GROWTH, QUALITY AND PRODUCTIVITY OF CARNATION (*Dianthus caryophyllus* L.) UNDER COST-EFFECTIVE GREENHOUSE AS INFLUENCED BY LEVELS OF FERTIGATION, SOURCES OF FERTILIZERS AND BIO-INOCULANT

G. GOPINATH, M.Sc.(Agri.) Hort.

DIVISION OF HORTICULTURE
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G. GOPINATH, M.Sc.(Agri.) Hort.

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UNIVERSITY OF AGRICULTURAL SCIENCES
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CERTIFICATE

This is to certify that the thesis entitled "**GROWTH, QUALITY AND PRODUCTIVITY OF CARNATION (*Dianthus caryophyllus* L.) UNDER COST-EFFECTIVE GREENHOUSE AS INFLUENCED BY LEVELS OF FERTIGATION, SOURCES OF FERTILIZERS AND BIO-INOCULANT**" submitted in partial fulfilment of the requirements for the degree of **DOCTOR OF PHILOSOPHY in HORTICULTURE** to the University of Agricultural Sciences, Bangalore, is a record of bona-fide research work carried out by **Mr.G.GOPINATH** under my guidance and supervision and that no part of the thesis has been submitted for the award of any degree, diploma, associateship, fellowship or other similar titles.

Bangalore
September, 2001

(M.M.KHAN)
Director of Instruction (PGS)
& Major Advisor,
UAS, GKVK, Bangalore-65.

Approved by :

Chairperson : **(M.M.KHAN)**

Members : 1. **(J.V.NARAYANA GOWDA)**

2. **(R.SIDDARAMAPPA)**

3. **(T.G.PRASAD)**

4. **(K.SRINIVAS)**

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INTRODUCTION

I. INTRODUCTION

Flowers being one of the most exquisite beauties of nature have fascinated man since time immemorial and have become an integral part of civilization. No party, function or ceremony is complete without flowers. Apart from the several utilities of flowers, commercial production of cut flowers especially under greenhouse conditions for export is gaining lot of importance in recent years. Carnation (*Dianthus caryophyllus* L.) is one such cut flower (Plate-I) which has tremendous potential in the international flower market with a trade value of more than 93.42 million U.S. dollars (Anon., 1995).

The name 'carnation' is believed to have been derived from a Greek word "Coronation" as these flowers were used for decorating the crowns of Greek athletes. It belongs to the family 'Caryophyllaceae' and is native to Mediterranean region. The genus *Dianthus* has four important cultivated species of which *Dianthus caryophyllus* L. is mainly grown for cut flowers and the others are grown as border plants in landscaping. The plants are perennial, herbaceous, semi-hardy, medium tall (0.45 – 1.25 m.) with thick, narrow and linear succulent leaves. The stem is hardy, woody below, glabrous and possess 1 to 3 angles. Most cultivars are diploids and the tetraploid flowers are bigger in size but less productive. The flowers are solitary and terminally formed. The petals are broad having frilled margins with a cylindrical calyx.

Carnation is preferred to roses and chrysanthemums in several exporting countries, due to its wide range of colours, excellent keeping quality, ability to withstand long distance transportation and remarkable ability to rehydrate after continuous shipping.

Carnation is grown on an area of about 6000 ha in the world. It is extensively cultivated in Italy, Spain, Columbia, Kenya, Ceylon, Canary Islands, France, Holland, Germany and USA for production of cut flowers. While the major exporters are Columbia, Netherlands, Israel, Italy, Spain, Kenya, France, Peru, Greece, Mexico and Ecaudor, the major importers of carnation are Federal Republic of Germany, France, U.K., Netherlands, U.S.A. and Canada (Mukherjee, 1996).

In India, carnation is mostly grown in places like Ludhiana, Nasik, Pune, Kashmir, Coimbatore, Delhi and Bangalore (Arora and Gill, 1995). Taking advantage of the globalisation of trade and liberalisation policies of Government of India in recent years, there has been a spurt of high-tech. floriculture units in India by several corporate houses. At present, nearly 103 floricultural projects have been approved to set-up Export Oriented Units (EOU) in the country at an estimated cost of more than Rupees 1000 crores

(Khan *et al.*, 1997). These projects are supported with technology and marketing tie-up with collaborators from Netherlands, Israel and other countries. These are being set-up in and around Pune, Bangalore, Hyderabad and Delhi, mainly for growing roses. The area under greenhouses in India is estimated to be around 300 ha. There exists immense scope for developing indigenous technology of growing carnation besides other crops, targeting towards minimizing the cost of production while maintaining a high level of quality.

Balanced nutrition is one of the most important factors affecting the growth and productivity of carnation. The optimum levels at which the nutrients are to be applied and the sources from which they have to be derived are equally important. Excessive use of fertilizers for increasing the cut-flower production has led to nutrient leaching causing soil hazards. Optimisation of nutrients, use of bio-inoculants and their efficient application should receive importance. Fertigation, which combines fertilizer application with irrigation water has been recognised as one of the most efficient systems of delivery and convenient means of maintaining optimum level of fertility resulting in higher productivity with better quality produce. It also helps in economising the use of fertilizers and water.

Further, practice of supplementing a part of chemical fertilizers with biofertilizers is also gaining importance in recent years as they are known to be eco-friendly, cost effective and maintain the soil health. Azotobacter is one such bio-fertilizer which is a free-living nitrogen fixing bacterium used for non-leguminous crops. Besides, it is also known to promote production of certain growth regulators like auxins, gibberellins and cytokinens.

The development of standard type of carnation has revolutionised the carnation industry, because, the standard types fetch a premium price for their large sized multi-coloured blooms, enhanced keeping quality with strong stems, all making them highly suitable for floral decorations. The present day need is to develop cost-effective production technology for these types, which can very well be adapted even by small and marginal farmers.

Hence, the present studies on standard varieties of carnation, with different levels of fertigation using straight and water soluble fertilizers along with a bio-inoculant were carried out during 1997-98 at the Division of Horticulture, University of Agricultural Sciences, Bangalore with the following objectives :

i) To standardize the level of fertigation and determine the optimum source of nutrients for achieving best quality and higher productivity.

ii) To study the effects of bio-inoculant on growth, quality and yield of standard varieties of carnation.

iii) To identify the most suitable variety of standard type carnation for cultivation under naturally ventilated greenhouse.

iv) To assess the vase life of carnation as effected by Azotobacter, levels of fertigation and sources of nutrients.

v) To work out the economics of fertigation and production of carnation under cost-effective green house.

REVIEW OF LITERATURE

II. REVIEW OF LITERATURE

. Carnation (*Dianthus caryophyllus* L.) is one of the exotic flowers, which is gaining popularity in India in recent years. In order to meet the quality standards of both domestic and international markets, carnation needs to be grown under protected conditions. Its cultivation for commercial cut flowers under cost-effective greenhouse is one among the widely accepted present day practices. As it is an exotic crop, testing the suitability of its varieties to local situations is considered as a priority area of research. In addition, efficient management of nutrients using fertigation technique and bio-inoculants forms the basis for improving the quality and productivity of carnation. Hence, relevant research literature pertaining to this subject is presented under the following headings.

2.1 Evaluation of carnation varieties for growth, flowering, quality and yield.

2.2 Nutritional studies in carnation.

2.3 Studies on fertigation in carnation

2.4 Effects of bio-fertilizers on uptake of nutrients, growth, flowering, quality and yield.

2.5 Calyx splitting

2.6 *Fusarium* wilt and gray mould

2.7 Studies on vase life

2.8 Economics of protected cultivation of carnation

2.1 EVALUATION OF CARNATION VARIETIES FOR GROWTH, FLOWERING, QUALITY AND YIELD

Mahesh (1996) reported that the genotype with Red edge had the least and 'Sterile Dop' had the most number of primary branches (1.87 and 4.20, respectively).

Carnation varieties 'Minister', 'Goldstar', 'Minigold', 'Pepitolancruso' and 'Landrino' flowered early, while late flowering was observed in 'Yellow Stone' and 'Jolvitte' varieties as reported by Miske (1982).

Variation between genotypes of carnation (*Dianthus caryophyllus* varieties and interspecific hybrids) in time of flowering and response to long days was studied by Sparnaaij *et al.* (1990). Early flowering carnation varieties, responding to artificial long days, can assist the grower to plan the onset of flowering and achieve a better distribution of flower production over the year. The main purpose of the experiment was to analyse the genetic factors responsible for the large differences in flowering behaviour between genotypes. Average flowering dates varied from 132 days from pinching in *Dianthus chinensis* hybrid to 181 days in the Mediterranean var. 'Raggio di sole'. Long day response was most pronounced in the earliest flowering *Dianthus* selections and least in the traditional commercial varieties.

The genetic variation in number of visible leaf pairs on each of the dates, in relation to shoot position and rate of unfolding of leaf pairs, was analysed by Sparnaaij (1992). On the basis of these analysis, between and within genotype variation in the time of flowering, yield distribution and long day response could be, atleast partly, related to variation in the above mentioned parameters. It was established that relevant genetic variation exists in (1) initial development of the axillary bud from which a primary shoot is produced after pinching; (2) rate of leaf unfolding; (3) minimum number of leaf pairs required for flower initiation and (4) within plant variation in the above three characters in relation to shoot position.

Ten carnation varieties were compared by Bhautkar (1994) for cut flower production in pot trials under protected cultivation. Var. 'Eveline' produced most flowers but took longest to initiate flower buds (119 days) and had a vase life of only 5 days. However, varieties 'Barbara', 'Lena' and 'Bianca' took shortest time to initiate flower buds (74-76 days). 'Thalassa' and 'Bianca' had the longest vase life of 8 days.

The carnation varieties viz., 'Caravelle', 'Arthur Sim', 'Clear Yellow Sim' and 'Caravelle Saugus' were outstanding with respect to flower diameter (Oszkinis and Kus, 1971). Among the carnation varieties studied, var. 'Castellan' had the largest flower diameter of 76 mm (Loeser, 1986). Mahesh

(1996) observed that the flower diameter ranged from 4.66 cm in 'White Sim' to 7.11 cm in 'Arthur Sim'.

The var. 'Castelleno' was the tallest (140 cm) with longest stem (> 60 cm) out of carnation varieties studied (Loeser, 1986). The Mediterranean type had longer flower shoots compared to Sim type carnations (Snijbloementelt, 1987). Kim *et al.* (1992) assessed the suitability of 15 carnation varieties for cut flower production and reported that 'Gallil', 'Rimon' and 'Beta' of standards had longer flower stems.

Adillon *et al.* (1985) obtained higher flower production in Mediterranean types than in Sim type varieties. The varieties 'Barbara' and 'Starlight' were grown in a greenhouse in containers holding a mixture of sandy soil, gravel and organic matter with major and micronutrients. The flower yield of 'Starlight' was 97 per cent greater than that of 'Barbara' (Zornoza *et al.*, 1989). Six varieties of carnation grown in soil differed with regard to cut flower production. In the soil, No.43 produced the most followed by No.46, 24, 48, 31 and 41(Chen *et al.*, 1990).

Flower production under greenhouse conditions was determined by Bucan (1990) for 'Scania', 'White Sim' and 'Lena' varieties of carnation (*Dianthus caryophyllus*) obtained from three different suppliers. An average production of 6.94 flowers per plant was recorded. The variety and provenance of the varieties had significant influence on height, quality and flower yield as well as on economics of production.

Gelder (1987) gave methods and procedures for testing carnations in varietal trials. Keeping quality of cut flowers, resistance to Fusarium wilt and productivity were considered as important characters for evaluating carnation varieties. Among 6 varieties grown in a greenhouse for assessing productivity, cut flower quality and resistance to *Fusarium*, varieties 'Orange Triumph', 'Hellas' and 'Palma' were found to be the best (Bchvarova *et al.*, 1988).

Satish (1997) observed that 'IAHS-23' of standard type and 'IAHS-27' of spray type performed better compared to other varieties of carnation. He obtained maximum stem length and branches (80 cm and 6.84, respectively) in var. 'IAHS-23' and minimum (71.10 cm and 6.70, respectively) in var. 'IAHS-5'. Further, maximum stem girth (7.49 cm) and minimum (0.47 cm) were obtained in varieties 'IAHS-5' and 'IAHS-25', respectively. Further, bud length, bud diameter and flower diameter of standard type carnations grown under greenhouse were maximum in var. 'IAHS-23' (3.45, 2.13 and 7.10 cm, respectively) and minimum in var. 'IAHS-5' (3.34, 1.79 and 7.10 cm, respectively). Flowers per plant, per square metre and percentage of marketable flowers of standard type carnation grown under greenhouse were maximum in var. 'IAHS-23' (5.24, 172.76 and 72.40 %, respectively) and minimum in var. 'IAHS-5' (5.17, 107.42 and 72.4 %, respectively). However, the lowest percentage of unmarketable flowers (17.57 %) under greenhouse conditions was produced by var. 'IAHS-23' and highest (27.60 %) by var. 'IAHS-5'.

2.2 NUTRITIONAL STUDIES IN CARNATION

Boodley (1975) brought out the importance and role of balanced nutrition in deciding the quality of carnation flower crop.

2.2.1 STUDIES ON DEFICIENCIES OF NUTRIENTS

Carnation flower production was depressed by liming and was highest at pH 4.3 – 5.9. Due to boron deficiency < 10% of the buds formed failed to develop; the leaves contained 8-11 ppm B. The deficiency reduced flower production and average bloom diameter and increased the incidence of calyx splitting (Adams *et al.*, 1980).

The effects of N, P, K, S, Ca, Mg and B deficiencies were studied by Medina (1992) on carnation var. 'Tanga'. Nitrogen deficiency symptoms consisted of generalised chlorosis with poor growth and short internodes. K deficiency was exhibited as irregular necrotic spots on leaves, brittle stems and sugar exudation from the stems. P deficiency was seen as darkening of the foliage and Ca deficiency as general weakening and slight chlorosis in young shoots. Mg deficiency caused stem shortening and S deficiency increased the proportion of weak flowers. N deficiency reduced flower production by 40% and dry matter production by 30%. Calyx splitting was greatest with K deficiency.

2.2.2 NUTRITIONAL DIAGNOSIS OF CARNATION

Nelson and Boodley (1963) recommended that carnation leaves be collected only between 8 AM and noon.

About 2% of nitrogen, 0.2 to 0.8 % phosphorus and 2 to 4 % potash in the carnation leaf were found to be optimum for flower yields (Fernades *et al*., 1975).

Miura (1979) reported that increase in soil potash decreased leaf Mg content in carnations.

Leaf nutrient concentrations of 3.12 to 3.50, 0.228 to 0.427 and 3.10 to 3.50 per cent NPK respectively were obtained in carnation for the application of N, P and K at 130 g, 77 g and 182 g per square meter annually (Farina and Lupi, 1987).

Effect of N, P and K on growth, flowering and chemical composition of carnation was studied by Mukhopadhyay and Sadhu (1988). N, P and K were applied in the form of urea, SSP and MOP. Leaf samples (fully expanded mature 5th leaf from the apex.) were collected at vegetative and flowering stages. There was sharp reduction in leaf N content in the flowering stage, compared to vegetative stage, due to utilisation of N during flowering. High N fertilization was found to be associated with low K content in the foliage. Nitrogen and phosphate fertilization improved flower yield considerably over control. The effect of fertilizer on field life of flowers was only marginal and not of much practical value.

A technique is described by Hasegawa (1992) for nutritional diagnosis of carnation using small amounts of exudate from the leaf base. In 2 varieties, the levels of N in the exudate showed a relationship with the soil N level and decreased as the plants increased in weight. The level of K in the exudate tended to increase as plant weight increased.

Leaf mineral nutrient content (N, P, K, Ca, Mg, Fe, Cu and Zn) in both varieties 'Amapola' and 'Hydra' of carnation at each nutrient solution pH of 5.0, 6.0 and 7.0 was estimated (Guba *et al.*, 1993).

The critical electrical conductivity value was 3.9 for carnation. The concentrations of mineral nutrients in shoots were in the order of $K_20 > T - N > CaO > Mg > P_2O_5 > Na_2O$ for carnations, 60 days after transplanting. The optimum concentrations of N, P_2O_5, K_2O, CaO, MgO and Na_2O in shoots for maximum biomass yields were 3.10, 0.50, 4.60, 2.20, 0.60 and 0.40 %, respectively, for carnations at 60 days after transplanting (Hwang and Yoon, 1994).

Analysis of fully expanded leaf tissue indicated that NO_3-N was significantly lower than in leaves from plants grown in pumice irrigated with nutrient solution (Challinor *et al*, 1995).

2.2.3 Uptake of nutrients as affected by time of application of nutrients

Investigations were conducted by Jhon and Arora (1978) to find out the effects of different levels of N (20, 40 and 60 g/m^2), their time of application and plant density on the uptake of N, P and K by carnation plants at two stages : tufting and peak flowering. Nitrogen and phosphorus content of leaves was comparatively low at peak flowering stage than at tufting stage, whereas the uptake of potassium increased at peak flowering stage than at tufting stage. The application of N in three splits enhanced the uptake of N and P by carnation plants than other treatments. While there was a close positive correlation between nitrogen and phosphorus content of leaves, there was a negative correlation between K and N content.

2.2.4 Influence of growing media on growth, quality, yield and dry mass

The best cut flower yields were obtained with perlite at 3.6 l/plant, followed by perlite and rockwool mixture (Kaplan, 1993b).

Studies on the effect of different growing media on yield and quality of carnation (*Dianthus caryophyllus*) production revealed that highest cut flower yield (stems /m^2) and stem length were obtained on pumice medium for all the 3 varieties : 'Manon', 'Astor' and 'Miledy' (Boztok *et al.*, 1995).

Carnation varieties 'Indios' and 'Michelle' were grown on perlite or on traditional compost mixture (soil, peat and leaf mould). Plants grew better on perlite than on traditional compost, producing more shoots and being taller. 'Indios' performed better than 'Michelle' (Minuto and Accati, 1995).

Dianthus shoot dry mass, size and height increased as the percentage of compost in the medium increased from 0 to 60% but decreased at 100% level of compost. Initial nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), Magnesium (Mg) and soluble salt concentration linearly increased as the percentage of compost in the medium increased from 0 to 100% (Klock, 1997).

2.2.5 EFFECTS OF NUTRIENTS ON GROWTH, FLOWERING, QUALITY AND YIELD

Holley *et al.* (1951) reported that in carnation varieties 'Willian Sim' and 'White Patrican' there was an increased production of flowers with increased dose of nitrogen.

Studies on the nutritional requirements of the perpetual carnation were initiated by Chan *et al.* (1958). The variety 'Appollo' was subjected to different levels of N, P, K and Ca. Nitrogen and potassium treatments were highly significant, but phosphorus showed no significant response. Anova showed N and K interaction to be significant. It was interesting to note that K (> 90 ppm) effects were only significant at higher N levels (> 120 ppm).

Eck *et al.*, (1962) evaluated the effect of different N and K levels on carnation quality, plant composition and soil nutrient reserves. Ammonium nitrate and potassium nitrate were the sources used. The sleepy flowers were most prevalent when the K concentration in the plant tissues dropped below 22% and the N content approached 3%. The negative correlation between exchangeable K and soil nitrate levels was highly significant. Superior growth and flower quality were obtained at 180 ppm N and 200 ppm K levels.

Rushmini and Baldi (1974) inferred that the ratio of 1:2:1 NPK increased stem length in carnation.

Arora and Saini (1976) reported that greater number of flowers was obtained with the application of N, P_2O_5 and K_2O at 40, 10 and 30 g/m^2, respectively.

Arora and Jhon (1978) experimented to findout the optimum level of N, its suitable time of application and plant density for good growth and flowering of carnation (*Dianthus caryophyllus* L.). Out of three levels of N tried 400 g N/m^2 significantly improved the vegetative parameters and production of flowers. Application of nitrogen in 3 splits had a significant effect in increasing vegetative parameters and flower production of blue grade in comparison to the application of N in single basal dose or in two splits. More blue grade flowers were produced by the application of 20 g/ m^2.

Response of nitrogen to flower production and flower size and relation between N, P and K content of leaves and flower production in carnation (*Dianthus caryophyllus* L.) var. 'Marguerite Scarlet' was studied by Jhon *et al.* (1979). Maximum production of flowers was obtained when N was applied at 40 g/m^2. The flower size was maximum with nitrogen application of 20 g N/m^2. Higher doses of N, however, had a detrimental effect on the size of flowers. The maximum number of flowers was produced against 5.37 per cent N, 3.1 per cent P and 3.8 per cent K content in the leaves.

Mukhopadhyay (1981) observed that N (40 g/m^2) and P (20 g/m^2) stimulated vegetative growth of plants and increased flower yield per plant in carnation.

Biswas *et al.* (1982) studied the effect of different levels of N, P and K and their interactions on growth and flowering of carnations. N, P and K were supplied through urea, SSP and MOP respectively. The height of plant, number of branches and flowers per plant increased significantly with increasing level of nitrogen. Significant promotion of flower number was also recorded due to interactions of higher levels of N, P and K.

When an NPK fertilizer mixture (1 N : 0.5 P_2O_5 : 1.4 K_2O) was applied at 160 g/m^2, 192 cut flowers of marketable quality (miniature carnations) were obtained per square metre under a population density of 43 per square metre (Fischer and Kurzmann, 1987).

Kerlor *et al.* (1988) reported that in varieties 'Sumantha' and 'Lena', highest yield and best quality cut flowers were produced by alternate spraying with 2 lactofol products : Lactofol Zn (N : K : Mg : Fe = 25 : 12.5 : 4 : 2) + B, Cu, Mn, Zn, Mo and Co + Physiologically active substances, and Lactofol K (differing in microelement composition).

Starck *et al.* (1991) studied the effect of fertilizer nitrogen and potassium upon yield and quality of carnations grown in peat and sawdust. The number of flowers produced ranged from 207 to 216 per square metre but differences between treatments were not significant. In most cases, plants grown in peat + sawdust mixtures had longer stems and bigger flowers than those grown in peat or sawdust alone. The higher nitrogen rate produced bigger flowers in plants grown in sawdust or 25 % peat + 75% sawdust. The higher K rate promoted stem elongation in plants grown in 50% peat + 50% sawdust.

Hosni and Shoura (1996) reported the effects of N (10.3 g/plot) + P (0.3 g/plot) + K (0.3, 0.6 or 0.9 g/plot) on the stem diameter of carnation var. 'Lucena'. The stem diameter increased significantly with highest rate of potash.

Mukherjee (1996) reported that N, P, K, Ca and Mg in the proportion of 250 g, 60 g, 200 g, 125 g and 40 g per square metre per annum, respectively, were better in producing carnation flowers.

2.2.6 EFFECTS OF SOURCE OF NUTRIENT ON GROWTH AND FLOWER PRODUCTION

An experiment on the effects of different treatments of pinching, sources and doses of N on the growth and flower production of carnation var. 'Marguerite White' was conducted by Patel and Arora (1983). The effects of dose of N and the interaction between pinching, sources and doses of N did not affect the plant height significantly. The superiority of CAN over urea was attributed to its readily availability and as it contained ammonical as well as nitrate form of N. Application of N through CAN recorded highest plant height and higher number of flowers per plant than urea.

Fe EDDHA stimulated chlorophyll synthesis in both 'Lena' and 'Pallas' varieties (Duijff *et al.*, 1994).

2.3 STUDIES ON FERTIGATION IN CARNATION

Scientists and enterprising farmers have made several attempts in the past to fertigate the crops for yield advantage (Goldberg and Shmueli, 1970).

Bruce *et al.* (1980) recommended four different ways of fertilizer injection in a fertigation system : (i) Injection of material on the suction side of an irrigation pump (ii) pressure injection into the irrigation line, (iii) use of venturi-principle unit to create suction into a pressurised irrigation line, and (iv) development of a pressure differential created by a line construction or pilot tub across with which an air tight supply tank is connected. A portion of the irrigation water flows through the supply tank containing the chemicals to be injected.

According to Greef (1975a) fertigation would be successful when the : (i) system is designed efficiently to see that every emitter delivers the same amount of water, (ii) nutrients are distributed such that there is no blockage, (iii) a constant and uniform mixing of plant nutrients with irrigation water and (iv) constant flow of water throughout the system occurs.

Neutral chemical molecules like urea and negatively charged nutrient ions such as nitrate and sulphate primarily move into the soil profile with the flow of water. Thus, irrigation in excess of the plant moisture requirement could lead to leaching of urea and nitrate (Greef, 1975b).

In some countries, the practice of fertigation, through drip or sprinkler, is in vogue in several horticulture crops (Bester *et al.*, 1977).

Improperly designed irrigation system which does not satisfy the coverage of fertilizer material leads to poor results (Kao, 1980).

Percolation losses of fertilizers were reduced by the application of nutrients along with drip irrigation (Assaf, 1985).

Pergola and Farina (1990) recommended that for determining fertigation, irrigation rate and EC value of the percolate should be considered and that when ever EC exceeded 4000 μl/cm, water alone should be used.

With the increase in area under drip and sprinkler irrigation systems in India, agricultural scientists are going ahead with fertigation using costly fertilizers (Sivanappan, 1994).

An expert system for managing fertigation of cut flowers to ensure appropriate and efficient distribution of nutrients to the crop with minimal wastage was developed and tested by Farina *et al.* (1996). The equipment used by the system was relatively simple and suited to the economic realities faced by small / medium growers. In the 5 years of experimentation on carnations utilizing this expert system no malnutrition problems surfaced. Carnation produced high cut flower yields.

2.3.1 GROWTH, QUALITY AND YIELD AS INFLUENCED BY FERTIGATION

Hart (1970) observed that production of glasshouse carnation was highest in plots which received 160 - 230 ppm N, 130 – 230 ppm P_2O_5 and 130 – 230 ppm K_2O.

The optimal level of N, P, K, Ca and B are 25 – 40 ppm, 5 – 10 ppm, 25 – 40 ppm, 150 – 200 ppm and 20 –25 ppm respectively. Boron deficiency increased calyx splitting (Adams *et al.*, 1979).

Yasui *et al.* (1980) grew rooted cuttings of carnation var. Lena at temperatures ranging from 15-30°C and at different nutrient levels i.e., N at 15-50 ppm, P_2O_5 at 10-60 ppm and K_2O at 20-120 ppm. The best results with respect to plant height and stem length were obtained at 20°C, and N, P_2O_5 and K_2O at 75, 30 and 60 ppm, respectively.

Carnations grown under plastic at a density of 29.6 plants per square metre were fertigated at weekly or every three weeks intervals with a 19 : 9 : 27 NPK fertilizer. Both the treatments providing 30 g NPK per square metre at monthly frequency produced no effect on flower yield or quality (Saver *et al.*, 1985).

Desirable quantities of nutrients in the solution are 175 ppm N, 150 ppm K, 40 ppm P and 25 ppm Mg. The total trace element concentration must be around 150 ppm (Jan Hujig, 1991).

A formulation with an NPK ratio of 1.0 : 0.25 : 0.9 gave the highest yield and highest percentage of Grade -I flower in carnation (Kowalezyk *et al.*, 1992).

Mineral nutrition of carnation varieties 'Tanga' and 'Pallas Orange' grown in a greenhouse was studied by Strojny *et al.* (1992). Both the varieties were grown in a mixture of 40% mineral soil + 20% composted pine bark + 20% sphagnum peat + 20% sand. First year yields were highest with 100 mg N + 25 mg P + 100 mg K/l for both varieties. This treatment also gave the highest 2 year yield of 'Tanga' but the 200 mg N + 25 mg P + 400 mg K/l treatment gave the highest 2 year yield of 'Pallas Orange', 'Tanga' was more susceptible to *Fusarium oxysporum* f. sp. *dianthi* than 'Pallas Orange'.

The effects of three nutrient solution formulations on the production and quality of the Sim carnation varieties 'Raggio di sole', 'White Sim', 'Manon' and 'Doria' grown in rockwool substrate were evaluated over 12 months by Huett (1994). Production from the Std + NH_4^+ (Standard solution with 10% of the N as NH_4^+) treatment (20.8 flowers/plant) exceeded that for the other formulations. More than 75% of these flowers were of first grade.

Stem diameter, stem strength and vase life were unaffected by nutrient formulation, while flowers produced in March had thinner and weaker stems than those produced in October. The mean K : N ratio in mature carnations (leaf + stem + flower) was 1.39 : 1.00 and this ratio with 10% of the N as NH_4^+ was recommended for commercial hydroponic carnation production.

Quality and yield of carnation in a closed nutrient system as affected by sodium chloride were investigated by Baas *et al.* (1995). In carnation, peduncle length decreased at salinities ≥ 23 mM NaCl. Post-harvest vase-life was not affected by salinity. Average electrical conductivity (EC) needed to compensate for mineral uptake was 0.7 to 0.8 $ds.m^{-1}$.

2.3.2 Effects of Sources of Nutrients on Yield and Quality

The effects of ammonium N rate (6, 15 and 24% in the nutrient solution) and 15% ammonium N + a nitrification inhibitor (N – serve) on quality and yield of spray carnation var. 'Elsy' and standard var. 'Pallas' grown on rockwool were studied by Kaplan (1993a) under greenhouse conditions. Increased ammonium N rates did not significantly affect flower yield of 'Elsy' but increased individual flower weight, stem length and total leaf N. Increasing ammonium nitrogen had no effect on flower yield or other characteristics of 'Pallas' carnations. N – Serve application had negative effects on flower weight and flower stem length of 'Elsy' carnations. It was concluded that optimum rate of ammonium N application was 15% for 'Elsy' and ≤ 6% for 'Pallas'.

2.4 EFFECTS OF BIO-FERTILIZERS ON UPTAKE OF NUTRIENTS, GROWTH, FLOWERING, QUALITY AND YIELD

2.4.1 UPTAKE OF NUTRIENTS

Bagyaraj and Powell (1985) reported that VAM inoculation increased P uptake in marigold. Balasubramaniam (1987) recorded increased foliar P levels besides, enhanced contents of N, K, Mg and Zn in French marigold seedlings with VAM inoculation.

2.4.2 GROWTH

Inoculation with *Glomus mosseae* increased plant height of container grown woody ornamental plants viz., Viburnum, Podocarpus and Pittosporum (39.6, 34.4 and 31.2 cm, respectively) (Crews *et al.*, 1978).

Chrysanthemum plants inoculated with VAM and given 75 per cent recommended NPK had put up maximum height (Hemavathi, 1997).

China aster var. 'Ostrich Plume' inoculated by *Glomus* sp. at 75 per cent of the recommended P rate showed greater plant height (Naik *et al.*, 1995).

Significant increase in the number of branches (24.7) was produced by treating the plants of aster with *Glomus marginata* + 75 per cent NPK (Naik *et al*., 1995).

Foliage development in marigold was enhanced by inoculating with mycorrhiza (Calvet *et al*., 1993).

Roncadon and Pokorny (1982) recorded significant increase in the crown spread of *Juniperus chinensis* var. 'Sargentris' inoculated with spore mixture of *Gigaspora marginata, G. fasiculatus* and *G. mosseae.*

Bagyaraj and Powell (1985) and Balasubramaniam (1987) obtained similar results when marigold plants were inoculated with VAM.

McGraw and Schenck (1980) obtained increased vegetative growth in chrysanthemum inoculated with *Glomus* sp.

Johnson *et al.* (1982) studied the influence of VAM fungi at different levels on the growth of *Chrysanthemum morifolium* and recorded increased shoot dry weight.

Manomani (1992) obtained beneficial effects in gundumalli inoculated with *Azospirillum.*

2.4.3 FLOWERING, QUALITY AND YIELD

McGraw and Schenck (1980) reported that chrysanthemum plants inoculated with *G. etunicuters* and *G. fasciculaters* flowered earlier and there was 100 per cent increase in the number of flowers produced. Advancement in flowering by 7-10 days was obtained by inoculating chrysanthemum with *Glomus* sp. (Kandaswamy *et al.*, 1986; Camprubi *et al.*, 1987).

Flowering in gerbera and zinnia was advanced by 16 and 24 days, respectively by colonization with *Glomus etunicaters and Glomus mossae* respectively, compared to control (Cheng, 1989). Gerbera colonized by *G. etunicaters* flowered 16 days earlier than the non-mycorrhizal plants (Wen, 1991).

Significant effects were produced by *G. intraradices* (VAM fungi) on flower number, diameter and stem length of gerbera and number of flower buds per plant in zinnia (Bonita *et al.*, 1994).

Maximum number of flower stalks of tuberose was obtained in the treatment involving N @ 150 kg per ha + Azospirillum (Wange *et al.*, 1995).

Mycorrhizal infection stimulated flower production in petunias as reported by Daft and Okusanya (1973).

2.5 CALYX SPLITTING

Number of petals per flower and percentage of carnation flowers (var. Sopheria) with split calyces increased as the temperature was reduced. And also, the plants grown at a high night temperature and occasionally given a low night temperature resulted in the production of more splits than those grown at a continuous low temperature (Snedel, 1937).

In case of carnation flowers, as the flower buds open and petals approach their full size, the calyx may split down either half or completely causing calyx splitting. Thus, petals are deprived of support, which results into bending down of petals, thereby regularity of shape and structure of the flower are destroyed, rendering it as useless (Arora and Jhon, 1976).

The primary causes for calyx splitting are unknown. The general opinion is that there is no single factor responsible for splitting, but is the result of genetic, environmental, nutritional and cultural factors (Arora and Jhon, 1978; Gopinath and Khan, 1997).

Gill and Arora (1988) reported that higher splitting of calyces was observed in the variety Scania (15.7%) while the lowest was in var. 'Clear Yellow' (10.3 %).

2.6 *FUSARIUM* WILT AND GRAY MOULD

High dose of nitrate nitrogen, soil amendment with sulphur or peat and shortage of calcium increased the disease severity (Blanc *et al*., 1983).

Increased resistance of carnation to *Fusarium oxysporum* with basal dressing with Mg at 50 – 150 mg/l was reported by Lyakh (1986).

