumar, S. and Verraragavathatahm, D. (2001. Effect of integrated nutrient management on yield and quality attributes of brinjal (*Solanum Melongena*) cv. plr1. *South Indian Hort.* **49** (Special), 195-198.

Narasimha Raju, S. and Haripriya, K. (2001. Integrated nutrient management in crossandra (*Crossandra influndibuliformis* L.) cv. Dindigul local. *South Indian Hort.* **49** (Special), 181-184.

Narula, N. and Yadav, K.S. 1989. Nitrogen fixation research in India with *Azotobacter*, In Biological Nitrogen Fixation Research Status in India.

Narutla, N., Lakshminarayan, K. and Tauro, P. 1981. Ammonium excretion by *Azotobacter chroococcum. Biotech. and Bioeng.* **23**: 467-470.

Neuer, G.; Kronenberg, A. and Bothe, H. 1985. Denitrification and nitrogen fixation by *Azospirillum.* III. Properties of a wheat- *Azospirillum* association. *Archives of Microbiology,* **141** (4): 364-370.

Olsen, S.R., Cole, C.V., Waternape, F.S. and Dean, L.S. 1954. Estimation of available P in soil using $NaHCO_3$. USDA Cir. No. 939.

Packorsky, R.S., Paul, E.A. and Belhlenfalvay, G.J. 1985. Nutrition of sorghum plants fertilized with nitrogen or inoculated with *Azospirillum*. *Plant Soil.* **85**: 145-148.

Page, W. 1987. Iron dependent production of hydroxamate by sodium dependent *Azotobacter chroococcum*. *Appl. Environ. Microbial.* **53**: 1418-1424.

Pandey, A. and Kumar, S. 1989. Potential of Azotobacters and *Azospirilla* as biofertilizers for upland agriculture. A review. *J. Scient. Indus. Res.* **48** (3): 134-144.

Panwar, J.D.S.; [illegible] and Singh, O. (2000. Response of *Azospirillum* and *Bacillus* on growth and yield of wheat under field conditions. *Ind. J. Plant Physio.* **5** (1): 108-110.

Parthiban, S. and Abdul Khader, M.D. 1991. Effect of N, P and K on yield components and yield of tuberose. *South Indian Horticulture.* **39** (6): 363-367.

Parthiban, S.; Vadivelu, T.E. and Pappiah, C.M. (2001. Integrated nutrient management in globe amaranth (*Gomphrena globosa* L.). *South Indian Hort.* **49** (Special), 187-190.

Patel, B.M.; Patel, B.N. and Patel, R.L. 1997. Effect of spacing and fertilizer levels on growth and yield of tuberose (*Polianthes tuberosa* L.) cv. Double. *J. Applied Hort. Navsari,* **3** (1-2): 98-104.

Patil, B.A.; Bhore, D.P.; Patil, J. D. and Patil, A.V. 1980. Effect of planting density on production of flower stalks and

flowers in tuberose (*Polianthes tuberosa* L.). "National Seminar on Production Technology for Commercial flower crops.", 71-72.

Patil, J.D.; Patil, B.A.; Chougule, B.B. and Bhat, N.R. 1987. Effect of bulb size and spacing on stalk and flower yield in tuberose (*Polianthes tuberosa* L.) cv. Single. *Current Research Reporter, Mahatma Phule Agricultural University,* **3** (2): 81-82.

Patra, S.K.; Padhi, A.K. and Mishra, S.N. 1989. Effect of biofertilizers at graded levels of nitrogen on the yield of wheat and toria in the north eastern Ghat region of Orissa. *Environment and Ecology,* **7** (3): 533-536.

Pinochet, J., Calvet, C., Comprubi, A. and Fernandez, C. 1995. Interaction between the root-lesion nematode Pratylenchus vulnus and the mycorrhizal association of Glomus intraradices and Santa Lucia 64 Cherry root stock. *Plant and Soil.* **170**: 323-329.

Piper, C.S. 1950. Soil and plant analysis. The University of Adelaide Monograph Adelaide, Australia.

Piper, C.S. 1966. Soil and plant Analyses. Hans Publication, Bombay, pp. 368.

Plenchette, C., Fortin, J.A. and Furlan, V. 1983. Growth responses of several plant spp. to mycorrhizae in a soil of moderate P fertility-I. Mycorrhizal dependency under field condition with VAM inoculation. *Can. J. Bot.* **59**: 2003-2008.

