SUPPLEMENTARY EFFECT OF BIOFERTILIZERS IN *Dendrobium*

By

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THESIS

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2003

DECLARATION

I hereby declare that this thesis entitled **"Supplementary effect of biofertilizers in *Dendrobium*"** is a bonafide record of research work done by me during the course of research and that this thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

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CERTIFICATE

Certified that this thesis, entitled **"Supplementary effect of biofertilizers in *Dendrobium*"** is a record of research work done independently by **Miss.S. Binisha** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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Dedicated

to my

Beloved Parents

Introduction

INTRODUCTION

Orchids, which are known as the wonder flowers of the world have become increasingly popular as flowers of the 21^{st} century.The prime importance and use of orchids,however, confines to the bewitchingly beautiful flowers,which exhibit an incredible range of size,shape and colour,long life of flowers on the plants and amazingly long keeping quality,which no other plant can claim (Rajeevan *et al.*, 2002).

Orchidaceae, the family to which orchids belong, is the largest family of the flowering plants coming under the group monocotyledons. The nearest estimate of the species range from 25,000 to 35,000 in over 600-800 genera. Orchids are important primarily for their horticultural and floricultural appeal.

Orchid cut flowers have emerged as the leader in the international market and have immensely contributed to the economy of several developed and developing countries.They remain the only cut flower crop grown as a pot plant in most parts of the world due to the epiphytic nature of the commercially cultivated orchids.

In India orchids are known since Vedic period. But,commercial cultivation of orchids was started only in the late 90's (Chadha, 1992). *Dendrobium* is the most commonly cultivated genera of orchids in India. It is undoubtedly one of the most exquisite and elegant member of the family orchidaceae which comprises the largest and most diverse genera of orchids.

Kerala is said to be an ideal location with adequate climatic conditions for tropical orchids to get well established. However,to exploit the available agro-climatic conditions, slight changes are required in the practices being adopted here (Rajeevan,1997). More than thirty hybrids of *Dendrobium* are under commercial cultivation in Kerala. These hybrids differ not only with respect to morphological features of plants and blooms but also in their response to various external factors.

The heavy demand for cut flowers, highlights the importance of increased potential of this crop. Among the cultural practices, application of nutrients in optimum proportion with adequate major and minor elements in combination with inorganic forms is the key factor in regulating growth and flowering in orchids. Conventional nutritional application in liquid form has been found to be very effective in orchids.

But in the present scenario of organic farming it is essential to assess the novel impact of biofertilizers on the growth and yield of orchids. Biofertilizers are not alternatives for inorganic fertilizers in orchids. But they are useful in increasing yield, quality and production of crops when they are used in combination with inorganic fertilizers in balanced proportion.

The commonly used biofertilizers are *Azospirillum*, phosphobacteria and Arbuscular Mycorrhizal Fungi (AMF) which are associated with root tissues and potting media and live in harmony with the plant, helping in fixation of nitrogen as well as solublisation and easy translocation of nutrients. The use of biofertilizers in floriculture is gaining momentum and the earlier works conducted reveal that biofertilizers can be used as a potential inoculant for orchids too.

In this context, a study was undertaken in *Dendrobium* var. Sonia 17 with an objective to determine the effect of biofertilizers on growth and flowering of *Dendrobium* in combination with inorganic fertilizers.

Review of Literature

2. REVIEW OF LITERATURE

In India the commercial cultivation of orchid is still rudimentary and orchids are grown on small scale in different parts of the country. Kerala is found to be an ideal location for orchid cultivation due to its agro-ecological position Orchid industry is slowly gaining momentum here due to the high returns obtained from this crop. *Dendrobium* Sonia 17 is one among the most popular variety cultivated in Kerala. Efforts have been made in this chapter to review the available information regarding nutritional factors not only inorganic, but also that of biofertilizers providing better growth and development of flower crops.

2.1 EFFECT OF INORGANIC NUTRIENTS

Early investigations on the nutrition of epiphytic orchids in their natural habitat led to the assumption that cultivated orchids also needed little supplementary nutrition other than provided by their growing medium (Sanford,1974)

Nitrogen, phosphorus and potassium are the most important macro nutrients required by orchids in varied amounts.Various scientist have reported the effect of inorganic fertilizers on overall improvement of orchids..In a comparison study of different levels of N on growth of *Phalaenopsis* and *Cattleya* seedlings Sheehan (1960), reported an increase in leaf growth with increase in N application.

An increase in N was found to have a favourable effect on plant height as reported by Sagarik and Siripong (1963) in young *Dendrobium* hybrids. Nutrient culture studies of *Cattleya*, *Cymbidium* and *Phalaenopsis* undertaken by Poole and Seeley (1978) revealed that N concentration was the most important factor determining growth of all the three orchid genera.

In *Cattleya*, phosphorus was found to enter the plants through the foliage and that three year old roots were able to absorb and translocate ^{32}P as actively as one year old roots (Sheehan, 1966). Northen (1970) observed that excess N leads to increased vegetative growth and delayed flowering in orchids.

Bhattacharjee (1977) observed that spraying N, P_2O_5 and K_2O 100 ppm each at fortnightly intervals was beneficial in *Bulbophyllum.*

The growth of orchids are markedly improved by regular schedule of fertilizing the plants in liquid form (Bose and Bhattacharjee, 1980). Khaw and Chew (1980) reported that frequency of application of nutrient mixture resulted in favourable effect on plant height. Arditti and Ernst (1981) opined that ammonium nitrate is the best source of N during the early *ex vitro* stage of orchids.

Bhattacharjee (1981) reported that with each increment of N level,in general,there was marked improvement in vegetative growth.Earlier flower bud appearance was recorded with 500 ppm N spray.Addition of P_2O_5 significantly influenced vegetative growth.The beneficial effect was,however restricted to the application of 500ppm each of P_2O_5 and K_2O and an increase above that level had no effect in *Dendrobium moschatum* grown in hard wood charcoal.

A fertilizer mixture of (30:10:10) NPK rich in nitrogen was found to be good for vegetative growth and this mixture was recommended for orchids by Boodley (1981); Linda (1987); Stewart (1988); Marguerite (1989) and Peter (1990). Liang and Pan (1994) and Yoneda *et al.* (1997) reported that P deficiency cause stunting in orchids.

Nichols (1982) observed an overall increase in vegetative growth in the seedlings of *Cymbidium* 'Pharoah Pathfinder' when liquid fertilizer containing 500 ppm potassium nitrate, 500 ppm ammonium nitrate and 100 ppm ammonium sulphate were applied as spray at weekly intervals for a period of 6 month. Increase in N application rate helped in increasing the shoot production in *Cymbidium* 'Pendragon Sikkim' (Bik and Berg , 1983).

Nutrient solution containing 100 ppm N, 20 ppm P and 75 ppm K were recommended for improving growth in *Cymbidium* and *Cattleya* (Johnson, 1984) Higher dose of N was found to be beneficial under outdoor cultivation of orchids and longer pseudobulbs were produced when N was applied at 48 mg l^{-1} (Sakai *et al.*, 1985).

Schum and Fisher (1985) and Higaki and Imamura (1987) reported that N and K have a beneficial effect on number of leaves and girth of stem.Yadav and Bose (1986) found that 1000 ppm each of N, P and K enhanced the length and number of leaves, the number of spikes and the number of flowers per spike in orchids.

Seeni and Latha (1990) suggested that a combination of commercial diammonium phosphate and potassium nitrate 20:10:10 NPK was the most effective in terms of rapid leaf and root growth in *Phalaenopsis*. One year old seedlings of *Dendrobium phalaenopsis* fed with MS nutrient solution in the ratio of 2:1:1 grew better than two year old seedlings of the same variety (Koval'skaya and Zeimenko, 1991).

Abraham and Vatsala (1981) and Singh (1992) reported that N has significant influence on the vegetative growth of orchids.Effect of nitrate nitrogen and ammoniacal nitrogen on the growth and development in *Cymbidium sinensis* was studied by Ruichi *et al.* (1994)..