The pH value of 7.5 and fertilization using calcium nitrate significantly decreased the incidence of *Fusarium oxysporum* on carnation var. 'Scania' (Orlikowski *et al*., 1990). The use of antagonist *Bacillus subtillus* T99 for biological control of *Fusarium* wilt of carantions in 2 types of hydroponic systems was recommended by Olieglo *et al*. (1990).

Thermal dip treatment was found effective against gray mould of cut flowers. Dipping of flowers in tap water at 50°C for 20 – 40 s was more effective. Moreover, the combination of heat with 3 mM catehol was additively more efficient in reducing gray mould of carnations. The surfactant Tween 20 (0.01%) improved the effect of treatment at 45° C for 20 s (Elad and Volpin, 1991).

There was no conclusive evidence for the presence of an independent extravascular resistance mechanism, except for 'Lena' plants in which, additional to the vascular resistance components, independent root-bound factors causing retardation of the colonization and wilting process were found

(Baayen and Van der plas, 1992). Analysis of isolated HPLC peak fractions of extracts of var. 'Pallas' carnation (*Dianthus caryophyllus*) stems infected with *Fusarium oxysporum* f. sp. *dianthi* race 2 yielded a number of 2 aryl 1, 3 benzoxazin and dianthramides in addition to several known ones. At least one N – aroylaniline was also found to be a natural carnation phytoalexin (Niemann *et al.*, 1992).

Response of carnation varieties to *Fusarium oxysporum* f. sp. *dianthi* in the field was evaluated by Ben Yephet *et al.* (1993). The general response of the tested variety was classified as resistant or susceptible on the basis of disease incidence values recorded 180 days after planting. Empirical analysis of the data revealed that a disease incidence level of 75% may be taken as a reliable cut-off point for separation of varieties into the two groups.

Temperature of > 25°C was necessary for effective screening of resistant varieties of carnation to *Fusarium* wilt (Mizuno, 1993).

Effects of inoculum depth and density on *Fusarium* wilt in carnations were studied by Ben Yephet *et al.* (1994). At 15-30 cm depth, mean wilt incidence 185 days after planting was 50% and reduced as the depth increased. Mean yield loss was 39% when inoculum was placed at a depth of 15 cm and increase in depth lowered yield losses. At a density of 3500 propagules per gram of soil, mean percentage of infected plants 185 days after planting was 57 %. Flower yields were related inversely to inoculum density.

Effects of solar radiation intensity and temperature on wilt induced by *Fusarium oxysporum* f. sp. *dianthi* in carnation were examined by Ben Yephet and Shtienberg (1994). The most severe epidemics were developed at low radiation intensities (200 – 300 mu – E m^{-2} S^{-1}) and at temperatures close to 25-26°C. At solar radiation intensities above 1000 mu – E m^{-2} S^{-1} and temperatures below 18°C, plants remained symptomless.

The effectiveness of methyl bromide (80 g/m^2) on the control of *Fusarium oxysporum* f. sp. *dianthi* was studied by Ben Yephet *et al.* (1994) at soil depths of 0 to 60 cm, in five carnation greenhouses during four successive growth seasons. Methyl bromide reduced the *Fusarium oxysporum* f. sp. *dianthi* propagule count at all soil depths between 0 and 60 cms, but was most effective in the upper 30 cm. The correlation between inoculum level in the soil after fumigation and inoculum or *Fusarium* wilt incidence at the end of the growth season indicated that in monocultures of susceptible carnation varieties, methyl bromide can not give total protection even for one growing season.

Effects of initial inoculum and variety resistance on the incidence of *Fusarium* wilt were studied by Ben Yephet *et al.* (1996b). The disease incidence increased significantly with increasing initial inoculum levels for susceptible, but not for resistant varieties.

The effects of abiotic variables (solar radiation intensity, temperature and growth substrate) on the response of carnation varieties to *Fusarium oxysporum* f. sp. *dianthi* were examined in experiments conducted by Ben Yephet *et al.* (1996a) under semi-controlled environments. It was concluded that the carnation response to *Fusarium oxysporum* f. sp. *dianthi* was substantially influenced by the environmental conditions of the test.

The resistant variety 'Candy' had twice the levels of phenolics as the susceptible variety 'Rosana' (Higuera *et al.*, 1996).

'Arbel' and 'Scarlette' varieties of carnation exhibited a novel type of resistance to *Fusarium* wilt induced by *Fusarium oxysporum* f. sp. *dianthi* race 2 (Ben Yephet *et al.*, 1997).

The effect of the Mycorrhizal fungus *Glomus intraradices* on disease development caused by *Fusarium oxysporum* f. sp. *dianthi* in the nonmycorrhizal species *Dianthus caryophyllus* was studied by co-culture of carnation plants with the Mycorrhizal species *Tagetes patula*. Presence of VAM *T. patula* plants more than doubled the survival of *D. caryophyllus*, significantly reduced the disease symptoms and decreased *Fusarium oxysporum* f. sp. *dianthi* propagules by 4:1 in soil. *Glomus intraradices* alone had no effect on *T. patula* or *D. caryophyllus* shoot biomass (St. Arnaud *et al.*, 1997).

The pathogen (*Fusarium oxysporum* f. sp. *dianthi*) may infect the plants at any time during the growing season. To minimise the losses induced by *Fusarium* wilt, growers use carnation cuttings free of *Fusarium* sp. and fumigate the soil with methyl bromide prior to planting. The information available on the effect of the host, the pathogen and the environment, and their interactions, on *Fusarium* wilt in carnation was summerised by Ben Yephet and Shtienberg (1997).

The *Fusarium* wilt of carnation is considered to be severe since it erases out the crop completely once it is noticed. Strategies such as evolving resistant varieties, following proper cultural practices, disinfection of media, treating with fungicides and use of biological agents would bring about effective control of the disease. However, integrated disease management programme involving cultural, physical, mechanical, biological and chemical methods would certainly minimise the problem (Gopinath *et al.*, 1997).

2.7 STUDIES ON VASE LIFE

For improving quality and prolonging vaselife of carnation flowers, it is necessary to inhibit microbial contamination and ethylene production, increase fresh weight, water uptake, flower diameter and leaf chlorophyll content (Lee *et al.*, 1980).

2.7.1 VARIETAL SPECIFICITY TO VASE LIFE

Wu *et al.* (1991) reported that cut flowers of the 'Sandra' and 'Chinera' varieties of carnation *(Dianthus caryophyllus* L.) lasted about twice as long (appox. 14 days) as those of 'White Sim'. Vase life of 'White Sim' was unaffected by the age of the flower at harvest, but the life of 'Sandra' and 'Chinera' fell as flower age at harvest increased.

Longevity of carnation (*Dianthus caryophyllus* L.) var. 'Chinera' was much longer than that of var. 'White Sim'. The studies revealed that the decreased sensitivity and the associated longer vase life is an inherited feature (Woltering *et al.*, 1993).

Response to 8- HQC was variety specific. Vase life was longer for carnation flowers raised in greenhouses than in open conditions (Lukaszewska, 1995).

2.7.2 PRE-TREATMENT AND PULSING

Effects of pre-treatment, storage methods and preservative solutions on vase life and quality of *Dianthus barbatus* "Kag Kwag" was studied by Bang Changseok *et al.* (1996). Pre-treatments containing STS + Sucrose extended vase life by about 2 days compared with the control. The preservative solution containing HQS + Sucrose extended vase life by 7 days and improved quality significantly as judged by increased percentage of flowering, flower diameter and fresh weight compared with the control.

The effect of calcium nitrate and alpha-aminoisobutyric acid (AIB) on the vase life of cut carnation flowers (varieties 'Soana' and 'Nora') was investigated by Onozaki *et al.* (1998). In pretreatment trials, exposure of cut flowers to 60 mM AIB + 10 mM calcium nitrate for 21 h enhanced vase life by 20 per cent over AIB treatment alone.

2.7.3 FRESH WEIGHT

Typically fresh weight of cut flowers initially increases and subsequently decreases (Roger, 1973).

From the research conducted to investigate the changes in fresh weight of various floral parts during the senescence of cut carnations and the effects of pulsing with Silverthiosulphate (STS) on these changes, it was observed that ‘White Sim’ carnations harvested at open stage and pulsed with 4 mM STS for 30 minutes and kept in distilled water at 21°C, recorded increased fresh weight of petals until day 3, and then it was maintained at the similar level until day 12, indicating that pulsing with STS affected sink-source relationship and petals acted as a strong sink until day 12 (Lee *et al.*, 1995).

2.7.4 UPTAKE OF WATER

Fresh weight and solution uptake data indicated that germicides acted primarily by improving solution uptake in *Dianthus caryophyllus* L. and *Dianthus barbatus* L. as reported by Jones and Hill (1993).

Experiments were carried-out to clarify why STS treatment on spray carnations was less effective than that on standard carnations so as to develop an improved pre-treatment for the spray carnation. Petal wilting in spray carnation was attributed to water deficiency caused by large transpirational losses from more flowers and ethylene action. Treating flowers with the surfactant, polyoxyethylenelaurylether (PLE) enhanced water uptake (Uda *et al*., 1994).

2.7.5 TRANSPIRATIONAL LOSS OF WATER

Gao Jun Ping *et al*. (1996) concluded that water absorption through the stem of cut flowers of carnation could prevent water loss.

2.7.6 ETHYLENE PRODUCTION AS AFFECTED BY CHEMICALS

Ethylene production was drastically reduced in the AIB (α-aminoisobutyric acid) treated carnations, but free ACC accumulated within the petals, suggesting an inhibitory effect of AIB on the ethylene forming enzyme (Serrano *et al*., 1990).

Brandt and Woodson (1992) investigated the patterns of ethylene biosynthesis in carnation (*Dianthus caryophyllus* L.) genotypes that exhibit extended vase life in comparison to flowers of 'White Sim'. 'White Sim' flowers exhibited typical symptoms of senescence, including petal in-rolling and rapid wilting, beginning 5 days after harvest.

Gibberllic acid (GA_3) when applied to stems of cut carnations var. 'White Sim' at 10^{-4} M delayed their senescence by delayed onset and reduced climacteric peak of C_2H_4 production. Pre-treatment with 10^{-4} M for 48 h. reduced the sensitivity of flowers to Ethrel (Ethephon) (Saks and Staden, 1992).

Effects of cobalt on ethylene production and senescence of carnation flowers were studied by Fujii *et al*. (1993). Treating flowers of carnation (*Dianthus caryophyllus* L.) with cobalt by dipping stems into cobalt EDTA solution reduced ethylene production and delayed the onset of senescence.

A study was conducted by Lee and Kim (1993) to investigate the effects of aminooxyacetic acid (AOA) and Silver thiosulphate (STS) on ethylene biosynthesis and related enzymes activities of carnation (*Dianthus caryophyllus* L.) flowers. Vase life of STS or AOA pretreated flowers was extended more than 2 times as compared with control flowers. This act by STS or AOA was derived from the complete inhibition of ethylene production. STS completely inhibited ACC accumulation, ACC synthase activity and ethylene forming enzyme activity of petals.

As low a concentration of 0.5 ml/l of 1 methyl cyclopropene (1-MCP) is sufficient to protect carnation flowers for several days against ehylene (Sisler and Serek, 1997).

2.7.7 VASE LIFE AS AFFECTED BY CHEMICALS

Locally developed preservative AR-9 whose composition is sucrose @ 60 g / 1 + 8 HQS @ 250 mg/l + CCC @ 70 mg/l + $AgNO_3$ @ 50 mg/l extended the vase life of carnation (var. 'William Sim') by 100% (Piskornik, 1981).

Piskornik and Mareczek (1987) reported that, the mean vase life was the longest (16.8 days) in a solution containing 5 per cent sucrose + 0.63 mM 8 – HQS + STS, compared to 5.94 days in distilled water.

Standing cut flowers of carnation var. 'William Sim' in solutions containing both $Ca(NO_3)_2$ @ 0.5 g/l and tannins @ 2 mg/l increased flower longevity (13 days) compared with standing them in water (8.7 days) or in either $Ca(NO_3)_2$ (9.4 days) or tannin (9.6 days) solution alone (Michalezak *et al.*, 1989).

The effects of antiethylene agents, aminooxyyacetic acid (AOA) and Silver thiosulphate (STS) on the fresh weight change and the vase life of cut carnation (*D. caryophyllus* L.) var. 'White Sim' were investigated by Han and Lee (1992). AOA and STS at 8 mM and 1 mM, respectively, minimized the loss of fresh weight and extended the vase life of cut carnation flowers by 7 to 8 days when harvested at stage-II. AOA was superior to STS for the extension of the vase life of cut carnations.

Treating ‘Elliott’s White’ cut carnations with 50 or 100 mM aminotriazole for four days inhibited the respiratory climacteric and significantly extended vase life by inhibiting ACC synthase activity (Altman and Solomos, 1994).

Vase life was longer for flowers raised in greenhouses compared to open field production when placed in a solution containing 5% sucrose + 30 ppm $AgNO_3$ +200 ppm 8 HQC (Lukaszewska, 1995).

The effect of cis-propenyl phosphoric acid (PPOH) and alpha – aminoisobutyric acid (AIB) on the vase life of cut carnation var. 'Coral' flowers was investigated by Yamamoto *et al.* (1995). In both continuous and pulse treatments, vase life increased markedly with PPOH + AIB (upto 12.2 days with continuous treatment) compared with each compound alone.

The commercial cut flower preservatives spring and chrysal were compared with a mixture prepared from 40 mg silver nitrate, 50 mg sodium benzoate, 30 mg sugar, 7.5 mg aluminum sulphate and 2 mg kinetin per litre of water for extending the vase life of cut carnations. The experimental mixture gave the longest vase life (Yildirim *et al.*, 1995).

2.8 ECONOMICS OF PROTECTED CULTIVATION OF CARNATION

While describing the cultural practices and costs and returns of carnation cultivation, Zouari (1976) reported that, protected crops are twice as profitable, but demand greater initial investments; their extension is not advised unless export markets are generated.

The highest gross income was obtained from carnation var. 'Scania' planted with 75-100 plants per square metre (Rejman and Mynett, 1979).

Totth (1986) reported that cultivation of carnations for cut flowers was no longer profitable due to increasing production costs. However, profitability can be improved by adopting improved cultural methods and also by the introduction of highly productive good quality varieties.

Stock was the major production cost in carnations. The pay-back period for facility investment was 1-2 years for carnations (Lin and Chiu, 1990).

Aragon *et al.* (1992) have given information on unit costs of production of carnations under protected cultivation and in the field, types of labour employed, marketing systems and problems experienced.

Ferrato and Benedeotto (1994) concluded that 30 per cent increase in yields and prices was necessary to obtain positive economic results in view of the supplementary heating provided in the greenhouse for carnations.

Though, greenhouse cultivation results in higher returns by producing higher yields of good quality produce, initial higher investments and maintenance costs will reduce the additional income unless they are managed intensively. Therefore, growers should be provided with the latest technology and optimum structures at lower costs to suit local situations. This would result in better feasibility and profitability (Khan *et al*., 1997).

Jaganath and Gopinath (1997) reported that cultivation of carnations under cover was found to be profitable. A net profit of Rs. 59,000 per 100 m^2 area could be obtained per annum.

MATERIAL AND METHODS

III. MATERIAL AND METHODS

Investigations on standard type varieties of carnation were conducted at the Horticultural Research Station, Division of Horticulture, University of Agricultural Sciences, Gandhi Krishi Vigyana Kendra, Bangalore, during 1997-98 to study the effects of levels of fertigation, sources of fertilizers and bio-inoculant on growth, quality and productivity under cost-effective greenhouse.

3.1 LOCATION, CLIMATE AND SOILS OF THE SITE

The experimental station is located at 12' 58° N latitude and 77' 35° E longitude at an altitude of 930 metres above MSL. The minimum and the maximum temperatures during the year 1997-98 were 16.6°C and 33.5°C, respectively. An annual rainfall of 1142.10 mm was received during the period.

The mean monthly meteorological data of the Station during the cropping period is furnished in Appendix-I.

The soils of the experimental station was red sandy loam. The salient characteristics of the soil is furnished in Appendix-VI.

3.2 DETAILS OF GREENHOUSE

3.2.1 CONSTRUCTION

The details of the naturally ventilated cost-effective greenhouse (Plate-2) constructed and used for the studies are furnished here under :

a) Type	:	Gothic – arch
b) Month of construction	:	November, 1996
c) Orientation	:	East – West
d) Size	:	16 m. l x 8.5 m. b x 3.5 m. h
e) Area	:	136 m^2
f) Frame work	:	GI Pipe-size : 1.25" (Over head) : 1.50" (Rest)
g) No. of spans	:	Four (each of 4.00 m length)
h) Cladding material	:	UV stabilised LDPE-film of 200 μ (800 gauge)
i) Ventilation	:	White colour Rambo-net of 60 mesh/sq. in. used on all sides and on the top.
j) Rollable flaps	:	Provided outside with UV stabilized film, all along the sides
k) Shade	:	Shade net of 50% on the top, in the front and at the back

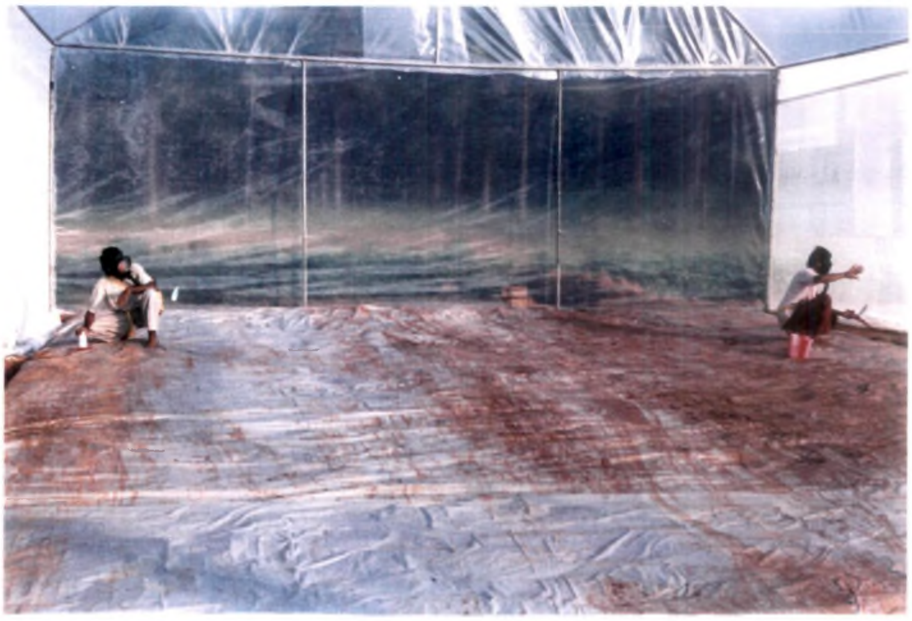
3.2.2 PREPARATION OF LAND

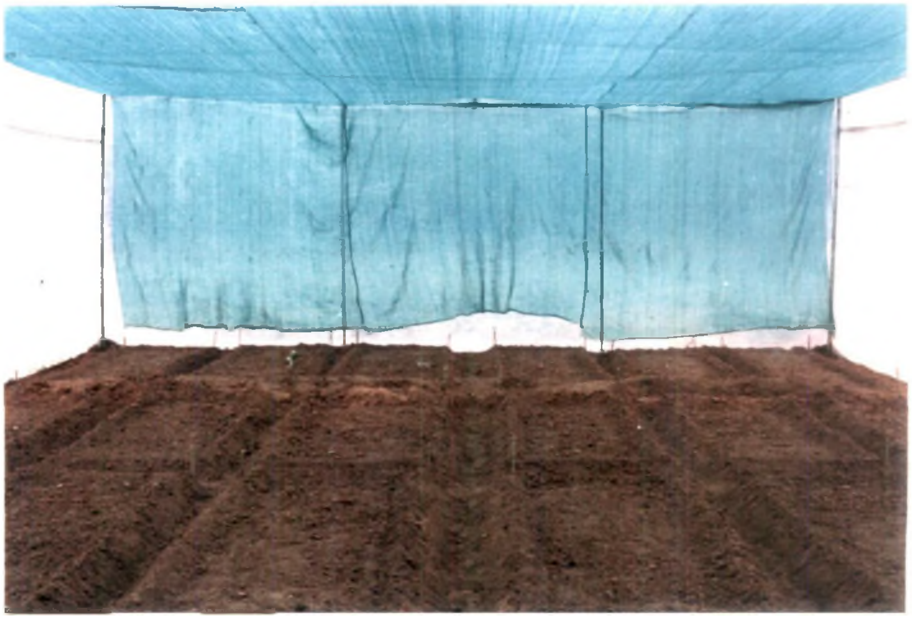
The area within greenhouse was irrigated a few days earlier to facilitate its preparation. It was dug / ploughed upto a depth of about 30 cm. and the bigger sized clods were crushed to bring the soil into fine tilth. Deep rooted

Plate 2 : A view of the top ventilated cost-effective greenhouse

Plate 3 : Fumigation of soil with methyl bromide

Plate 4 : Preparation of raised beds for planting





weeds, pebbles and trash were removed. Farm yard manure (½ tractor load @ 75 tonnes/ha), coir pith (1 tractor load @ 75 tonnes/ha) and sand (1 tractor load @ 150 tonnes/ha) were applied and mixed well with the soil. The media was then brought to a fine tilth by ploughing the land and incorporating the same into the soil with the help of a tractor drawn cultivator.

3.2.3 FUMIGATION OF LAND

A day before fumigation, the area was thoroughly irrigated. Methyl bromide at the rate of 50 g/m^2 was applied as a fumigant to the soil. Soon after the application, the surface was covered fully with a black polyethylene sheet and it was retained in the same place for 3 days in order to increase its effectiveness. After removal of the black polyethylene sheet, the area was irrigated thrice at an interval of two days to leach-out any residues of the chemical (Plate-3).

3.2.4 SYSTEM OF IRRIGATION

Bore-well water served as the source of water. The water was drawn, from the bore-well water storage-tank, through PVC pipelines installed in the soil. A pressure of about 2.00 kg/cm^2 was maintained at the discharge point. Main lines of 2.5" dia. were laid out on either sides of the greenhouse. Two sub-mains of 2.0" dia. were drawn into the greenhouse from each main. A number of laterals (16 mm) were drawn from each sub-main. Mains and sub-mains were burried in the soil to a depth of about 40 cm. Three laterals per bed, so as to have one lateral for two rows each, were provided along with a tap in between to control the flow of water into the laterals. Drippers (4 l. capacity/hr.) were provided on the laterals at 30 cm apart.

3.2.5 PREPARATION OF BEDS

Raised beds were prepared separately for both the experiments leaving space in between the beds and all along the boundaries of the greenhouse for passage. The land was irrigated thoroughly and the beds were dug once again to bring the soil to a fine tilth (Plate-4).

3.3 DETAILS OF EXPERIMENTS

3.3.1 EFFECTS OF LEVELS OF FERTIGATION AND SOURCES OF FERTILIZERS ON QUALITY AND PRODUCTIVITY OF STANDARD CARNATION VARIETY 'TRENDY' GROWN UNDER COST-EFFECTIVE GREENHOUSE (Fig.1)

Experimental details :

a) Variety : Trendy

b) Type of fertilizers(2) : S_1- Straight
S_2- Water Soluble

c) Levels (3) :
1. F_1 – 100% recommended dose (250:60:200 g N, P_2O_5 and K_2O /sq.m/annum)
2. F_2 – 80% recommended dose
3. F_3 – 60% recommended dose

d) Treatments (6) :

$T_1(F_1S_1)$: 100% Recommended dosage in the form of straight fertilizers

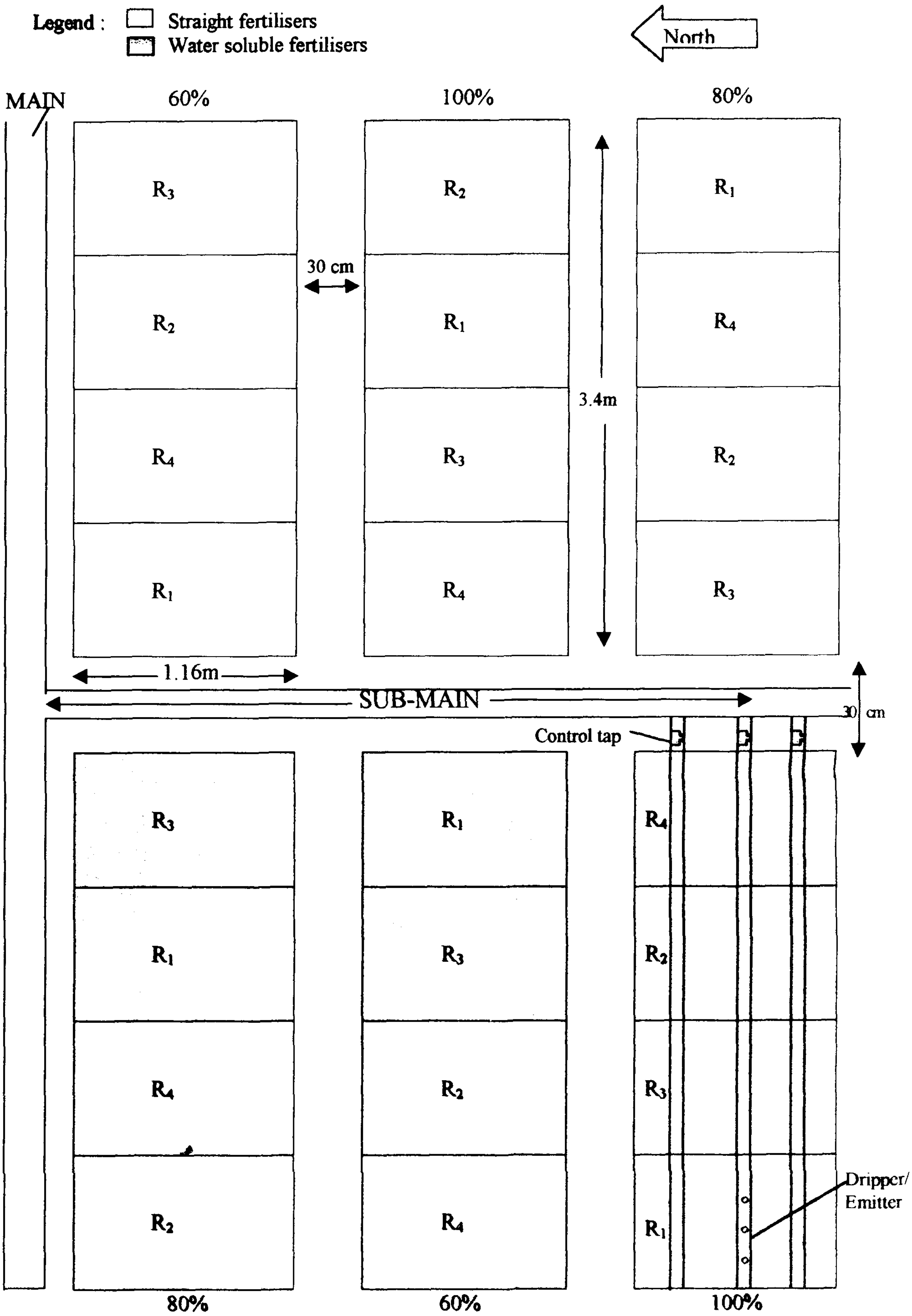


Fig. 1: LAYOUT PLAN OF EXPERIMENT-I

$T_2(F_1S_2)$: 100% Recommended dosage in the form of water soluble fertilizers.

$T_3(F_2S_1)$: 80% Recommended dosage in the form of straight fertilizers

$T_4(F_2S_2)$: 80% Recommended dosage in the form of water soluble fertilizers

$T_5(F_3S_1)$: 60% Recommended dosage in the form of straight fertilizers

$T_6(F_3S_2)$: 60% Recommended dosage in the form of water soluble fertilizers

e) Design : Factorial RCBD

f) No. of replications : Four

g) Size of bed : 3.40 m x 1.16 m x 0.10 m.(Fig.3)

h) No. of beds : Six

i) No. of plants / treatment / replication : 24

j) No. of plants/bed : 96

3.3.2 EFFECTS OF BIO-INOCULANT ON GROWTH, QUALITY AND PRODUCTIVITY OF STANDARD VARIETIES OF CARNATION GROWN UNDER COST-EFFECTIVE GREENHOUSE (Fig.2)

Experimental details :

a) Bio-inoculant : Azotobacter

b) Varieties (5) (Plate-5, 6, 7 & 8) :
1. 'MONACO'
2. 'GOLD RUSH'
3. 'REGINA'
4. 'INTERNET'
5. 'TRENDY'

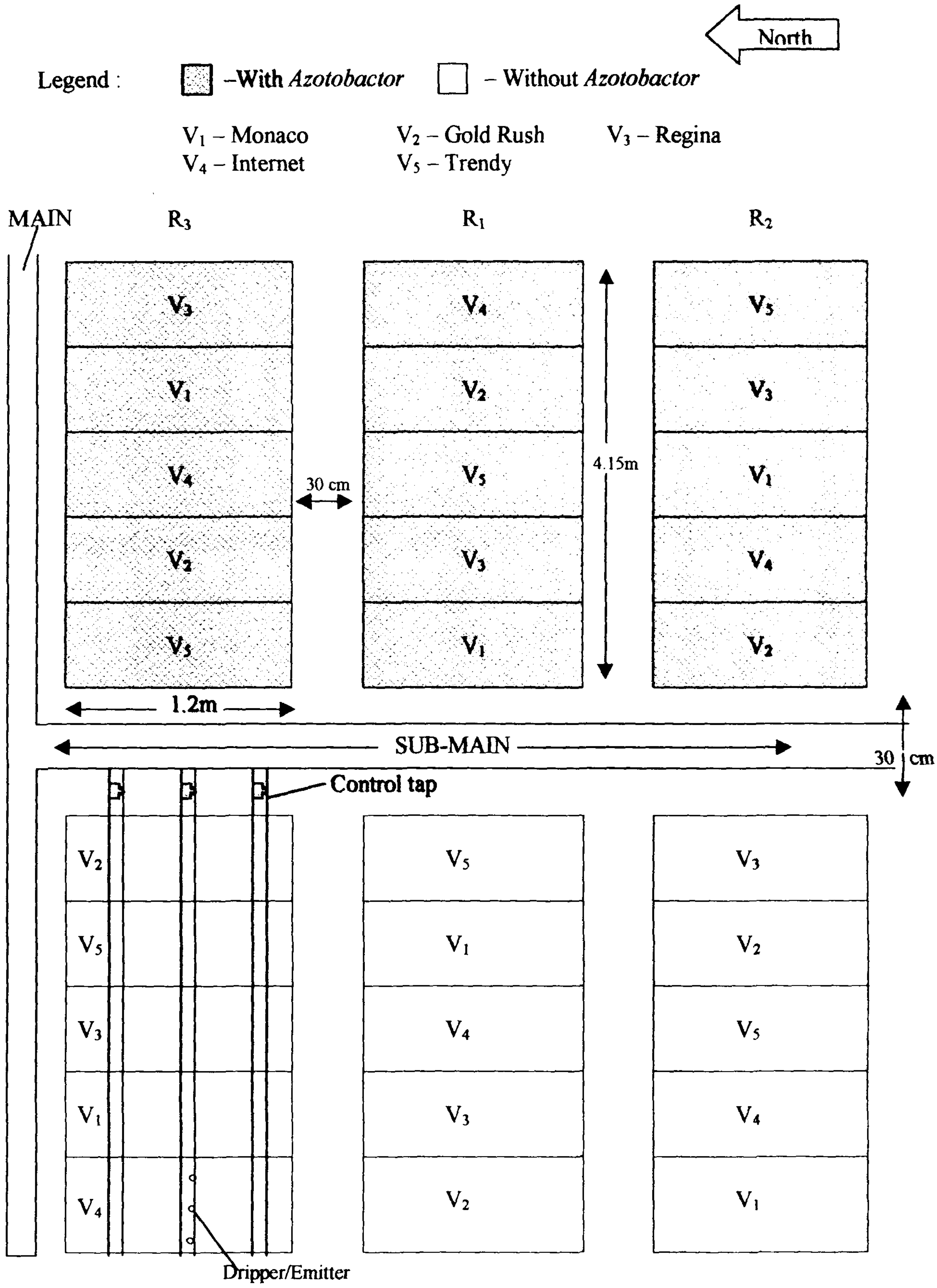


Fig. 2: LAYOUT PLAN OF EXPERIMENT-II

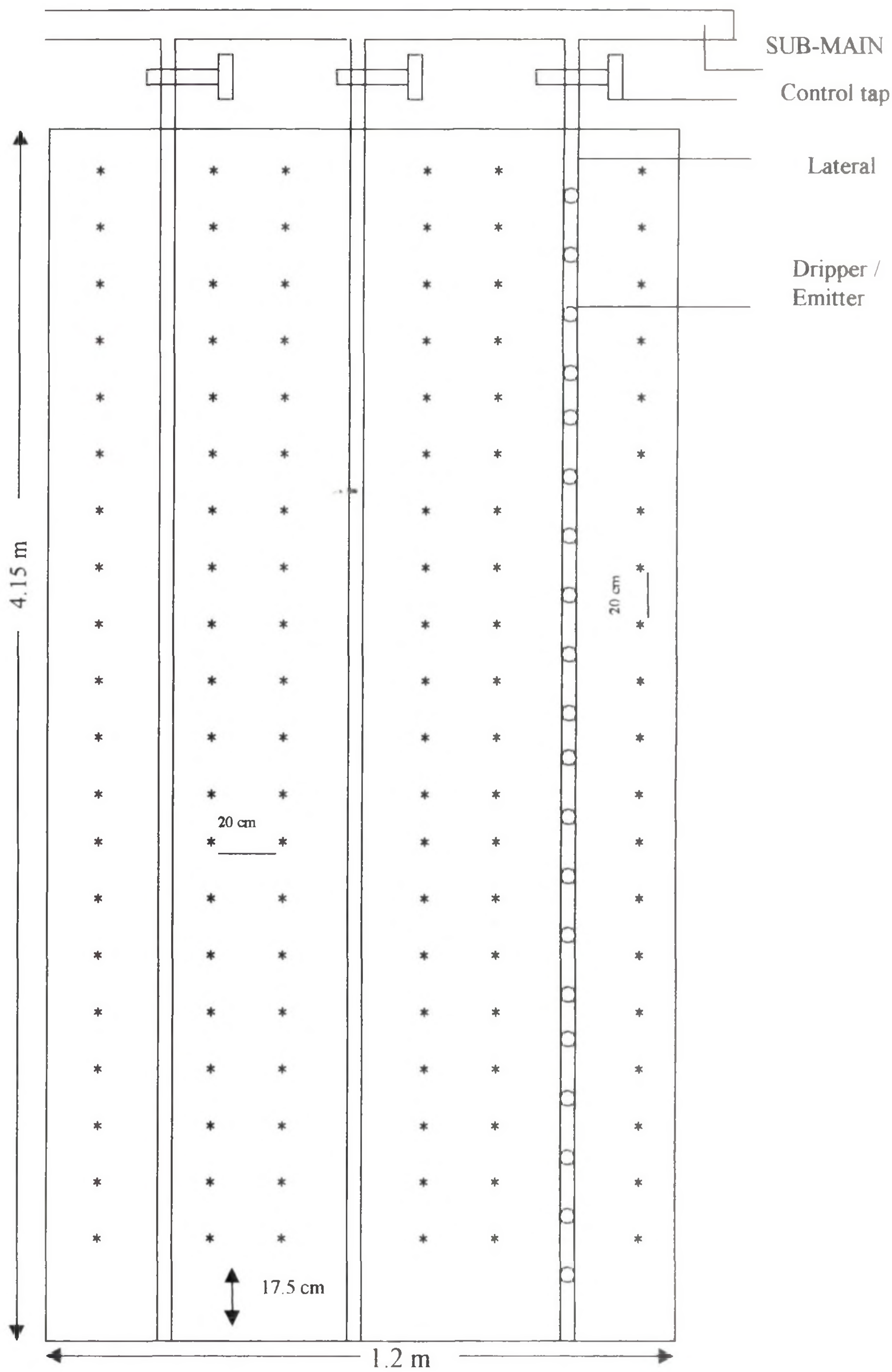


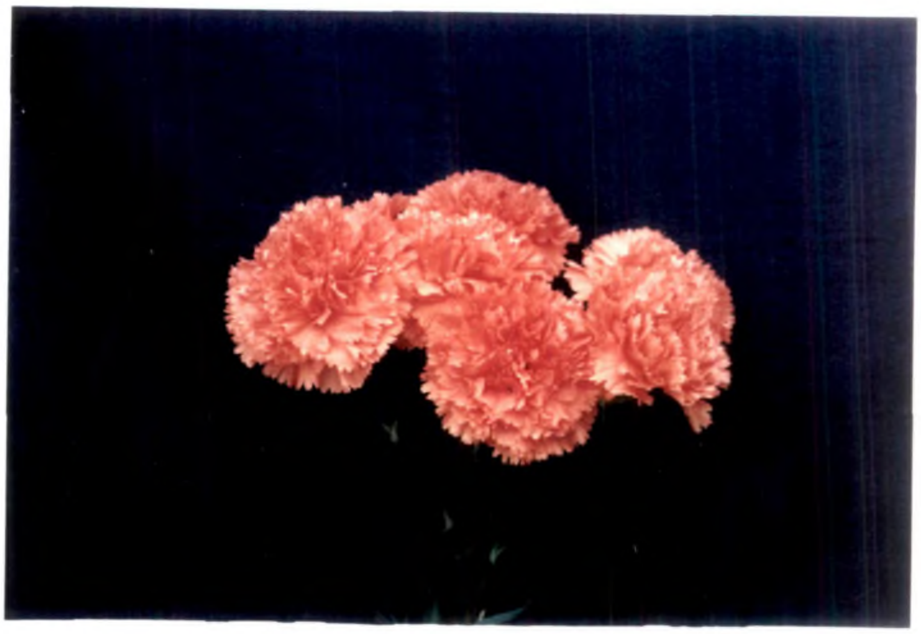
Fig.3 : LAYOUT PLAN OF A GROUND-BED OF EXPERIMENT - II