Potti, S.K. and Arora, J.S. 1986. Nutritional studies in gladiolus cv. Sylvia. I. Effect of N, P and K on growth, flowering, corm and cormel production. *Punjab Hort. J.* **26** (1-4): 125-128.

Preethi, T.L.; Pappiah, C.M. and Anbu, S. 1999. Studies on the effect of *Azospirillum* sp., nitrogen and ascorbic acid on the growth and flowering of Edward rose (*Rosa bourboniana* Desp.. *South Indian Hort.* **47** (1-6): 106-110.

Rahman, M.M. and Mitra, S.N. 1974. Effects of nitrogen on growth and flowering of Dahlia variabilies willd. *Bangladesh Hort.* **2** (2): 15-18.

Ram, G.; Joshi, B.S. and Agrawal, R.P. 1986. Biofertilizers for rice and their residual effect on rabi crops in Madhya Pradesh, India. *International Rice Research, News Letter,* **11** (6): 33.

Ramamoorthy, A. 1982. Studies on interaction between phosphobacteria and nitrogen fixing microorganism in relation to production of pearl millet (*Pennisetum americanum*) and cowpea (*Vigna unguiculata*) M.Sc. (Ag.) thesis, T.N.A.U., Coimbatore.

Rao, A.V. and Dass, H.C. 1989. Growth of fruit plants as influenced by nitrogen fixing bacteria. *Annal Arid Zone* **28**: 143-147.

Rao, D.L.N. 1975. *Azotobacter* inoculants. In: Soil Microorganisms and plant growth, N.S. Subba Rao (ed) Oxford and IBH Pub. Co., New Delhi.

Reddy, B.S. 1993. Pre and post harvest management in tuberose (*Polianthes tuberosa* L.) cv. Double. Ph.D. thesis submitted to CCS HAU, Hisar.

Rudolah, M. and Rudolah, R. 1998. Association between diameter and weight of mother bulb and between seed stalk height and umbel diameter in the seed plant of the onion. *Variety, Zittauer Gelba. Archive Fur, Zuchtungi-Foreching,* **18** (6): 417-423.

Sadhu, M.K. and Bose, T.K. 1973. Tuberose for most artistic garlands. *Indian J. Hort.* **18** (3): 17-21.

Sadhu, M.K., S.K. Ghosh and Bose, T.K. 1978. Mineral nutrition of fruit plants. Effects of different levels of N, P and K on growth, flowering and fruit set. *Mysore J. Agric. Sci.* **12**: 101-113.

Sanders, F.E. and Tinker, P.B. 1973. Phosphate flow into mycorrhizal roots. *Pest Sci.* **4**: 385-395.

Sapatnekar, H.G., Rasal, P.H. and Patil, P.L. (2001a. Effect of super phosphate and phosphate solubilizers on yield of green gram. *J. Maharastra Agric. Univ.* **26** (1): 120-121.

Sapatnekar, H.G., Rasal, P.H. and Patil, P.L. (2001b. Efficient utilization of P-sources through P-solubilizers in wheat. *J. Maharastra Agric. Univ.* **26** (1): 121-123.

Sardana, V. 1997. Agronomic evaluation of biofertilizers to supplement inorganic fertilizers for sustained crop production – *A critical review. Agric. Rev.* **18** (2): 69-95.

Selvarajan, M. and Chezhiyan, N. (2001a. Studies on the influence of *Azospirillum* and different levels of nitrogen on growth and yield of turmeric (*Curcuma Longa* L.. *South Indian Hort.* **49** (Special), 140-141.

Selvarajan, M. and Chezhiyan, N. (2001b. Effect of *Azospirillum* in combination with different levels of nitrogen on growth and yield of fenugreek (*Trigonella foenum-graecum* L.) *South Indian Hort.* **49** (Special., 173-174.

Shah, J.P. and Joshi, H.U. 1986. Biofertilizers for improving production of cereal crops. *Fertilizer News,* **31** (12): 75-77.

Sharma, C.K., Barman, D., Singh, I.P. and De, L.C. 1995. Effect of spacing on tuberose (*Polianthes tuberosa* L.).*J. Hill Res.,* **8** (2): 271-273.

Sharma, P.K., Dey, S.K. and Chahal, V.P.S. 1986. In vitro interaction between phytopathogens and two *Azotobacter* sps. *Phytopathol. Notes.* **39**: 117-119.