In *Cymbidium* and *Phalaenopsis* seedlings, 100 ppm N together with 50 ppm and 25 ppm K was found to be optimal (Poole and Seeley, 1978). Sobhana and Rajeevan (1995) reported that plants sprayed with NPK 17:17:17 complex at weekly intervals @ 10 g l^{-1} could increase the number of shoots and leaves in *Cymbidium traceanum*. Wang (1995) observed that higher N rate produced wider leaf spread, more and larger leaves and greater total leaf area, regardless of the type of fertilizer used in young seedlings of *Phalaenopsis* cv. Tam Butterfly.

According to Thekkayam (1996) application of 300 ppm N, 400 ppm P and 300 ppm K from the time of planting to nine months after planting and thereafter a dosage of 400 to 500 ppm N, 400 ppm P and 500 ppm K showed positive results in *Arachnis* 'Maggie Oei Red Ribbon' under trench culture. Nutrient recommendation of 2.0 mg NPK each from three to six months, 6:2:2 NPK from six to nine months and 6:2:6 NPK from nine to twelve months were made by Umamaheswari (1999).

Yoneda *et al.* (1999) studied the effect of macro element concentration on growth, flowering and nutrient absorption in *Odontoglossum* hybrid. They observed that low N rates resulted in shorter and thinner stalks, fewer flowers and advanced flowering date. Swapna (2000) noticed that application of NPK as ammonium nitrate, orthophosphoric acid and potassium nitrate 10:20:20 at 0.2 per cent was significantly superior to all other nutrient treatments for highest spike production in *Dendrobium* var. Sonia 17.

Ex-vitro established, six months old tissue culture plantlets of *Dendrobium* cv. Sonia 17 when treated with NPK 30:10:10 at 0.2 per cent concentration along with BA 200 ppm proved very effective in improving the leaf parameters such as length of the leaf (12.85 cm), width of the leaf (6.04 cm) and perimeter of the leaf (32.15 cm) (Nandini, 2000).

Nair (2001) reported that the concentration of N significantly influenced the shoot emergence in Sonia 17. Fertilizer mixture of $N:P_2O_5:K_2O$ 3:1:1 applied during vegetative period and 1:2:2 applied during flowering period is very effective in orchids (KAU, 2002).

2.2 BIOFERTILIZERS

Biofertilizers, or microbial inoculants are products containing living cells of different micro-organisms, which have the ability to mobilize nutritionally important elements from non-usable forms to usable forms through biological processes. They also include diazotrophic microorganisms like *Azospirillum*, phosphate solubilizing microorganisms and arbuscular mycorrhizal fungi.

2.2.1 Effect of *Azospirillum* on plant growth

Azospirillum is an aerobic nitrogen fixing bacterium that occurs as associative symbiont in the rhizosphere of many crop plants in tropics. Smith *et al.* (1978) found that *Azospirillum* inoculation has increased root and shoot growth and biomass accumulation in crop plants. Tarrand *et al.* (1978) reported that all wild types of *Azospirillum* strains fix atmospheric nitrogen efficiently either as free living bacteria or in association with plants.

The critical growth response to *Azospirillum* inoculation might be due to the secretion of growth promoting substances rather than biological nitrogen fixation (Purushothaman *et al.*, 1987). Ravichandran (1991) reported that N along with *Azospirillum* soil inoculation three months after planting in crossandra resulted in improvement in vegetative characters. *Azospirillum* seed treatment showed the highest germination, optimum growth and higher vigour index of the seedlings in African marigold and recorded the maximum plant height and number of branches in the field (Mariappan, 1992).

Results of pot experiments investigating the effect of inoculation with strains of *Azospirillum brasiliense* and *Azospirillum lipoferum* at different N levels showed increased flower yield and bulb productivity particularly in sandy loam and clay loam soil (Naggar and Mahmoud, 1994). Gnanasekar (1994) reported that there was an increase in growth characters like plant height, number of primary, secondary and tertiary branches, length of primary shoot and internode in jathimalli inoculated with *Azospirillum.*

Application of azotobacter and *Azospirillum* mixture significantly increased the number of flowers per stalk, flowering shoots and bulb yield in tuberose (Wange and Patil, 1994). Wange *et al.* (1995) reported that 50 kg N along with *Azospirillum* increased bulb yield where as 150 kg N along with *Azospirillum* increased cut flower yield in tuberose var. Single .

Preethi *et al.*, (1998) reported that 37.5 kg N ha^{-1} + *Azospirillum* 2 kg ha^{-1} + 1000 ppm of ascorbic acid spray applied at 6^{th} month after planting in Edward rose gave the highest number of total and flowering shoots, less number of blind shoots and highest value for pedicel length, flower weight, flower diameter, concrete recovery and nutrient content of plant. Swaminathan and Sambandamurthi (2000) reported that *Azospirillum* along with N, K and FYM gave an increase in vegetative as well as floral characters in crossandra var. Delhi.

2.2.2 Effect of phosphobacteria on growth and yield

In tuberose, Ailingai (1960) found that an application of granular super phosphate at 60 g m^{-2} combined with phosphobacterium increased the number of flowering plants. Rangarajan *et al.* (1989) observed significant increase in seedling height of *Rhododendron nilgiricans* and *Syzygium aromaticum*, six months after phosphobacterium inoculation. Rao (1989) stated that inoculation of seeds with phosphate solubilizing bacteria could correct the deficiency of P in plants.

Manonmani (1992) reported that phosphobacterium treated rooted cuttings of *Jasminum sambac* have given higher establishment per cent in the field as well as increased plant height, number of primary, secondary and tertiary branches. Gupta *et al.* (1999) reported that treatment with 100 per cent nitrogen along with azotobacter and phosphobacteria has given increased growth and highest flower yield in marigold.

2.2.3 Effect of AMF on growth and yield

Daft and Okusanya (1973) reported that AMF stimulated flower production in petunia. Arbuscular mycorrhizal fungi (AMF) are the most spectacular and wide spread type known to be associated with most agricultural crops and natural plant communities (Gerdemann, 1975).

AMF is characterized by vesicules and arbuscules. The arbuscules help in the transfer of nutrients especially phosphates from soil and it improve plant growth through increased uptake of phosphorus and other minerals especially in soils of low fertility (Tinker, 1975). Mycorrhizal fungus *Glomus fasciculatum* improved flower, stem and root dry weight and also increased plant height significantly in chrysanthemum (Johnson *et al.*, 1982).

Maronek *et al.* (1982) reported that *Glomus* and *Gigaspora* sp. exhibited enhanced growth in *Rosa multiflora*. Bagyaraj and Powell (1985) reported that AMF have a positive influence on the growth and yield of marigold. Davies Jr (1987) observed that in *Rosa multiflorà* cv. Brooks 56 plants inoculated with *Glomus mosseae* and *G. fasciculatum* exhibited better growth parameters.

Kale *et al.* (1987) studied the influence of AMF on aster and salvia in worm cast amended soils and found that mycorrhizal root colonization was influenced by the amendment of worm cast and inturn the shoot P content and yield of these two ornamental plants were increased by VAM fungi.

Balasubramanian (1989) observed that pre-transplant inoculation of AMF increased the vigour of seedlings in French marigold. Association of mycorrhizae are essential for germination of orchid seeds in most species and for access to carbohydrate sources as the orchid roots are capable of absorbing only fungal sugars like trehalose and not cellulose directly (Peterson, 1990).

Wang *et al.* (1993) observed an increase in shoot number and root dry weight in plants inoculated with *Glomus intraradices* and *Glomus vesiculiferum* in Gerbera. Chang and Wen (1994) reported that, application of *Glomus mosseae* along with *Glomus etunicatum* induced an increase in lateral shoots, cut flower yield and advance flowering in gerbera cultivar Tennussee and Regina.

Increased shoot dry weight and lowered mortality rate were observed in orchid plants inoculated with VAM (Wang and Gregg, 1994). Duke *et al.* (1994) observed that inoculation with *Glomus intraradices* increased the number of flower buds in Zinnia. Plants inoculated with *Glomus etunicatum* showed a faster flowering rate when compared to control in *Zinnia elegans* (Nasr, 1996).

Nagesh and Reddy (1997) reported that the use of oil cake 15 g plant^{-1} along with *Glomus mosseae* (1000 clamydospores plant^{-1}) in pot experiments promoted better plant growth and reduced nematode multiplication rate. The field application of *Glomus intraradius* has shown an increase in flower yield along with decrease in disease severity caused by *Fusarium oxysporum* in carnation (St. Arnaud *et al.*, 1997).