Plate 5 : **Carnation Var. 'Monaco'**

Plate 6 : **Carnation Var. 'Gold Rush'**

Plate 7 : Carnation Var. 'Internet'

Plate 8 : Carnation Var. 'Trendy'



c) Treatments (10) :

$T_1(V_1B_1)$	:	var. 'Monaco' without Azotobacter
$T_2(V_1B_2)$	:	var. 'Monaco' with Azotobacter
$T_3(V_2B_1)$	:	var. 'Gold Rush' without Azotobacter
$T_4(V_2B_2)$	:	var. 'Gold Rush' with Azotobacter
$T_5(V_3B_1)$	:	var. 'Regina' without Azotobacter
$T_6(V_3B_2)$	:	var. 'Regina' with Azotobacter
$T_7(V_4B_1)$	:	var. 'Internet' without Azotobacter
$T_8(V_4B_2)$	:	var. 'Internet' with Azotobacter
$T_9(V_5B_1)$	:	var. 'Trendy' without Azotobacter
$T_{10}(V_5B_2)$	:	var. 'Trendy' with Azotobacter

d) Design	:	Factorial RCBD
e) No. of replications	:	Three
f) Size of beds	:	4.15 m x 1.20 m x 0.10 m.
g) No. of beds	:	Six
h) No. of plants / treatment / replication	:	24
i) No. of plants/bed	:	120

3.4 CULTIVATION PRACTICES

3.4.1 PLANTING

Rooted cuttings of standard type varieties of carnation were procured from 'Bangalore Bulbs and Blooms' in the last week of March, 1997 and kept in cold storage. The beds were lightly irrigated in the morning and the planting was done in the afternoon at a spacing of 20 cm x 20 cm. The planting of rooted cuttings of carnation was completed on 31st March 1997 at one stretch in two hours of time. While planting, the rooted cuttings along with mass and perlite were slowly introduced into the dibbled holes till the mass and perlite adhering to the root system was visible and then the media was slightly pressed to make sure that the plants were firmly held in their respective positions. As soon as planting was over, the plants were watered using a watercan with a rose.

3.4.2 APPLICATION OF AZOTOBACTER

Azotobacter procured from the Department of Agricultural Microbiology, University of Agricultural Sciences, Gandhi Krishi Vigyana Kendra, Bangalore was applied in between the rows to respective treatments a day after the planting at the rate of 2 g/plant by mixing it with a pot full of sand.

3.4.3 FRAMEWORK FOR TRAINING

Carnation plants do not grow erect on their own unless support is provided in the form of nets. In order to provide support nets, wooden poles, plastic wire (rope) and GI wire were used. Wooden poles of 1.5 m. length were prepared from the jungle wood. Each bed required six wooden poles. The bottom portion of the pole was sharpened and the bottom 30 cm. length of the pole was smeared with waste oil to avoid the attack of termites. The bark was scraped out to give smooth surface and better appearance. After smearing, they were kept under sunlight for drying. The wooden poles were fixed in the ground to 30 cm depth by hammering. Wooden poles were fixed for each bed, one each at the corners and at the mid-points of the length. In order to have tight and firm layers of nets, instead of providing GI wire alround, small wooden sticks made from jungle-wood and the bark scraped-off were fixed all along the width of the beds as per requirement. Ten such small wooden sticks were fixed per bed. Medium-thick and thin plastic ropes were used for netting. The first layer of support net, generally called as planting net, was placed immediately after the planting of the rooted cuttings of carnation. In between the rows of plants and plants in each row, two layers each of medium thick and thin plastic ropes were placed for the planting net. However, it was ensured that both the ropes were about 5 cm. away from the plants. For the second and subsequent layers of nets, one each of medium thick and thin plastic rope/wire came in between the rows of plants and plants in a row, respectively. This facilitated for both the ropes to stay at 10 cm. away from the plants. Totally, five layers of support-nets were fixed. The first layer of support-net was placed at a height of 12.50 cm from the surface of the bed and the subsequent layers at 12.50 to 15.00 cm space in between (Plate-10 and 11).

Plate 10 : **A close-up of side view**

Plate 11 : **A close-up of top view**

3.4.4 IRRIGATION

The crop was drip irrigated once in two days depending upon the soil and weather conditions. During winter, the frequency and intensity of irrigations were reduced suitably to maintain optimum moisture level in the beds. On an average 4-5 litres of water was supplied per square meter per application.

3.4.5 FERTIGATION

Two types of fertilizers viz., straight (urea, single super phosphate and muriate of potash) and water soluble (obtained from Kemira Ltd., Finland) were used for the studies as per the treatments through fertigation. The entire quantity of fertilizers was applied through fertigation in splits once in 15 days throughout the year. Micro-nutrients (Make : Multiplex) and, calcium and magnesium were given in the form of foliar sprays once in a month, till the commencement of flowering, at the rate of 2.50 ml/*l* of water.

Recommended dosage of fertilizers were applied for Experiment-2.

The details regarding the quantity of nutrient elements and sources of fertilizers applied are presented in the Table- 1(a) and 1(b), respectively.

3.4.6 PINCHING

All the plants were pinched uniformly by retaining only 6 pairs of leaves from the basal portion at first pinching. This operation was done early

Table 1(a) : Quantum of nutrient elements applied during the experimental period

Nutrient element and source	Level of application	Quantity (g) / Sq.m./fortnight	Quantity (g) / Sq.m./month	Quantity (g) / Sq.m./annum
N	100 % of Recommended dose	10.416	20.833	250
(Urea)	80 % of Recommended dose	8.333	16.666	200
	60 % of Recommended dose	6.250	12.500	150
P_2O_5	100 % of Recommended dose	2.500	5.000	60
(Single Super Phosphate)	80 % of Recommended dose	2.000	4.000	48
	60 % of Recommended dose	1.500	3.000	36
K_2O	100 % of Recommended dose	8.333	16.666	200
(Muriate of Potash)	80 % of Recommended dose	6.666	13.333	160
	60 % of Recommended dose	5.000	10.000	120

Table 1(b) : Quantum of different sources of fertilizers applied during the experimental period

Treatments	Water Soluble Fertilizer (20:5:30)			Straight Fertilizer								
				Urea			Single Super Phosphate			Muriate of Potash		
	Quantity (g) / Sq.m./ fortnight	Quantity (g) / Sq.m./ month	Quantity (g) / Sq.m./ annum	Quantity (g) / Sq.m./ fortnight	Quantity (g) / Sq.m./ month	Quantity (g) / Sq.m./ annum	Quantity (g) / Sq.m./ fortnight	Quantity (g) / Sq.m./ month	Quantity (g) / Sq.m./ annum	Quantity (g) / Sq.m./ fortnight	Quantity (g) / Sq.m./ month	Quantity (g) / Sq.m./ annum
$T_1(F_1S_1)$	-	-	-	22.68	45.30	543.48	15.63	31.25	375.00	13.89	27.78	333.33
$T_2(F_1S_2)$	27.78	55.56	666.67	7.55	15.10	181.16	6.94	13.88	166.67	-	-	-
$T_3(F_2S_1)$	-	-	-	18.12	36.23	434.78	12.50	25.00	300.00	11.11	22.22	266.67
$T_4(F_2S_2)$	22.22	44.44	533.33	6.04	12.08	144.93	5.56	11.11	133.33	-	-	-
$T_5(F_3S_1)$	-	-	-	13.59	27.18	326.07	9.38	18.75	227.00	8.33	16.67	200.00
$T_6(F_3S_2)$	16.67	33.33	400.00	4.53	9.06	108.70	4.17	8.33	100.00	-	-	-

in the morning to facilitate easy breaking-away of the terminal portion at the nodal region. To perform pinching, the terminal portion of the plant was bent at the required nodal region with the left hand holding the plant and the right hand carrying out the operation. Pinching is essential to produce laterals. The first pinching was done when the plants were 30-40 days old and the second pinching was done when the plants were 60-70 days old. In the second pinching, only 1 to 2 laterals were pinched-off retaining a minimum of 4 nodes. The second pinching was necessary to stagger flowering and to produce quality flowers. The whole process of pinching fell in the category of one and a half pinching method.

3.4.7 DISBUDDING

Disbudding was practiced to obtain only one quality cut flower per stalk as required in standard type of carnations. Since, both the experiments under study comprised of only standard type of carnations, all the axillary buds were removed from the plants except retaining the terminal bud. Disbudding was a continuous operation as flowering season was spread-over for more than two months. This operation was carried out with left hand holding the stalk firmly and the right hand nipping off the pea size axillary buds.

3.4.8 Maintenance of beds

The side-walls of beds which used to get damaged by the movement of people in between the beds were made straight with the help of a spade and pressed from outside to make them firm. In order to avoid any algal growth on the soil, it was raked-up at least once a month, by using a pointed stick in between the plant rows taking care not to disturb the root system and the support nets.

3.4.9 Training

The frame-work provided in the form of support nets itself performed the function of training the carnation plants. However, whenever the laterals swayed away from the support nets, they were made to follow the right route (respective cubicles) for getting straight long stalks.

3.4.10 Pests and diseases

Pests such as red spider mites, semi-loopers and catterpillars were noticed during the cropping period. Red spider mites would suck the sap of leaves, semi-loopers would feed on the tender leaves and the catterpillars would bore into the unopened flower-buds. Semi-loopers, catterpillars and red spider mites were controlled by spraying Hostothion @ 1.5 ml/ l of water or Lannate @ 2 ml/*l* and Kelthane or Hexil @ 2 ml/ l of water, respectively, as and when they were noticed.

Diseases such as *Fusarium* wilt and *Botrytis* rot were observed during growth and flowering stages, respectively. *Fusarium* wilt was controlled by drenching the beds of the affected plants with Captan @ 3 g / l of water. Due to increase in the level of humidity at certain times inside the greenhouse, there was development of a black colour sponge like thick fungal growth (mould) on the top-most upper surface edge of the petals starting from the centre of the flower which was identified as *Botrytis* rot. Even, some of the unopened buds were also affected by this fungus. Such attacked flowers never to opened causing loss of the produce. The greenhouse conditions were manipulated with the existed facilities, to minimize the occurrence of diseases and fungicidal spraying was also taken up regularly to manage the diseases.

3.4.11 DISORDERS

Disorders such as calyx splitting and petal burn or marginal browning of petals were noticed during the flowering period. Lack of misting unit was thought as the probable reason for petal burn or marginal browning and further necrosis of petal margins. Misting was required at times of higher temperature or light intensity. Marginal browning and necrosis of petals was brought down by regulating shade in the greenhouse.

3.4.12 Harvesting and handling

Harvesting of carnation cut flowers also served as a practise of pinching carnation plants which further produced tertiary branches. The cut-flowers were harvested at half to full open stage retaining 4-6 nodes from the base of the shoot. The crop started producing flowers 110 to 120 days after planting. Soon after harvesting, the basal portions of the cut-flower stalks were immersed in a bucket containing water upto one-fourth of its height.

3.4.13 Grading, packing and marketing

Harvested cut flowers were graded based on their size, colour, stiffness etc., i.e., based on characteristics such as diameter of flower, length and thickness of stalk, firmness of stalk and lustre of flowers including the incidence of pests and diseases. A bundle consisting of 10 cut flowers was rolled in a newspaper, with the edge of the newspaper remaining slightly above the flower heads and the other edge for more than half-way along the stalk length. The bundle used to be tied at two or three points : top, middle and / or bottom and sent immediately to local florist shops for their disposal.

3.5 OBSERVATIONS RECORDED

The following observations were recorded in all the three seasons viz., rainy, winter and summer.

3.5.1 GROWTH PARAMETERS

3.5.1.1 Height of plant

Height of plant was measured from the base of the plant starting from the uppermost level of the soil upto the growing tip and expressed in centimetres. Height of plant was recorded at fortnightly intervals.

3.5.1.2 Number of laterals per plant

Number of laterals produced per plant was recorded at fortnightly intervals.

3.5.1.3 Number of pairs of leaves per lateral

Total number of pairs of leaves produced per lateral was recorded at the time of appearance of terminal flower bud.

3.5.1.4 Days for appearance of first flower bud

Number of days taken for the appearance of the first flower-bud was counted from the day of planting and recorded.

3.5.1.5 Days for development of first flower bud

Number of days taken for the development of the first flower bud was counted from the day of its appearance till it started opening.

3.5.1.6 Days for fifty per cent flowering

Number of days taken for fifty per cent of the plants to produce flowers was counted from the day of planting and recorded.

3.5.1.7 Days for first harvesting of cut flowers

Number of days taken for first harvesting of cut flowers starting from the day of planting was counted and recorded.

3.5.2 QUALITY PARAMETERS

3.5.2.1 Length of flower bud

Length of fully matured flower-bud was measured and expressed in centimetres.

3.5.2.2 Thickness of flower bud

A line joining the points at which the maximum width of the fully matured bud occurs was measured as the thickness of the flower-bud and expressed in centimetres.

3.5.2.3 Length of flower stalk

Length of cut flower stalk was measured after harvest from its cut base end to the point of attachment of the flower bud to the stalk and expressed in centimetres.

3.5.2.4 Girth of flower stalk

Girth of cut-flower stalk was measured after harvest at three portions i.e., neck, middle and basal, and the average of the three was recorded as the girth of cut flower stalk and expressed in millimeteres.

3.5.2.5 Diameter of flower

A line joining the points at which the maximum diameter of the fully opened flower occurs was measured and expressed in centimetres.

3.5.2.6 Number of petals per flower head

Total number of petals that were found in a fully opened cut flower were counted and recorded.

3.5.2.7 Percentage of calyx splitting

From among the cut flowers harvested, the number of flowers exhibiting split calyces was recorded and expressed in percentage.

3.5.3 YIELD PARAMETERS

Cut flowers that were produced true to the characteristics of the variety were regarded as first grade i.e., having characteristic colour, length and firmness of stalk, and any injury, damage, occurred either during harvesting and handling or its course of production due to pest / disease attack or fluctuations in greenhouse environmental conditions that had led to slight change in the appearance of the flower like calyx splitting, petal margin necrosis, bent in stalk etc. were regarded as second grade.

3.5.3.1 Number of first grade cut flowers per plant

Total number of first quality cut flowers produced per plant in a particular season was counted and recorded. The total number of first grade flowers produced by plants in all the seasons gave the total number of first grade flowers produced per plant per annum.

3.5.3.2 Number of first grade cut flowers per square metre and per hectare

The total number of first quality cut flowers produced per square metre in all the seasons throughout the year was counted and computed per hectare and recorded.

3.5.3.3 Number of second grade cut flowers per plant

Number of second grade cut flowers produced per plant in a particular season was calculated by keeping the total number of second grade cut flowers per plant per season as the base. The total number of second grade flowers produced by plants in all the seasons gave the total number of second grade flowers produced per plant per annum.

3.5.3.4 Number of second grade cut flowers per square metre and per hectare

The total number of second grade cut flowers produced per square metre in all the seasons throughout the year was counted and computed per hectare and recorded.

3.5.3.5 Per cent first grade cut flowers per square metre

Considering the total number of cut flowers, irrespective of grades, produced per square metre in a season, per cent first grade cut flowers per square metre was found-out. Similarly, per cent first grade cut flowers per square metre per annum was found-out considering the total number of cut flowers, irrespective of grades, produced per square metre per annum.

3.5.3.6 Per cent second grade cut flowers per square metre

Considering the total number of cut flowers, irrespective of grades, produced per square metre in a season, per cent second grade cut flowers produced per square metre was found-out. Similarly, per cent second grade cut flowers per square metre per annum was found-out considering the total number of cut flowers, irrespective of grades, produced per square metre per annum.

3.5.4 VASE LIFE STUDIES

From the flowers harvested in both the experiments, certain flowers were subjected to vase-life studies to ascertain, the effect of azotobacter on vase-life or varietal behaviour on vase-life and also, the effects of levels and sources of fertilizers on vase-life. The cut flowers harvested in both the experiments were placed in bottles containing 200 ml. of distilled water with sucrose at five per cent as the pulsing agent. The cut flowers were then observed for the following parameters.

3.5.4.1 Fresh weight of cut flower

The difference between the weight of bottle plus solution plus cut flower and weight of bottle plus solution on the same day represents the fresh weight of cut flower in grams on that particular day.

3.5.4.2 Uptake of water

The difference between the consecutive weights of bottle plus solution represents the uptake of water in grams for that period.

3.5.4.3 Transpirational loss of water

The difference between the consecutive weights of bottle plus solution plus flower represents the transpirational loss of water in grams for that period.

3.5.4.4 Vase-life

The vase life was expressed in days from the day of harvest and placement in vase-solution till they became unfit for continuing in the vase.

3.5.5 ENVIRONMENTAL PARAMETERS

The parameters pertaining to outside environment such as temperature (maximum and minimum), relative humidity (%), bright sunshine hours and rainfall and greenhouse environment such as temperature (maximum and mimimum), relative humidity (%) and light intensity (lux) were recorded at fortnightly intervals and expressed as monthly averages in Appendix-I and Appendix-II, respectively.

3.5.6 WATER ANALYSIS

The bore-well water which was the source for irrigation was analysed for pH, EC, Ca, Mg and bicarbonates (Appendix – III).

3.5.7 SOIL ANALYSIS

Samples for soil analysis were collected twice : once before starting the experiment and after the completion of the experiment. The samples were analysed for major physical and chemical parameters (Appendix-IV & VI).

3.5.7.1 Soil pH

The soil pH was measured in 1:2.5 soil water suspension after stirring the contents intermittently for half-an-hour. The pH value was recorded using ELICO pH meter (Jackson, 1973).

3.5.7.2 Electrical Conductivity

The soil water suspension used for measuring pH was filtered and the electrical conductivity of the solution was measured with the help of a conductivity bridge and expressed in dSm^{-1}.

3.5.7.3 Organic Carbon

Organic carbon was estimated by Walkley and Black wet oxidation method as described by Piper (1957).

3.5.7.4 Phosphorus

The available phosphorus in the soil was extracted with the help of Brays No.1 extract (0.03 N ammonium fluoride + 0.025 N NH_4Cl). Further, phosphorus in the filtered extract was determined by chlorostamoul reduced molybdophosphate blue colour method (Baker and Amacher, 1982). The intensity of colour was read on spectronic 20D spectrophotometer.

3.5.7.5 Potassium

The available potassium in the soil was extracted by neutral normal ammonium acetate and determined by flame photometric method as described by Jackson (1973).

3.5.7.6 Zinc

The minor nutrient element was estimated by using DTPA (Diethylene Triamine Penta Acetic Acid) by using atomic absorption spectrophotometer as mentioned by Lindsay and Norvell (1978).

3.5.8 AZOTOBACTER COUNT

The population of *Azotobacter chroococcum* in the experimental soil was analysed both before starting the experiment and after completion by using serial dilution plate technique. The population was estimated by plating the appropriate soil dilution on Waksman 77 media (Appendix-VIII).

3.5.9 LEAF ANALYSIS

Leaf samples were collected treatmentwise from both the experiments. The sixth pair of leaves from the top i.e., counting from below the bud and going downwards, was selected as the leaf sample for subjecting it to chemical analysis. The leaf samples collected were put in butter paper bags, treatmentwise and dried in a hot air oven at 40-50°C. At the end of the second or third day, the butter paper bags containing the dried leaf samples were taken out and the dried leaves were crushed in a mechanical grinder to obtain powdered leaf samples which were subjected to analysis later (Appendix – V and VII).

3.5.9.1 Total nitrogen

The total nitrogen was determined by Microkjeldahl's method as outlined by Tandon (1973).

3.5.9.2 Total phosphorus

The phosphorus content of the leaves was determined by Vanadomolybdate method (Tandon, 1973).

3.5.9.3 Total potash

The potash content in the leaves was determined by flame photometer method as mentioned by Tandon (1973).

3.5.10 FLOWER YIELD TO FERTILIZERS APPLIED RATIO

This was calculated as ratio of flower yield obtained to the quantity of fertilizers applied.

3.5.11 ECONOMICS OF FERTIGATION

The cost of cultivation was worked-out treatmentwise as it differed with respect to the levels of fertigation and the sources of fertilizers used. However, the yield obtained in terms of cut flowers of carnation as a result of the effects of those variables formed the major factor in determining the costs of cultivation. Considering the cost of cultivation and the gross returns, profit in terms of net-returns and benefit : cost ratio were worked out (Table-21).

3.5.12 STATISTICAL ANALYSIS

Observations were recorded from five randomly selected plants of net plot per treatment per replication. The data comprising the calculated average values of each observation treatmentwise and replicationwise were subjected to computerised statistical analysis using Analyis of Variance method (Fisher, 1974) for Factorial Randomised Complete Block Design. The test of significance (F-test) and critical difference (CD) were made at 0.05 probability, wherever 'F' test was found significant for comparing the means of two treatments. Duncan's Multiple Range test was adopted for ranking the treatment means.

EXPERIMENTAL RESULTS

IV. EXPERIMENTAL RESULTS

The results of the investigations carried-out during 1997-98 at the Division of Horticulture, University of Agricultural Sciences, Gandhi Krishi Vigyana Kendra, Bangalore on standard type varieties of carnation (*Dianthus caryophyllus* L.) as influenced by levels of fertigation, sources of fertilizers and bioinoculant under cost-effective greenhouse (Plate-9) are presented under the following headings :

4.1 EFFECTS OF LEVELS OF FERTIGATION AND SOURCES OF FERTILIZERS ON GROWTH, QUALITY AND PRODUCTIVITY OF STANDARD CARNATION VARIETY 'TRENDY' GROWN UNDER COST-EFFECTIVE GREENHOUSE

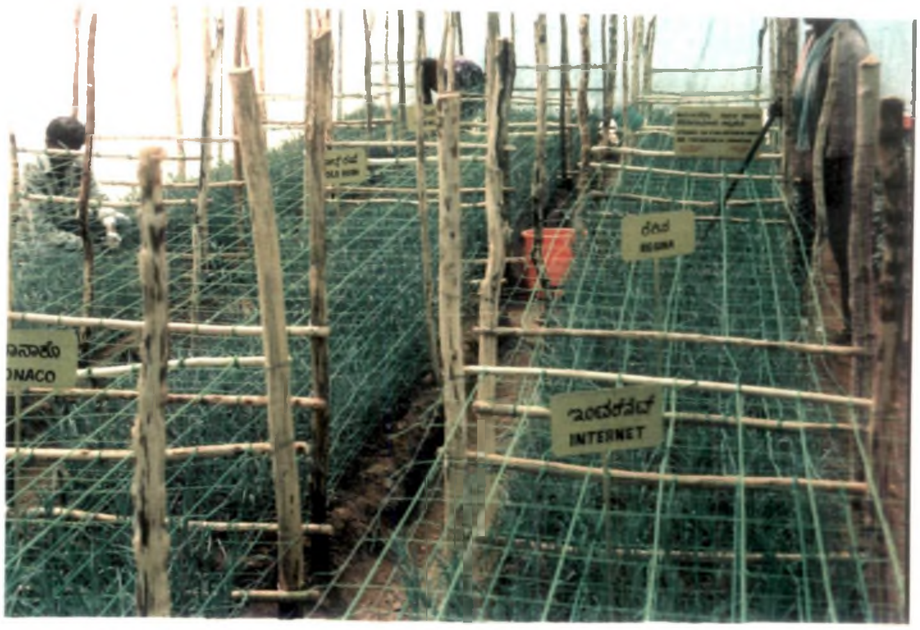
4.1.1 HEIGHT OF PLANTS

The data on height of carnation variety 'Trendy' at different days after planting and during winter and summer seasons as influenced by levels of fertigation, sources of fertilizers and their interactions are presented in Table-2 and 3, respectively.

4.1.1.1 Height of plants at different days after planting

Height of plants differed significantly among levels of fertigation at 105 and 120 days after planting. At 120 days after planting, F_3 resulted in

Plate 9 : A General view of the experiments



ONACO
INTERNET

Table-2 : Height of plants of carnation var. 'Trendy' at different days after planting as influenced by levels of fertigation, sources of fertilizers and their interactions

Particulars	Height of plants (cm)						
	30 DAP	45 DAP	60 DAP	75 DAP	90 DAP	105 DAP	120 DAP
Levels of fertigation							
F_1(100% Rec. dose)	12.03	25.68	30.98	38.64	43.06	54.91 ^{b}	73.79 ^{b}
F_2(80% Rec. dose)	12.79	26.53	32.53	40.70	46.18	56.29 ^{b}	71.88 ^{b}
F_3(60% Rec. dose)	11.98	25.19	31.79	40.05	47.35	65.00 ^{a}	76.01 ^{a}
'F' test	NS	NS	NS	NS	NS	*	*
S.Em±	0.25	0.50	0.56	0.84	1.28	1.98	0.99
CD at 5%	-	-	-	-	-	5.96	2.99
Sources of fertilizers							
S_1(Normal fertilizers)	12.16	25.87	31.66	39.63	44.57	56.93	74.35
S_2(Water soluble fertilizers)	12.37	25.73	31.87	39.96	46.48	60.54	73.43
'F' test	NS	NS	NS	NS	NS	NS	NS
S.Em±	0.21	0.41	0.46	0.69	1.04	1.62	0.81
CD at 5%	-	-	-	-	-	-	-
Interactions							
F_1S_1	11.95	24.58 ^{c}	29.40 ^{c}	38.18	42.06	55.55	74.75
F_1S_2	12.10	26.78 ^{ab}	32.55 ^{ab}	39.10	44.05	54.28	72.83
F_2S_1	12.85	27.75 ^{a}	34.40 ^{a}	41.20	45.00	51.45	72.58
F_2S_2	12.73	25.30 ^{bc}	30.65 ^{bc}	40.20	47.35	61.13	71.18
F_3S_1	11.68	25.28 ^{bc}	31.18 ^{bc}	39.53	46.65	63.78	75.73
F_3S_2	12.28	25.10 ^{bc}	32.40 ^{ab}	40.58	48.05	66.23	76.30
'F' test	NS	*	*	NS	NS	NS	NS
S.Em±	0.36	0.71	0.80	1.19	1.80	2.80	1.40
CD at 5%	-	2.13	2.41	-	-	-	-

DAP = Days after planting
Rec. = Recommended

Table-3 : Height of plants of carnation var. 'Trendy' in winter and summer seasons as influenced by levels of fertigation, sources of fertilizers and their interactions

Particulars	Height of plants (cm)	
	Winter (Nov.'97 –Jan.'98)	Summer (Feb.'98 – April'98)
Levels of fertigation		
F_1(100% Rec. dose)	79.90 [ab]	93.94
F_2(80% Rec. dose)	81.20 [a]	96.22
F_3(60% Rec. dose)	75.38 [b]	96.12
'F' test	*	NS
S.Em±	1.51	1.36
CD at 5%	4.55	-
Sources of fertilizers		
S_1(Normal fertilizers)	80.05	95.61
S_2(Water soluble fertilizers)	77.60	95.23
'F' test	NS	NS
S.Em±	1.23	1.11
CD at 5%	-	-
Interactions		
F_1S_1	79.45	95.75 [ab]
F_1S_2	80.35	92.12 [c]
F_2S_1	85.10	98.95 [ab]
F_2S_2	77.30	93.48 [bc]
F_3S_1	75.60	92.13 [c]
F_3S_2	75.15	100.10 [a]
'F' test	NS	*
S.Em±	2.13	1.93
CD at 5%	-	5.80

Rec. = Recommended

producing significantly the tallest plants (76.01 cm) compared with the other levels of fertigation.

The differences between sources of fertilizers with regard to height of plants were not significant at all the stages of growth.

Interactions between levels of fertigation and sources of fertilizers were significant only at 45 and 60 days after planting.

4.1.1.2 Height of plants during winter and summer seasons

The differences in height of plants among levels of fertigation were significant during winter season. The plant height with F_1 was significantly higher (81.20 cm) as compared to F_3 (75.38 cm) but was on par with F_2 (79.90 cm). However, the differences were non-significant during summer.

Sources of fertilizers did not differ significantly with respect to height of plants both during winter and summer seasons.

Interaction effects differed significantly with respect to height of plants only during summer.

4.1.2 NUMBER OF LATERALS PER PLANT

The data pertaining to number of laterals that were produced per plant in carnation variety 'Trendy' at different days after planting and during winter

Table-4 : Number of laterals produced per plant in carnation var. 'Trendy' as influenced by levels of fertigation, sources of fertilizers and their interactions

Particulars	Number of laterals / plant				
	45 DAP	60 DAP	75 DAP	90 DAP	105 DAP
Levels of fertigation					
F_1(100% Rec. dose)	4.95 [b]	5.33 [b]	5.55 [b]	5.80 [b]	5.80 [c]
F_2(80% Rec. dose)	5.40 [a]	5.83 [a]	5.95 [a]	6.18 [a]	6.28 [a]
F_3(60% Rec. dose)	5.58 [a]	5.70 [a]	5.73 [b]	6.00 [a]	6.10 [b]
'F' test	*	*	*	*	*
S.Em±	0.15	0.09	0.07	0.06	0.05
CD at 5%	0.44	0.28	0.20	0.19	0.15
Sources of fertilizers					
S_1(Normal fertilizers)	5.23	5.57	5.73	6.05	6.05
S_2(Water soluble fertilizers)	5.38	5.67	5.75	5.93	6.07
'F' test	NS	NS	NS	NS	NS
S.Em±	0.12	0.08	0.05	0.05	0.04
CD at 5%	-	-	-	-	-
Interactions					
F_1S_1	4.90	5.30	5.65	5.80	5.80
F_1S_2	5.00	5.35	5.45	5.80	5.80
F_2S_1	5.25	5.75	5.85	6.25	6.25
F_2S_2	5.55	5.90	6.05	6.10	6.35
F_3S_1	5.55	5.65	5.70	6.10	6.15
F_3S_2	5.60	5.75	5.75	5.90	6.05
'F' test	NS	NS	NS	NS	NS
S.Em±	0.21	0.13	0.09	0.09	0.07
CD at 5%	-	-	-	-	-

DAP = Days after planting
Rec. = Recommended

Table-5: Number of laterals produced per plant in carnation var. 'Trendy' during winter and summer seasons as influenced by levels of fertigation, sources of fertilizers and their interactions

Particulars	Number of laterals / plant	
	Winter (Nov.'97 –Jan.'98)	Summer (Feb.'98 – April'98)
Levels of fertigation		
F_1(100% Rec. dose)	4.13 [a]	4.74
F_2(80% Rec. dose)	4.35 [a]	4.45
F_3(60% Rec. dose)	3.99 [b]	4.39
'F' test	*	NS
S.Em±	0.07	0.15
CD at 5%	0.22	-
Sources of fertilizers		
S_1(Normal fertilizers)	4.13	4.49
S_2(Water soluble fertilizers)	4.18	4.56
'F' test	NS	NS
S.Em±	0.06	0.12
CD at 5%	-	-
Interactions		
F_1S_1	4.25	4.90
F_1S_2	4.00	4.58
F_2S_1	4.25	4.50
F_2S_2	4.45	4.40
F_3S_1	3.90	4.08
F_3S_2	4.09	4.70
'F' test	NS	NS
S.Em±	0.10	0.21
CD at 5%	-	-

Rec. = Recommended

and summer seasons as influenced by levels of fertigation, sources of fertilizers and their interactions are presented in Table-4 and 5, respectively.