Shashikala, B.N., Reddy, B.J.D. and Bagyaraj, D.J. 1999. Influence of Glomus mossease on the growth of micropropagated syngonium and spalhiphyllum at varied levels of fertilizer phosphrous. *Crop Res.* **18** (3): 454-460.

Shende, S.T., Apte, R.G. and Singh, T. 1977. Influence of *Azotobacter* on germination of rice and cotton seeds. *Curr. Sci.* **46**: 675.

Shende, S.T., Arora, C.K. and Sen, A. 1973. Interaction between *Azotobacter chroococcum, B. megatherium* var.

phosphaticum and *Rhizobium* sp. Zentral. *Fuer Bakt. Abstract II.* **128**: 668-677.

Shinde, V.S. 1990. Ph.D. Dissertation, Division of Agronomy, IARI, New Delhi.

Siddiqui, S.A., Anamika, N. and Shukla, N.P. 1993. The role of *Azotobacter* inoculation in mulberry cultivation. *Indian Forester.* **119** (7): 559-563.

Sidhu, G.S. and Arora, J.S. 1989. Response of gladiolus varieties to nitrogen application. *Indian J. Hort.* **46** (2): 250-254.

Singh, A., Godara, N.R. and Kumar, A. 1996. Effect of NPK on bulb production in tuberose (*Polianthes tuberosa* L.) cv. Single. *Haryana Agricultural University, J. Research.* **26** (3): 187-190.

Singh, C. and Sharma, B.B. 1993. Studied leaf nutrient composition of sweet orange as affected by combined use of bio and chemical fertilizers. *South Indian Hort.,* **41**(3): 131-134.

Singh, K.P. and Uma 1996. Response of graded levels of nitrogen on growth and flowering in 'Shringar' tuberose (*Polianthes tuberosa* L.). *Indian J. Agril. Sciences* **66** (11): 655-657.

Singh, Kartar, 1997. Agro techniques in Horticultural crops. Deptt. of Horticulture CCS Haryana Agril. Univ. Hisar. pp. 14-24.

Singh, P.V.; Manoj, Kumar and Kumar, M. 1999. Effect of spacing, depth and time of planting on growth, flowering and bulb production of tuberose cv. Double. *J. Ornamental Hort. New Series,* **2** (2): 127-130.

Sita Ram, Attri, B.L., Sharma, T.V.R.S. and Kumar, A. 1997. Standardization of agro-techniques in tuberose under Andman conditions-I Effect of Nitrogen on growth and flowering. *J. Ornamental Horticulture* **5** (1-2): 1-6.

Skalska, E. 1970. A study on timing fertilizer application to gladioli. Vedecke Prace Vyzteumeno ustern alerasneho. *Zaheranic tviv Pruhanicich.* **5**: 261-270.

Subba Rao 1982. Biofertilizers in Agriculture pp. 77-91 (New Delhi : Oxford and IBH Publishing Co..

Subba Rao, N.S. 1979. Crop response to microbial inoculation. In Recent Advances in Biological Nitrogen Fixation pp. 406-420. Ed., N.S. Subba Rao (New Delhi): Oxford and IBH Publishing Co..

Subba Rao, N.S., Tilak, K.V.B.R., Singh, C.S. and Lingegouda, B.K. 1983. Field response of finger millet (Eleusine coracana) to inoculation with *Azospirillum. Curr. Sci.* **52**: 439-440.

Subramanian, S. and Vijaya Kumar, M. (2001. Effect of various levels of nitrogen and azospirillum on growth and yield of CO_3 coriander (*Coriandrum sativum* L.). *South Indian Hort.* **49** (Special), 191-194.

Sukhda, M. 1999. Biofertilizers for horticultural crops. Indian Horticultural, (Jan.-March): 32.35.

Sundara Rao, W.V.B., Bajpai, P.D., Sharma, J.P. and Subbiah, B.V. 1963. *Journal of Indian Society of Soil Sciences* **11**: 209-211.

Suneja, S. and Lakshminarayan, K. 1993. Production of hydroxamate and catechol siderophoress by *Azotobacter chroococcum. Ind. J. Exp. Biol.* **31**: 878-881.

Swaminathan, V. and Sambandamurthi, S. (2000. Studies on integrated nutrient management on growth and yield of triploid Crossandra [*Crossandra infundibuli*formis (L.) Nees]. Cv. Delhi. *Crop Research Hisar,* **20** (2): 334-337.