Field trials conducted with AM fungi *Gigaspora margarita* with phosphorus has shown an increase in plant height, number of branches and flower yield with a cost benefit ratio of 1:6:3 (Naik *et al.*, 1998). Soroa *et al.* (1998a) observed an increase in plant growth in *Callistephus chinensis* inoculated with *Scutellospora pellucida* by seed pelleting. In *Antirrhinum majus* also,seed pelleting with *Glomus mosseae* resulted in increased growth (Soroa *et al.* 1998b).

Three cultivars of chrysanthemum namely Bangalore White, Local Yellow and Shymal were inoculated with three types of AM fungi, *Acaulospora larvis, Glomus mosseae* and *Glomus fasiculatum*. The results showed that plants inoculated with *Glomus fasiculatum* has given an increase in plant height, number of flowers $plant^{-1}$ and flower yield in all the three varieties (Gnanadevi and Haripriya, 1999). Wu *et al.* (1999) reported that oriental lily inoculated with AM fungi resulted in the increase of bulblet size.

Besmer and Koide (1999) reported that phosphorus + AM fungi treatment decreased the ethylene production in snapdragon thereby increasing vase life. Application of AM culture - *Glomus* sp., *Gigaspora* sp. and *Scutellospora* sp. resulted in marked improvement in height of plants, number of flowers and an early flowering of 15 days in *Petunia hybrida*(Gaur *et al.*, 2000). Plants inoculated with *Glomus mosseae* and *Acaulospora scrobiculata* showed an increase in plant height, P, K, Cu and Zn content in leaves, N, Ca, Cu and Zn content in roots (Pedraza *et al.*, 2001).

Scagel (2001) reported that application of AMF inoculum into the rooting medium has increased the number of rooted cuttings and number of roots per cutting in three miniature rose cultivars. In AMF inoculated chrysanthemum plants plant height, leaf area, root length, fresh and dry weight of shoots were significantly higher and the plants came to early flowering compared to control (Sohn *et al.*, 2003).

2.2.4 Effect of *Azospirillum* and phosphobacteria on growth and yield

Manonmani (1992) observed an increase in plant height, leaf area and yield in *Jasminum sambac,* treated with *Azospirillum* and phosphobacteria along with N and P. An increase in leaf area, stalk length and flower diameter were observed in *Jasminum grandiflorum* when inoculated with *Azospirillum* and phosphobacteria in combination with N and P (Gnanasekar, 1994).

Subramanian (1997) reported that 30:20:10 NPK + *Azospirillum* + phosphobacteria has given the highest plant height in carnation. Velmurugan (1998) reported that application of 20 g *Azospirillum* and phosphobacteria along with 45:90:120 NPK has given an increased effect on plant height, hundred flower weight and yield in *Tagetes erecta*

Bhavanisanker and Vanangamudi (1999a) reported that a combination of 75 per cent N and P along with *Azospirillum* and phosphobacteria registered the highest flower yield in *Jasminum sambac.*In another experiment, Bhavanisanker and Vanangamudi (1999b) observed that 15 per cent N + *Azospirillum* + phosphobacteria gave the highest flower yield, ten months after planting in crossandra.

Chandrikapure *et al.* (1999) reported that application of NPK along with *Azospirillum*, phosphobacteria has given highest plant height, flower weight and flower diameter in marigold. A study on *Crossandra* cv. Dindigal local found that application of 100 per cent NPK + *Azospirillum* + phosphobacteria each incorporated at 2 kg ha^{-1} gave the highest flower yield (Raju and Haripriya, 2001).

2.2.5 Effect of AMF and *Azospirillum* on growth and yield

The application of three fourth of recommended dose of N and P, 93.75 kg ha^{-1} and 90 kg ha^{-1} respectively along with *Azospirillum* and AMF resulted in increased growth in French marigold (Balasubramanian, 1989). Application of NPK 45:45:37.5 mg kg^{-1} along with *Azospirillum* and AMF exhibited increased growth with respect to plant height, number of leaves, laterals per plant and early flowering (Rajadurai *et al.*, 2000).

2.2.6 Effect of AMF and phosphobacteria on growth and yield

Wang and Ling (1997) reported that inoculation of AMF along with phosphate solubilizing bacteria increased fresh weight, number of branches and number of flowers in petunia along with an advanced flowering of 20-30 days. In Asian hybrid lily, dual inoculation of AMF and phosphate solubilizing bacteria showed the best promotion of growth (Lin *et al.*, 1999).

Kumar *et al.* (2003) reported that application of three fourth of the recommended dose of N and P in combination with full K + VAM + phosphobacteria proved to be most effective in increasing the plant height, number of leaves, leaf area, number of branches, flower weight, flower diameter, number of flowers and flower yield.

2.2.7 Effect of *Azospirillum*, phosphobacteria and AMF on growth and yield

Combined dose of biofertilizer and inorganic NPK gave highest flower yield, weight and plant content of N, P, K, Ca and Mg and reducing sugars and total carbohydrates (Subramanian, 1997). Application of NPK 200:40:200 ppm $plant^{-1}$ combined with *Azospirillum*, phosphobacteria and AMF exhibited better performance with respect to growth characters, early flowering, maximum number of flowers and maximum hundred flower weight in chrysanthemum cv. Bronze spray and Red spray (Hakkeem, 1998).

Velmurugan (1998) reported that application of NPK at 45:90:75 kg ha^{-1} combined with *Azospirillum*, phosphobacteria and AMF resulted in better growth responses in respect to plant height, branches, leaf area and drymatter production in African marigold.

Materials and Methods

3. MATERIALS AND METHODS

The present study entitled "Supplementary effect of biofertilizers in *Dendrobium*" was conducted to determine the effect of biofertilizers on growth and flowering of *Dendrobium* in combination with inorganic fertilizers. It was carried out in the orchidarium of All India Co-ordinated Floriculture Improvement Project in the Department of Pomology and Floriculture from July 2002 to August 2003.

3.1 MATERIALS UTILIZED

3.1.1 Variety

The commercially important hybrid variety of *Dendrobium* Sonia 17 was used for the experiment (Plate 1).

3.1.2 Planting material

Ex-vitro established, one month old tissue cultured plants of the variety were used.

3.1.3 Potting media

A mixture containing equal quantities of tile pieces,charcoal and FYM were used.

3.1.4 Shading

The plants were grown under 50 per cent shade provided by green coloured shade nets.

3.1.5 Inorganic fertilizers

Ammonium nitrate (35% N) was used as the source of nitrogen, orthophosphoric acid (31.63% P) was used as the source of phosphorus and potassium nitrate (38.61% K) was used as the source of potassium.

3.1.6 Biofertilizers

Biofertilizers used were *Azospirillum*, phosphobacteria and arbuscular mycorrhizal fungi (AMF)

Plate 1. Variety used for the study - *Dendrobium* Sonia 17

3.2 METHODS

3.2.1 Design of the experiment

The experiment was laid out in CRD with 3 replications and 42 treatments.

3.2.2 Nutrient treatments

Treatments comprised of a combination of bio- fertilizers along with inorganic fertilizers @ 0.2 per cent spray, weekly twice.