4.1.2.1 Number of laterals per plant at different days after planting

Number of laterals produced per plant differed significantly among levels of fertigation in carnation variety 'Trendy' at different days after planting. At 105 days after planting, F_2 influenced in producing significantly the maximum number of laterals per plant (6.28 laterals/plant) compared with the other two treatments.

Both sources of fertilizers and interactions showed non-significant results with regard to number of laterals produced per plant at different stages of growth.

4.1.2.2 Number of laterals per plant during winter and summer seasons

Number of laterals produced per plant differed significantly among levels of fertigation in carnation variety 'Trendy' during winter season. During winter season, F_1 and F_2 were on par and resulted in producing significantly higher number of laterals per plant (4.13 and 4.35 laterals / plant, respectively) in carnation variety 'Trendy' compared to F_3 (3.99 laterals / plant). However, the differences were non-significant during summer.

Non-significant differences with regard to number of laterals produced per plant were obtained between sources of fertilizers and among interactions.

Table-6 : Number of pairs of leaves per lateral in carnation var. 'Trendy' in different seasons as influenced by levels of fertigation, sources of fertilizers and their interactions

Particulars	Number of pairs of leaves / lateral at bud appearance		
	Rainy (July'97 –Oct.'97)	Winter (Nov.'97 –Jan.'98)	Summer (Feb.'98–April'98)
Levels of fertigation			
F_1(100% Rec. dose)	13.35	18.73	13.00
F_2(80% Rec. dose)	13.03	18.70	12.73
F_3(60% Rec. dose)	12.68	16.85	13.32
'F' test	NS	NS	NS
S.Em±	0.22	0.66	0.59
CD at 5%	-	-	-
Sources of fertilizers			
S_1(Normal fertilizers)	13.08	18.55	13.74
S_2(Water soluble fertilizers)	12.95	17.63	12.30
'F' test	NS	NS	NS
S.Em±	0.18	0.54	0.48
CD at 5%	-	-	-
Interactions			
F_1S_1	13.25	19.20	14.19
F_1S_2	13.45	18.25	11.81
F_2S_1	13.55	19.55	13.46
F_2S_2	12.50	17.85	12.00
F_3S_1	12.45	16.90	13.56
F_3S_2	12.90	16.80	13.09
'F' test	NS	NS	NS
S.Em±	0.31	0.94	0.83
CD at 5%	-	-	-

Rec. = Recommended

4.1.3 NUMBER OF PAIRS OF LEAVES PER LATERAL

The data on number of pairs of leaves produced per lateral in carnation variety 'Trendy' at the time of bud appearance in different seasons as influenced by levels of fertigation, sources of fertilizers and their interactions are presented in Table-6.

Non-significant results were obtained with regard to number of pairs of leaves produced per lateral in carnation variety 'Trendy' at the time of bud appearance in all the three seasons viz., rainy, winter and summer.

4.1.4 DAYS TAKEN FOR FIRST FLOWER BUD'S APPEARANCE, DEVELOPMENT AND HARVEST, AND FIFTY PER CENT FLOWERING

The data pertaining to number of days taken for first flower bud's appearance, development, and harvest, and fifty per cent flowering in carnation variety 'Trendy' as influenced by levels of fertigation, sources of fertilizers and their interactions are presented in Table-7 (Fig.4) (Plate-12).

Significant differences were obtained within each parameter mentioned above, as effected by levels of fertigation. Significantly maximum number of days was taken by F_1 not only for first flower bud's appearance (101.50 days) but also for development (17 days), for harvest (118.50 days) and for 50 per cent flowering (183.75 days) as compared with the other levels of fertigation.

Table-7 : Days for first flower bud's appearance, development, harvest and fifty per cent flowering in carnation var. 'Trendy' as influenced by levels of fertigation, sources of fertilizers and their interactions

Particulars	Days for first flower bud's			Days for 50% flowering
	Appearance	Development	Harvest	
Levels of fertigation				
F_1(100% Rec. dose)	101.50 [a]	17.00 [a]	118.50 [a]	183.75 [a]
F_2(80% Rec. dose)	94.88 [b]	12.00 [b]	106.88 [b]	164.75 [b]
F_3(60% Rec. dose)	92.75 [b]	13.50 [b]	106.13 [b]	168.63 [b]
'F' test	*	*	*	*
S.Em±	1.35	1.06	1.16	1.86
CD at 5%	4.06	3.19	3.49	5.61
Sources of fertilizers				
S_1(Normal fertilizers)	97.25	15.17	112.33 [a]	172.08
S_2(Water soluble fertilizers)	95.50	13.17	108.67 [b]	172.67
'F' test	NS	NS	*	NS
S.Em±	1.10	0.87	0.96	1.52
CD at 5%	-	-	2.85	-
Interactions				
F_1S_1	101.75	16.50	118.25 [a]	183.50 [a]
F_1S_2	101.25	17.50	118.75 [a]	184.00 [a]
F_2S_1	98.00	14.00	112.00 [b]	168.00 [b]
F_2S_2	91.75	10.00	101.75 [d]	161.50 [c]
F_3S_1	92.00	15.00	106.75 [c]	164.75 [bc]
F_3S_2	93.50	12.00	105.50 [c]	172.50 [b]
'F' test	NS	NS	*	*
S.Em±	1.91	1.50	1.64	2.63
CD at 5%	-	-	4.44	7.93

Rec. = Recommended

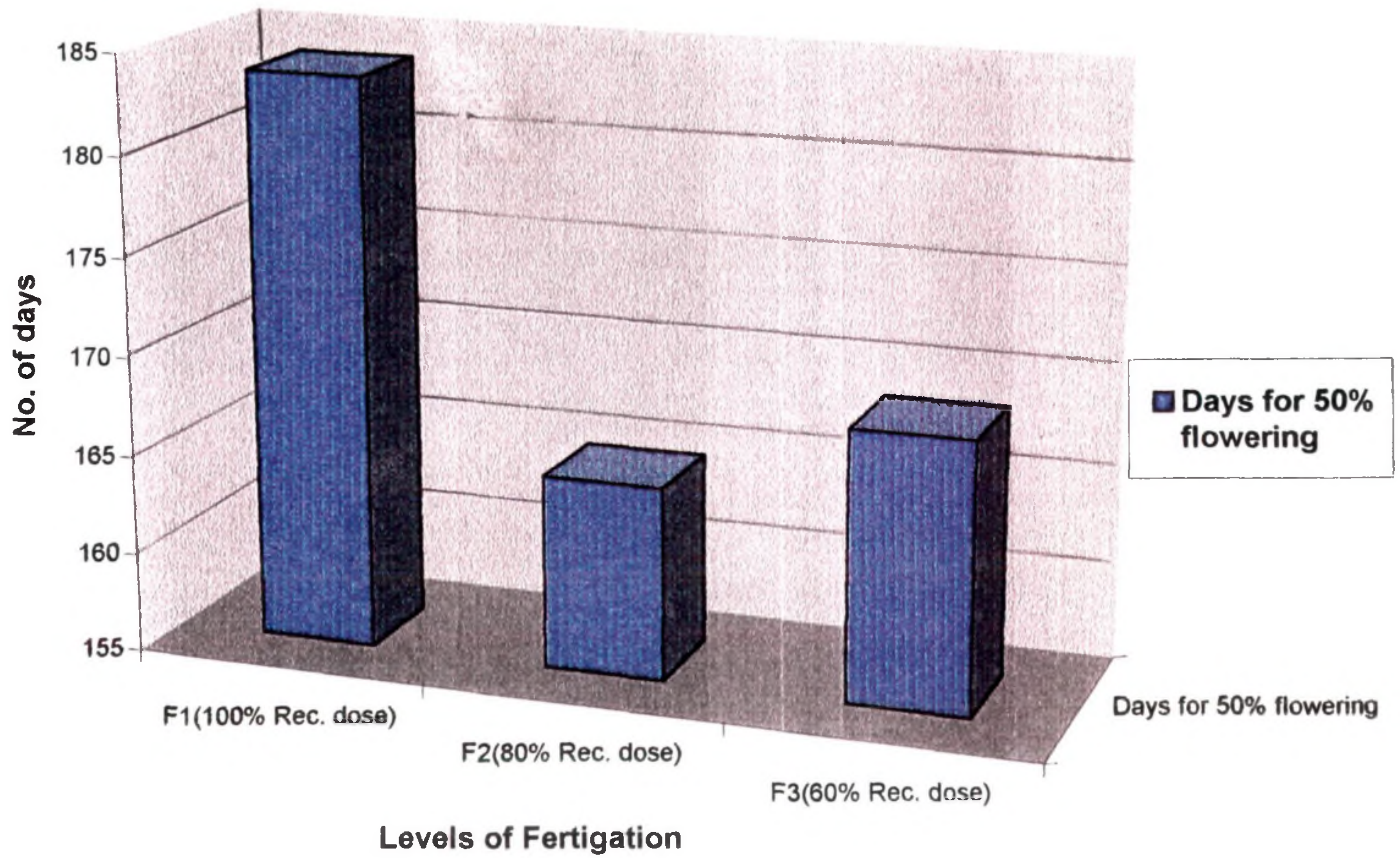


Fig.4: Number of days taken for fifty per cent flowering in carnation var. 'Trendy' as influenced by levels of fertigation

Sources of fertilizers and their interactions with levels of fertigation did not show significance with respect to the above mentioned parameters, except days taken for first flower bud's harvest as affected by sources of fertilizers and interactions and days taken for 50% flowering as affected by interactions. While S_1 delayed harvesting of first flower bud (112.33 days), S_2 advanced harvesting (108.67 days).

4.1.5 LENGTH AND THICKNESS OF FLOWER BUDS

The data pertaining to length and thickness of flower buds of carnation variety 'Trendy' in different seasons as influenced by levels of fertigation, sources of fertilizers and their interactions are presented in Table-8 and 9, respectively.

4.1.5.1 Length of flower buds during different seasons

Length of flower buds differed significantly among levels of fertigation during winter only. During winter, F_1 and F_2 were on par and resulted in producing significantly longer flower buds (1.81 cm and 1.93 cm, respectively) as compared to F_3 (1.51 cm).

Significant differences were obtained between sources of fertilizers with respect to length of flower buds during summer. Water soluble fertilizers (S_2) influenced in producing significantly longer flower buds (3.83 cm) during

Table-8 : Length of flower buds of carnation var. 'Trendy' in different seasons as influenced by levels of fertigation, sources of fertilizers and their interactions

Particulars	Length of flower buds (cm)		
	Rainy (July'97 –Oct.'97)	Winter (Nov.'97 –Jan.'98)	Summer (Feb.'98–April'98)
Levels of fertigation			
F_1(100% Rec. dose)	2.17	1.81 [a]	3.26
F_2(80% Rec. dose)	2.24	1.93 [a]	3.40
F_3(60% Rec. dose)	2.27	1.51 [b]	3.11
'F' test	NS	*	NS
S.Em±	0.04	0.06	0.09
CD at 5%	-	0.19	-
Sources of fertilizers			
S_1(Normal fertilizers)	2.21	1.74	3.13 [b]
S_2(Water soluble fertilizers)	2.25	1.76	3.83 [a]
'F' test	NS	NS	*
S.Em±	0.03	0.05	0.08
CD at 5%	-	-	0.23
Interactions			
F_1S_1	2.28 [ab]	1.67	3.13
F_1S_2	2.06 [c]	1.95	3.40
F_2S_1	2.12 [bc]	1.97	3.33
F_2S_2	2.37 [a]	1.90	3.46
F_3S_1	2.23 [abc]	1.58	2.94
F_3S_2	2.31 [a]	1.44	3.29
'F' test	*	NS	NS
S.Em±	0.06	0.09	0.13
CD at 5%	0.17	-	-

Rec. = Recommended

Table-9 : Thickness of flower buds of carnation var. 'Trendy' in different seasons as influenced by levels of fertigation, sources of fertilizers and their interactions

Particulars	Thickness of flower buds (mm)		
	Rainy (July'97 –Oct.'97)	Winter (Nov.'97 –Jan.'98)	Summer (Feb.'98–April'98)
Levels of fertigation			
F_1(100% Rec. dose)	1.72	1.24 [a]	1.81 [a]
F_2(80% Rec. dose)	1.72	1.34 [a]	1.80 [a]
F_3(60% Rec. dose)	1.71	1.01 [b]	1.64 [b]
'F' test	NS	*	*
S.Em±	0.02	0.03	0.05
CD at 5%	-	0.10	0.14
Sources of fertilizers			
S_1(Normal fertilizers)	1.68 [b]	1.12 [b]	1.68 [b]
S_2(Water soluble fertilizers)	1.74 [a]	1.27 [a]	1.82 [a]
'F' test	*	*	*
S.Em±	0.01	0.03	0.04
CD at 5%	0.04	0.09	0.11
Interactions			
F_1S_1	1.69	1.15	1.72
F_1S_2	1.75	1.32	1.89
F_2S_1	1.67	1.27	1.74
F_2S_2	1.76	1.42	1.86
F_3S_1	1.69	0.95	1.58
F_3S_2	1.73	1.07	1.70
'F' test	NS	NS	NS
S.Em±	0.02	0.05	0.07
CD at 5%	-	-	-

Rec. = Recommended

summer as compared to straight fertilizers. However, the differences during rainy and winter seasons were not significant.

Interactions between levels of fertigation and sources of fertilizers were significant only during rainy season.

4.1.5.2 Thickness of flower buds during different seasons

Thickness of flower buds differed significantly among levels of fertigation during winter and summer seasons. Significantly thicker flower buds produced were due to F_1 and F_2 which were on par both during winter (1.24 mm and 1.34 mm, respectively) and summer (1.81 mm and 1.80 mm, respectively) when compared to F_3. However, the differences were non-significant during rainy season.

Significant differences between sources of fertilizers were obtained with respect to thickness of flower buds during all the three seasons viz., rainy, winter and summer. Significantly thicker flower buds were produced as a result of water soluble fertilizers (S_2) during all the three seasons viz., rainy (1.74 mm), winter (1.27 mm) and summer (1.82 mm).

Interactions between levels of fertigation and sources of fertilizers were non-significant with regard to thickness of flower buds.

4.1.6 LENGTH AND GIRTH OF CUT FLOWER STALKS

The data pertaining to length and girth of flower stalks of carnation variety 'Trendy' in different seasons as influenced by levels of fertigation, sources of fertilizers and their interactions are presented in Table-10 and 11, respectively.

4.1.6.1 Length of cut flower stalks

Length of cut flower stalks of variety 'Trendy' (Fig.5) differed significantly among levels of fertigation during rainy season. During rainy season, F_1 and F_2 were on par and influenced in producing significantly longer flower stalks (56.74 cm and 58.31 cm, respectively) as compared to F_3. However, the differences were non-significant both during winter and summer seasons.

Sources of fertilizers did not differ significantly between themselves during all the three seasons viz., rainy, winter and summer with regard to length of cut flower stalks.

Interaction effects differed significantly during rainy season.

4.1.6.2 Girth of cut flower stalks

Girth of cut flower stalks of variety 'Trendy' differed significantly among levels of fertigation during summer season. The thickest girth of flower stalks was recorded during summer in F_2 (2.99 mm). However, non-

Table-10 : Length of cut flower stalks of carnation var. 'Trendy' in different seasons as influenced by levels of fertigation, sources of fertilizers and their interactions

Particulars	Length of cut flower stalks (cm)		
	Rainy (July'97 –Oct.'97)	Winter (Nov.'97 –Jan.'98)	Summer (Feb.'98–April.'98)
Levels of fertigation			
F_1(100% Rec. dose)	56.74 [a]	58.64	60.41
F_2(80% Rec. dose)	58.31 [a]	58.01	60.40
F_3(60% Rec. dose)	54.15 [b]	58.37	58.62
'F' test	*	NS	NS
S.Em±	0.79	0.84	1.08
CD at 5%	2.39	-	-
Sources of fertilizers			
S_1(Normal fertilizers)	56.47	58.42	59.02
S_2(Water soluble fertilizers)	56.34	58.26	60.59
'F' test	NS	NS	NS
S.Em±	0.65	0.69	0.88
CD at 5%	-	-	-
Interactions			
F_1S_1	60.78 [a]	59.55	61.54
F_1S_2	52.71 [b]	57.72	59.27
F_2S_1	53.60 [b]	56.23	58.62
F_2S_2	63.02 [a]	59.78	62.18
F_3S_1	55.02 [b]	59.47	56.92
F_3S_2	53.28 [b]	57.26	60.32
'F' test	*	NS	NS
S.Em±	1.12	1.19	1.52
CD at 5%	3.38	-	-

Rec. = Recommended

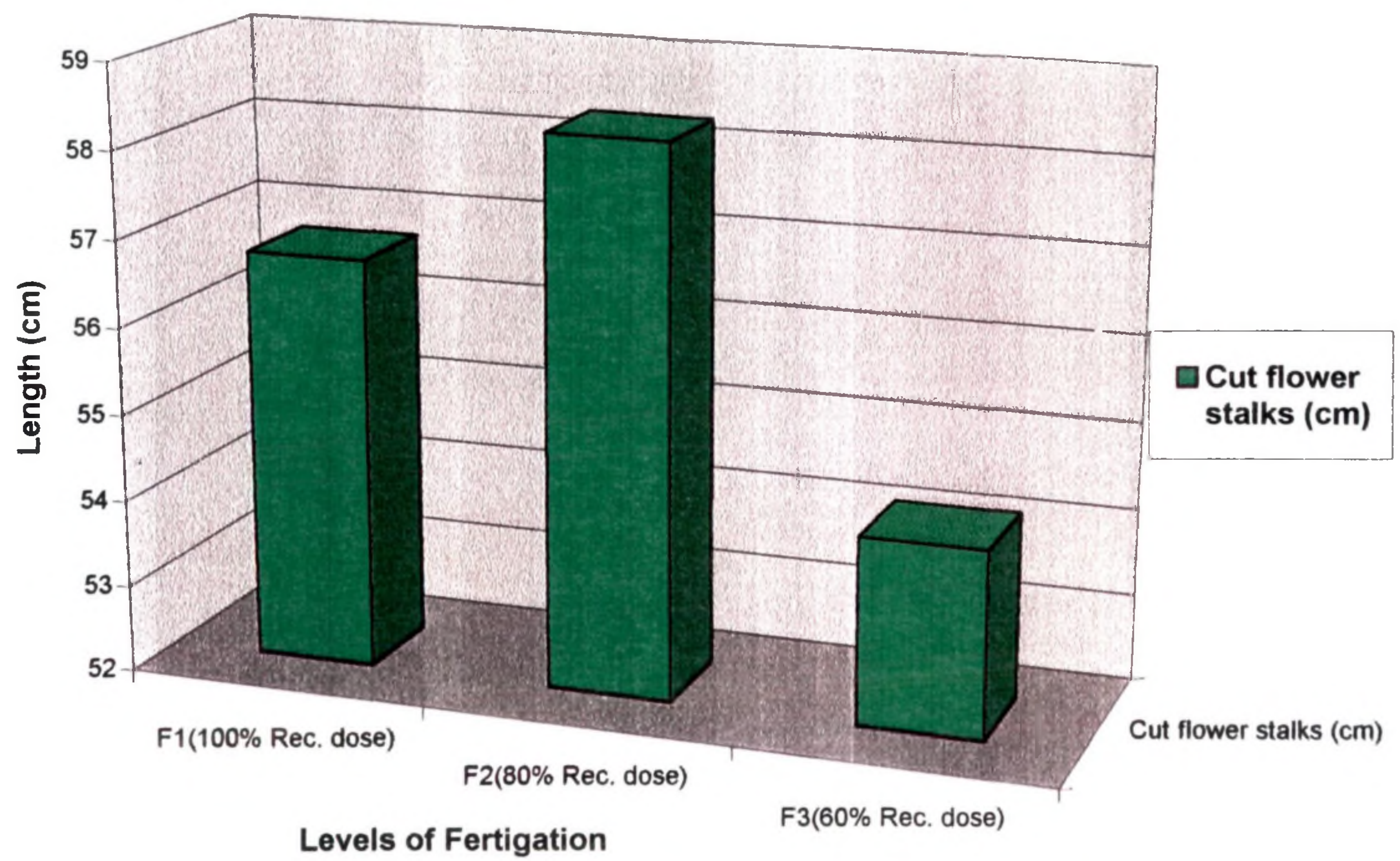


Fig.5 : Length of cut flower stalks of carnation var. 'Trendy' in rainy season as influenced by levels of fertigation

Table-11 : Girth of carnation stalks of var. 'Trendy' in different seasons as influenced by levels of fertigation, sources of fertilizers and their interactions

Particulars	Girth of cut flower stalks (mm)		
	Rainy (July'97 –Oct.'97)	Winter (Nov.'97 –Jan.'98)	Summer (Feb.'98–April'98)
Levels of fertigation			
F_1(100% Rec. dose)	2.87	2.72	2.84 [b]
F_2(80% Rec. dose)	3.03	2.87	2.99 [a]
F_3(60% Rec. dose)	2.96	2.74	2.81 [b]
'F' test	NS	NS	*
S.Em±	0.06	0.05	0.03
CD at 5%	-	-	0.10
Sources of fertilizers			
S_1(Normal fertilizers)	2.95	2.83	2.98 [a]
S_2(Water soluble fertilizers)	2.96	2.72	2.78 [b]
'F' test	NS	NS	*
S.Em±	0.05	0.04	0.03
CD at 5%	-	-	0.09
Interactions			
F_1S_1	2.97 [abc]	2.86 [a]	2.90 [b]
F_1S_2	2.77 [c]	2.58 [c]	2.78 [b]
F_2S_1	2.86 [bc]	2.79 [ab]	2.91 [b]
F_2S_2	3.21 [a]	2.94 [a]	3.08 [a]
F_3S_1	3.03 [ab]	2.84 [ab]	3.12 [a]
F_3S_2	2.89 [bc]	2.64 [bc]	2.50 [c]
'F' test	*	*	*
S.Em±	0.08	0.07	0.05
CD at 5%	0.25	0.20	0.15

Rec. = Recommended

significant differences with respect to girth of cut flower stalks were obtained both during rainy and winter seasons.

Water soluble fertilizers (S_2) did not influence in improving the girth of flower stalks.

Interactions between levels of fertigation and sources of fertilizers differed significantly in all the three seasons.

4.1.7 NUMBER OF PETALS PER FLOWER HEAD

The data on number of petals per flower head of carnation variety 'Trendy' in different seasons as influenced by levels of fertigation, sources of fertilizers and their interactions are presented in Table-12.

Number of petals produced per flower head differed significantly among levels of fertigation both during rainy and winter seasons. While, F_1 and F_2 were on par and resulted in producing significantly more number of petals per flower head (67.51 and 68.11 petals / flower head, respectively) as compared to F_3 during rainy season, F_2 during winter resulted in producing significantly the maximum number of petals per flower head (63.38 petals / flower head). However, the differences were non-significant during summer.

Significant differences were obtained between sources of fertilizers and among their interactions with levels of fertigation during winter season.

Table-12 : Number of petals per flower head of carnation var. 'Trendy' in different seasons as influenced by levels of fertigation, sources of fertilizers and their interactions

Particulars	Number of petals / flower head		
	Rainy (July'97 –Oct.'97)	Winter (Nov.'97 –Jan.'98)	Summer (Feb.'98–April'98)
Levels of fertigation			
F_1(100% Rec. dose)	67.51 [a]	60.69 [b]	58.84
F_2(80% Rec. dose)	68.11 [a]	63.38 [a]	63.61
F_3(60% Rec. dose)	61.16 [b]	60.01 [b]	60.43
'F' test	*	*	NS
S.Em±	1.56	0.84	4.39
CD at 5%	4.70	2.54	-
Sources of fertilizers			
S_1(Normal fertilizers)	65.69	59.45 [b]	60.55
S_2(Water soluble fertilizers)	65.49	63.28 [a]	61.37
'F' test	NS	*	NS
S.Em±	1.27	0.69	3.58
CD at 5%	-	2.08	-
Interactions			
F_1S_1	67.14	60.64 [bc]	66.31
F_1S_2	67.88	60.75 [bc]	51.37
F_2S_1	66.33	59.51 [bc]	58.22
F_2S_2	69.89	67.25 [a]	69.00
F_3S_1	63.61	58.20 [c]	57.11
F_3S_2	58.72	61.83 [b]	63.75
'F' test	NS	*	NS
S.Em±	2.21	1.19	6.21
CD at 5%	-	3.59	-

Rec. = Recommended

Water soluble fertilizers (S_2) as such and their interaction with F_2 influenced in producing significantly more (63.28 petals/flower head) and maximum (67.25 petals/flower head) number of petals per flower head, respectively, during winter.

4.1.8 DIAMETER OF CUT FLOWERS

The data on diameter of flowers of carnation variety 'Trendy' in different seasons as influenced by levels of fertigation, sources of fertilizers and their interactions are presented in Table-13.

Diameter of cut flowers differed significantly among levels of fertigation during all the three seasons viz., rainy, winter and summer. While F_1 and F_2 were on par and resulted in producing higher diameter of cut flowers both during rainy (6.78 cm and 6.94 cm, respectively) and winter (5.56 cm and 5.52 cm, respectively) seasons, F_2 resulted in producing the highest diameter of cut flowers (5.23 cm) during summer.

Diameter of cut flowers differed significantly between sources of fertilizers and among their interaction with levels of fertigation during winter season only. Water soluble fertilizers (S_2) (5.57 cm) as such and their interactions with F_1 and F_2 (on par) (5.79 cm 5.97 cm, respectively) resulted in producing higher diameter of cut flowers.

Table-13 : Diameter of flowers of carnation var. 'Trendy' in different seasons as influenced by levels of fertigation, sources of fertilizers and their interactions

Particulars	Diameter of cut carnation flowers (cm)		
	Rainy (July'97 –Oct.'97)	Winter (Nov.'97 –Jan.'98)	Summer (Feb.'98–April'98)
Levels of fertigation			
F_1(100% Rec. dose)	6.78 [a]	5.56 [a]	4.67 [b]
F_2(80% Rec. dose)	6.94 [a]	5.52 [a]	5.23 [a]
F_3(60% Rec. dose)	6.40 [b]	5.12 [b]	4.70 [b]
'F' test	*	*	*
S.Em±	0.11	0.10	0.11
CD at 5%	0.32	0.30	0.33
Sources of fertilizers			
S_1(Normal fertilizers)	6.79	5.23 [b]	4.87
S_2(Water soluble fertilizers)	6.61	5.57 [a]	4.86
'F' test	NS	*	NS
S.Em±	0.09	0.08	0.09
CD at 5%	-	0.25	-
Interactions			
F_1S_1	6.91	5.32 [b]	4.52
F_1S_2	6.65	5.79 [a]	4.82
F_2S_1	6.90	5.07 [b]	5.36
F_2S_2	6.97	5.97 [a]	5.09
F_3S_1	6.57	5.29 [b]	4.73
F_3S_2	6.22	4.96 [b]	4.68
'F' test	NS	*	NS
S.Em±	0.15	0.14	0.16
CD at 5%	-	0.43	-

Rec. = Recommended

4.1.9 YIELD OF CUT FLOWERS

4.1.9.1 Yield of first grade cut flowers per square meter

The data on yield of first grade cut flowers of carnation variety 'Trendy' per square meter in different seasons as influenced by levels of fertigation, sources of fertilizers and their interactions are presented in Table-14 (Fig.6).

Number of first grade cut flowers produced per square meter differed significantly among levels of fertigation. While F_2 and F_3 were on par and influenced in producing significantly higher number of first grade cut flowers per square meter during rainy (105.76 and 100.99 cut flowers/sq.m) season, F_2 during winter, summer and on cumulative basis (56.56, 62.38 and 224.70 cut flowers/sq.m., respectively) was significantly superior over the other two and influenced in producing maximum number of cut flowers per square meter.

Number of first grade cut flowers produced per square meter differed significantly between sources of fertilizers with respect to seasonal and cumulative yields. Water soluble fertilizers (S_2) effected in producing significantly higher number of first grade cut flowers per square meter during all the three seasons viz., rainy, winter and summer (101.68, 55.12 and 67.73 cut flowers/sq.m., respectively) and on cumulative basis (224.53 cut flowers/sq.m.).

Table-14 : Yield of first grade cut flowers of carnation var. 'Trendy' per square meter in different seasons as influenced by levels of fertigation, sources of fertilizers and their interactions

Particulars	No. of first grade cut flowers/sq.m.			
	Rainy (July'97 – Oct.'97)	Winter (Nov.'97 – Jan.'98)	Summer (Feb.'98– April.'98)	Cumulative (1997-98)
Levels of fertigation				
F_1(100% Rec. dose)	72.81 [b]	46.49 [b]	53.29 [b]	172.59 [b]
F_2(80% Rec. dose)	105.76 [a]	56.56 [a]	62.38 [a]	224.70 [a]
F_3(60% Rec. dose)	100.99 [a]	39.11 [b]	43.33 [c]	183.43 [b]
'F' test	*	*	*	*
S.Em±	4.02	2.92	2.08	6.05
CD at 5%	12.11	8.80	6.27	18.23
Sources of fertilizers				
S_1(Normal fertilizers)	84.69 [b]	39.65 [b]	38.27 [b]	162.61 [b]
S_2(Water soluble fertilizers)	101.68 [a]	55.12 [a]	67.73 [a]	224.53 [a]
'F' test	*	*	*	*
S.Em±	3.28	2.38	1.70	4.94
CD at 5%	9.89	7.18	5.12	14.88
Interactions				
F_1S_1	68.21	42.18	48.87 [c]	159.25 [d]
F_1S_2	77.41	50.81	57.71 [b]	185.93 [c]
F_2S_1	97.49	47.31	39.25 [d]	184.05 [c]
F_2S_2	114.04	65.81	85.51 [a]	265.36 [a]
F_3S_1	88.38	29.48	26.69 [e]	144.54 [d]
F_3S_2	113.60	48.75	59.97 [b]	222.31 [b]
'F' test	NS	NS	*	*
S.Em±	5.68	4.13	2.94	8.55
CD at 5%	-	-	8.87	25.78

Rec. = Recommended

Interactions between sources of fertilizers and levels of fertigation were significant with respect to number of first grade cut flowers produced per square meter during summer and on cumulative basis. Maximum number of first grade cut flowers per square meter was produced by F_2S_2 which was significantly superior over all the others during summer and on cumulative basis (85.51 and 265.36 cut flowers/sq.m., respectively)

4.1.9.2 Per cent yield of first grade cut flowers

The data on per cent yield of first grade cut flowers of carnation variety 'Trendy' in different seasons as influenced by levels of fertigation, sources of fertilizers and their interactions are presented in Table-15.

Per cent cumulative yield and yield of first grade cut flowers during winter and summer seasons differed significantly among levels of fertigation. Significantly superior and maximum per cent cumulative yield (98.26%) and yield of first grade cut flowers were obtained with F_2 during winter and summer seasons (98.26% and 96.58%, respectively).

Significant differences between sources of fertilizers were obtained with respect to per cent cumulative yield and yield of first grade cut flowers during winter and summer seasons. Water soluble fertilizers (S_2) effected in producing significantly higher per cent cumulative yield (98.52 %) and yield

Table-15 : Per cent yield of first grade cut flowers of carnation var. 'Trendy' in different seasons as influenced by levels of fertigation, sources of fertilizers and their interactions

Particulars	Per cent yield of first grade cut flowers			
	Rainy (July'97 – Oct.'97)	Winter (Nov.'97 – Jan.'98)	Summer (Feb.'98– April.'98)	Cumulative (1997-98)
Levels of fertigation				
F_1(100% Rec. dose)	98.86	97.81 [b]	95.48 [b]	97.51 [b]
F_2(80% Rec. dose)	98.49	98.26 [a]	96.58 [a]	98.26 [a]
F_3(60% Rec. dose)	97.48	96.91 [c]	93.98 [c]	97.35 [b]
'F' test	NS	*	*	*
S.Em±	0.62	0.02	0.03	0.13
CD at 5%	-	0.05	0.08	0.38
Sources of fertilizers				
S_1(Normal fertilizers)	97.73	96.78 [b]	93.71 [b]	96.89 [b]
S_2(Water soluble fertilizers)	98.83	98.53 [a]	96.98 [a]	98.52 [a]
'F' test	NS	*	*	*
S.Em±	0.50	0.01	0.02	0.10
CD at 5%	-	0.04	0.06	0.31
Interactions				
F_1S_1	98.49	96.95 [e]	93.97 [e]	96.66
F_1S_2	99.24	98.66 [b]	96.99 [b]	98.36
F_2S_1	98.72	97.55 [d]	95.15 [d]	97.64
F_2S_2	98.26	98.96 [a]	98.00 [a]	98.88
F_3S_1	95.98	95.85 [f]	92.01 [f]	96.39
F_3S_2	98.99	97.97 [c]	95.95 [c]	98.32
'F' test	NS	*	*	NS
S.Em±	0.87	0.02	0.04	0.18
CD at 5%	-	0.07	0.11	-

Rec. = Recommended

of first grade cut flowers during winter and summer seasons (98.53% and 96.98%, respectively).