Swedrzynska, D. and Sawicka, A. (2001. Effect of inoculation on population number of *Azospirillum* bacteria under winter wheat, oat and maize. Polish *J. Environ. Studies,* **10** (1): 21.25.

Terry, E.; Pino-M-de- Los, A. and Medina, N. 1998. Agronomic effectiveness of Azofert and Ecomic in tomato (*Lycopersicon esculentum,* mill) cultivation. *Cultivos Tropicales* **19** (3): 33-37.

Tilak, K.V. 1993. Electrical Fertilizers. ICAR Publication. New Delhi. pp 1-55.

Tilak, K.V.B.R. 1991. Bacterial Fertilizers. Tech. Bull. ICAR, New Delhi, pp. 66.

Tilak, K.V.B.R. and Annapurna, K. 1993. *Proc. Indian National Acad. Sci.* **B59** (3-4): 315-324.

Tilak, K.V.B.R., Singh, B.R., Roy, C.S. and Subba Rao, N.S. 1982. *Azospirillum brasilense* and *Azotobacter chroococcum* inoculum: *Effect on yield of maize and sorghum. Soil Biol. Biochem.* **14**: 147-148.

US Salinity Laboratory Staff 1954. Diagnosis and imporvement of saline and alkaline soils. USDA Hand book No. 60.

Verma, L.N. and Bhattacharya, P. 1990. Role of biotechnology in supplying plant nutrients in the nineties. *Fertilizer News* **35**(12): 87-97.

Wadleigh, C.H. 1957. Growth and plant, Soil Year Book of Agriculture USDA, Washington, D.C.

Wang, H., Parent, A., Gosselin, A. and Desjardins, Y. 1993. Vesicular-arbuscular mycorrhizal peat-based substrates enhance symbiosis establishment and growth of three micropropagated species. *J. Amer. Soc. Hort. Sci.* **118** (6): 896-901.

Wange, S.S. and Patil, P.L. 1994. Response of tuberose to biofertilizers and nitrogen. *J. Maharashtra Agri. Univ.*, **19** (3): 484-485.

Wange, S.S.; Patil, P.L. and Patil, J.J. 1995. Effect of biofertilizers alone and with nitrogen levels on tuberose cv. single *petaled. J. Soils and Crops.* **5**(2): 97-99.

Wani, P.V., More, B.B. and Patil, P.L. 1978. Effect of seed inoculation with some PSM on P uptake and yield of gram. *J. Maharastra Agric. Univ.* **3**(3): 271-272.

Wani, S.P., Upadhyaya, M.N. and Dart, P.J. 1984. An intact plant assay for estimating nitrogenase activity (C_2H_2 reduction) of sorghum and millet plants grown in pots. *Plant and Soil.* **82**: 15-29.

Wani., S.P., Dart, P.J. and Upadhyaya, M.N. 1983. Factor affecting nitrogenase activity (C_2H_2 reduction) associated with sorghum and millet estimated using the soil core assay. *Canadian J. Microbiology.* **29**: 1063-1069.

Wedding, R.T., Black, M.K. and Harley, J.L. 1978. Metabolic pools in the spadix of arum during floral development. *New Phytologist.* **8**: 211-222.

Yadav, B.R.D. and Kumar, T.D.N. 1984. Combined inoculation of *Azospirillum* and *Azotobacter* isolates on yield and nitrogen uptake of mulberry (M. India L. Abs) Micon International and 35th Annual Conference of Association of Microbiologists of India. Defense Food Research Laboratory, Mysore, India.

Yadav, L.P, Bose, T.K. and Maiti, R.G. 1985. Response of tuberose (*Polianthes tuberosa* L.) to nitrogen and phosphorus fertilization. *Prog. Ressive Hort.* **17**(2): 83-86.

Yadav, L.P. and Maiti, R.G. 1989. Tuberose In: Bose, T.K. and Yadav, L.P. (eds.) Commercial Flowers pp. 519-544. Calcutta: Naya Parkash.

Yoshiba, M.; Aso, S. and Hosoya, T.H. 1981. Nutrition and physiology of ornamental flowering plants. *J. Agric. Sci. Japan.* **26** (1): 68-81.

ANNEXURE – I

Meteorological data recorded during the course of investigation (May 2001 to December 2002).