T_1 - NPK 20:10:10 + A

T_2 - NPK 20:10:10 + P

T_3 - NPK 20:10:10 + AMF

T_4 - NPK 20:10:10

T_5 - NPK 10:10:10 + A

T_6 - NPK 10:10:10 + P

T_7 - NPK 10:10:10 +AMF

T_8 - NPK 10:10:10

T_9 - NPK 0:10:10 + A

T_{10} - NPK 0:10:10 + P

T_{11} - NPK 0:10:10 + AMF

T_{12} - NPK 0:10:10

T_{13} - NPK 20:5:10 + A

T_{14} - NPK 20:5:10 + P

T_{15} - NPK 20:5:10 + AMF

T_{16} - NPK 20:5:10

T_{17} - NPK 20:0:10 + A

T_{18} - NPK 20:0:10 + P

T_{19} - NPK 20:0:10 + AMF

T_{20} - NPK 20:0:10

T_{21} - NPK 10:5:10 + A

T_{22} - NPK 10:5:10 + P

T_{23} - NPK 10:5:10 + AMF

T_{24} - NPK 10:5:10

T_{25} - NPK 10:0:10 + A

T_{26} - NPK 10:0:10 + P

T_{27} - NPK 10:0:10 + AMF

T_{28} - NPK 10:0:10

T_{29} - NPK 0:0:10 + A

T_{30} - NPK 0:0:10 + P

T_{31} - NPK 0:0:10 + AMF

T_{32} - NPK 0:0:10

T_{33} - NPK 20:10:10 + A + AMF

T_{34} - NPK 20:10:10 + A + P

T_{35} - NPK 20:10:10 + AMF + P

T_{36} - NPK 20:10:10 + A +AMF + P

T_{37} - NPK 10:5:10 + A +AMF

T_{38} - NPK 10:5:10 + A + P

T_{39} - NPK 10:5:10 + AMF + P

T_{40} - NPK 10:5:10 + A +AMF + P

T_{41} - A + P + AMF (no inorganic fertilizer)

T_{42} - Absolute control (no inorganic and organic fertilizer)

* A → *Azospirillum*

* P → phosphobacteria

* AMF→ arbuscular mycorrhizal fungi

3.2.3 Biofertilizer application

Azospirillum and phosphobacteria were applied as 40 per cent slurry made in water and the roots were dipped in the slurry for 30 minutes before planting. AMF (arbuscular mycorrhizal fungi) was mixed with the potting media and filled in the pots (50 g AMF kg^{-1} media).

3.2.4 Plant protection

For fungal rot akomin (3ml l^{-1}) was sprayed weekly once and indofil M-45 (3g l^{-1}) was sprayed once in a month. For bacterial leaf rot streptomycin sulphate (0.20 g l^{-1}) was applied once in 3 months. Snails were controlled by metaldehyde bait 2.5 percent pellet and ekalux spray (3ml l^{-1}).

3.3 OBSERVATIONS

Observations were recorded at monthly interval from July 2002 to August 2003, for all the growth characters except for root parameters and drymatter production which were taken during destructive sampling for nutrient analysis.

3.3.1 Growth characters

3.3.1.1 Plant height (cm)

The height of the plant was measured from the base of the plant to the new emerging leaf and was expressed in cm.

3.3.1.2 Number of leaves

Number of leaves on each shoot was counted, totalled and recorded.

3.3.1.3 Number of leafy shoots

Number of leafy shoots on each plant was counted and recorded

3.3.1.4 Number of pseudobulbs

Number of pseudobulbs per plant was counted and recorded.

3.3.1.5 Girth of the shoot (cm)

Stem girth was measured and expressed in cm.

3.3.1.6 Internodal length (cm)

Internodal length was measured and expressed in cm.

3.3.1.7 Number of roots per plant

Number of roots per plant was taken at the time of destructive sampling.

3.3.1.8 Root length (cm)

Root length was taken at the time of sampling and expressed in cm.

3.3.1.9 Root volume (ml)

Root volume was measured at the time of sampling and expressed in ml.

3.3.1.10 Dry matter production (g)

The fresh and dry weight of the plants were recorded and dry matter production was calculated and expressed in g.

3.3.2 Flower characters

3.3.2.1 Days to first flowering

Total number of days taken for the first flower to open was recorded.

3.3.2.2 Number of spikes per plant

Number of spikes initiated in each plant,during the period of observation was counted and recorded.

3.3.2.3 Size of flower (cm)

Size of individual flowers were recorded by noting down the length and breadth of the flowers, expressed in cm.

3.3.2.4 Spike length (cm)

Length of the spike was measured from the point of emergence to the tip of flower pedicel emergence and expressed in cm.

3.3.2.5 Number of flowers per spike

Number of flowers per spike was counted and recorded

3.3.2.6 Internodal length (cm)

Internodal length was measured and expressed in cm .

3.3.2.7 Flower pedicel length (cm)

The length of the pedicel of individual flowers in each spike was measured and recorded.

3.3.2.8 Longevity of spike on the plant (days)

The time period between emergence of inflorescence to the wilting of first flower was recorded in days.

3.3.2.9 Vase life in water (days)

The time period taken for the wilting of first flower on the cut spike in water was recorded.

3.3.2.10 Colour variation

Colour of the flowers were closely observed to differentiate any colour variation and recorded.

3.3.3 Incidence of pests and diseases

Incidence of pests and diseases were also observed during the study period and proper prophylactic measures were taken.

3.3.4 Nutrient analysis

The plants were uprooted at spike emergence stage,washed and dried in shade for two weeks,and then were dried in oven at 65-70° C for 6 hours.The dried plant samples were ground and then chemically analysed for nitrogen,phosphorus and potassium .

3.3.4.1 Nitrogen

One gram dried plant sample was digested using concentrated sulphuric acid and was estimated by Microkjeldahl method.(Jackson,1958).

3.3.4.2 Phosphorus

The plant sample (0.5g) was taken and digested using diacid mixture of nitric acid and perchloric acid taken in the ratio of 9:4 (Johnson and Ulrich, 1959). Finally phosphorus was estimated using vanadomolybdophosphoric yellow colour method (Jackson, 1958). The intensity of yellow colour was read in Spectronic-20 at 470 nm.

3.3.4.3 Potassium

From the digested sample as mentioned above, an aliquot was prepared and estimated using a flame photometer.

3.4 ESTIMATION OF INFECTION BY MICROBIAL INOCULANTS

3.4.1 *Azospirillum*

The population of *Azospirillum* was enumerated by Most Probable Number (MPN) technique (Okon *et al.*,1977) using Okon's semisolid malic acid medium. After incubation at 37°C for two days, presence of blue colour and dense white pellicles, 1-2 mm below the upper surface of the medium were observed.

3.4.2 Phosphobacteria

For estimating the growth of phosphate solubilizing microorganisms, Pikovskaya's solid medium containing tricalcium phosphate was prepared and enumerated by the method described by Rao and Sinha (1963). One gram of potting media was suspended in sterile water and serial dilutions were plated using pour plate method and incubated for 4-5 days at 28 ± 2°C. Clear transparent zones around colonies indicated the presence of phosphobacteria.

3.4.3 Arbuscular Mycorrhizal Fungi (AMF)

Feeder roots of the plants were collected and cut into bits of about 1cm and transferred to test tubes containing FAA (Formalin, Acetic acid and Ethanol @ 5:5:90ml) for three hours. The root bits were hydrolysed in 10 per cent KOH solution at 90°C for 1 hour. After washing with water it was neutralized with one per cent HCl and then stained with 0.05 per cent trypan blue in lactophenol by boiling for three minutes. The roots were observed under the microscope for AMF colonization (Philips and Hayman, 1970).

The per cent infection was worked out as given below:

$$\text{Per cent infection} = \frac{\text{Total number of positive root segments}}{\text{Total number of root segments observed}} \times 100$$

3.5 STATISTICAL ANALYSIS

The experimental data were analysed by the Analysis of Variance technique (Panse and Sukhatme, 1985). MSTATC and MS-Excel softwares were used for computation of data.

Results

4. RESULTS

The results of the experiment entitled "Supplementary effect of biofertilizers in *Dendrobium"* are presented in this chapter.

4.1 VEGETATIVE CHARACTERS

Bi-monthly observations on growth parameters of the variety Sonia 17 upto 12th month of planting are presented in Tables 1 to 6 and Plate 2.

4.1.1 Plant height

The effect of biofertilizers on plant height at bimonthly intervals are presented in Table 1.

When plant height was considered there was not much influence of biofertilizers during second and fourth month after planting. During this period the treatment T_{24} recorded the maximum value of about 9.8 cm and 13.50 cm respectively and was found to be statistically on par with majority of the treatments and the lowest value was recorded for the treatment T_{27}..

From sixth month onwards there was significant difference among the treatments in data pertaining to plant height. The treatment T_{21} recorded the highest value (14.11 cm) followed by T_{20} and T_1 and all these treatments were found to be statistically superior and on par. The minimum value for plant height was recorded by the treatment T_{38} which was on par with all the treatments except treatments T_{21}, T_{20}, T_1, T_{34}, T_{35}, T_{28}, T_{30}, T_{14} and T_{24}.