Differences among interactions between levels of fertigation and sources of fertilizers were significant during winter and summer seasons. Significantly superior and maximum per cent yield of first grade cut flowers obtained was due to F_2S_2 over all the others during winter and summer seasons (98.96% and 98%, respectively).

4.1.9.3 Yield of second grade cut flowers per square meter

The data pertaining to yield of second grade cut flowers of carnation variety 'Trendy' per square meter in different seasons as influenced by levels of fertigation, sources of fertilizers and their interactions are presented in Table-16 (Fig.6).

Number of second grade cut flowers produced per square meter differed significantly among levels of fertigation during rainy and summer seasons and also with respect to cumulative yield. While F_1 and F_2 were on par and effected in producing significantly lower number of second grade cut flowers per square meter (0.82 and 0.93 cut flowers/sq.m., respectively) during rainy season, F_2 during summer season and on cumulative basis effected in producing lowest number of second grade cut flowers (1.87 and 3.73 cut flowers/sq.m., respectively).

Table-16 : Yield of second grade cut flowers of carnation var. 'Trendy' per square meter in different seasons as influenced by levels of fertigation, sources of fertilizers and their interactions

Particulars	No. of second grade cut flowers / sq.m.			
	Rainy (July'97 – Oct.'97)	Winter (Nov.'97 – Jan.'98)	Summer (Feb.'98– April'98)	Cumulative (1997-98)
Levels of fertigation				
F_1(100% Rec. dose)	0.82 [b]	1.01	2.46 [a]	4.28 [b]
F_2(80% Rec. dose)	0.93 [b]	0.94	1.87 [b]	3.73 [c]
F_3(60% Rec. dose)	1.49 [a]	1.14	2.42 [a]	4.92 [a]
'F' test	*	NS	*	*
S.Em±	0.05	0.07	0.11	0.18
CD at 5%	0.16	-	0.32	0.53
Sources of fertilizers				
S_1(Normal fertilizers)	1.38 [a]	1.26 [a]	2.48 [a]	5.04 [a]
S_2(Water soluble fertilizers)	0.78 [b]	0.79 [b]	2.02 [b]	3.59 [b]
'F' test	*	*	*	*
S.Em±	0.04	0.06	0.09	0.14
CD at 5%	0.13	0.17	0.26	0.43
Interactions				
F_1S_1	1.04	1.33	3.13 [a]	5.50 [a]
F_1S_2	0.60	0.69	1.79 [d]	3.07 [c]
F_2S_1	1.27	1.19	2.00 [c]	4.45 [b]
F_2S_2	0.59	0.69	1.74 [d]	3.02 [c]
F_3S_1	1.82	1.28	2.32 [c]	5.16 [ab]
F_3S_2	1.16	1.01	2.53 [b]	4.69 [b]
'F' test	NS	NS	*	*
S.Em±	0.07	0.10	0.15	0.25
CD at 5%	-	-	0.46	0.75

Rec. = Recommended

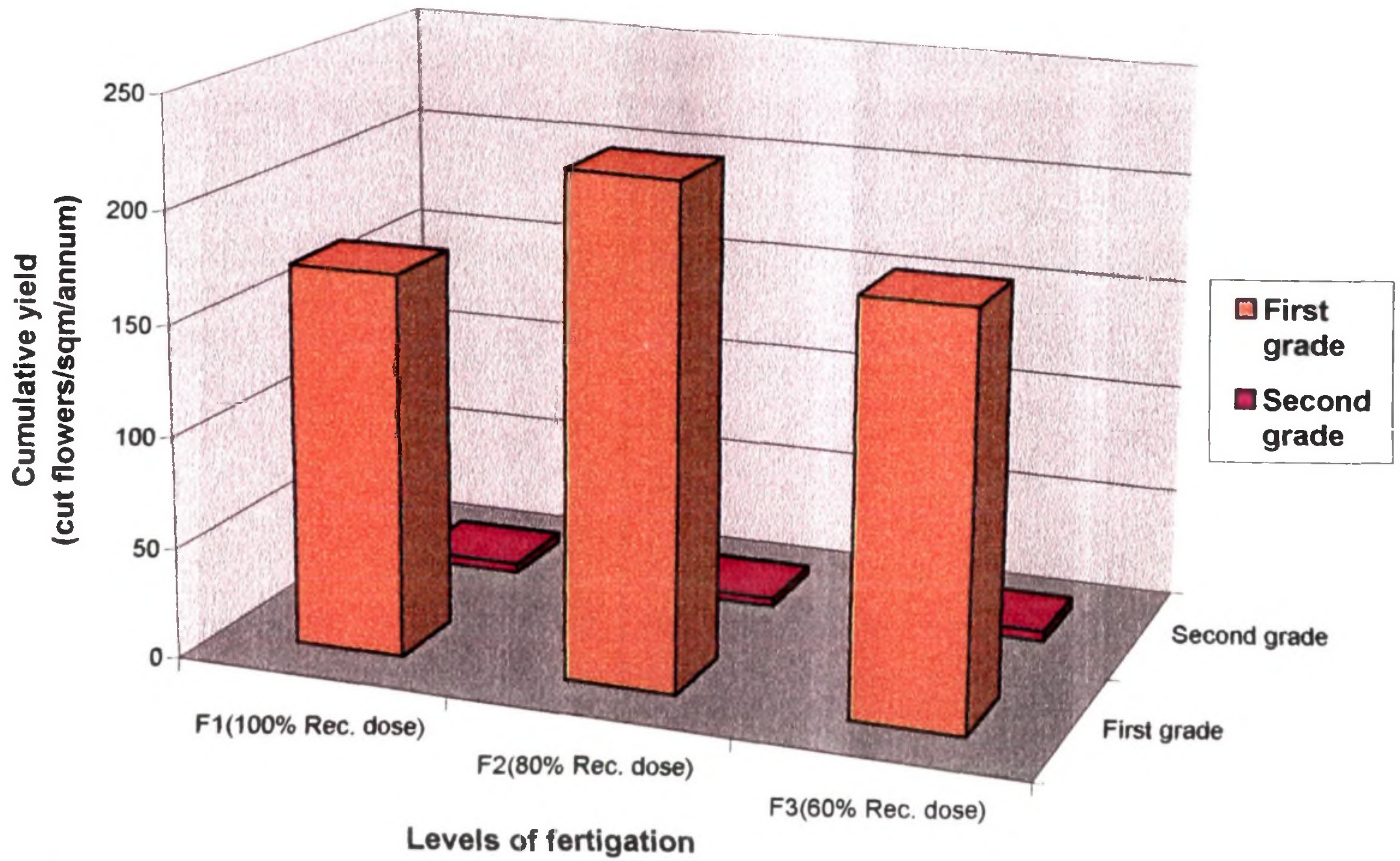


Fig.6 : Cumulative yield of first and second grade cut flowers of carnation var. 'Trendy' per square meter per annum as influenced by levels of fertigation

Sources of fertilizers differed significantly with respect to number of second grade cut flowers produced per square meter both on seasonal and cumulative basis. Significantly lower number of second grade cut flowers per square meter during rainy, winter and summer seasons (0.78, 0.79 and 2.02 cut flowers / sq.m., respectively) and on cumulative (3.59 cut flowers / sq.m.) basis was effected by water soluble fertilizers (S_2).

Interactions between levels of fertigation and sources of fertilizers differed significantly with respect to number of second grade cut flowers produced per square meter during summer and on cumulative basis. Lower summer and cumulative yields (3.13 and 5.50 cut flowers / sq.m., respectively) of second grade cut flowers per square meter were due to the effect of F_1S_1.

4.1.9.4 Per cent yield of second grade cut flowers

The data pertaining to per cent yield of second grade cut flowers of carnation variety 'Trendy' in different seasons as influenced by levels of fertigation, sources of fertilizers and their interactions are presented in Table-17.

Per cent yield of second grade cut flowers differed significantly among levels of fertigation both on seasonal and cumulative basis. Significantly lowest per cent cumulative (1.74%) and seasonal i.e., rainy, winter and

Table-17 : Per cent yield of second grade cut flowers of carnation var. 'Trendy' in different seasons as influenced by levels of fertigation, sources of fertilizers and their interactions

Particulars	Per cent yield of second grade cut flowers			
	Rainy (July'97 – Oct.'97)	Winter (Nov.'97 – Jan.'98)	Summer (Feb.'98– April.'98)	Cumulative (1997-98)
Levels of fertigation				
F_1(100% Rec. dose)	1.13 [b]	2.19 [b]	4.51 [b]	2.48 [b]
F_2(80% Rec. dose)	0.90 [c]	1.74 [c]	3.42 [c]	1.74 [c]
F_3(60% Rec. dose)	1.51 [a]	3.08 [a]	6.01 [a]	2.78 [a]
'F' test	*	*	*	*
S.Em±	0.01	0.02	0.02	0.09
CD at 5%	0.03	0.06	0.07	0.26
Sources of fertilizers				
S_1(Normal fertilizers)	1.60 [a]	3.21 [a]	6.28 [a]	3.04 [a]
S_2(Water soluble fertilizers)	0.76 [b]	1.46 [b]	3.01 [b]	1.62 [b]
'F' test	*	*	*	*
S.Em±	0.01	0.02	0.02	0.07
CD at 5%	0.02	0.05	0.06	0.21
Interactions				
F_1S_1	1.50 [b]	3.04 [b]	6.02 [b]	3.33
F_1S_2	0.76 [e]	1.33 [e]	3.00 [e]	1.63
F_2S_1	1.29 [c]	2.44 [c]	4.84 [c]	2.35
F_2S_2	0.51 [f]	1.03 [f]	1.99 [f]	1.12
F_3S_1	2.02 [a]	4.15 [a]	7.98 [a]	3.45
F_3S_2	1.00 [d]	2.02 [d]	4.04 [d]	2.12
'F' test	*	*	*	NS
S.Em±	0.01	0.03	0.03	0.12
CD at 5%	0.04	0.08	0.10	-

Rec. = Recommended

summer yields (0.90%, 1.74% and 3.42%, respectively) with respect to per cent second grade cut flowers were produced as a result of F_2 when compared with the other two.

Differences between sources of fertilizers with respect to per cent seasonal and cumulative yields of second grade cut flowers were significant. Water soluble fertilizers (S_2) effected in producing significantly lowest per cent seasonal i.e., rainy, winter and summer (0.76%, 1.46% and 3.01%, respectively) and cumulative (1.62%) yields.

Among interactions between levels of fertigation and sources of fertilizers, significant differences were obtained during all the three seasons viz., rainy, winter and summer. The F_2S_2 interaction significantly effected in producing lowest per cent yield of second grade cut flowers during rainy, winter and summer seasons (0.51%, 1.03% and 1.99%, respectively).

4.1.9.5 Yield of first and second grade cut flowers per plant per annum and per hectare per annum

The data with regard to yield of first and second grade cut flowers of carnation variety 'Trendy' per plant per annum and per hectare per annum as influenced by levels of fertigation, sources of fertilizers and their interactions are presented in Table-18 (Fig.7).

Table-18 : Yield of cut flowers of carnation var. 'Trendy' per plant per annum and per hectare per annum as influenced by levels of fertigation, sources of fertilizers and their interactions

Particulars	No. of cut flowers / annum			
	Per plant		Per hectare ('000)	
	First grade	Second grade	First grade	Second grade
Levels of fertigation				
F_1(100% Rec. dose)	7.19[b]	0.17[b]	1725.91[b]	42.84[b]
F_2(80% Rec. dose)	9.36[a]	0.15[b]	2247.04[a]	37.34[b]
F_3(60% Rec. dose)	7.64[b]	0.21[a]	1834.26[b]	54.24[a]
'F' test	*	*	*	*
S.Em±	0.25	0.01	60.49	2.31
CD at 5%	0.76	0.02	182.27	6.97
Sources of fertilizers				
S_1(Normal fertilizers)	6.78[b]	0.21[a]	1626.13[b]	53.70[a]
S_2(Water soluble fertilizers)	9.36[a]	0.15[b]	2245.34[a]	35.91[b]
'F' test	*	*	*	*
S.Em±	0.21	0.01	49.39	1.89
CD at 5%	0.62	0.02	148.82	5.69
Interactions				
F_1S_1	6.64[de]	0.23[a]	1592.53[d]	54.98
F_1S_2	7.75[c]	0.13[c]	1859.30[c]	30.70
F_2S_1	7.67[cd]	0.19[b]	1840.48[c]	44.53
F_2S_2	11.06[a]	0.13[c]	2653.60[a]	30.15
F_3S_1	6.02[c]	0.22[ab]	1445.40[d]	61.60
F_3S_2	9.26[b]	0.20[ab]	2223.13[b]	46.88
'F' test	*	*	*	NS
S.Em±	0.36	0.01	85.54	3.27
CD at 5%	1.07	0.03	257.76	-

Rec. = Recommended

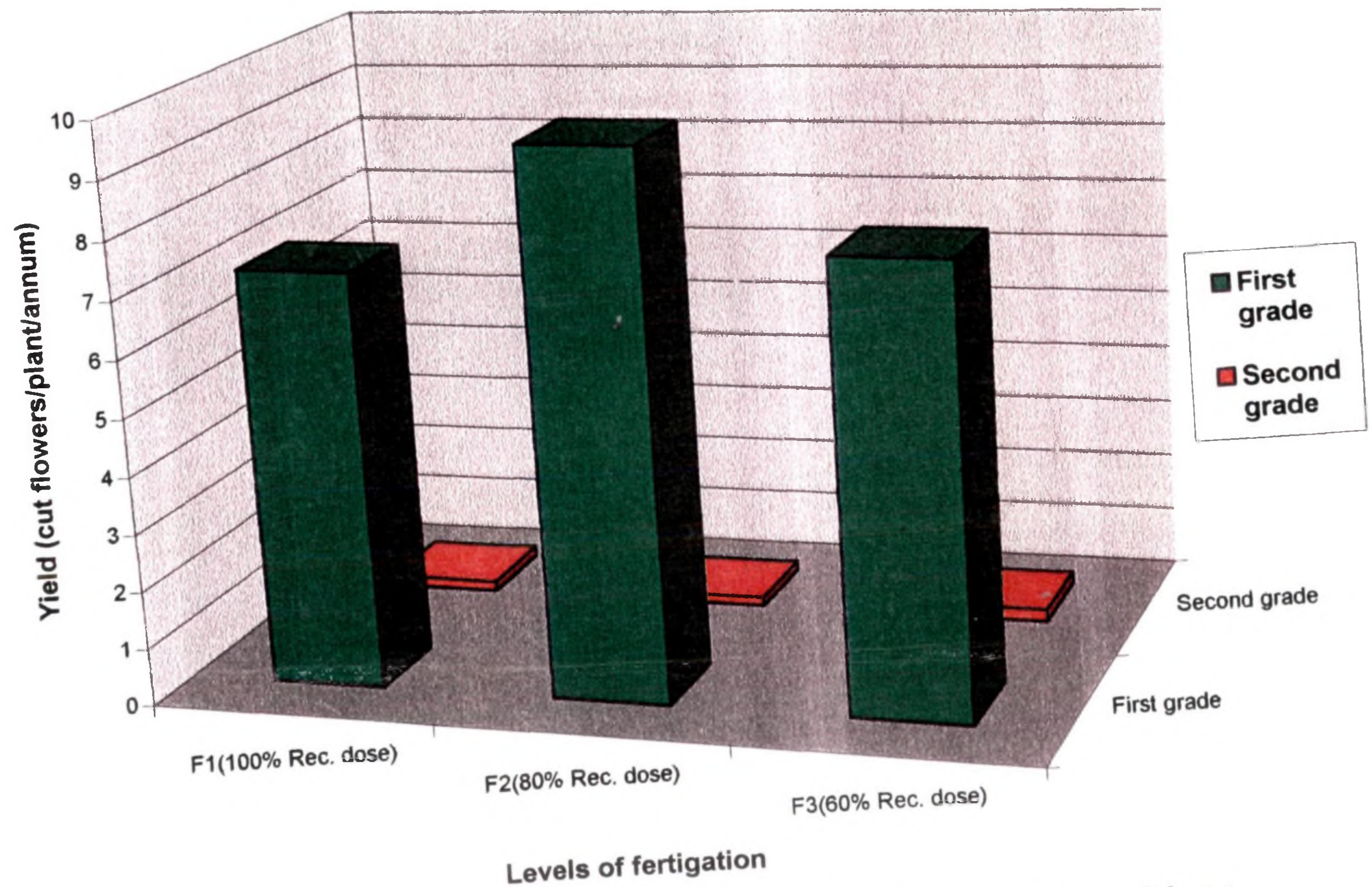


Fig.7 : Yield of first and second grade cut flowers of carnation var. 'Trendy' per plant per annum as influenced by levels of fertigation

Number of first and second grade cut flowers per plant per annum and per hectare per annum differed significantly among levels of fertigation. While significantly highest number of first grade cut flowers per plant per annum (9.36 cut flowers/plant/annum) and per hectare per annum (2247.04 thousand cut flowers/ha/annum) were effected by F_2, lower number of second grade cut flowers per plant per annum (0.17 and 0.15 cut flowers per plant per annum, respectively) and per hectare per annum (42.84 and 37.34 cut flowers/ha/annum, respectively) were effected by F_1 and F_2 (on par) when compared with others.

Significant differences were obtained between sources of fertilizers with respect to first and second grade cut flowers per plant per annum and per hectare per annum. Water soluble fertilizers (S_2) not only effected in producing higher number of first grade cut flowers per plant per annum (9.36 cut flowers/plant/annum) and per hectare per annum (2245.34 thousand cut flowers/ha/annum) but also lower number of second grade cut flowers per plant per annum (0.15 cut flowers/plant/annum) and per hectare per annum (35.91 thousand cut flowers/ha/annum).

Significant differences among interactions between levels of fertigation and sources of fertilizers were obtained in all except second grade cut flowers per hectare per annum. While, F_2S_2 effected in producing significantly highest number of first grade cut flowers per plant per annum (11.06 cut

Table-19 : Flower yield to fertilizers applied ratio in carnation var. 'Trendy' as influenced by levels of fertigation, sources of fertilizers and their interactions

Particulars	No. of cut-flowers/sq.m./annum / kg of fertilizer
Levels of fertigation	
F_1(100% Rec. dose)	144.54 [c]
F_2(80% Rec. dose)	233.94 [b]
F_3(60% Rec. dose)	256.82 [a]
'F' test	*
S.Em±	6.43
CD at 5%	19.39
Sources of fertilizers	
S_1(Normal fertilizers)	173.18 [b]
S_2(Water soluble fertilizers)	250.35 [a]
'F' test	*
S.Em±	5.25
CD at 5%	15.83
Interactions	
F_1S_1	131.59 [d]
F_1S_2	157.50 [d]
F_2S_1	188.35 [c]
F_2S_2	279.53 [b]
F_3S_1	199.62 [c]
F_3S_2	314.03 [a]
'F' test	*
S.Em±	9.10
CD at 5%	27.42

Rec. = Recommended

flowers/plant/annum) and per hectare per annum (2653.60 thousand cut flowers/ha/annum), F_2S_2 and F_1S_2 were on par and produced significantly lower number of second grade cut flowers per plant per annum (0.13 cut flowers each /plant/annum) as compared with others.

4.1.10 FLOWER YIELD TO FERTILIZERS APPLIED RATIO

The data on flower yield to fertilizers applied ratio in carnation variety 'Trendy' as influenced by levels of fertigation, sources of fertilizers and their interactions are presented in Table-19.

Flower yield to fertilizers applied ratio differed significantly among levels of fertigation. Significantly maximum flower yield to fertilizers applied ratio (256.82) was obtained with F_3.

Sources of fertilizers differed significantly with respect to flower yield to fertilizers applied ratio. Water soluble fertilizers (S_2) effected in producing significantly higher flower yield to fertilizers applied ratio (250.35).

Differences among interactions between levels of fertigation and sources of fertilizers were also significant. Significantly maximum flower yield to fertilizers applied ratio (314.03) was obtained with F_3S_2.

4.1.11 VASE LIFE DEPENDANT PARAMETERS

The data pertaining to cumulative fresh weight of cut flowers, cumulative uptake of water by cut flowers, cumulative loss of water by cut flowers and vase life of cut flowers of carnation variety 'Trendy' as influenced by levels of fertigation, sources of fertilizers and their interactions are presented in Table-20.

4.1.11.1 Cumulative fresh weight of cut flowers

Cumulative fresh weight of cut flowers differed significantly among levels of fertigation during winter season. During winter, F_1 and F_2 were on par and recorded significantly higher cumulative fresh weight (7.25 and 8.88 g/flower, respectively) compared to F_3 (4.75 g/flower). However, the differences were non-significant during rainy season.

Non-significant differences were obtained between sources of fertilizers and among their interaction with levels of fertigation with respect to cumulative fresh weight of cut flowers during both rainy and winter seasons.

4.1.11.2 Cumulative uptake of water by cut flowers

Cumulative uptake of water by cut flowers differed significantly among levels of fertigation during rainy season. During rainy season, F_2 and F_3 were on par and resulted in significantly higher cumulative uptake of water (21.37 g and 22.25 g/flower, respectively) by cut flowers as compared to F_1 (16.37 g/flower). However, the differences were non-significant during winter.

Table-20 : Cumulative fresh weight, cumulative uptake of water, cumulative loss of water and vase life of cut flowers of carnation var. 'Trendy' as influenced by levels of fertigation, sources of fertilizers and their interactions

Particulars	Cumulative fresh weight (g/flower)		Cumulative uptake of water (g/flower)		Cumulative loss of water (g/flower)		Vase life (days)	
	Rainy (July'97- Oct.'97)	Winter (Nov.'97 -Jan.'98)	Rainy (July'97- Oct.'97)	Winter (Nov.'97 -Jan.'98)	Rainy (July'97- Oct.'97)	Winter (Nov.'97 -Jan.'98)	Rainy (July'97- Oct.'97)	Winter (Nov.'97 -Jan.'98)
Levels of fertigation								
F_1(100% Rec. dose)	9.75	7.25 [a]	16.37 [b]	11.62	20.75	12.25	5.12	6.12
F_2(80% Rec. dose)	10.13	8.88 [a]	21.37 [a]	15.37	23.50	12.50	5.37	6.62
F_3(60% Rec. dose)	10.88	4.75 [b]	22.25 [a]	11.87	21.75	12.75	5.50	6.00
'F' test	NS	*	*	NS	NS	NS	NS	NS
S.Em±	0.96	0.55	0.85	1.83	1.70	1.40	0.20	0.28
CD at 5%	-	1.65	2.54	-	-	-	-	-
Sources of fertilizers								
S_1(Normal fertilizers)	9.83	7.25	22.33 [a]	13.08	23.50	12.16	5.00 [b]	6.33
S_2(Water soluble fertilizers)	10.67	6.67	17.66 [b]	12.83	20.50	12.83	5.66 [a]	6.16
'F' test	NS	NS	*	NS	NS	NS	*	NS
S.Em±	0.79	0.45	0.69	1.49	1.39	1.14	0.16	0.23
CD at 5%	-	-	2.07	-	-	-	0.49	-
Interactions								
F_1S_1	11.00	7.00	17.75 [cd]	12.00	21.25	11.25	4.75	5.75
F_1S_2	8.50	7.50	15.00 [d]	11.25	20.25	13.25	5.50	6.50
F_2S_1	8.25	9.50	21.25 [bc]	15.50	23.25	13.50	5.00	6.75
F_2S_2	12.00	8.25	21.50 [b]	15.25	23.75	11.50	5.75	6.50
F_3S_1	10.25	5.25	28.00 [a]	11.75	26.00	11.75	5.25	6.50
F_3S_2	11.50	4.25	16.50 [d]	12.00	17.50	13.75	5.75	5.50
'F' test	NS	NS	*	NS	NS	NS	NS	NS
S.Em±	1.36	0.78	1.21	2.59	2.40	1.98	0.28	0.39
CD at 5%	-	-	3.59	-	-	-	-	-

Rec. = Recommended

Water soluble fertilizers (S_2) as such and their interaction with levels of fertigation did not influence cumulative uptake of water by cut flowers.

4.1.11.3 Cumulative loss of water by cut flowers

Non-significant results were obtained with regard to cumulative loss of water by cut flowers of carnation variety 'Trendy' as influenced by levels of fertigation, sources of fertilizers and their interactions.

4.1.11.4 Vase life

Significant differences with respect to vase life of cut flowers of carnation variety 'Trendy' were obtained between sources of fertilizers during rainy season. Water soluble fertilizers (S_2) effected in producing longer vase life (5.66 days) during rainy season. However, vase life did not differ significantly among levels of fertigation and interaction effects both during rainy and winter seasons.

4.1.12 ECONOMICS OF CARNATION GROWN UNDER DIFFERENT LEVELS OF FERTIGATION

The data on economics of carnation variety 'Trendy' grown under different levels of fertigation per hundred square meter per annum are presented in Table-21 (Fig.8).

Table-21 : Economics of carnation var. 'Trendy' grown under different levels of fertigation per 100 square meter per annum

Sl. No.	Particulars	Total cost (Rs.)	Depreciated cost of fixed costs (Rs.)	Treatments					
				T_1 (100% NF)	T_2 (100% WSF)	T_3 (80% NF)	T_4 (80% WSF)	T_5 (60% NF)	T_6 (60% WSF)
1.	FIXED COSTS								
a)	Structure (excluding cladding material) @ Rs. 300/Sq.m. for the life span of 10 years	30000	3000	-	-	-	-	-	-
b)	Cladding material + shade net @ Rs.35/sq.m for 380 square meter (280 sq.m + 100 sq.m) for the life span of 3 years	13300	4433	-	-	-	-	-	-
c)	Irrigation system (Drip) @ Rs.45/sq.m. for the life span of 10 years	4500	450	-	-	-	-	-	-
d)	Planting material @ Rs.11/rooted cutting (24 rooted cuttings/sq.m.) for 2 years for 70 square meter area.	18480	9240	-	-	-	-	-	-
e)	Framework for training @ Rs. 17.50/sq.m. for the life span of 2 years	1750	875	-	-	-	-	-	-
2.	REPAIR AND MAINTENANCE PER ANNUM	-	300	-	-	-	-	-	-
3.	INTEREST ON FIXED COSTS*	-	3240	-	-	-	-	-	-
4.	TOTAL APPORTIONAL COSTS**	-	21538	-	-	-	-	-	-
5.	COST OF CULTIVATION @ Rs. 120/sq.m./annum	-	-	12429	13246	12343	12997	12257	12748
6.	TOTAL COST OF CULTIVATION (4+5) (Rs.)	-	-	33967	34784	33881	34535	33795	34286
7.	REVENUE @ Rs.4/I Grade cutflower and Rs.2/II Grade cutflower	-	-	64800	74986	74510	106748	58848	89862
8.	NET PROFIT (Rs.) (7-6)	-	-	30833	40202	40629	72213	25053	55576
9.	BENEFIT : COST RATIO (8/6)	-	-	0.91	1.16	1.20	2.09	0.74	1.62

* $\frac{(a+c)\ 0.18}{\text{No.of years}} + \frac{(b)\ 0.18}{\text{No.of years}} + \frac{(d)\ 0.18}{\text{No.of years}} + \frac{(e)\ 0.18}{\text{No.of years}}$

** All depreciated costs (a+b+c+d+e+2+3)

NOTE : NF = Normal fertilizers
WSF = Water Soluble Fertilizers

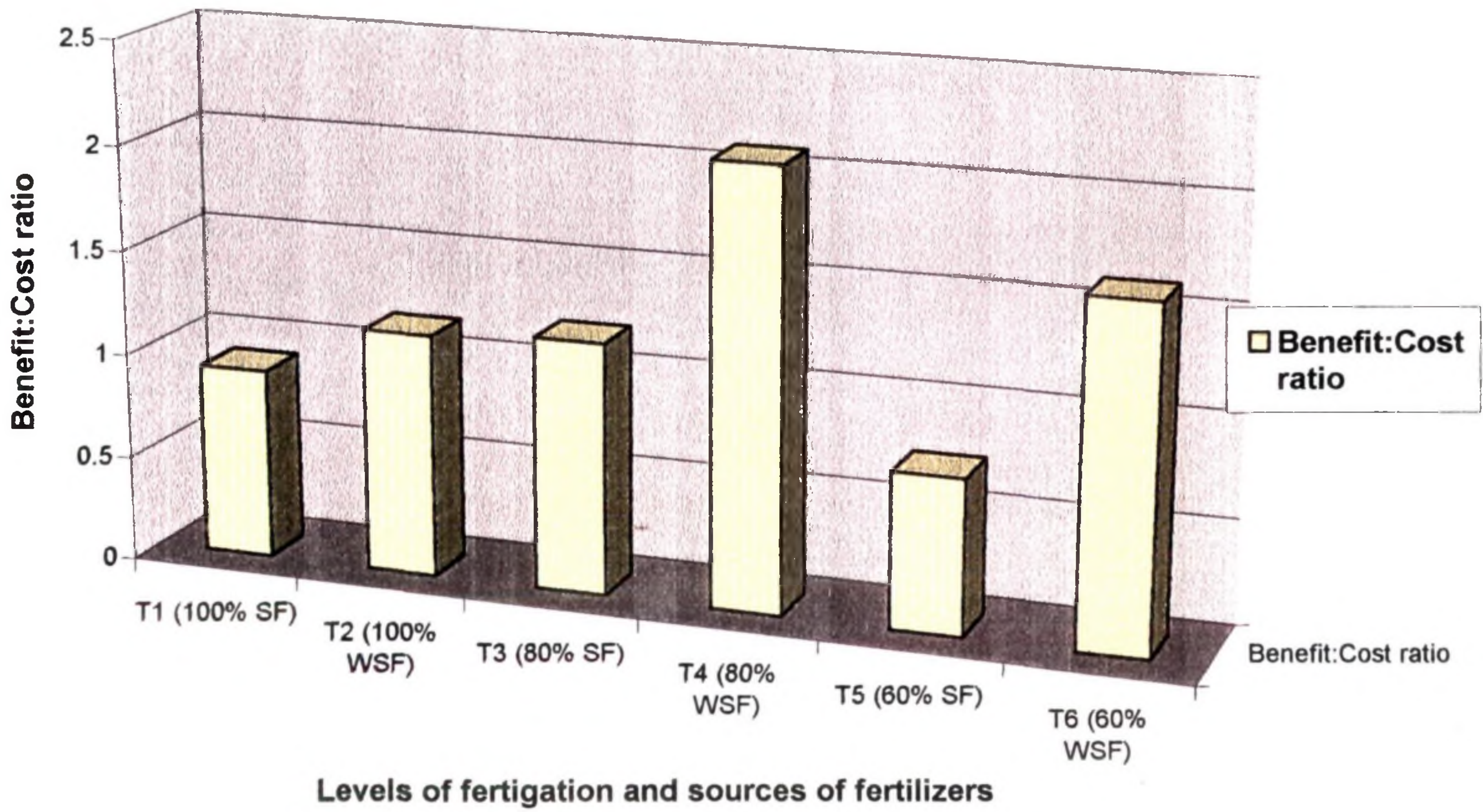


Fig. 8: Economics of carnation var. 'Trendy' per 100 square meter per annum as influenced by levels of fertigation and sources of fertilizers

Among different levels of fertigation, T_4 (80% recommended dose in the form of water soluble fertilizers) recorded the maximum revenue (Rs.1,06,748 / 100 sq.m./annum), net profit (Rs.72,213 / 100 sq.m./annum) and benefit : cost ratio (2.09).

4.2 EFFECTS OF BIOINOCULANT ON GROWTH, QUALITY AND PRODUCTIVITY OF STANDARD VARIETIES OF CARNATION GROWN UNDER COST-EFFECTIVE GREENHOUSE

4.2.1 HEIGHT OF PLANTS

The data on height of plants of different varieties of carnation at different days after planting and during winter and summer seasons as influenced by Azotobacter are presented in Table-22 and 23, respectively.

4.2.1.1 Height of plants at different days after planting

Height of plants differed significantly among varieties at different stages of plant growth. Variety 'Monaco' (V_1) produced significantly the tallest plants (104.37 cm) at 120 days after planting as compared with all the other varieties.

However, bio-inoculant treatments as well as interactions between varieties and bio-inoculant did not differ significantly.