Month	Temperature (°C)		Relative humidity (%)		Sunshine hrs.	Total rainfall (mm)
	Maximum	Minimum	Morning	Evening		
May, 2001	40.2	22.9	58	28	6.9	102.7
June, 2001	36.3	23.3	77	54	6.9	168.7
July, 2001	34.8	24.5	82	64	6.2	209.8
August, 2001	34.4	23.5	82	62	7.9	133.3
September, 2001	36.4	21.6	78	41	9.6	26.2
October, 2001	34.6	17.6	83	31	8.7	2.5
November, 2001	29.7	9.4	87	26	8.6	0.0
December, 2001	22.8	6.3	93	49	6.9	0.0

Month	Temperature (°C)		Relative humidity (%)		Sunshine hrs.	Total rainfall (mm)
	Maximum	Minimum	Morning	Evening		
January, 2002	19.8	4.5	94.5	58.0	6.3	0.0
February, 2002	22.5	6.4	91	54	7.6	35.2
March, 2002	29.4	11.5	83	35	9.1	2.1
April, 2002	38.2	18.3	60	19	8.8	0.0
May, 2002	42.0	26.8	47	23	7.8	87.0
June, 2002	39.9	27.6	65	37	7.7	20.3
July, 2002	39.8	28.5	61	37	6.6	12.9
August, 2002	37.0	27.1	78	48	6.5	22.6
September, 2002	34.4	21.6	89	47	8.8	35.9
October, 2002	33.9	16.9	85	31	9.0	0.0
November, 2002	28.7	9.8	92	31	7.9	0.0
December, 2002	23.8	6.4	92	41	6.8	10.0

Source: Meteorological Department, CCS HAU, Hisar.

ABSTRACT

Title of Dissertation	:	"Studies on the effect of nitrogen, plant geometry and biofertilizers on growth, flowering and bulb production in tuberose (*Polianthes tuberosa* L.) cv. Double."
Full name of degree holder	:	**BIJENDER SINGH YADAV**
Admission No.	:	99A41D
Title of degree	:	Doctor of Philosophy
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Degree awarding University/ Institute	:	CCS Haryana Agricultural University Hisar-125 004 (Haryana), India
Year of award of degree	:	2003
Major Subject	:	Horticulture (Floriculture)
Total number of pages in dissertation	:	166 + xxviii
Number of words in abstract	:	Approximately 375

The present investigation was aimed to studing the effect of nitrogen, plant geometry and biofertilizers on the performance of tuberose cv. Double. The investigation was carried out in field for two years 2001 and 2002 at CCS Haryana Agricultural University, Hisar. The treatments consisted of four levels of N i.e. 0(N_0), 10 (N_1), 20(N_2) and 30(N_3) g N per square meter, three spacing distance i.e. 20 x 20cm (S_1), 20 x 25 cm (S_2) and 20 x 30cm (S_3) and different biofertilizers i.e. control (BF_0), Azotobacter (BF_1), Phosphorus solubilizing bacteria (BF_2) and Azospirillum (BF_3) in all possible

combinations. The treatments were replicated thrice in split plot design.

The increasing levels of nitrogen, plant geometry (spacing) and different biofertilizers significantly advanced the sprouting of bulbs over the control when applied alone and in combination in both the years. Per cent sprouting, plant height, number of leaves per plant, length and area of leaf significantly increased over the control with increasing levels of nitrogen, plant geometry (spacing) and with different biofertilizers except plant height which decreased with increasing plant geometry (spacing) when applied alone and in combination in both the years. Initiation of spike and opening of basal florets were delayed with increasing levels of nitrogen and plant geometry (spacing) but shortened with biofertilizers in both the years. Length of spike, number of florets per spike, spike girth, rachis length and duration of flowering were significantly higher over the control with increasing levels of nitrogen, plant geometry (spacing) and with the addition of biofertilizers when applied alone and in combination in both the years. Number of bulbs, bulb diameter, bulb weight, total root biomass, number of roots per plant and root length increased significantly over control with the increasing levels of nitrogen, plant geometry (spacing) and with application of different biofertilizers when applied alone and in combination in both the years. The N, P, K, and Zn content in leaf at flowering stage increased with increasing levels of nitrogen, plant geometry (spacing) and biofertilizers when applied alone and in combination with each other except K and Zn, K content decreased with added doses of nitrogen, whereas biofertilizers had no effect on Zn content of leaf in both the years.

MAJOR ADVISOR

4.4.03

SIGNATURE OF STUDENT

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HEAD OF THE DEPARTMENT