Eighth month after planting, treatment T_{21} recorded maximum plant height (17.11 cm) followed by T_{20} (15.00 cm) and the minimum was reported by treatment T_9 (6.94 cm).

Height of the plants made a progressive increase during tenth month after planting and significant results were obtained for the treatment T_{21} (18.33 cm). The least recorded value was 10.44 cm for the treatment T_9.

Table 1. Plant height (cm) in *Dendrobium* var. Sonia 17 as influenced by different levels of inorganic fertilizers and biofertilizers

Treat-ment	At planting	2 MAP	4 MAP	6 MAP	8 MAP	10 MAP	12 MAP
1	4.38^{ab}	8.77^{abc}	11.83^{ab}	12.47^{abc}	13.72^{bc}	18.00^{abc}	18.78^{ab}
2	4.22^{abc}	7.56^{abcdef}	$8.72^{bcdefgh}$	$9.70^{bcdefgh}$	12.00^{bcdefg}	$15.55^{abcdefg}$	$16.00^{acdefgh}$
3	4.4^{ab}	6.11^{cdef}	$8.33^{bcdefgh}$	$10.69^{abcdefgh}$	13.83^{bc}	18.11^{ab}	17.94^{abcde}
4	4.37^{ab}	7.28^{abcdef}	7.41^{defgh}	8.93^{cdefgh}	$11.50^{bcdefghij}$	16.33^{abcdef}	$16.67^{abcdefg}$
5	4.48^{a}	5.39^{ef}	6.55^{fgh}	7.05^{gh}	8.48^{ghijkl}	11.89^{efgh}	11.90^{hij}
6	3.92^{bc}	7.17^{abcdef}	$8.44^{bcdefgh}$	8.88^{cdefgh}	$10.84^{cdefghijk}$	$15.56^{abcdefgh}$	$15.78^{abcdefghi}$
7	4.08^{abc}	6.56^{bcdef}	7.72^{cdefgh}	8.49^{defgh}	$10.89^{cdefghijk}$	12.72^{defgh}	$14.78^{abcdefghij}$
8	4.22^{abc}	7.22^{abcdef}	$8.44^{bcdefgh}$	$10.44^{bcdefgh}$	$11.89^{bcdefgh}$	17.11^{abcd}	16.94^{abcdef}
9	4.38^{ab}	7.50^{abcdef}	6.67^{fgh}	6.96^{h}	6.95^{l}	10.44^{h}	10.59^{j}
10	3.32^{bc}	7.33^{abcdef}	$8.28^{bcdefgh}$	8.81^{cdefgh}	$10.28^{cdefghijkl}$	14.28^{cdefgh}	$13.72^{cdefghij}$
11	3.89^{bc}	8.44^{abc}	10.78^{abcde}	$10.20^{bcdefgh}$	$11.45^{bcdefghij}$	$14.83^{abcdefgh}$	$16.39^{abcdefgh}$
12	4.50^{ab}	8.22^{abcd}	10.67^{abcde}	$10.56^{abcdefgh}$	$11.22^{cdefghijk}$	$15.11^{abcdefgh}$	$16.11^{abcdefgh}$
13	4.25^{abc}	5.50^{def}	6.39^{fgh}	7.06^{gh}	8.61^{ghijkl}	$13.17^{abcdefgh}$	$14.06^{cdefghij}$
14	3.87^{bc}	8.11^{abcde}	$9.11^{bcdefgh}$	$10.81^{abcdefg}$	$12.17^{bcdefgh}$	$16.50^{bcdefgh}$	18.00^{abcde}
15	4.00^{bc}	6.89^{bcdef}	$10.11^{abcdefg}$	$9.65^{bcdefgh}$	$11.67^{bcdefghij}$	16.39^{abcde}	17.61^{abcde}
16	4.22^{abc}	6.78^{bcdef}	$10.11^{abcdefg}$	$9.52^{bcdefgh}$	$11.17^{cdefghijk}$	17.72^{abc}	17.55^{abcde}
17	4.44^{ab}	5.11^{f}	7.39^{defgh}	7.57^{efgh}	8.46^{ghijkl}	12.39^{defgh}	$13.67^{cdefghij}$
18	4.17^{abc}	7.55^{abcdef}	$8.38^{bcdefgh}$	$10.13^{bcdefgh}$	$11.45^{bcdefghij}$	17.94^{abc}	18.22^{abcd}
19	3.50^{bc}	6.89^{bcdef}	7.72^{cdefgh}	8.64^{defgh}	$9.56^{defghijkl}$	$14.84^{abcdefgh}$	$15.33^{abcdefghi}$
20	3.44^{bc}	7.99^{abcde}	11.56^{abc}	13.14^{ab}	15.00^{ab}	17.95^{abc}	18.39^{abc}
21	4.50^{ab}	7.53^{abcdef}	$9.56^{abcdefgh}$	14.11^{a}	17.11^{a}	18.33^{a}	19.33^{a}
22	4.32^{ab}	6.22^{cdef}	7.28^{defgh}	7.56^{defgh}	$9.33^{efghijkl}$	12.56^{defgh}	$13.56^{defghij}$
23	3.98^{bc}	6.89^{bcdef}	$8.11^{bcdefgh}$	8.99^{cdefgh}	$8.78^{fghijkl}$	$13.78^{bcdefgh}$	$13.56^{defghij}$
24	4.05^{bc}	9.83^{a}	13.50^{a}	$10.74^{abcdefgh}$	$17.11^{bcdefghi}$	$15.45^{abcdefg}$	18.83^{ab}
25	4.35^{ab}	8.28^{abcd}	$7.95^{bcdefgh}$	8.88^{cdefgh}	$8.94^{fghijkl}$	$13.61^{bcdefgh}$	$14.17^{bcdefghij}$
26	4.00^{bc}	5.60^{def}	6.17^{gh}	7.87^{defgh}	8.22^{hijkl}	13.00^{cdefgh}	$13.83^{cdefghij}$
27	4.40^{ab}	4.84^{f}	6.20^{gh}	8.10^{defgh}	8.17^{ijkl}	11.94^{efgh}	13.28^{efghij}
28	3.89^{bc}	7.95^{abcde}	11.05^{abcd}	11.30^{abcde}	$11.78^{bcdefghi}$	$13.55^{bcdefgh}$	$14.56^{abcdefghij}$
29	4.11^{abc}	5.33^{ef}	5.89^{h}	7.00^{h}	7.55^{kl}	12.00^{efgh}	12.67^{fghij}
30	4.27^{abc}	8.89^{abc}	10.00^{abcdef}	10.98^{abcdef}	13.17^{bcd}	16.55^{abcde}	16.89^{abcdef}
31	4.35^{ab}	6.50^{bcdef}	$7.99^{bcdefgh}$	8.91^{cdefgh}	$10.00^{defghijkl}$	$13.11^{bcdefgh}$	$13.72^{cdefghij}$
32	4.00^{bc}	6.22^{cdef}	7.78^{cdefgh}	$10.35^{bcdefgh}$	$9.94^{defghijkl}$	$14.04^{bcdefgh}$	12.44^{fghij}
33	4.33^{ab}	6.33^{cdef}	6.67^{fgh}	8.54^{defgh}	$10.00^{defghijkl}$	12.11^{defgh}	$14.05^{cdefghij}$
34	3.44^{bc}	7.34^{abcdef}	10.72^{abcde}	11.43^{abcd}	12.73^{bcde}	16.55^{abcde}	18.17^{abcd}
35	4.44^{ab}	9.17^{ab}	10.28^{abcdef}	11.40^{abcd}	13.00^{bcde}	15.89^{abcdef}	$15.67^{abcdefgh}$
36	3.99^{bc}	7.44^{abcdef}	7.44^{defgh}	$9.75^{bcdefgh}$	$11.00^{cdefghijk}$	16.22^{abcdef}	$16.39^{abcdefgh}$
37	3.83^{bc}	6.45^{bcdef}	$8.33^{bcdefgh}$	8.37^{defgh}	$9.83^{defghijkl}$	$13.17^{bcdefgh}$	$14.22^{abcdefghij}$
38	4.50^{ab}	6.11^{cdef}	7.33^{defgh}	6.94^{h}	8.05^{jkl}	10.72^{gh}	12.61^{fghij}
39	4.38^{ab}	8.06^{abcde}	$9.94^{abcdefg}$	$10.13^{bcdefgh}$	12.94^{bcde}	16.06^{abcdef}	17.06^{abcdef}
40	3.99^{bc}	6.89^{bcdef}	$8.50^{bcdefgh}$	8.70^{cdefgh}	12.33^{bcdef}	$14.78^{abcdefgh}$	$15.44^{abcdefghi}$
41	4.25^{ab}	7.00^{bcdef}	7.00^{efgh}	7.48^{fgh}	$8.72^{fghijkl}$	11.33^{fgh}	11.28^{ij}
42	4.11^{ab}	7.55^{abcdef}	$8.56^{bcdefgh}$	9.35^{cdefgh}	$10.44^{cdefghijkl}$	12.00^{efgh}	12.00^{ghij}