4.2.1.2 Height of plants during winter and summer seasons

Height of plants differed significantly among varieties during both winter and summer seasons. In winter season, while all the varieties except

Table-22 : Height of carnation plants at different days after planting as influenced by varieties, Azotobacter and their interactions

Particulars	Height of plants (cm)						
	30 DAP	45 DAP	60 DAP	75 DAP	90 DAP	105 DAP	120 DAP
Varieties							
V_1(Monaco)	11.85^b	29.28^a	34.38^b	44.43^b	59.72^c	80.52^b	104.37^a
V_2(Gold Rush)	13.37^a	28.18^{ab}	38.52^a	54.18^a	77.93^a	90.68^a	97.62^b
V_3(Regina)	9.68^c	23.28^c	26.08^c	30.33^d	36.13^e	46.07^d	66.18^d
V_4(Internet)	13.20^{ab}	27.12^b	37.79^a	54.87^a	70.70^b	81.12^b	87.43^c
V_5(Trendy)	12.37^{ab}	26.85^b	32.62^b	39.47^c	44.90^d	54.28^c	70.65^d
'F' test	*	*	*	*	*	*	*
S.Em±	0.45	0.60	0.68	1.31	1.34	1.53	1.68
CD at 5%	1.35	1.77	2.03	3.88	3.97	4.54	4.99
Bio-inoculant							
B_1(Without Azotobacter)	12.45	27.25	34.05	44.50	58.38	69.66	85.60
B_2(With Azotobacter)	11.74	26.64	33.71	44.81	57.37	71.41	84.90
'F' test	NS	NS	NS	NS	NS	NS	NS
S.Em±	0.29	0.38	0.43	0.83	0.85	0.97	1.06
CD at 5%	-	-	-	-	-	-	-
Interactions							
V_1B_1	12.37	29.47	34.47	45.53	60.47	79.97	104.53
V_1B_2	11.33	29.10	34.30	43.33	58.97	81.07	104.20
V_2B_1	13.33	29.30	39.13	53.23	79.23	89.52	73.30
V_2B_2	13.40	27.07	37.90	55.13	76.63	91.83	79.00
V_3B_1	10.73	23.67	26.77	31.30	37.83	46.83	65.57
V_3B_2	8.63	22.90	25.40	29.37	34.43	45.30	66.80
V_4B_1	13.30	27.47	37.89	53.53	71.43	81.03	88.93
V_4B_2	13.10	26.77	37.70	56.20	69.97	81.20	85.93
V_5B_1	12.50	26.33	32.00	38.90	42.93	50.93	71.63
V_5B_2	12.23	27.37	33.23	40.03	46.87	57.63	69.67
'F' test	NS	NS	NS	NS	NS	NS	NS
S.Em±	0.64	0.84	0.96	1.85	1.89	2.16	2.38
CD at 5%	-	-	-	-	-	-	-

DAP = Days after planting

Table-23 : Height of carnation plants in winter and summer seasons as influenced by varieties, Azotobacter and their interactions

Particulars	Height of plants (cm)	
	Winter (Nov.'97 –Jan.'98)	Summer (Feb.'98 – April'98)
Varieties		
V_1(Monaco)	109.67^{a}	145.68^{a}
V_2(Gold Rush)	104.50^{ab}	122.78^{b}
V_3(Regina)	101.80^{ab}	111.98^{c}
V_4(Internet)	99.43^{b}	106.83^{c}
V_5(Trendy)	78.70^{c}	92.37^{d}
'F' test	*	*
S.Em±	3.04	2.32
CD at 5%	9.04	6.89
Bio-inoculant		
B_1(Without Azotobacter)	99.21	116.35
B_2(With Azotobacter)	98.43	115.51
'F' test	NS	NS
S.Em±	1.93	1.47
CD at 5%	-	-
Interactions		
V_1B_1	108.53	148.20
V_1B_2	110.80	143.17
V_2B_1	103.73	118.17
V_2B_2	105.27	127.40
V_3B_1	101.80	114.42
V_3B_2	101.80	109.53
V_4B_1	100.40	107.78
V_4B_2	98.47	105.87
V_5B_1	81.60	93.16
V_5B_2	75.80	91.57
'F' test	NS	NS
S.Em±	4.31	3.28
CD at 5%	-	-

'Internet' (V_4) and 'Trendy' (V_5) produced shorter plants, only 'Monaco' attained the tallest stature (145.68 cm) when compared with all the other varieties during summer.

Whereas, the differences were non-significant between bio-inoculant treatments as well as among interactions between varieties and bio-inoculant in both the seasons.

4.2.2 NUMBER OF LATERALS PER PLANT

The data pertaining to number of laterals that were produced by different varieties of carnation at different days and during winter and summer seasons as influenced by Azotobacter are presented in Table-24 and 25, respectively.

4.2.2.1 Number of laterals per plant at different days after planting

Number of laterals produced per plant differed significantly among varieties at different days after planting. 'Trendy' (V_5) produced the maximum number of laterals (5.7 laterals / plant) at 105 days after planting, as compared with all the other varieties.

However, the influence of bio-inoculant did not have any favourable effect on production of laterals. Interactions between varieties and bio-inoculant were not significant at different stages of growth.

Table-24 : Number of laterals produced per plant as influenced by varieties, Azotobacter and their interactions

Particulars	Number of laterals / plant				
	45 DAP	60 DAP	75 DAP	90 DAP	105 DAP
Varieties					
V_1(Monaco)	3.33 [c]	3.63 [d]	4.23 [d]	4.28 [c]	4.57 [cd]
V_2(Gold Rush)	3.90 [c]	4.10 [c]	4.23 [d]	4.40 [c]	4.33 [d]
V_3(Regina)	4.27 [b]	4.47 [b]	4.83 [b]	4.93 [b]	5.10 [b]
V_4(Internet)	4.30 [b]	4.53 [b]	4.77 [c]	4.87 [b]	4.87 [bc]
V_5(Trendy)	5.00 [a]	5.23 [a]	5.50 [a]	5.67 [a]	5.70 [a]
'F' test	*	*	*	*	*
S.Em±	0.15	0.11	0.12	0.11	0.11
CD at 5%	0.46	0.34	0.35	0.33	0.34
Bio-inoculant					
B_1(Without Azotobacter)	4.29	4.52 [a]	4.81	4.90	5.00
B_2(With Azotobacter)	4.03	4.27 [b]	4.61	4.76	4.83
'F' test	NS	*	NS	NS	NS
S.Em±	0.10	0.07	0.08	0.07	0.07
CD at 5%	-	0.21	-	-	-
Interactions					
V_1B_1	3.67	3.80	4.47	4.50	4.80
V_1B_2	3.00	3.47	4.00	4.07	4.33
V_2B_1	3.93	4.13	4.40	4.47	4.47
V_2B_2	3.87	4.07	4.07	4.33	4.20
V_3B_1	4.40	4.60	4.93	5.00	5.20
V_3B_2	4.13	4.33	4.73	4.87	5.00
V_4B_1	4.40	4.60	4.73	4.80	4.80
V_4B_2	4.20	4.47	4.80	4.93	4.93
V_5B_1	5.07	5.47	5.53	5.73	5.73
V_5B_2	4.93	5.00	5.47	5.60	5.67
'F' test	NS	NS	NS	NS	NS
S.Em±	0.22	0.16	0.17	0.16	0.16
CD at 5%	-	-	-	-	-

DAP = Days after planting

Table-25 : Number of laterals produced per plant during winter and summer seasons as influenced by varieties, Azotobacter and their interactions

Particulars	Number of laterals / plant	
	Winter (Nov.'97 –Jan.'98)	Summer (Feb.'98 – April.'98)
Varieties		
V_1(Monaco)	3.33[ab]	3.40[c]
V_2(Gold Rush)	2.80[b]	3.07[c]
V_3(Regina)	3.70[a]	5.93[a]
V_4(Internet)	2.88[b]	2.83[c]
V_5(Trendy)	3.83[a]	4.02[b]
'F' test	*	*
S.Em±	0.26	0.21
CD at 5%	0.78	0.61
Bio-inoculant		
B_1(Without Azotobacter)	3.73[a]	4.01
B_2(With Azotobacter)	2.89[b]	3.69
'F' test	*	NS
S.Em±	0.17	0.13
CD at 5%	0.50	-
Interactions		
V_1B_1	3.87	3.47
V_1B_2	2.80	3.33
V_2B_1	3.13	3.47
V_2B_2	2.47	2.67
V_3B_1	4.07	6.13
V_3B_2	3.33	5.73
V_4B_1	3.67	3.00
V_4B_2	2.10	2.67
V_5B_1	3.93	4.00
V_5B_2	3.73	4.03
'F' test	NS	NS
S.Em±	0.37	0.29
CD at 5%	-	-

4.2.2.2 Number of laterals per plant during winter and summer seasons

Significant differences in the number of laterals produced per plant were obtained among varieties during winter and summer seasons. While 'Monaco' (V_1), 'Regina' (V_3) and 'Trendy' (V_5) were found to be on par and significantly superior in producing more number of laterals (3.33, 3.70 and 3.83 laterals / plant, respectively), as compared to others during winter, 'Regina' (V_3) produced the maximum number of laterals (5.93 laterals / plant) during summer.

Use of bio-inoculant did not have any beneficial effect on production of laterals per plant.

Interaction effects did not differ significantly during both the seasons.

4.2.3 Number of pairs of leaves per lateral

The data on number of pairs of leaves produced per lateral by different varieties of carnation at the time of bud appearance in different seasons as influenced by Azotobacter are presented in Table-26.

Number of pairs of leaves produced per lateral during rainy, winter and summer seasons differed significantly among varieties. While 'Monaco' (V_1), 'Gold Rush' (V_2) and 'Internet' (V_4) were on par (15.83, 15.93 and 14.93 pairs of leaves / lateral, respectively) and produced higher number of pairs of leaves per lateral over the other varieties during rainy season, 'Regina' (V_3) produced

Table-26 : Number of pairs leaves per lateral in different seasons as influenced by varieties, Azotobacter and their interactions

Particulars	Number of pairs of leaves / lateral at bud appearance		
	Rainy (July'97 –Oct.'97)	Winter (Nov.'97 –Jan.'98)	Summer (Feb.'98–April'98)
Varieties			
V_1(Monaco)	15.83[a]	18.80[b]	11.31[c]
V_2(Gold Rush)	15.93[a]	18.90[b]	13.68[abc]
V_3(Regina)	13.84[b]	23.20[a]	14.82[a]
V_4(Internet)	14.93[ab]	17.43[bc]	14.67[ab]
V_5(Trendy)	12.33[c]	16.93[c]	12.16[bc]
'F' test	*	*	*
S.Em±	0.45	0.58	0.86
CD at 5%	1.34	1.73	2.56
Bio-inoculant			
B_1(Without Azotobacter)	14.84	19.75[a]	13.42
B_2(With Azotobacter)	14.31	18.36[b]	13.23
'F' test	NS	*	NS
S.Em±	0.28	0.37	0.54
CD at 5%	-	1.09	-
Interactions			
V_1B_1	15.87	19.87	11.73
V_1B_2	15.80	17.73	10.89
V_2B_1	16.07	19.07	13.20
V_2B_2	15.80	18.73	14.17
V_3B_1	14.47	23.67	15.00
V_3B_2	13.22	22.73	14.64
V_4B_1	14.87	18.67	15.38
V_4B_2	15.00	16.20	13.97
V_5B_1	12.93	17.47	11.80
V_5B_2	11.73	16.40	12.51
'F' test	NS	NS	NS
S.Em±	0.64	0.82	1.22
CD at 5%	-	-	-

the highest number (23.20 pairs of leaves / lateral) during winter, and 'Gold Rush' (V_2), 'Regina' (V_3) and 'Internet' (V_4) which were on par (13.68, 14.82, 14.67 pairs of leaves / lateral, respectively) produced higher number as compared with the other varieties, during summer.

In general, it could be inferred that Azotobacter did not have any positive influence on production of leaves in any of the seasons.

Interaction effects of varieties with bio-inoculant were, however, non-significant during all the three seasons.

4.2.4 DAYS TAKEN FOR FIRST FLOWER BUD'S APPEARANCE, DEVELOPMENT AND HARVEST, AND FIFTY PER CENT FLOWERING

The data pertaining to the number of days taken for first flower bud's appearance, development and harvest, and fifty per cent flowering by different varieties of carnation as influenced by Azotobacter are presented in Table-27 (Fig.9).

Varieties differed significantly for all the above parameters. 'Regina' (V_3) took more number of days not only for first flower bud's appearance (108.33 days) but also for development (on par with 'Monaco'; 27 and 22 days, respectively), for harvest (135.33 days) and for 50 per cent flowering (178.17 days) as compared with all the other varieties.

Table-27 : Days taken for first flower bud's appearance, development, harvest and fifty per cent flowering in carnation as influenced by varieties, Azotobacter and their interactions

Particulars	Days taken for first flower bud's			Days for 50% flowering
	Appearance	Development	Harvest	
Varieties				
V_1(Monaco)	102.67 [b]	22.00 [ab]	124.67 [b]	151.00 [b]
V_2(Gold Rush)	84.00 [d]	18.17 [b]	102.17 [d]	134.33 [d]
V_3(Regina)	108.33 [a]	27.00 [a]	135.33 [a]	178.17 [a]
V_4(Internet)	87.50 [d]	20.00 [b]	107.50 [cd]	134.67 [d]
V_5(Trendy)	97.17 [c]	17.83 [b]	115.00 [c]	144.67 [c]
'F' test	*	*	*	*
S.Em±	1.33	1.95	2.64	1.84
CD at 5%	3.95	5.78	7.84	5.46
Bio-inoculant				
B_1(Without Azotobacter)	96.80	20.33	117.13	150.20
B_2(With Azotobacter)	95.07	21.67	116.73	146.93
'F' test	NS	NS	NS	NS
S.Em±	0.84	1.23	1.67	1.16
CD at 5%	-	-	-	-
Interactions				
V_1B_1	104.00	19.67	123.67	152.00
V_1B_2	101.33	24.33	125.67	150.00
V_2B_1	83.67	17.00	100.67	135.00
V_2B_2	84.33	19.33	103.67	133.33
V_3B_1	110.33	28.33	138.67	178.00
V_3B_2	106.33	25.67	132.00	178.33
V_4B_1	87.00	19.33	106.33	136.33
V_4B_2	88.00	20.67	108.67	133.00
V_5B_1	99.00	17.33	116.33	149.33
V_5B_2	95.33	18.33	113.67	140.00
'F' test	NS	NS	NS	NS
S.Em±	1.88	2.75	3.73	2.60
CD at 5%	-	-	-	-

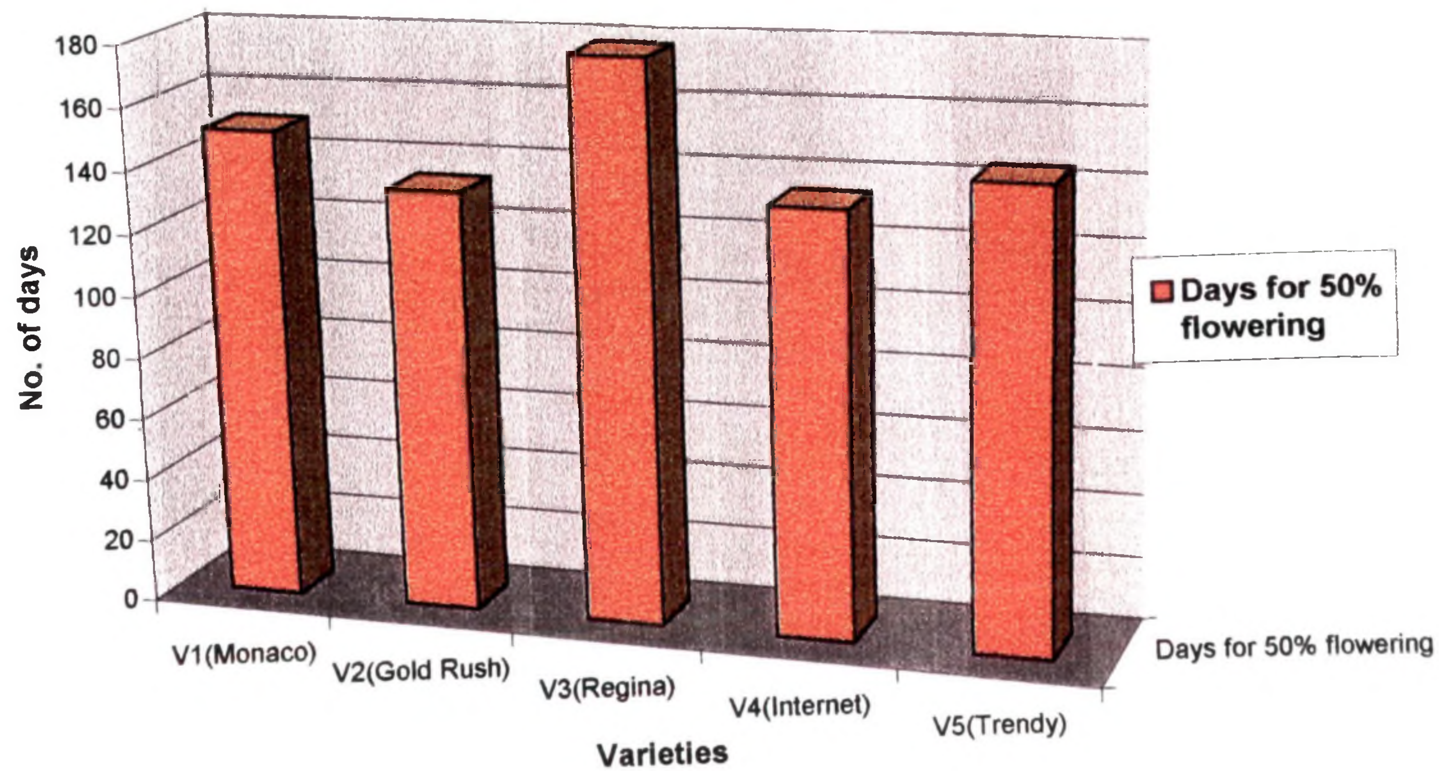


Fig.9 : Number of days taken for 50 per cent flowering in carnation varieties

Neither bio-inoculant's effect nor its interaction with varieties were significant.

4.2.5 LENGTH AND THICKNESS OF FLOWER BUDS

The data pertaining to length and thickness of flower buds of different varieties of carnation in different seasons as influenced by Azotobacter are presented in Table-28 and 29, respectively.

4.2.5.1 Length of flower buds during different seasons

Length of flower buds differed significantly among varieties during rainy and winter seasons. 'Monaco' (V_1), 'Gold Rush' (V_2) and 'Internet' (V_4) were on par (3.03 cm, 3.08 cm and 2.90 cm, respectively) and significantly superior over 'Regina' (V_3) and 'Trendy' (V_5) in producing longer flower buds during rainy season. Whereas during winter, all the varieties except 'Trendy' (V_5) were on par and produced longer flower buds. However, the differences were non-significant during summer.

Neither bio-inoculant nor its interaction with varieties significantly influenced length of carnation flower buds in any of the seasons.

4.2.5.2 Thickness of flower buds during different seasons

Significant differences in thickness of flower buds were obtained among varieties during rainy, winter and summer seasons. While 'Regina' (V_3) produced significantly thickest flower buds during rainy (2.12 cm) and

Table-28 : Length of carnation flower buds in different seasons as influenced by varieties, Azotobacter and their interactions

Particulars	Length of flower buds (cm)		
	Rainy (July'97 –Oct.'97)	Winter (Nov.'97 –Jan.'98)	Summer (Feb.'98–April'98)
Varieties			
V_1(Monaco)	3.03 [ab]	2.63 [a]	2.93
V_2(Gold Rush)	3.08 [a]	2.35 [a]	2.86
V_3(Regina)	2.87 [b]	2.54 [a]	2.74
V_4(Internet)	2.90 [ab]	2.51 [a]	2.46
V_5(Trendy)	2.21 [c]	1.85 [b]	2.48
'F' test	*	*	NS
S.Em±	0.07	0.15	0.15
CD at 5%	0.20	0.45	-
Bio-inoculant			
B_1(Without Azotobacter)	2.83	2.29	2.79
B_2(With Azotobacter)	2.81	2.46	2.59
'F' test	NS	NS	NS
S.Em±	0.04	0.10	0.10
CD at 5%	-	-	-
Interactions			
V_1B_1	3.01	2.42	2.75
V_1B_2	3.05	2.83	3.10
V_2B_1	3.09	2.47	2.92
V_2B_2	3.07	2.23	2.80
V_3B_1	2.87	2.58	2.97
V_3B_2	2.88	2.50	2.50
V_4B_1	2.95	2.31	2.76
V_4B_2	2.86	2.72	2.17
V_5B_1	2.22	1.70	2.57
V_5B_2	2.19	2.00	2.39
'F' test	NS	NS	NS
S.Em±	0.10	0.22	0.22
CD at 5%	-	-	-

Table-29 : Thickness of carnation flower buds in different seasons as influenced by varieties, Azotobacter and their interactions

Particulars	Thickness of flower buds (mm)		
	Rainy (July'97 –Oct.'97)	Winter (Nov.'97 –Jan.'98)	Summer (Feb.'98–Apri'98)
Varieties			
V_1(Monaco)	1.77 [cd]	1.25 [b]	1.61 [bc]
V_2(Gold Rush)	1.86 [bc]	1.46 [ab]	1.72 [b]
V_3(Regina)	2.12 [a]	1.58 [a]	2.02 [a]
V_4(Internet)	1.91 [b]	1.43 [ab]	1.56 [bc]
V_5(Trendy)	1.71 [d]	1.24 [b]	1.47 [c]
'F' test	*	*	*
S.Em±	0.03	0.09	0.08
CD at 5%	0.09	0.25	0.23
Bio-inoculant			
B_1(Without Azotobacter)	1.90	1.45	1.68
B_2(With Azotobacter)	1.84	1.34	1.67
'F' test	NS	NS	NS
S.Em±	0.02	0.05	0.05
CD at 5%	-	-	-
Interactions			
V_1B_1	1.76	1.27	1.63 [bcd]
V_1B_2	1.77	1.23	1.58 [cd]
V_2B_1	1.91	1.53	1.62 [bcd]
V_2B_2	1.81	1.38	1.83 [abc]
V_3B_1	2.21	1.73	2.11 [a]
V_3B_2	2.02	1.43	1.92 [ab]
V_4B_1	1.93	1.52	1.76 [bc]
V_4B_2	1.87	1.34	1.37 [d]
V_5B_1	1.69	1.18	1.30 [d]
V_5B_2	1.73	1.30	1.63 [bcd]
'F' test	NS	NS	*
S.Em±	0.04	0.12	0.11
CD at 5%	-	-	0.33

summer (2.02 cm) seasons, 'Gold Rush' (V_2), 'Regina' (V_3) and 'Internet' (V_4) were on par and significantly superior over others during winter.

Bio-inoculant had no influence on increasing thickness of flower buds in any of the seasons.

Interaction effects were significant during summer season.

4.2.6 LENGTH AND GIRTH OF CUT FLOWER STALKS

The data pertaining to length and girth of flower stalks of different varieties of carnation in different seasons as influenced by Azotobacter are presented in Table-30 and 31, respectively.

4.2.6.1 Length of cut flower stalks

Length of flower stalks differed significantly among varieties (Plate-14) in all the three seasons viz., rainy, winter and summer. While 'Monaco' (V_1) produced the longest stalks (79.28 cm) during rainy season, 'Monaco' (V_1) and 'Gold Rush' (V_2) were on par and produced longer stalks during winter (82.98 cm and 83 cm, respectively) and summer (86.97 cm and 87.65 cm, respectively) seasons.

Bio-inoculant as such and its interaction with varieties did not produce significant differences.

Table-30 : Length of cut carnation stalks in different seasons as influenced by varieties, Azotobacter and their interactions

Particulars	Length of cut carnation stalks (cm)		
	Rainy (July'97 –Oct.'97)	Winter (Nov.'97 –Jan.'98)	Summer (Feb.'98–April'98)
Varieties			
V_1(Monaco)	79.28 [a]	82.98 [a]	86.97 [a]
V_2(Gold Rush)	64.40 [b]	83.00 [a]	87.65 [a]
V_3(Regina)	66.92 [b]	69.85 [b]	75.04 [b]
V_4(Internet)	62.76 [bc]	73.64 [b]	75.32 [b]
V_5(Trendy)	57.50 [c]	58.74 [c]	58.63 [c]
'F' test	*	*	*
S.Em±	2.29	3.13	2.96
CD at 5%	6.81	9.30	8.78
Bio-inoculant			
B_1(Without Azotobacter)	66.49	72.17	77.20
B_2(With Azotobacter)	65.85	75.11	76.24
'F' test	NS	NS	NS
S.Em±	1.45	1.98	1.87
CD at 5%	-	-	-
Interactions			
V_1B_1	82.22	77.72	88.03
V_1B_2	76.33	88.24	85.92
V_2B_1	60.83	87.39	88.07
V_2B_2	67.98	78.61	87.22
V_3B_1	68.19	68.63	79.25
V_3B_2	65.64	71.08	70.83
V_4B_1	63.73	71.70	74.36
V_4B_2	61.79	75.57	76.28
V_5B_1	57.50	55.42	56.32
V_5B_2	57.50	62.06	60.94
'F' test	NS	NS	NS
S.Em±	3.24	4.43	4.18
CD at 5%	-	-	-

Table-31 : Girth of carnation stalks in different seasons as influenced by varieties, Azotobacter and their interactions

Particulars	Girth of cut carnation stalks (mm)		
	Rainy (July'97 –Oct.'97)	Winter (Nov.'97 –Jan.'98)	Summer (Feb.'98–April'98)
Varieties			
V_1(Monaco)	3.04	2.99 [a]	3.28 [ab]
V_2(Gold Rush)	3.03	2.86 [a]	3.35 [a]
V_3(Regina)	3.29	3.15 [a]	3.21 [ab]
V_4(Internet)	3.14	2.90 [a]	2.77 [c]
V_5(Trendy)	3.13	2.36 [b]	2.90 [bc]
'F' test	NS	*	*
S.Em±	0.12	0.11	0.13
CD at 5%	-	0.32	0.39
Bio-inoculant			
B_1(Without Azotobacter)	3.09	2.82	3.18
B_2(With Azotobacter)	3.15	2.88	3.02
'F' test	NS	NS	NS
S.Em±	0.08	0.07	0.08
CD at 5%	-	-	-
Interactions			
V_1B_1	3.00	2.96	3.76 [a]
V_1B_2	3.08	3.01	2.80 [cd]
V_2B_1	2.97	2.92	3.30 [abc]
V_2B_2	3.08	2.81	3.41 [ab]
V_3B_1	3.10	3.02	3.36 [abc]
V_3B_2	3.47	3.28	3.06 [bcd]
V_4B_1	3.16	2.85	2.59 [d]
V_4B_2	3.11	2.95	2.95 [bcd]
V_5B_1	3.22	2.36	2.91 [bcd]
V_5B_2	3.03	2.36	2.89 [bcd]
'F' test	NS	NS	*
S.Em±	0.18	0.15	0.19
CD at 5%	-	-	0.56

4.2.6.2 Girth of cut flower stalks

Girth of carnation stalks differed significantly among varieties during winter and summer seasons. While higher girth of carnation stalks produced by varieties 'Monaco' (V_1), 'Gold Rush' (V_2), 'Regina' (V_3) and 'Internet' (V_4) were on par (2.99 mm, 2.86 mm, 3.15 mm and 2.90 mm, respectively) compared to 'Trendy' (V_5) during winter, 'Monaco' (V_1), 'Gold Rush' (V_2) and 'Regina' (V_3) were on par (3.28 mm, 3.35 mm and 3.31 mm, respectively) and significantly superior over the others during summer.

Bio-inoculant did not influence girth of carnation flower stalk.

Interaction effects were significant during summer season.

4.2.7 NUMBER OF PETALS PER FLOWER HEAD

The data on number of petals per flower head of different varieties of carnation in different seasons as influenced by Azotobacter are presented in Table-32.

Number of petals per flower head differed significantly between varieties during all the three seasons viz., rainy, winter and summer. While 'Regina' (V_3) and 'Gold Rush' (V_2) were significantly superior over all others during rainy and winter seasons, respectively, and produced maximum number of petals per flower head (71.78 and 75.88 petals / flower head, Table-32 : Number of petals per flower head of carnation in different seasons as influenced by varieties, Azotobacter and their interactions

Particulars	Number of petals / flower head		
	Rainy (July'97 –Oct.'97)	Winter (Nov.'97 –Jan.'98)	Summer (Feb.'98–April'98)
Varieties			
V_1(Monaco)	42.00[c]	52.58[c]	48.92[c]
V_2(Gold Rush)	62.67[b]	75.88[a]	56.39[b]
V_3(Regina)	71.78[a]	68.17[b]	65.84[a]
V_4(Internet)	65.01[b]	51.97[c]	65.13[a]
V_5(Trendy)	62.25[b]	67.60[b]	67.19[a]
'F' test	*	*	*
S.Em±	1.78	2.08	2.04
CD at 5%	5.30	6.18	6.07
Bio-inoculant			
B_1(Without Azotobacter)	58.81[b]	58.89[b]	59.55
B_2(With Azotobacter)	62.67[a]	67.59[a]	61.83
'F' test	*	*	NS
S.Em±	1.13	1.32	1.29
CD at 5%	3.35	3.91	-
Interactions			
V_1B_1	34.00[f]	44.17	39.67[c]
V_1B_2	50.00[e]	61.00	58.17[b]
V_2B_1	62.17[cd]	73.58	55.66[b]
V_2B_2	63.17[bcd]	78.17	57.11[b]
V_3B_1	73.57[a]	64.71	64.50[ab]
V_3B_2	70.00[ab]	71.62	67.17[a]
V_4B_1	66.28[abc]	48.78	67.42[a]
V_4B_2	63.75[bcd]	55.17	62.83[ab]
V_5B_1	58.05[d]	63.21	70.50[a]
V_5B_2	66.44[abc]	71.99	63.88[ab]
'F' test	*	NS	*
S.Em±	2.52	2.94	2.89
CD at 5%	7.50	-	8.58

respectively), 'Regina' (V_3), 'Internet' (V_4) and 'Trendy' (V_5) were on par and produced higher number of petals per flower head during summer.

Bio-inoculants influenced in producing higher number of petals per flower head during rainy and winter seasons (62.67 abd 67.59 petals/flower head, respectively).

Interaction effects differed significantly during rainy and summer seasons.

4.2.8 Diameter of cut flowers

The data on diameter of cut flowers of different varieties of carnation in different seasons as influenced by Azotobacter are presented in Table-33 (Plate-13).

Diameter of cut flowers differed significantly among varieties during all the three seasons viz., rainy, winter and summer. Significantly higher diameter of carnation cut flowers was produced by varieties 'Gold Rush' (V_2), 'Internet' (V_4) and 'Trendy' (V_5) which were on par during rainy, 'Monaco' (V_1), 'Gold Rush' (V_2) and 'Trendy' (V_5) which were on par during winter, and 'Gold Rush' (V_2), 'Regina' (V_3), 'Internet' (V_4) and 'Trendy' (V_5) which were on par during summer seasons.

Table-33 : Diameter of carnation flowers in different seasons as influenced by varieties, Azotobacter and their interactions

Particulars	Diameter of cut carnation flowers (cm)		
	Rainy (July'97 –Oct.'97)	Winter (Nov.'97 –Jan.'98)	Summer (Feb.'98–April'98)
Varieties			
V_1(Monaco)	6.44^{b}	6.46^{abc}	4.62^{b}
V_2(Gold Rush)	6.94^{a}	6.86^{ab}	5.36^{a}
V_3(Regina)	6.42^{b}	6.08^{c}	5.25^{a}
V_4(Internet)	6.58^{ab}	6.31^{bc}	4.91^{ab}
V_5(Trendy)	6.75^{ab}	6.88^{a}	5.30^{a}
'F' test	*	*	*
S.Em±	0.12	0.18	0.15
CD at 5%	0.36	0.55	0.45
Bio-inoculant			
B_1(Without Azotobacter)	6.75^{a}	6.15	5.36^{a}
B_2(With Azotobacter)	6.50^{b}	6.08	4.81^{b}
'F' test	*	NS	*
S.Em±	0.08	0.12	0.10
CD at 5%	0.23	-	0.28
Interactions			
V_1B_1	6.48	6.58	4.86
V_1B_2	6.39	6.35	4.39
V_2B_1	7.03	6.86	5.70
V_2B_2	6.85	6.86	5.02
V_3B_1	6.54	5.83	5.73
V_3B_2	6.31	6.33	4.76
V_4B_1	6.70	6.45	5.02
V_4B_2	6.47	6.17	4.79
V_5B_1	7.00	5.03	5.50
V_5B_2	6.50	4.72	5.09
'F' test	NS	NS	NS
S.Em±	0.17	0.26	0.21
CD at 5%	-	-	-

Plate 12 : Carnation Var. 'Trendy' in flowering

Plate 13 : A top view of carnation flowers depicting differential diameter


TRENDY
INTERNET
GOLDRUSH
REGINA
MONACO

Azotobacter did not influence the diameter of carnation cut flowers in any of the seasons.

Non-significant differences were obtained among interactions between bio-inoculant and varieties in all the three seasons.

4.2.9 YIELD OF CUT FLOWERS

4.2.9.1 Yield of first grade cut flowers per square meter

The data on yield of first grade cut flowers of different varieties of carnation per square meter in different seasons as influenced by Azotobacter are presented in Table-34 (Fig.10).

Number of first grade cut flowers obtained per square meter during all the three seasons viz., rainy, winter and summer and cumulative yield differed significantly among varieties. During rainy season, varieties 'Gold Rush' (V_2), 'Internet' (V_4) and 'Trendy' (V_5) were on par and produced higher yield of first grade cut flowers per square meter, while 'Trendy' (V_5) was significantly superior over all the others and produced maximum seasonal i.e., winter and summer (79.55 and 93.77 cut flowers / sq.m., respectively) and cumulative (276.25 cut flowers/sq.m.) yields of first grade cut flowers.

Bio-inoculant influenced in producing higher number of first grade cut flowers per square meter during summer.