At Planting

Six month after planting **Twelve month after planting**

Plate 2. View of the experimental plot at different stages of growth

The data recorded to twelfth month after planting revealed that the biofertilizer *Asospirillum* was having a progressive effect on plant height. Treatments receiving this biofertilizer showed a significant difference in plant height. The peak value was obtained for treatment T_{21} (19.33 cm). The treatment effect was least pronounced in treatment T_9 (10.59 cm).

4.1.2 Number of leaves per plant

Data pertaining to number of leaves per plant are in Table 2.

Treatments did not record significant difference with regard to leaf number produced upto fourth month of plant growth. However treatments T_{20} (8.79) and T_2 (7.56) recorded the highest number of leaves during second and fourth month after planting respectively.

Even after sixth month of planting the variations were non-significant but there was a progressive increase in leaf number and the treatment T_{21} recorded the maximum number of leaves (7.11) and the treatment T_{41} recorded the minimum number of leaves (3.45).

Significant variation was noticed in the case of leaves produced due to the effect of different treatments after eighth month of planting. The data revealed that treatment T_{21} recorded the highest number of leaves (8.67) and the treatments T_6, T_4, T_{17}, T_{29}, T_{39}, T_{38}, T_{22}, T_{26} and T_{28} were on par with T_{21}. The lowest number of leaves were produced by the plants which received the treatment T_{27}.

Tenth month after planting, leaf production showed a decreasing trend in some of the treatments and among the treatments T_{21} recorded the largest number of leaves (8.57).

Even after twelve months, leaf production showed a decreasing trend. Again the treatment T_{21} recorded the highest value (8.60) and were found to be statistically on par with the treatments T_4, T_{22} and T_{14}. Majority of the treatments were

Table 2. Number of leaves per plant in *Dendrobium* var. Sonia 17 as influenced by differeent levels of inorganic fertilizers and biofertilizers

Treat-ment	At planting	2 MAP	4 MAP	6 MAP	8 MAP	10 MAP	12 MAP
1	6.33^{abc}	6.68^{abcde}	6.00^{abcdefgh}	5.22^{abcdef}	4.89^{fghi}	6.89^{ab}	6.00^{abcdef}
2	5.78^{abc}	5.11^{de}	5.22^{abcdefgh}	5.44^{abcdef}	6.00^{cdefghi}	6.11^{ab}	5.56^{abcdef}
3	5.22^{abc}	5.56^{bcde}	5.89^{abcdefgh}	4.22^{bcdef}	6.56^{bcdefgh}	6.56^{ab}	6.00^{abcdef}
4	6.78^{abc}	6.22^{abcde}	6.11^{abcdefg}	6.89^{ab}	8.11^{abc}	8.06^{ab}	7.78^{ab}
5	5.67^{abc}	5.67^{bcde}	4.44^{defg}	4.11^{cdef}	5.45^{cdefghi}	5.33^{ab}	5.56^{abcdef}
6	7.22^{ab}	7.44^{abcd}	7.11^{abc}	6.22^{abcde}	8.22^{ab}	7.00^{ab}	6.00^{abcdef}
7	6.11^{abc}	5.58^{bcde}	5.67^{abcdefg}	4.22^{bcdef}	5.11^{defghi}	6.55^{ab}	6.56^{abcde}
8	5.89^{abc}	7.22^{abcde}	5.78^{cdefg}	5.67^{abcdef}	5.89^{cdefghi}	5.55^{ab}	5.11^{cdef}
9	6.55^{abc}	5.44^{bcde}	4.56^{cdefg}	5.22^{abcdef}	5.56^{cdefghi}	5.89^{ab}	5.11^{cdef}
10	5.89^{abc}	6.56^{abcde}	4.55^{gh}	5.11^{abcdef}	6.56^{bcdefgh}	5.67^{ab}	5.00^{cdef}
11	6.33^{abc}	6.56^{abcde}	3.56^{abcdefgh}	3.67^{ef}	5.00^{efghi}	5.33^{ab}	5.44^{bcdef}
12	6.56^{abc}	7.22^{abcde}	5.00^{abcdefgh}	3.89^{def}	4.22^{ghi}	6.11^{ab}	5.55^{abcdef}
13	6.44^{abc}	6.44^{abcde}	4.99^{abcdefgh}	5.11^{abcdef}	6.22^{bcdefghi}	6.67^{ab}	5.67^{abcdef}
14	5.56^{abc}	5.78^{bcde}	5.00^{abcdefgh}	4.66^{abcdef}	5.00^{efghi}	6.89^{ab}	6.89^{abc}
15	5.11^{abc}	6.00^{abcd}	5.89^{abcdefgh}	5.22^{abcdef}	5.89^{cdefghi}	6.78^{ab}	6.00^{abcdef}
16	5.44^{abc}	6.44^{abcde}	5.22^{abcdefgh}	4.45^{abcdef}	4.78^{fghi}	5.78^{ab}	5.56^{abcdef}
17	6.22^{abc}	6.33^{abcde}	6.33^{abcdef}	6.78^{abc}	7.78^{abcd}	8.11^{ab}	6.78^{abcd}
18	5.33^{abc}	6.33^{abcde}	5.56^{abcdefgh}	5.45^{abcdef}	6.44^{bcdefgh}	6.67^{ab}	5.55^{abcdef}
19	4.99^{c}	5.11^{de}	4.00^{fgh}	4.11^{cdef}	5.22^{defghi}	5.78^{ab}	5.44^{bcdef}
20	6.67^{abc}	8.79^{a}	7.56^{a}	5.44^{abcdef}	6.44^{bcdefghi}	7.33^{ab}	6.22^{abcdef}
21	6.56^{abc}	8.33^{ab}	6.79^{abcde}	7.11^{a}	8.67^{a}	8.57^{a}	8.60^{a}
22	6.22^{abc}	7.17^{abcde}	5.56^{abcdefgh}	5.00^{abcdef}	6.89^{abcdefg}	6.89^{ab}	7.00^{abc}
23	6.89^{abc}	7.22^{abcde}	5.78^{abcdefgh}	5.78^{abcdef}	6.11^{bcdefghi}	7.67^{ab}	6.56^{abcde}
24	7.67^{a}	8.22^{abc}	7.33^{ab}	5.56^{abcdef}	6.33^{bcdefgh}	6.22^{ab}	6.33^{abcdef}
25	5.78^{abc}	5.78^{bcde}	6.33^{abcdef}	5.89^{abcdef}	6.67^{bcdefg}	7.33^{ab}	6.78^{abcd}
26	6.33^{abc}	5.44^{bcde}	5.33^{abcdefgh}	6.33^{abcde}	6.78^{abcdefg}	6.67^{ab}	5.78^{abcdef}
27	5.11^{abc}	5.88^{bcde}	4.89^{abcde}	4.11^{cdef}	3.67^{i}	4.56^{b}	4.22^{f}
28	5.78^{abc}	8.22^{abc}	6.78^{abcdefgh}	6.22^{abcde}	6.78^{abcdefg}	4.78^{b}	4.89^{cdef}
29	7.67^{a}	7.44^{abcd}	6.00^{abcdefgh}	5.56^{abcdef}	7.67^{abcde}	7.00^{ab}	6.33^{abcdef}
30	7.67^{a}	7.88^{abcd}	6.22^{abcdef}	5.89^{abcdef}	6.67^{bcdefg}	7.11^{ab}	6.22^{abcdef}
31	7.67^{abc}	5.11^{de}	4.33^{efgh}	4.00^{def}	4.78^{fghi}	5.11^{ab}	4.44^{ef}
32	5.89^{abc}	6.22^{abcde}	6.44^{abcdef}	5.22^{abcdef}	6.33^{bcdefgh}	7.00^{ab}	5.67^{abcdef}
33	4.56^{c}	5.00^{de}	4.45^{defg}	5.34^{abcdef}	5.67^{cdefghi}	5.33^{ab}	4.89^{cdef}
34	6.11^{abc}	6.33^{abcde}	4.89^{bcdefg}	5.44^{abcdef}	5.89^{cdefghi}	6.00^{ab}	5.55^{abcdef}
35	7.22^{ab}	7.67^{abcd}	7.11^{abc}	5.89^{abcdef}	5.22^{defghi}	7.56^{ab}	4.89^{cdef}
36	4.78^{bc}	6.11^{abcde}	6.11^{abcdefg}	5.11^{abcdef}	5.89^{cdefghi}	6.44^{ab}	5.22^{bcdef}
37	5.56^{abc}	5.33^{cde}	5.67^{abcdefgh}	5.22^{abcdef}	6.66^{bcdefg}	6.11^{ab}	5.55^{abcdef}
38	6.78^{abc}	6.89^{abcde}	7.00^{abcd}	6.56^{abcd}	7.00^{abcdef}	6.55^{ab}	5.22^{bcdef}
39	5.78^{abc}	6.33^{abcde}	5.89^{abcdefgh}	6.78^{abc}	7.67^{abcde}	5.00^{ab}	5.33^{bcdef}
40	4.66^{bc}	5.22^{de}	4.78^{bcdefgh}	3.89^{def}	4.33^{fghi}	5.56^{ab}	5.33^{bcdef}
41	4.78^{bc}	4.33^{e}	3.44^{h}	3.45^{f}	3.89^{hi}	4.78^{b}	4.56^{def}
42	6.00^{abc}	5.55^{bcde}	5.11^{abcdefgh}	5.00^{abcdef}	4.67^{fghi}	5.11^{ab}	4.44^{ef}