Table-34 : Yield of first grade cut carnation flowers per square meter in different seasons as influenced by varieties, Azotobacter and their interactions

Particulars	No. of first grade cut flowers/sq.m.			
	Rainy (July'97 – Oct.'97)	Winter (Nov.'97 – Jan.'98)	Summer (Feb.'98– April'98)	Cumulative (1997-98)
Varieties				
V_1(Monaco)	80.41 [bc]	21.02 [c]	24.44 [c]	124.87 [c]
V_2(Gold Rush)	83.86 [ab]	53.59 [b]	42.32 [b]	179.77 [b]
V_3(Regina)	60.03 [c]	30.70 [c]	27.51 [c]	118.25 [c]
V_4(Internet)	94.43 [ab]	50.31 [b]	44.38 [b]	189.13 [b]
V_5(Trendy)	102.93 [a]	79.55 [a]	93.77 [a]	276.25 [a]
'F' test	*	*	*	*
S.Em±	7.35	4.51	3.23	8.18
CD at 5%	21.83	13.41	9.60	24.32
Bio-inoculant				
B_1(Without Azotobacter)	83.93	43.28	43.32 [b]	170.14
B_2(With Azotobacter)	84.74	50.79	49.64 [a]	185.17
'F' test	NS	NS	*	NS
S.Em±	4.65	2.85	2.04	5.18
CD at 5%	-	-	6.07	-
Interactions				
V_1B_1	78.15	19.48	23.24 [e]	118.87 [d]
V_1B_2	82.68	22.56	25.63 [e]	130.86 [d]
V_2B_1	87.10	51.83	43.76 [cd]	182.69 [c]
V_2B_2	80.62	53.36	40.87 [cd]	176.85 [c]
V_3B_1	61.87	25.53	31.12 [de]	118.51 [d]
V_3B_2	58.20	35.87	23.91 [e]	117.98 [d]
V_4B_1	93.15	47.14	44.93 [c]	185.23 [c]
V_4B_2	95.72	53.48	43.82 [cd]	193.02 [c]
V_5B_1	99.40	72.43	73.56 [b]	245.39 [b]
V_5B_2	106.47	86.67	113.99 [a]	307.12 [a]
'F' test	NS	NS	*	*
S.Em±	10.39	6.38	4.57	11.57
CD at 5%	-	-	13.58	34.38

Interactions between varieties and bio-inoculant were significant with respect to number of first grade cut flowers during summer and cumulative yield.

4.2.9.2 Per cent yield of first grade cut flowers

The data on per cent yield of first grade cut flowers of different varieties of carnation in different seasons as influenced by Azotobacter are presented in Table-35.

Per cent seasonal and cumulative yields of first grade cut flowers differed significantly among varieties. While, 'Trendy' (V_5) produced significantly higher per cent yield of first grade cut flowers (98.36%) over all the other varieties during rainy season, 'Regina' (V_3) and 'Trendy' (V_5) were on par and produced higher per cent yield during winter and summer. However, 'Trendy' (V_5) was found to be on par with 'Gold Rush' (V_2) and 'Regina' (V_3) in producing higher cumulative yield of per cent first grade cut flowers.

Non-significant results were obtained with respect to bio-inoculant treatments.

Significant differences among interactions between varieties and bio-inoculant were obtained during rainy season.

Table-35 : Per cent yield of first grade cut carnation flowers in different seasons as influenced by varieties, Azotobacter and their interactions

Particulars	Per cent yield of first grade cut flowers			
	Rainy (July'97 – Oct.'97)	Winter (Nov.'97 – Jan.'98)	Summer (Feb.'98– April'98)	Cumulative (1997-98)
Varieties				
V_1(Monaco)	96.49 [e]	92.65 [d]	88.30 [d]	93.38 [c]
V_2(Gold Rush)	97.50 [c]	95.83 [b]	93.33 [c]	96.06 [ab]
V_3(Regina)	98.08 [b]	96.84 [a]	94.80 [ab]	97.07 [a]
V_4(Internet)	96.98 [d]	95.20 [c]	94.19 [b]	95.12 [b]
V_5(Trendy)	98.36 [a]	96.88 [a]	95.05 [a]	96.81 [a]
'F' test	*	*	*	*
S.Em±	0.08	0.20	0.26	0.45
CD at 5%	0.23	0.58	0.77	1.33
Bio-inoculant				
B_1(Without Azotobacter)	97.45	95.44	92.71	95.56
B_2(With Azotobacter)	97.52	95.52	92.35	95.82
'F' test	NS	NS	NS	NS
S.Em±	0.05	0.12	0.16	0.28
CD at 5%	-	-	-	-
Interactions				
V_1B_1	96.47 [e]	92.73	88.29	92.63
V_1B_2	96.51 [e]	92.56	88.30	94.14
V_2B_1	97.49 [c]	95.80	93.78	96.19
V_2B_2	97.52 [c]	95.85	92.88	95.92
V_3B_1	98.18 [b]	97.00	95.27	97.15
V_3B_2	97.98 [b]	96.68	94.32	96.98
V_4B_1	97.02 [d]	94.77	91.09	94.97
V_4B_2	96.94 [d]	95.62	91.28	95.27
V_5B_1	98.07 [b]	96.87	95.13	96.85
V_5B_2	98.65 [a]	96.90	94.97	96.77
'F' test	*	NS	NS	NS
S.Em±	0.11	0.28	0.37	0.63
CD at 5%	0.32	-	-	-

Table-36 : Yield of second grade cut carnation flowers per square meter in different seasons as influenced by varieties, Azotobacter and their interactions

Particulars	No. of second grade cut flowers/sq.m.			
	Rainy (July'97 – Oct.'97)	Winter (Nov.'97 – Jan.'98)	Summer (Feb.'98– April'98)	Cumulative (1997-98)
Varieties				
V_1(Monaco)	2.92 [a]	1.65 [b]	3.23 [b]	7.80 [b]
V_2(Gold Rush)	2.15 [b]	2.25 [ab]	3.19 [b]	7.58 [b]
V_3(Regina)	1.13 [c]	0.97 [c]	1.50 [c]	3.60 [c]
V_4(Internet)	2.90 [a]	2.69 [a]	4.29 [a]	9.88 [a]
V_5(Trendy)	1.73 [b]	2.45 [a]	4.89 [a]	9.10 [a]
'F' test	*	*	*	*
S.Em±	0.17	0.21	0.26	0.33
CD at 5%	0.49	0.63	0.74	0.97
Bio-inoculant				
B_1(Without Azotobacter)	2.20	1.85	3.22	7.28 [b]
B_2(With Azotobacter)	2.13	2.15	3.62	7.90 [a]
'F' test	NS	NS	NS	*
S.Em±	0.10	0.13	0.16	0.21
CD at 5%	-	-	-	0.61
Interactions				
V_1B_1	2.84	1.52	3.09 [d]	7.45
V_1B_2	2.99	1.78	3.37 [bc]	8.14
V_2B_1	2.23	2.18	3.24 [cd]	7.65
V_2B_2	2.06	2.31	3.13 [cd]	7.51
V_3B_1	1.13	0.81	1.58 [e]	3.52
V_3B_2	1.13	1.13	1.42 [e]	3.68
V_4B_1	2.85	2.52	4.40 [b]	9.77
V_4B_2	2.95	2.85	4.18 [bc]	9.98
V_5B_1	1.93	2.24	3.77 [bc]	7.98
V_5B_2	1.53	2.67	6.01 [a]	10.21
'F' test	NS	NS	*	NS
S.Em±	0.23	0.30	0.35	0.46
CD at 5%	-	-	1.05	-

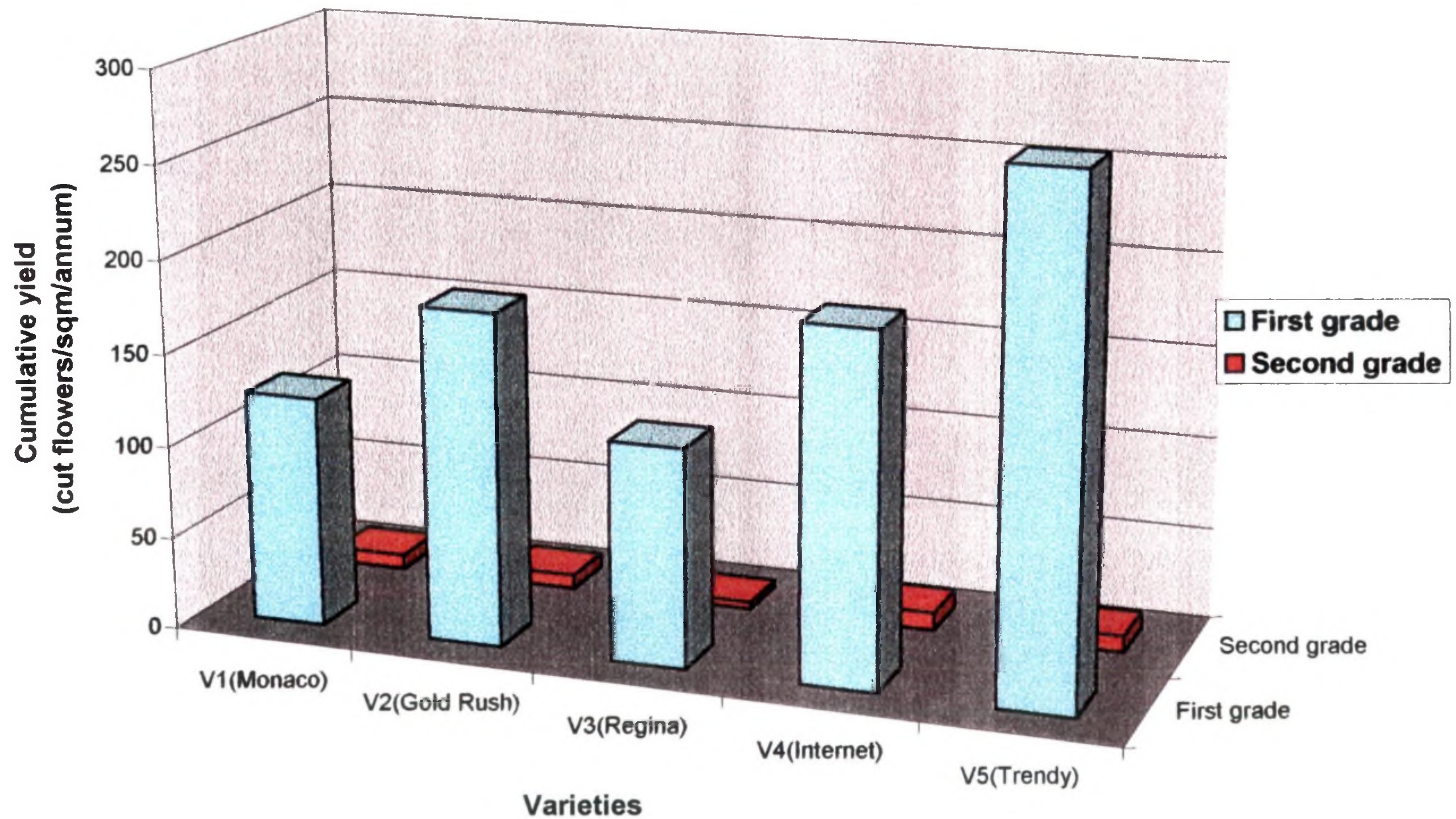


Fig.10 : Cumulative yield of first and second grade cut carnation flowers per square meter per annum as influenced by varieties

4.2.9.3 Yield of second grade cut flowers per square meter

The data pertaining to yield of second grade cut flowers of different varieties of carnation per square meter in different seasons as influenced by Azotobacter are presented in Table-36 (Fig.10).

Both seasonal and cumulative yields of second grade cut flowers per square meter differed significantly among varieties. 'Regina' (V_3) produced lowest number of second grade cut flowers per square meter during all the three seasons viz., rainy, winter and summer (1.13, 0.97and 1.50 cut flowers / sq.m., respectively) and on cumulative basis (3.6 cut flowers / sq.m.).

Bio-inoculant did not influence in lowering the cumulative yield of second grade cut flowers.

Significant differences were obtained among interactions between varieties and bio-inoculant with respect to yield of second grade cut flowers per square meter during summer.

4.2.9.4 Per cent yield of second grade cut flowers

The data pertaining to per cent yield of second grade cut flowers of different varieties of carnation in different seasons as influenced by Azotobacter are presented in Table-37.

Table-37 : Per cent yield of second grade cut carnation flowers in different seasons as influenced by varieties, Azotobacter and their interactions

Particulars	Per cent yield of second grade cut flowers			
	Rainy (July'97 – Oct.'97)	Winter (Nov.'97 – Jan.'98)	Summer (Feb.'98– April'98)	Cumulative (1997-98)
Varieties				
V_1(Monaco)	3.50 [a]	7.24 [a]	11.69 [a]	5.83 [a]
V_2(Gold Rush)	2.48 [c]	4.03 [c]	7.02 [c]	4.05 [c]
V_3(Regina)	1.85 [d]	3.05 [d]	5.25 [d]	3.11 [d]
V_4(Internet)	3.00 [b]	5.09 [b]	8.81 [b]	4.96 [b]
V_5(Trendy)	1.63 [e]	2.97 [e]	4.94 [e]	3.19 [d]
'F' test	*	*	*	*
S.Em±	0.06	0.04	0.19	0.12
CD at 5%	0.19	0.12	0.57	0.35
Bio-inoculant				
B_1(Without Azotobacter)	2.55	4.47	7.45	4.17
B_2(With Azotobacter)	2.44	4.48	7.64	4.28
'F' test	NS	NS	NS	NS
S.Em±	0.04	0.03	0.12	0.07
CD at 5%	-	-	-	-
Interactions				
V_1B_1	3.50 [a]	7.19	11.70	5.80
V_1B_2	3.48 [a]	7.29	11.69	5.85
V_2B_1	2.48 [c]	4.04	6.93	4.02
V_2B_2	2.49 [c]	4.01	7.11	4.07
V_3B_1	1.81 [d]	3.06	4.83	2.87
V_3B_2	1.88 [d]	3.04	5.67	3.34
V_4B_1	3.02 [b]	5.08	8.91	5.02
V_4B_2	2.98 [b]	5.09	8.71	4.91
V_5B_1	1.92 [d]	2.99	4.87	3.15
V_5B_2	1.34 [e]	2.96	5.02	3.22
'F' test	*	NS	NS	NS
S.Em±	0.09	0.06	0.27	0.17
CD at 5%	0.27	-	-	-

Per cent second grade cut flowers seasonal and cumulative yields differed significantly among varieties. While 'Trendy' (V_5) produced significantly lowest per cent yield of second grade cut flowers during all the three seasons viz., rainy (1.63%), winter (2.97%) and summer (4.94%), 'Regina' (V_3) and 'Trendy' (V_5) were on par with respect to the cumulative yield.

Non-significant results were obtained with respect to bio-inoculant treatment.

Interactions between varieties and bio-inoculant differed significantly during rainy season.

4.2.9.5 Yield of first and second grade cut flowers per plant per annum and per hectare per annum

The data with regard to yield of first and second grade cut flowers of different varieties of carnation per plant per annum and per hectare per annum as influenced by Azotobacter are presented in Table-38 (Fig.11).

Yield of first and second grade cut flowers per plant per annum and first grade cut flowers per hectare per annum differed significantly among varieties.

Table-38 : Yield of cut carnation flowers per plant per annum and per hectare per annum as influenced by varieties, Azotobacter and their interactions

Particulars	No. of cut flowers / annum			
	Per plant		Per hectare ('000)	
	First grade	Second grade	First grade	Second grade
Varieties				
V_1(Monaco)	5.20 [c]	0.32 [b]	1248.68 [c]	77.95
V_2(Gold Rush)	7.49 [b]	0.31 [b]	1796.87 [b]	75.80
V_3(Regina)	4.93 [c]	0.14 [c]	1182.47 [c]	36.03
V_4(Internet)	7.88 [b]	0.41 [a]	1891.25 [b]	51.35
V_5(Trendy)	11.51 [a]	0.37 [a]	2762.20 [a]	74.17
'F' test	*	*	*	NS
S.Em±	0.34	0.01	81.89	11.61
CD at 5%	1.01	0.04	243.29	-
Bio-inoculant				
B_1(Without Azotobacter)	7.09	0.30	1700.91	60.66
B_2(With Azotobacter)	7.71	0.32	1851.67	65.46
'F' test	NS	NS	NS	NS
S.Em±	0.22	0.01	51.79	7.34
CD at 5%	-	-	-	-
Interactions				
V_1B_1	4.95 [d]	0.31	1188.73 [d]	74.53
V_1B_2	5.45 [d]	0.33	1308.63 [d]	81.37
V_2B_1	7.61 [c]	0.31	1825.27 [c]	76.53
V_2B_2	7.37 [c]	0.31	1768.47 [c]	75.07
V_3B_1	4.94 [d]	0.14	1185.10 [d]	35.23
V_3B_2	4.91 [d]	0.15	1179.83 [d]	36.83
V_4B_1	7.72 [c]	0.40	1852.27 [c]	37.22
V_4B_2	8.04 [c]	0.41	1930.23 [c]	65.48
V_5B_1	10.23 [b]	0.33	2453.20 [b]	79.80
V_5B_2	12.80 [a]	0.42	3071.20 [a]	68.53
'F' test	*	NS	*	NS
S.Em±	0.48	0.02	115.82	16.42
CD at 5%	1.43	-	344.07	-

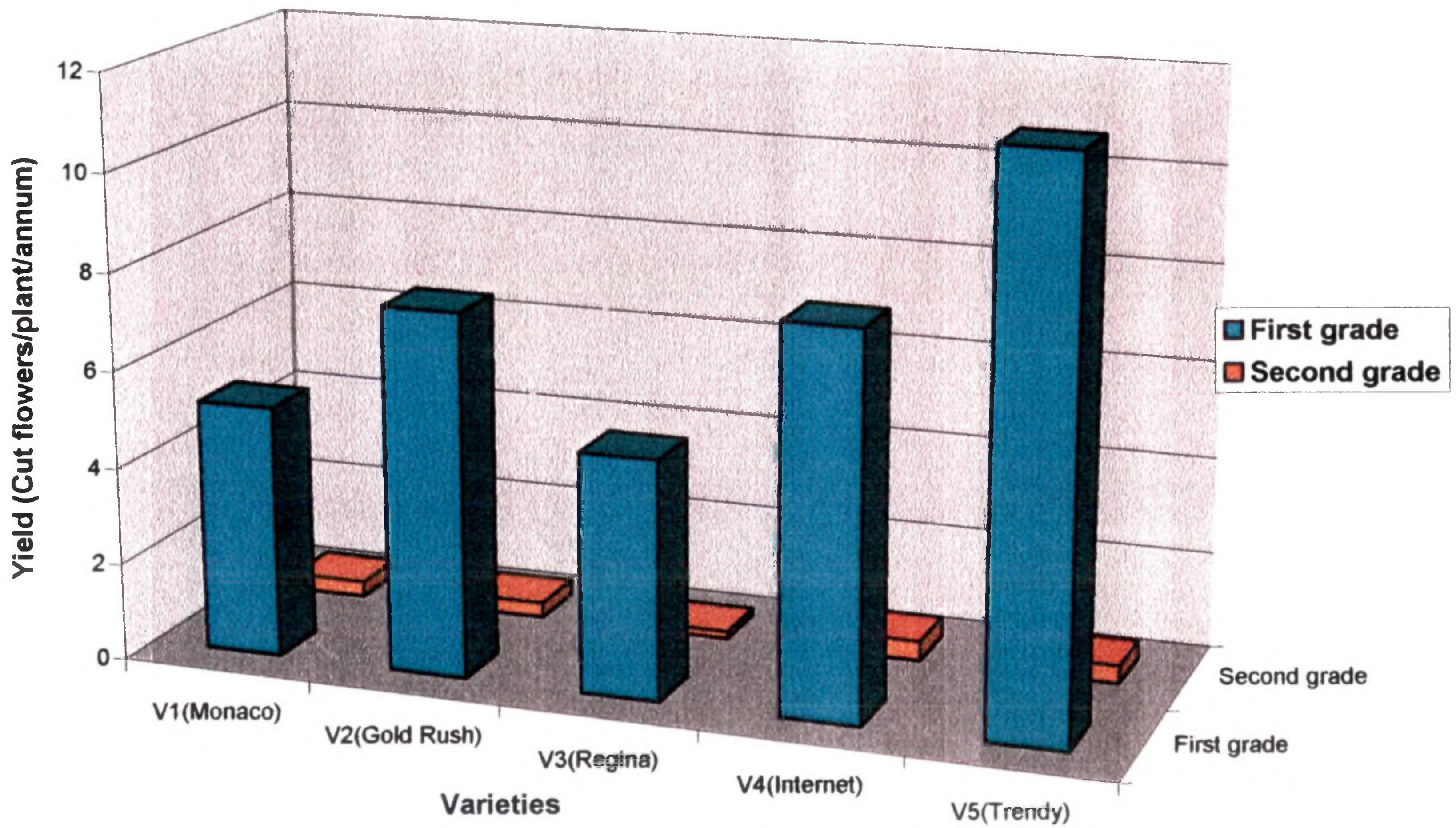


Fig.11 : Yield of first and second grade cut carnation flowers per plant per annum as influenced by varieties

'Trendy' (V_5) produced highest number of first grade cut flowers per plant per annum (11.51 cut flowers/plant/annum) and per hectare per annum (2762.20 thousand cut flowers/ha/annum), while 'Regina' (V_3) recorded the lowest number of second grade cut flowers per plant per annum (0.14 cut flowers/plant/annum).

Non-significant results were obtained with respect to bio-inoculant treatments.

Interactions between varieties and bio-inoculant differed significantly with respect to yield of first grade cut flowers per plant per annum and per hectare per annum.

4.2.10 Calyx splitting (%)

The data on calyx splitting in different varieties of carnation as influenced by Azotobacter are presented in Table-39 (Fig.12) (Plate-15).

Significant differences were observed with respect to calyx splitting among varieties. 'Trendy' (V_5) exhibited the lowest per cent calyx splitting (0.46%).

Bio-inoculant did not influence in lowering the calyx splitting.

Interaction effects differed significantly.

Table-39 : Calyx splitting in carnation as influenced by varieties, Azotobacter and their interactions

Particulars	Calyx splitting (%)
Varieties	
V_1(Monaco)	1.27[b]
V_2(Gold Rush)	2.56[a]
V_3(Regina)	2.36[a]
V_4(Internet)	1.09[b]
V_5(Trendy)	0.46[c]
'F' test	*
S.Em±	0.09
CD at 5%	0.27
Bio-inoculant	
B_1(Without Azotobacter)	1.19[b]
B_2(With Azotobacter)	1.90[a]
'F' test	*
S.Em±	0.06
CD at 5%	0.18
Interactions	
V_1B_1	1.06[ef]
V_1B_2	1.47[d]
V_2B_1	1.72[cd]
V_2B_2	3.40[a]
V_3B_1	1.95[c]
V_3B_2	2.76[b]
V_4B_1	0.84[fg]
V_4B_2	1.34[de]
V_5B_1	0.39[h]
V_5B_2	0.53[gh]
'F' test	*
S.Em±	0.13
CD at 5%	0.38

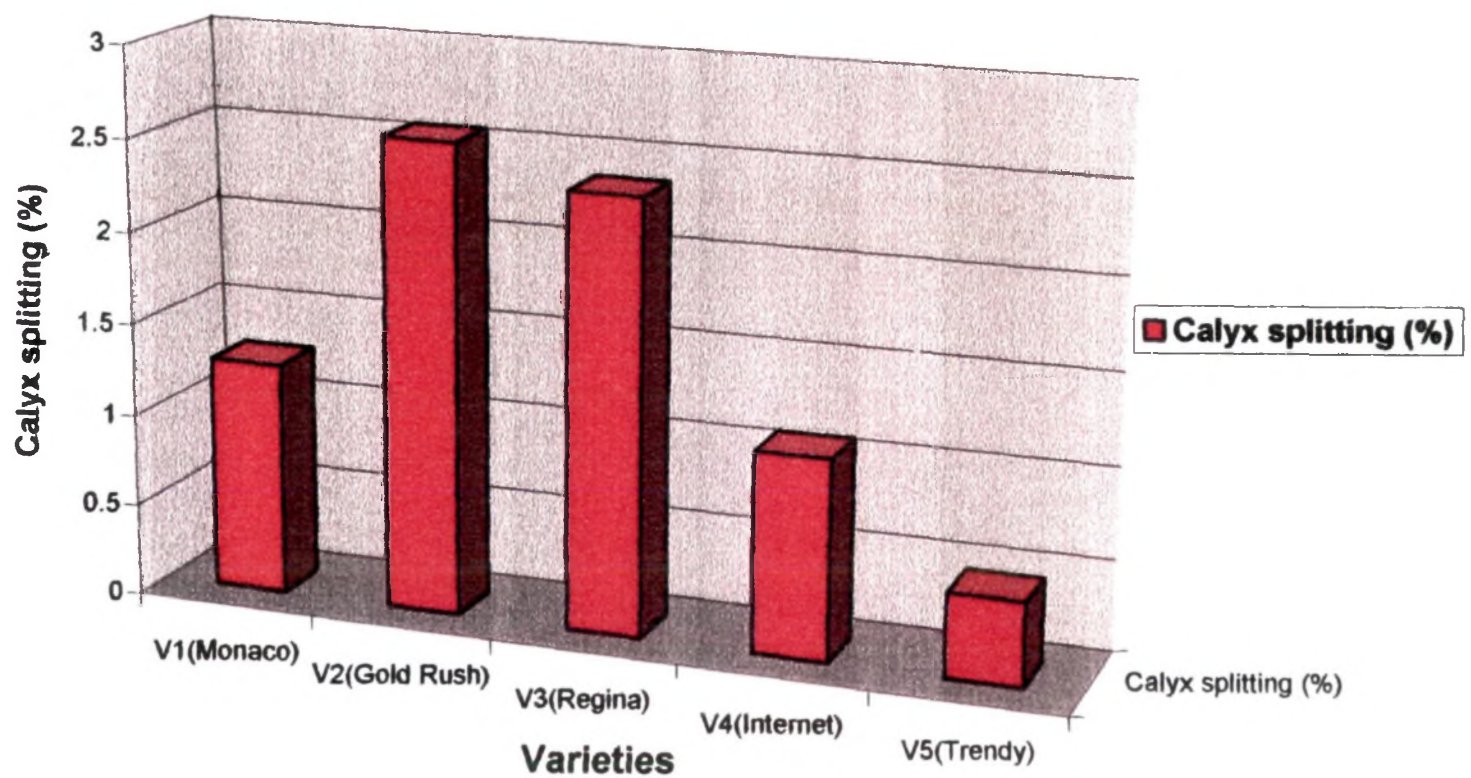
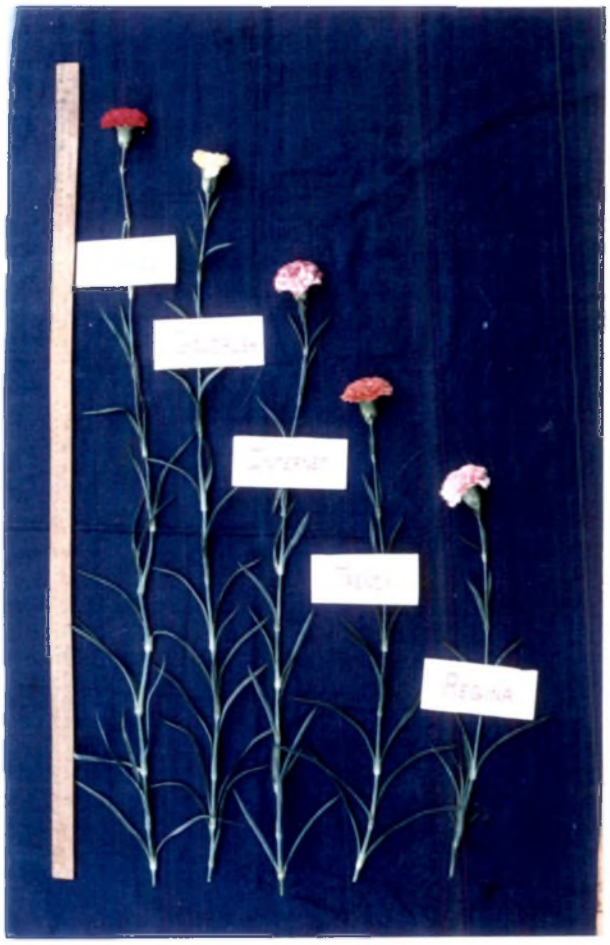


Fig.12 : Calyx splitting (%) in carnation as influenced by varieties

Plate 14 : Stalk length of different varieties of carnation

Plate 15 : Calyx splitting in carnation Var. 'Monaco'


REGINA

4.2.11 VASE LIFE DEPENDANT PARAMETERS

The data pertaining to cumulative fresh weight of cut flowers, cumulative uptake of water by cut flowers, cumulative loss of water by cut flowers and vase life of cut flowers of carnation varieties as influenced by Azotobacter are presented in Table-40.

4.2.11.1 Cumulative fresh weight of cut flowers

Cumulative fresh weight of cut flowers differed significantly among varieties during rainy season. Varieties 'Monaco' (V_1), 'Gold Rush'(V_2), 'Regina' (V_3) and 'Internet' (V_4) were on par and recorded significantly higher cumulative fresh weight (10, 12.5, 12.5 and 12.17 g/flower, respectively) among the varieties tried.

Non-significant results were obtained with regard to bio-inoculant and its interaction with varieties.

4.2.11.2 Cumulative uptake of water by cut flowers

Non-significant differences were obtained with regard to cumulative uptake of water among varieties during both the seasons.

Both bio-inoculant and its interaction with varieties did not influence cumulative uptake of water by carnation cut flowers.

Table-40 :Cumulative fresh weight, cumulative uptake of water, cumulative loss of water and vase life of carnation cut flowers as influenced by varieties, Azotobacter and their interactions

Particulars	Cumulative fresh weight (g/flower)		Cumulative uptake of water (g/flower)		Cumulative loss of water (g/flower)		Vase life (days)	
	Rainy (July'97-Oct.'97)	Winter (Nov.'97 –Jan.'98)	Rainy (July'97-Oct.'97)	Winter (Nov.'97 –Jan.'98)	Rainy (July'97-Oct.'97)	Winter (Nov.'97 –Jan.'98)	Rainy (July'97-Oct.'97)	Winter (Nov.'97 –Jan.'98)
Varieties								
V_1(Monaco)	10.00[ab]	9.50	15.73	11.75	17.18[b]	11.75[b]	5.50	5.33
V_2(Gold Rush)	12.50[a]	8.92	19.93	12.58	16.20[b]	12.83[b]	5.33	6.33
V_3(Regina)	12.50[a]	13.25	18.03	16.86	18.50[b]	18.05[a]	5.33	6.83
V_4(Internet)	12.17[a]	9.00	16.10	15.15	23.45[a]	11.73[b]	5.16	7.16
V_5(Trendy)	7.50[b]	9.50	16.63	15.30	15.76[b]	13.06[b]	5.00	5.33
'F' test	*	NS	NS	NS	*	*	NS	NS
S.Em±	1.02	1.32	1.30	1.78	1.27	1.35	0.22	0.62
CD at 5%	3.00	-	-	-	3.76	4.00	-	-
Bio-inoculant								
B_1(Without Azotobacter)	11.00	9.40	18.54[a]	14.42	18.71	12.13[b]	5.40	6.06
B_2(With Azotobacter)	10.87	10.67	16.03[b]	14.23	17.72	14.84[a]	5.13	6.33
'F' test	NS	NS	*	NS	NS	*	NS	NS
S.Em±	0.64	0.84	0.82	1.12	0.80	0.85	0.14	0.39
CD at 5%	-	-	2.43	-	-	2.52	-	-
Interactions								
V_1B_1	10.00	8.67	14.73	10.83	15.53[b]	12.83	5.66	5.66
V_1B_2	10.00	10.33	16.73	12.66	18.83[b]	10.66	5.33	5.00
V_2B_1	13.67	7.33	22.06	10.00	14.63[b]	12.00	5.66	7.00
V_2B_2	11.33	10.50	17.80	15.16	17.76[b]	13.66	5.00	5.66
V_3B_1	12.00	15.33	18.76	17.73	19.06[b]	14.18	5.33	6.33
V_3B_2	13.00	11.17	17.30	16.00	17.93[b]	21.93	5.33	7.33
V_4B_1	11.67	8.00	17.73	18.23	27.70[a]	11.66	5.33	6.66
V_4B_2	12.67	10.00	14.46	12.06	19.20[b]	11.80	5.00	7.66
V_5B_1	7.67	7.67	19.40	15.33	16.63[b]	10.00	5.00	4.66
V_5B_2	7.33	11.33	13.86	15.26	14.90[b]	16.13	5.00	6.00
'F' test	NS	NS	NS	NS	*	NS	NS	NS
S.Em±	1.44	1.87	1.84	2.52	1.80	1.91	0.31	0.88
CD at 5%	-	-	-	-	5.32	-	-	-

4.2.11.3 Cumulative loss of water by cut flowers

Cumulative loss of water differed significantly among varieties during both rainy and winter seasons. While varieties 'Monaco' (V_1) 'Gold Rush' (V_2), 'Regina' (V_3) and 'Trendy' (V_5) were on par and resulted in lower cumulative loss of water (17.18, 16.20, 18.50 and 15.76 g/flower, respectively) during rainy season, 'Monaco' (V_1), 'Gold Rush' (V_2), 'Internet' (V_4) and 'Trendy' (V_5) were on par and resulted in lower cumulative loss of water (11.75, 12.83, 11.73 and 13.06 g/flower, respectively) during winter season.

Bio-inoculant and its interaction with varieties did not influence in reducing cumulative loss of water.

4.2.11.4 Vase life

Non-significant results were obtained with respect to vase life as influenced by varieties, bio-inoculant and their interactions during both rainy and winter seasons.

DISCUSSION

V. DISCUSSION

Growth, development and productivity of any crop are regulated by a series of co-ordinated biological events involving biochemical, physiological and morphological changes that take place during its growth under the influence of light, water, temperature and nutrients (Donald, 1962). Boodley (1975) emphasized the importance and role of balanced nutrition in producing carnations. Supply of nutrients through drip irrigation called 'Fertigation' to enhance the productivity of a crop is now getting well established (Papadopoulas, 1992). In view of the above, the present investigations were carried out at the Division of Horticulture, University of Agricultural Sciences, Gandhi Krishi Vigyana Kendra, Bangalore during 1997-98 on carnation and the results obtained are discussed experiment-wise here under :

5.1 EFFECTS OF LEVELS OF FERTIGATION AND SOURCES OF FERTILIZERS ON GROWTH, QUALITY AND PRODUCTIVITY OF STANDARD CARNATION VARIETY 'TRENDY' GROWN UNDER COST-EFFECTIVE GREENHOUSE

5.1.1 GROWTH ATTRIBUTES

Growth in terms of height of plant, laterals produced and flowering determines the quality and ultimate yield of carnation cut flowers. The mode and the form of application of nutrients influence the growth attributes.