found to be on par with the treatment T_{17} (6.78) and the lowest value was obtained for the treatment T_{27} (4.22).

4.1.3 Number of leafy shoots per plant

Data regarding shoot production are presented in Table 3.

Second month of planting onwards a distinguishable variation was observed among treatments for the number of leafy shoots produced. Treatment T_{21} recorded the highest number of shoots (3.34) which was on par with the treatments T_{28} and T_{38}. Majority of the treatments were found to be statistically on par with the treatment T_{20} (2.89) and the lowest number of leafy shoots were recorded for the treatment T_{41} (1.89).

Treatments had significantly influenced the shoot number after fourth month of planting. Treatment T_{21} recorded the highest number (3.67) and the treatments T_6, T_{38} and T_{32} were on par with T_{21}.

After sixth month of planting the number of leafy shoots significantly differed among various treatments with the treatment T_{21} recording the maximum number of shoots with leaves (3.00). The treatments T_{23}, T_{24}, T_{18}, $T_{17}$and T_{20} were on par with T_{21}. Majority of the treatments were on par with the treatment T_{11} which recorded the lowest value (1.33).

At eighth month of planting the treatment T_{21} recorded the highest value of 3.44 followed by T_6 (3.33) and T_{12} (3.11). Treatments T_{38}, T_{25}, T_{20}, T_{23}, T_{40} and T_{22} were found to be statistically on par with T_{21}.The treatment T_{27} recorded the lowest value (1.67).

In the subsequent months, i.e., tenth and twelfth month after planting the treatments did not show much significant difference, eventhough a progressive increase in leafy shoots was observed. Again the treatment T_{21} recorded the highest number (3.50 and 3.62) during tenth and twelfth month after planting respectively.

Table 3. Number of leafy shoots per plant in *Dendrobium* var. Sonia 17 as influenced by different levels of inorganic fertilizers and biofertilizers

Treat-ment	At planting	2 MAP	4 MAP	6 MAP	8 MAP	10 MAP	12 MAP
1	2.22^{bc}	2.33^{abcde}	2.33^{bcde}	2.55^{cd}	$2.44^{cdefghi}$	2.00^{abc}	2.56^{abcd}
2	2.11^{bc}	2.00^{de}	2.22^{bcde}	2.00^{d}	2.56^{cdefgh}	2.00^{abc}	2.44^{abcd}
3	2.10^{c}	2.33^{abcde}	2.55^{abcde}	1.55^{d}	2.33^{defghi}	2.33^{abc}	2.22^{abcd}
4	3.11^{ab}	2.33^{abcde}	2.78^{abcde}	2.33^{cd}	2.78^{abcdef}	2.89^{abc}	3.00^{ab}
5	2.22^{bc}	2.33^{abcde}	2.00^{cde}	2.11^{d}	2.66^{bcdef}	2.11^{abc}	2.33^{abcd}
6	2.67^{abc}	2.78^{abcde}	3.33^{ab}	2.44^{cd}	3.33^{ab}	2.89^{abc}	2.55^{abcd}
7	2.11^{c}	3.11^{abc}	2.67^{abcde}	1.89^{d}	2.11^{fghij}	2.56^{abc}	2.99^{ab}
8	2.67^{abc}	2.77^{abcde}	2.55^{abcde}	2.11^{d}	$2.45^{cdefghi}$	2.11^{abc}	2.22^{abcd}
9	2.56^{bc}	2.44^{abcde}	2.55^{abcde}	2.33^{cd}	$2.44^{cdefghi}$	2.67^{abc}	2.78^{abcd}
10	2.11^{c}	2.44^{abcde}	2.44^{abcde}	2.11^{d}	2.55^{cdefgh}	2.11^{abc}	2.22^{abcd}
11	2.44^{bc}	3.00^{abcd}	1.67^{e}	1.33^{d}	1.89^{hij}	2.22^{abc}	2.44^{abcd}
12	3.67^{a}	2.89^{abcde}	2.67^{abcde}	2.44^{cd}	3.11^{abc}	2.44^{abc}	2.55^{abcd}
13	2.67^{abc}	2.78^{abcde}	2.00^{cde}	2.11^{d}	2.22^{efghij}	2.56^{abc}	2.78^{abcd}
14	2.11^{c}	2.11^{cde}	1.89^{de}	2.00^{d}	1.89^{hij}	2.44^{abc}	2.33^{abcd}
15	2.22^{bc}	2.55^{abcde}	2.67^{abcde}	1.78^{d}	2.11^{fghij}	2.67^{abc}	2.67^{abcd}
16	2.67^{abc}	2.56^{abcde}	2.22^{bcde}	1.78^{d}	1.89^{hij}	2.00^{abc}	2.00^{cd}
17	2.33^{bc}	2.67^{abcde}	3.00^{abcd}	2.99^{ab}	2.67^{bcdefg}	3.00^{ab}	2.78^{abcd}
18	2.22^{bc}	2.33^{abcde}	2.55^{abcde}	2.87^{ab}	2.67^{bcdefg}	2.33^{abc}	2.44^{abcd}
19	2.33^{bc}	2.44^{abcde}	2.11^{bcde}	2.68^{bc}	2.00^{ghij}	2.11^{abc}	2.44^{abcd}
20	2.56^{bc}	2.89^{abcde}	3.00^{abcd}	2.86^{ab}	2.89^{abcde}	2.55^{abc}	2.44^{abcd}
21	2.56^{bc}	3.34^{a}	3.67^{a}	3.00^{a}	3.44^{a}	3.50^{a}	3.62^{a}
22	2.33^{bc}	2.22^{bcde}	1.89^{de}	2.70^{b}	2.78^{abcdef}	2.33^{abc}	2.33^{abcd}
23	2.67^{abc}	2.45^{abcde}	2.56^{abcde}	2.95^{ab}	2.89^{abcde}	2.89^{ab}	2.89^{abc}
24	2.67^{abc}	3.22^{ab}	3.11^{abcd}	2.87^{ab}	2.22^{efghij}	2.45^{abc}	2.89^{abc}
25	2.22^{bc}	2.56^{abcde}	2.78^{abcde}	2.60^{cd}	3.00^{abcd}	3.00^{ab}	3.00^{ab}
26	2.89^{abc}	2.56^{abcde}	2.89^{abcde}	2.56^{cd}	2.00^{ghij}	2.33^{abc}	2.78^{abcd}
27	2.33^{bc}	2.55^{abcde}	2.44^{abcde}	1.77^{d}	1.67^{j}	1.78^{bc}	1.89^{d}
28	2.78^{abc}	3.33^{abcde}	3.11^{abcd}	2.44^{cd}	2.56^{cdefgh}	2.00^{abc}	2.67^{abcd}
29	2.77^{abc}	2.89^{abcde}	3.00^{abcd}	2.57^{cd}	$2.44^{cdefghi}$	3.00^{ab}	2.56^{abcd}
30	3.00^{ab}	2.78^{abcde}	2.44^{abcde}	2.11^{d}	2.11^{fghij}	2.55^{abc}	2.45^{abcd}
31	2.22^{bc}	2.33^{abcde}	2.11^{bcde}	1.78^{d}	1.78^{ij}	1.89^{bc}	1.89^{d}
32	2.44^{bc}	2.33^{abcde}	3.22^{abc}	2.11^{d}	2.56^{cdefg}	2.44^{abc}	2.67^{abcd}
33	2.45^{bc}	2.44^{abcde}	2.33^{bcde}	2.00^{d}	1.67^{j}	2.22^{abc}	2.22^{abcd}
34	2.89^{abc}	2.78^{abcde}	2.67^{abcde}	1.89^{d}	$2.33^{defghij}$	2.11^{abc}	2.11^{bcd}
35	2.89^{abc}	3.11^{abc}	2.89^{abcde}	2.22^{d}	2.56^{defgh}	2.56^{abc}	2.22^{abcd}
36	2.44^{bc}	2.78^{abcde}	2.89^{abcde}	2.33^{cd}	2.11^{fghij}	2.11^{abc}	2.22^{abcd}
37	2.22^{bc}	2.11^{cde}	2.56^{abcde}	2.55^{cd}	2.22^{efghij}	2.77^{abc}	3.00^{ab}
38	2.78^{abc}	3.33^{a}	3.22^{abc}	2.59^{cd}	3.00^{abcd}	2.89^{ab}	3.00^{ab}
39	2.22^{bc}	2.55^{abcde}	2.67^{abcde}	2.55^{cd}	1.67^{j}	2.00^{abc}	2.55^{abcd}
40	2.22^{bc}	2.00^{de}	2.00^{cde}	1.89^{d}	2.78^{abcdef}	2.22^{abc}	2.55^{abcd}
41	2.22^{bc}	1.89^{e}	1.67^{e}	1.77^{d}	1.78^{ij}	1.67^{c}	2.11^{bcd}
42	2.67^{abc}	2.33^{abcde}	2.44^{abcde}	2.11^{d}	1.89^{hij}	2.22^{abc}	2.22^{abcd}