The fertigation levels resulted in significant differences with respect to height of plants at 105 and 120 days after planting and during winter season. Number of laterals produced per plant at different stages of growth and during winter season, and days taken for first flower bud's appearance, development and harvest and fifty per cent flowering also showed significant differences.

Levels of fertigation did not differ significantly with respect to height of plants upto 90 days after planting. It is obvious that the levels of fertigation did not exert their influence on height of plants during the initial growth and development period. As carnation plants grew gradually during the establishment period of 3-4 months, non-significant differences were obtained. Once the period of establishment is over, change in the rate of growth would bring in differences among the levels of fertigation with respect to height of plants as was observed in the aftermath. The results are in agreement with those of Arora and Jhon (1978), Mukhopadhyay (1981), Biswas *et al.* (1982) and Yasui *et al.* (1980) who reported increase in height of carnation plants with increase in the level of nutrients applied.

Application of 80% recommended dose of fertilizers resulted in producing higher number of laterals per plant at 105 days after planting and during winter season (6.28 and 4.35 laterals / plant, respectively). This indicated that 80% recommended dose of fertilizers was optimum for producing higher number of laterals per plant. The results are in conformity with those of Naik *et al.* (1995).

While days taken for first flower bud's appearance (101.50 days), development (17 days), harvest (118.50 days) and fifty per cent flowering (183.75 days) were all delayed by the application of 100% recommended dose of fertilizers, reduced dose resulted in earliness of all. Higher the level of fertigation, better the vegetative growth and hence the delay.

Significant differences between sources of fertilizers were obtained with regard to days taken for first flower bud's harvest. Straight fertilizers resulted in delayed (112.33 days) harvest whereas water soluble fertilizers resulted in early (108.67 days) harvest. Delayed harvest, when straight fertilizers were applied, could be due to slow availability of nutrients in contrast to faster availability of nutrients when water soluble fertilizers were applied resulting in early harvest.

5.1.2 QUALITY ATTRIBUTES

Carnation cut flower quality depends largely on size of buds, length of stalk and diameter of flower. Levels of fertigation and sources of fertilizers affect these quality attributes. Quality is the main criterion in both domestic and international markets for successful marketing

Significant differences among levels of fertigation were obtained with respect to length of flower buds during winter, thickness of flower buds during winter and summer seasons, length and girth of cut flower stalks during rainy and summer seasons, number of petals per flower head during rainy and winter seasons and diameter of cut flowers during all the three seasons.

Application of 80% recommended dose of fertilizers resulted in producing longer flower buds during winter (1.93 cm), thicker flower buds during winter and summer (1.34 mm and 1.80 mm, respectively), longer length and thicker girth of flower stalks during rainy and summer (58.31 cm and 2.99 mm, respectively), higher number of petals per flower head during rainy and winter (68.11 and 63.38 petals / flower head, respectively) and increased diameter of cut flowers during all the three seasons viz., rainy, winter and summer (6.94 cm, 5.52 cm and 5.23 cm, respectively). These results indicated the view that optimisation of nutrients might have produced beneficial effects. Similar views were expressed by Eck *et al.* (1962), Starck *et al.* (1991), Rushmini and Baldi (1974), Yasui *et al.* (1980), Kaplan (1993a), Hosni and Shoura (1996) and Jhon *et al.* (1979) who obtained quality flowers with the optimum application of nutrients in carnation.

Sources of fertilizers differed significantly with respect to length of flower buds during summer season, thickness of flower buds during all the three seasons and number of petals per flower head and diameter of cut flowers during winter season.

Water soluble fertilizers effected in producing longer flower buds during summer season (3.83 cm), thicker flower buds during all the three seasons viz., rainy, winter and summer (1.74 mm, 1.27 mm and 1.82 mm, respectively) and higher number of petals per flower head (63.28 petals/flower head) and increased diameter of cut flowers (5.57 cm) during winter season. Probably, this could be due to quicker and easier availability of nutrients when supplied through water soluble fertilizers that might have resulted in producing good quality attributes. Similar results were obtained by Eck *et al.* (1962) and Yasui *et al.* (1980) who obtained superior quality flowers at optimum level of application of nutrients in carnation.

Interaction effects were significant with respect to number of petals per flower head and diameter of cut flowers during winter season. Eighty per cent recommended dose of fertilizers applied in water soluble form produced higher number of petals per flower head (67.25 petals / flower head) and increased the diameter of cut flowers (5.97 cm) during winter season. Optimum dose of fertilizers coupled with easier and quicker availability of nutrients might have helped in producing better quality flowers. Eck *et al.* (1962) and Yasui *et al.* (1980) reported similar results with respect to quality of flowers.

5.1.3 YIELD ATTRIBUTES

Yield not only in terms of productivity but quality is important from the profitable point of view. Marketable quality nothing but acceptable quality from the consumers point of view is the minimal ultimatum of any grower. Nutrients their source, level and mode of application determine productivity and quality, in a broad-sense.

Levels of fertigation recorded significant differences with respect to all yield attributes except per cent yield of first grade cut flowers during rainy season and yield of second grade cut flowers per square meter during winter season.

Application of 80% recommended dose of fertilizers not only effected in producing higher yield of first grade cut flowers per square meter both on seasonal i.e., rainy, winter and summer (105.76, 56.56 and 62.38 cut flowers/sq.m., respectively) seasons and cumulative (224.70 cut flowers/sq.m.) basis, and lower yield of second grade cut flowers per square meter during rainy and summer (0.93 and 1.47 cut flowers/sq.m., respectively) seasons and on cumulative basis (3.73 cut flowers/sq.m.), but also highest and lowest per cent yields of first grade and second grade cut flowers on cumulative basis, and highest yield of first grade cut flowers per plant per annum (9.36 cut flowers/plant/annum) and per hectare per annum (2247.04 Thousand cut flowers/ha/annum) and lower yield of second grade cut flowers per plant per annum. Application of optimum level of fertigation might have benefitted in producing these results. Trials conducted by Hart (1970), Fischer and Kurzmann (1987), Kowalezyx *et al.* (1992) and Strojny *et al.* (1992) produced higher yield of marketable quality flowers with the proportional application of nutrients in carnation.

Most of the yield attributes were markedly influenced by the fertilizer source.

Water soluble fertilizers not only influenced in producing higher seasonal i.e., rainy, winter and summer (101.68, 55.12 and 67.73 cut flowers/sq.m., respectively) and cumulative (224.63 cut flowers/sq.m.) yields of first grade cut flowers per square meter and lower seasonal i.e., rainy, winter and summer (0.78, 0.79 and 2.02 cut flowers/ sq.m., respectively) and cumulative (3.59 cut flowers/sq.m.) yields of second grade cut flowers per square meter, but also higher and lower per cent yields of first grade and second grade cut flowers per square meter on cumulative basis, and higher yield of first grade cut flowers per plant per annum (9.36 cut flowers/plant/annum) and per hectare per annum (2245.34 thousand cut flowers/ha/annum) and lower yield of second grade cut flowers per plant per annum and per hectare per annum. Water soluble fertilizers by their easier and quicker solubility and availability might have produced these beneficial effects. The results obtained are in accordance with the findings of Huett

(1994) who obtained higher yield of first grade flowers with the application of nutrients proportionately to obtain higher yield of marketable quality of carnation cut flowers. Soil and leaf analytical values provide support to the results obtained (Appendix-IV and V).

Interaction effects significantly differed with respect to all yield attributes either in one season or other or on cumulative or per plant per annum and per hectare per annum basis.

Application of 80% recommended dose of fertilizers in water soluble form not only effected in producing highest yield of first grade cut flowers per square meter during summer (85.51 cut flowers/sq.m.) and on cumulative (265.36 cut flowers/sq.m.) basis, and lower yield of second grade cut flowers per square meter during summer (1.74 cut flower/sq.m.) and on cumulative (3.02 cut flowers/sq.m.) basis, but also highest and lowest per cent yields of first and second grade cut flowers during winter and summer, and highest yield of first grade cut flowers per plant per annum (11.06 cut flowers / plant / annum) and per hectare per annum (2653.60 thousand cut flowers/ha/annum)and lower yield of second grade cut flowers per plant per annum. Supply of nutrients at optimum level in an easier and quicker available form might have produced these beneficial effects. The findings of Hart (1970), Fischer and Kurzmann (1987), Kowalezyx *et al.* (1992), Strojny *et al.* (1992) and Huett (1994) emphasized the need to apply nutrients proportionately to obtain higher yield of marketable quality of carnation cut flowers.

5.1.4 Flower yield to fertilizers applied ratio

The yield efficiency in terms of number and quality in carnation depends largely on the quantity of fertilizers applied.

Flower yield to fertilizers applied ratio differed significantly among levels of fertigation, between sources of fertilizers and among interactions between levels of fertigation and sources of fertilizers.

Application of 60% recommended dose of fertilizers in water soluble form resulted in higher ratio between flower yield and fertilizers applied. Higher efficiency of fertilizer associated with the lower level of application revealed the tendency of plants to take-up as much nutrients as possible without exceeding the limits under limited supply of nutrients. And, higher efficiency associated with water soluble fertilizers could be attributed to their higher solubility property, and easier and quicker availability of nutrients as they get disassociated faster in the solvent and reduce losses under fertigation.

5.1.5 Post-harvest studies

Pre-harvest factors will have their influence on the post-harvest aspects of a cut flower. Mode and form of application determine the longevity of a cut flower after harvest, measured in terms of its vase life.

Significantly higher cumulative fresh weight of cut flowers and cumulative uptake of water by cut flowers were obtained with the application of 80% recommended dose of fertilizers. Influence of water soluble fertilizers in obtaining significantly longer vase life (5.66 days) might be due to higher fertilizer use efficiency associated with water soluble fertilizers.

5.1.6 ECONOMICS

In protected cultivation of carnation, a major share is engulfed by the planting material and the infrastructure facilities. Hence, studies were carried-out in a cost-effective greenhouse. However, the profit depends not only on the productivity of the crop but also the quality of the produce in association with the competitive price in the market. This can be achieved by lowering the cost of production, parallely. In a way, this inturn is possible with the optimisation of nutrients, efficient mode and form of application.

Application of 80% recommended dose in the form of water soluble fertilizers resulted in the maximum revenue (Rs.1,06,748/100 sq.m./annum), net profit (Rs.72,213/100 sq.m./annum) and benefit : cost ratio (2.09). Optimum fertilizer dose provided by applying water soluble fertilizers through fertigation could be considered as probable reasons for obtaining the above results. Zouari (1976), Lin and Chiu (1990), Ferrato and Benedeotto (1994) and Jaganath and Gopinath (1997) opined that protected cultivation of carnation is profitable under higher productivity and competitive price for the product.

Based on the data obtained during the present investigation, it is evident that 20% reduction in the rate of application of fertilizers when applied as water soluble fertilizers had brought about significant beneficial effects on growth, quality, yield and vase life apart from higher benefit : cost ratio.

5.2 EFFECTS OF BIO-INOCULANT ON GROWTH, QUALITY AND PRODUCTIVITY OF STANDARD VARIETIES OF CARNATION GROWN UNDER COST-EFFECTIVE GREENHOUSE

5.2.1 GROWTH ATTRIBUTES

Growth attributes such as height of plant and laterals may influence flowering in carnation. In turn, a bio-inoculant like Azotobacter may alter the growth.

Varieties differed significantly for all the growth attributes.

Variety 'Monaco' produced tall statured plants (104.37 cm) at 120 days after planting and during winter and summer seasons (109.67 cm and 145.68 cm, respectively). This could be due to the varietal characteristic. Bucan (1990) also reported similar influence of the variety on height of plants.

Variety 'Trendy' produced higher number of laterals per plant (5.7 laterals/plant) at 105 days after planting and during winter season (3.83 laterals/plant), whereas variety 'Regina' produced the maximum number of laterals (5.93 laterals/plant) during summer season. This also could be attributed to the varietal characteristic as the nature of producing laterals depends on the genotype (Mahesh, 1996) or the variety (Satish, 1997).

While varieties 'Gold Rush' and 'Internet' produced higher number of leaves both during rainy (15.93 and 14.93 pairs of leaves / lateral) and summer (13.68 and 14.67 pairs of leaves / lateral), 'Regina' produced similar results during winter (23.20 pairs of leaves / lateral) and was on par with the former two during summer (14.82 pairs of leaves / lateral). This could be due to genetic make-up of the varieties (Sparnaaij *et al.*, 1990).

While delayed appearance of first flower bud (108.33 days), its development (27 days), harvest (135.33 days) and fifty per cent flowering (178.17 days) were recorded in 'Regina', varieties 'Gold Rush' and 'Internet' resulted in early flowering (by 3-4 weeks), development (by a week), harvest (by 4-5 weeks) and fifty per cent flowering (by one and a half months). This could be due to the differential flowering behaviour and characteristics of individual varieties. Similar results of production of flowers at different times by different varieties were reported by Miske (1982) and Bhautkar (1994).

Number of laterals per plant (at 60 days after planting and during winter) and number of pairs of leaves per lateral (during winter) were significantly influenced by the bio-inoculant, Azotobacter. This being a nitrogen fixing bacteria could sustain the phenomenon of apical dominance because of availability of more nitrogen to plants by which plants became more vegetative by way of growing and in its absence, tallness was not favoured and thus resulted in producing higher number of laterals per plant with more number of pairs of leaves per lateral.

5.2.2 QUALITY ATTRIBUTES

Cut flower quality is represented by size of bud, length and stiffness of stalk, diameter of flower etc. characteristic to the variety. Quality of flower produced may be attributed to greenhouse environment or cultural practices or genetic make-up of the variety.

With the exception of length of flower buds in summer and girth of flower stalks in rainy season, varieties differed significantly with respect to all the quality parameters in different seasons.

Longer flower buds produced during rainy and winter seasons by 'Monaco', 'Gold Rush' and 'Internet' and thicker flower buds produced by 'Regina' in all the three seasons i.e., rainy, winter and summer (2.12 mm, 1.58 mm and 2.02 mm, respectively) could be due to the differential characteristic nature of the varieties. Varietal differences with respect to length and thickness of flower buds have been reported by Satish (1997).

'Monaco' and 'Gold Rush' produced longer length and thicker girth of cut flower stalks both during winter and summer seasons. Length and girth of flower stalks are characteristics of varieties according to Bucan (1990). The results obtained by Loeser (1986), Kim *et al.* (1992) and Satish (1997) also support the views of Bucan (1990).

While 'Regina' produced higher number of petals per flower head both during rainy (71.78 petals/flower head) and summer (65.84 petals/flower head) seasons, 'Gold Rush' produced similar result during winter (75.88 petals/flower head). Variation in number of petals per flower head in association with change in greenhouse environment was reported by Snedel (1937).

'Gold Rush' and 'Trendy' produced cut flowers of significantly equal diameter during rainy (6.94 cm and 6.75 cm, respectively), winter (6.86 cm and 6.88 cm, respectively) and summer (5.36 cm and 5.30 cm, respectively) seasons. The results obtained are in accordance with the findings of Bucan (1990) who attributed it to the characteristic nature of the variety. Similar results of varietal differences with respect to diameter of flowers were also obtained by Oszkinis and Kus (1971), Loeser (1986), Mahesh (1996), Satish (1997) and by Bucan (1990).

Bio-inoculant treatment produced significant differences with regard to number of petals per flower head in rainy and winter seasons. Azotobacter influenced in producing maximum number of petals per flower head during both rainy and winter seasons (62.67 and 67.59 petals / flower head, respectively). Presence of Azotobacter might have helped in producing more petals per flower head probably because of the availability of nitrogen which might have been utilised in producing the same.

5.2.3 YIELD ATTRIBUTES

Growth of crop decides about the quality of flower. Both together decide about the yield. However, variety, cultural practices and greenhouse environment greatly influence the yield.

Varieties differed significantly with respect to all the yield attributes except production of second grade cut flowers per hectare per annum.

'Trendy' produced higher yield of first grade cut flowers per square meter during all the three seasons viz., rainy, winter and summer (102.93, 79.55 and 93.77 cut flowers/sq.m., respectively) and also maximum cumulative yield (276.25 cut flowers/sq.m). Similar results were obtained by Satish (1997) who pointed out that yield is specific to variety.

Higher per cent yield of first grade cut flowers was also produced by 'Trendy' during all the three seasons. The results obtained are in line with those of Zornoza *et al.* (1989) and Satish (1997) who reported differential per cent yield of first grade cut flowers in different varieties.

'Regina' and 'Trendy' produced significantly lower season-wise yield and per cent yield of second grade cut flowers, respectively. While, lower cumulative yield of second grade cut flowers was recorded in 'Regina', its lower per cent yield of second grade cut flowers equalised significantly with 'Trendy'. Varieties vary with respect to yield of per cent second grade cut flowers as reported by Satish (1997).

Whereas 'Trendy' produced maximum yield of first grade cut flowers per plant per annum (11.51 cut flowers/plant/annum) and per hectare per annum (2762.20 thousand cut flowers/ha/annum), the minimum yield of second grade cut flowers per plant per annum (0.14 cut flowers/plant/annum) was recorded in 'Regina' (V_3). Varieties differ with regard to cut flower production (Chen *et al.*, 1990). Similar views were expressed by Bchvarova *et al.* (1988), Bucan (1990) and Satish (1997).

Yield of first grade cut flowers per square meter differed significantly between bio-inoculant treatments during summer season. Azotobacter influenced in producing higher yield of first grade cut flowers per square meter (49.64 cut flowers/sq.m.) during summer. It is well known that Azotobacter plays dual role i.e., it fixes atmospheric nitrogen in the soil as well as triggers production of growth promoting substances (hormones) in the plant system. This might have helped in obtaining higher number of first grade cut flowers per square meter during summer. The results are in agreement with those of Bonita *et al.* (1994).

Interaction effects with respect to summer and cumulative yields of first grade cut flowers per square meter, per cent yield of first and second grade cut flowers during rainy season, and yield of first grade cut flowers per plant per annum and per hectare per annum were also significant.

'Trendy' treated with Azotobacter produced maximum summer and cumulative yields of first grade cut flowers per square meter (113.99 and 307.12 cut flowers/sq.m., respectively), maximum and minimum per cent yields of first and second grade cut flowers (98.65 % and 1.34 % respectively) during rainy season, and maximum yield of first grade cut flowers per plant per annum and per hectare per annum (12.80 cut flowers/plant/annum and 3071.20 thousand cut flowers / ha/ annum).

The results obtained clearly imply that the varietal characteristics coupled with the dual role of Azotobacter had brought out these positive yield differences. Soil and leaf analytical values provide support to the results obtained (Appendix-VI and VII).

5.2.4 CALYX SPLITTING (%)

Calyx splitting is observed, usually, wherever carnation is grown. This may be due to temperature fluctuations or varietal characteristic or nutritional imbalance or other cultural factors.

Calyx splitting differed significantly among varieties with respect to bio-inoculant and its interaction with varieties.

Lower per cent calyx splitting was observed in 'Trendy' grown with or without Azotobacter. Lower per cent calyx splitting associated with 'Trendy' could be a varietal characteristic (Gill and Arora, 1988; Gopinath and Khan, 1997 and Arora and Jhon, 1978).

5.2.5 POST-HARVEST STUDIES

Varieties differed significantly with respect to cumulative fresh weight of cut flowers during rainy and cumulative loss of water by cut flowers during rainy and winter seasons. 'Monaco', 'Gold Rush' and 'Regina' recorded higher cumulative fresh weight of cut flowers as well as lower cumulative loss of water by cut flowers. Gao Jun Ping *et al.* (1996) opined that higher absorption of water through the stem of cut flowers of carnation could reduce water loss and increase the shelf life.

Thus, it could be inferred that 'Trendy' excelled all other varieties by its overall performance and emerged as an ideal variety for growing under cost-effective greenhouse conditions.

PRACTICAL UTILITY OF INVESTIGATIONS CARRIED OUT ON STANDARD VARIETIES OF CARNATION

Experiment – I

Fertigation resulted in high ratio between flower yield and fertilizers applied as there was reduction in the quantity of fertilizers used, to an extent of 20 per cent besides causing (a) early flowering and harvest (b) production of more number of laterals, (c) better quality flower buds, flower stalks and flower heads and increased yields.

Use of water soluble fertilizers resulted in not only (a) early flowering and harvest (b) better quality buds and flower heads (c) increased yields and (d) extended vase life but also exhibited high ratio between flower yield and fertilizers applied.

Experiment – II

Studies for improving the production and quality of carnation flowers indicated that number of petals per flower head during rainy and winter seasons and yield of first grade cut flowers during summer season were significantly influenced by the use of Azotobacter. 'Gold Rush' and 'Internet' were found to be early varieties as compared to 'Regina' which was found to be a very late variety, while 'Trendy' was found to be a high yielding variety.

FUTURE LINE OF WORK

Studies to determine the role of levels of various bio-inoculants, bio-fertilizers, micro-nutrients and organic manures (either alone or in combination) with and without using inorganic fertilizers on the quality, productivity, calyx splitting, incidence of pests and diseases is crucial for cost-effective management of carnation.

SUMMARY

VI. SUMMARY

Growth, quality and productivity of carnation under cost-effective greenhouse as influenced by levels of fertigation, sources of fertilizers and bio-inoculant were studied during 1997-98 at the Division of Horticulture, University of Agricultural Sciences, GKVK, Bangalore. The findings are summarised here under :

EFFECTS OF LEVELS OF FERTIGATION AND SOURCES OF FERTILIZERS ON GROWTH, QUALITY AND PRODUCTIVITY OF STANDARD CARNATION VARIETY 'TRENDY' GROWN UNDER COST-EFFECTIVE GREENHOUSE

1. Application of 80% recommended dose of fertilizers resulted in producing significantly tall statured plants (81.20 cm) and higher number of laterals per plant (4.35 laterals / plant) during winter.
2. Precocity in appearance of first flower bud, its development, harvest and 50% flowering were significantly due to the application of 80% recommended dose of fertilizers.
3. While application of 80% recommended dose of fertilizers resulted in producing significantly longer flower buds (1.93 cm) during winter, water soluble fertilizers influenced in producing significantly longer flower buds (3.83 cm) during summer.

4. During winter and summer, significantly thicker flower buds (1.34 mm and 1.80 mm, respectively) were produced by the application of 80% recommended dose of fertilizers, while the application of fertilizers in water soluble form produced significantly thicker flower buds during rainy (1.74 mm), winter (1.27 mm) and summer (1.82 mm) seasons.
5. Significantly longer length of cut flower stalks (58.31 cm) were produced with the application of 80% recommended dose of fertilizers during rainy season.
6. The thickest girth of flower stalks (2.99 mm) was recorded with the application of 80% recommended dose of fertilizers during summer.
7. The maximum number of petals per flower head (67.25 petals / flower head) during winter was produced by the application of 80% recommended dose of fertilizers in the form of water soluble fertilizers.
8. Higher diameter of cut flowers (5.97 cm) produced during winter was significantly influenced by the application of 80% recommended dose of fertilizers in the form of water soluble fertilizers.
9. Significantly superior cumulative yield of first grade cut flowers per square meter (265.36 cut flowers / sq.m.) was produced by the application of 80% recommended dose in the form of water soluble fertilizers.
10. Lower cumulative yield of second grade cut flowers per square meter was due to the effect produced by the application of 80% recommended dose in the form of water soluble fertilizers.

11. Yields of first grade cut flowers per plant per annum (11.06 cut flowers/plant/annum) and per hectare per annum (2653.60 thousand cut flowers/ha/annum) were significantly higher with the application of 80% recommended dose in the form of water soluble fertilizers.
12. Water soluble fertilizers effected in producing significantly higher flower yield to fertilizers applied ratio.
13. Significantly longer vase life (5.66 days) was obtained by the application of water soluble fertilizers.
14. Application of 80% recommended dose in the form of water soluble fertilizers resulted in the maximum revenue (Rs.1,06,748/100 sq.m./annum), net profit (Rs.72,213/100 sq.m./annum) and benefit : cost ratio (2.09).

EFFECTS OF BIO-INOCULANT ON GROWTH, QUALITY AND PRODUCTIVITY OF STANDARD VARIETIES OF CARNATION GROWN UNDER COST-EFFECTIVE GREENHOUSE

1. 'Monaco' produced tall statured plants at different periods of growth as compared with all the other varieties.
2. While 'Regina' and 'Trendy' produced significantly higher and equivalent number of laterals per plant (3.83 and 3.70 laterals / plant) during winter, 'Regina' produced the maximum number of laterals (5.93 laterals / plant) per plant during summer season.

3. 'Gold Rush' and 'Internet' were on par and early with respect to the appearance of first flower bud, its harvest and number of days taken for 50 per cent flowering.
4. Significantly longer flower buds produced by 'Monaco' were on par with 'Gold Rush' and 'Internet' during rainy and winter seasons.
5. 'Regina' produced thicker flower buds during all the three seasons viz., rainy, winter and summer.
6. While 'Monaco' produced the longest length of flower stalks during rainy season, it was significantly on par with 'Gold Rush' during winter and summer.
7. 'Monaco', 'Gold Rush' and 'Regina' were on par and produced significantly thicker girth of flower stalks during winter and summer seasons.
8. 'Regina' produced significantly higher number of petals per flower head during all the three seasons viz., rainy, winter and summer.
9. 'Gold Rush' and 'Trendy' were on par and produced significantly higher diameter of cut flowers during all the three seasons viz., rainy, winter and summer.
10. 'Trendy' produced the maximum cumulative yield of first grade cut flowers per square meter (276.25 cut flowers/sq.m.).
11. 'Regina' produced the lowest cumulative yield of second grade cut flowers s per square meter (3.6 cut flowers/sq.m.).

12. 'Trendy' produced highest yield of first grade cut flowers per plant per annum (11.51 cut flowers/plant/annum) and per hectare per annum (2762.20 thousand cut flowers/ha/annum).
13. 'Trendy' exhibited the lowest per cent calyx splitting (0.46%).
14. Azotobacter treatment induced higher number of petals per flower head during rainy and winter seasons and also higher yield of first grade cut flowers per square meter during summer.

It was observed that of all the varieties tried, 'Trendy' was the most suitable for growing under cost-effective greenhouse conditions. The results have also indicated the need to reduce fertilizer dosage by 20 per cent and advocated use of water soluble fertilizers to be applied through fertigation.

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VII. REFERENCES

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APPENDICES

APPENDIX – I

Mean monthly weather data of G.K.V.K., U.A.S., Bangalore for the period from April 1997 to April 1998

Month and Year	Temperature (°C)		Relative Humidity (%)	Bright sunshine hours	Rainfall (mm)
	Max.	Min.			
April, 1997	32.10	19.20	59	9.40	71.00
May, 1997	33.50	20.70	58	9.00	94.80
June, 1997	31.40	20.60	63	7.70	53.00
July, 1997	28.90	20.00	71	4.50	30.40
August, 1997	28.00	19.80	72	4.60	67.80
September, 1997	28.50	19.40	74	6.00	294.90
October, 1997	28.20	18.70	72	7.00	316.80
November, 1997	26.30	19.20	78	4.70	193.80
December, 1997	26.10	18.10	78	6.20	18.80
January, 1998	28.20	16.60	68	9.20	0.00
February, 1998	30.20	17.10	63	9.70	0.00
March, 1998	33.20	19.60	57	9.40	0.80
April, 1998	33.40	20.50	57	9.00	-

APPENDIX - II

Mean monthly weather data under greenhouse for the period from April 1997 to April 1998

Month and Year	Temperature (°C)		Relative Humidity (%)		Light intensity ('00 lux)
	Max.	Min.	Max.	Min.	
April, 1997	31.00	27.00	79	72	255
May, 1997	30.00	26.00	70	67	250
June, 1997	29.00	23.50	74	71	240
July, 1997	29.50	24.00	66	62	235
August, 1997	29.00	25.00	82	58	215
September, 1997	29.00	25.00	82	58	200
October, 1997	27.50	22.00	80	64	185
November, 1997	27.50	22.00	65	64	135
December, 1997	28.00	22.00	65	63	134
January, 1998	28.50	22.50	66	65	135
February, 1998	29.50	23.50	71	68	236
March, 1998	32.50	26.50	83	60	240
April, 1998	30.00	26.00	83	71	250

APPENDIX-III

Chemical properties of water used for both biofertilizer and fertigation trials conducted on standard varieties of carnation

Particulars	Values
pH	6.56
E.C	0.44 ds/m
Ca	0.85 m.eq./l
Mg	1.15 m.eq/l
HCO_3	1.51 m.eq/l

APPENDIX - IV

Chemical properties of soil before the start and after the completion of the fertigation trial on carnation var. 'Trendy' as influenced by different levels of fertigation and sources of fertilizers

Particulars	pH	E.C. (ds/m)	O.C. (g/kg)	P_2O_5 (kg/ha)	K_2O (kg/ha)	Zn (ppm)
Before						
T_1:100% Rec. dose as Straight fertilizers	6.50	0.36	1.66	>200	300	7.80
T_2:100% Rec. dose as water soluble fertilizers	6.50	0.34	1.78	>200	328	5.40
T_3:80% Rec. dose as Straight fertilizers	6.20	0.46	1.75	>200	320	7.10
T_4:80% Rec. dose as water soluble fertilizers	6.80	0.20	1.13	>200	248	4.60
T_5:60% Rec. dose as Straight fertilizers	6.60	0.35	1.66	>200	192	6.70
T_6:60% Rec. dose as water soluble fertilizers	6.60	0.50	1.47	>200	270	5.70
After						
T_1:100% Rec. dose as Straight fertilizers	6.30	0.24	0.92	60	224	7.80
T_2:100% Rec. dose as water soluble fertilizers	5.90	0.90	1.84	>200	332	11.40
T_3:80% Rec. dose as Straight fertilizers	5.60	1.30	1.16	>200	370	10.10
T_4:80% Rec. dose as water soluble fertilizers	5.40	1.00	0.89	>200	302	9.50
T_5:60% Rec. dose as Straight fertilizers	5.10	2.20	1.23	>200	>400	9.10
T_6:60% Rec. dose as water soluble fertilizers	5.60	0.90	1.07	>200	>400	11.00

Rec. = Recommended

APPENDIX – V

Nutrient status of carnation var. 'Trendy' depicted by leaf analysis in different seasons/periods of growth as influenced by different levels of fertigation and sources of fertilizers

Treatments	Seasons/periods of growth								
	Rainy (July'97 to Oct' 97)			Winter (Nov.'97 to Jan'98)			Summer (Feb'98 to April 98)		
	N	P	K	N	P	K	N	P	K
	(Per cent dry matter)								
T_1:100% Rec. dose as Straight fertilizers	3.16	0.41	3.36	3.61	0.38	3.23	5.65	0.41	3.58
T_2:100% Rec. dose as water soluble fertilizers	3.63	0.40	3.42	3.83	0.43	3.15	3.89	0.37	3.23
T_3:80% Rec. dose as Straight fertilizers	3.29	0.51	3.22	4.83	0.39	3.20	3.43	0.36	3.22
T_4:80% Rec. dose as water soluble fertilizers	3.48	0.46	3.27	4.02	0.59	3.23	3.41	0.38	3.63
T_5:60% Rec. dose as Straight fertilizers	3.42	0.50	3.45	3.80	0.48	3.16	3.64	0.35	3.29
T_6:60% Rec. dose as water soluble fertilizers	3.35	0.42	3.23	3.28	0.46	3.03	3.39	0.40	3.03

Rec. = Recommended

APPENDIX – VI

Chemical properties of soil before the start and after the completion of the biofertilizer trial comprising standard varieties of carnation

Particulars	pH	E.C. (ds/m)	O.C. (g/kg)	P_2O_5 (kg/ha)	K_2O (kg/ha)	Zn (ppm)
	Before					
Without Azotobacter	6.60	0.34	2.14	>200	295	7.50
With Azotobacter	6.63	0.32	1.98	>200	331	7.50
	After					
Without Azotobacter	5.90	0.42	1.33	>200	321	12.80
With Azotobacter	5.80	1.87	1.59	>200	>400	9.63

APPENDIX – VII

Nutrient status of standard varieties of carnation depicted by leaf analysis in different seasons/periods of growth as influenced by Azotobacter

Treatments	Seasons/periods of growth								
	Rainy (July-Oct.) 1997			Winter (Nov.-Jan.) 1997-98			Summer (Feb-April) 1998		
	N	P	K	N	P	K	N	P	K
	(Per cent dry matter)								
T_1:Monaco	4.00	0.30	3.12	3.02	0.30	3.67	2.83	0.32	3.14
T_2:Gold Rush	2.92	0.45	3.61	3.83	0.34	3.23	3.26	0.75	3.17
T_3:Regina	3.70	0.50	3.24	3.19	0.56	3.18	3.90	0.52	3.29
T_4:Internet	2.82	0.39	3.12	3.05	0.36	3.13	3.36	0.32	3.25
T_5:Trendy	3.92	0.57	3.12	3.17	0.38	3.52	3.12	0.34	3.26
T_6:Monaco + Azotobacter	3.82	0.53	3.23	4.03	0.52	3.36	5.00	0.62	3.34
T_7:Gold Rush+Azotobacter	3.98	0.62	3.21	3.89	0.63	3.14	6.20	0.45	3.27
T_8:Regina+Azotobacter	4.02	0.60	3.41	3.88	0.65	3.17	3.43	0.38	3.28
T_9:Internet+Azotobacter	3.40	0.45	3.58	3.84	0.64	3.32	3.08	0.35	3.54
T_{10}:Trendy+Azotobacter	2.75	0.56	3.32	3.86	0.54	3.13	4.26	0.48	3.18

APPENDIX - VIII

Microbial analysis for Azotobacter before the start and after the completion of the biofertilizer trial comprising standard varieties of carnation

Test organism : ***Azotobacter chroococcum***

Sample type : Soil + inoculation

Particulars	**Average population of Azotobacter (cfu/ml.)**
Before	12×10^3
After	48×10^3