4.1.4 Number of pseudobulbs per plant

Data corresponding to number of pseudobulbs per plant as influenced by different treatments are presented in Table 4.

During the second and fourth month after planting there was no appreciable difference in pseudobulb production and the treatments were found to be statistically non-significant. At sixth month of planting treatment T_{38} reported the highest value (3.11). The least value was recorded for the treatment T_4 (1.11). The number of pseudobulbs produced differed significantly after eight months of planting. Superior results were again obtained for the treatment T_{38} (3.29) followed by T_{12} (3.11) and treatments T_{16}, T_{40}, T_{10}, T_{35}, T_{11}, T_{36}, T_7 and T_{23} were on par with T_{12}. The lowest number of pseudobulbs were recorded for the treatment T_{17} (1.22).

Data recorded after tenth month of planting revealed substantial increase in pseudobulb production. The treatment T_{38} (3.44) recorded the highest number of pseudobulbs produced followed by T_{26}, T_{12} and T_{30}. Least number of pseudobulbs produced were recorded for the treatment T_{22} (1.44).

Appreciable difference in pseudobulb production was noticed after twelfth month of planting and the treatment T_{38} recorded the highest value (4.33) followed by T_{23}, T_{38} and T_{12}. Majority of the treatments were on par with the treatment T_{30} (3.78) and the lowest number was obtained for T_4 (2.00).

4.1.5 Girth of the shoot

Data related to shoot girth are represented in Table 5.

Significant effect of treatments on shoot girth was observed after two months of planting. Treatment T_{21} recorded the highest value of 4.34 which was found to be statistically on par with the treatments T_{11}, T_{23}, T_{35}, T_{12}, T_7, T_{15} and T_{16} and the lowest value was recorded for the treatment T5 (2.04 cm).

Fourth month after planting a similar trend in shoot girth was noticed. The treatment T_{21} recorded the highest value (4.40 cm) and the lowest value was obtained

Table 4. Number of pseudobulbs per plant in *Dendrobium* var. Sonia 17 as influenced by different levels of inorganic fertilizers and biofertilizers

Treat-ment	At planting	2 MAP	4 MAP	6 MAP	8 MAP	10 MAP	12 MAP
1	0(0.70)^{b}	0.44(0.96)^{abc}	0.88(1.09)^{bcde}	1.22^{efg}	1.44^{ijk}	1.78^{ef}	2.33^{ghi}
2	0.22(0.71)^{b}	0.66(1.05)^{abc}	0.60(1.05)^{bcde}	1.22^{efg}	1.78^{fghijk}	1.99^{def}	2.22^{hi}
3	0(0.71)^{b}	0.55(1.02)^{abc}	0.55(1.02)^{bcde}	1.56^{cdefg}	1.33^{jk}	2.33^{abcdef}	2.44^{fghi}
4	0.11(0.71)^{b}	0.44(0.96)^{abc}	0.77(1.06)^{bcde}	1.11^{fg}	1.67^{ghijk}	1.89^{def}	2.00^{i}
5	0.22(0.83)^{ab}	0.66(1.05)^{abc}	1.22(1.10)^{abcde}	1.78^{bcdefg}	1.67^{ghijk}	2.67^{abcde}	3.00^{bcdefghi}
6	0.22(0.83)^{ab}	0.44(0.96)^{abc}	0.66(1.05)^{bcde}	2.11^{abcdefg}	2.44^{bcdef}	2.78^{abcde}	3.99^{abc}
7	0.11(0.71)^{b}	0.66(1.05)^{abc}	1.22(1.10)^{abcde}	2.67^{abc}	2.55^{abcde}	3.11^{abcd}	3.11^{abcdefghi}
8	0.22(0.83)^{ab}	0.33(0.94)^{abc}	1.00(0.99)^{bcde}	1.56^{cdefg}	2.00^{defghij}	2.89^{abcde}	3.33^{abcdefgh}
9	0.33(0.89)^{ab}	0.66(1.05)^{abc}	1.33(1.14)^{abcde}	2.22^{abcdef}	2.22^{cdefgh}	2.67^{abcde}	3.33^{abcdefgh}
10	0.11(0.71)^{b}	0.99(1.08)^{abc}	1.11(1.10)^{abcde}	2.22^{abcdef}	2.67^{abcd}	3,00^{abcd}	3.33^{abcdefgh}
11	0.22(0.83)^{ab}	0.44(0.96)^{abc}	1.44(1.18)^{abcde}	2.33^{abcde}	2.56^{abcde}	2.56^{abcdef}	3.22^{abcdefgh}
12	0.22(0.83)^{ab}	1.44(1.18)^{a}	2.00(1.55)^{a}	2.89^{ab}	3.11^{ab}	3.33^{ab}	4.22^{ab}
13	0.33(0.89)^{ab}	1.22(1.12)^{ab}	1.44(1.18)^{abcde}	2.22^{abcdef}	2.22^{cdefgh}	3.11^{abcd}	3.67^{abcdef}
14	0.11(0.71)^{b}	0.99(1.08)^{ab}	1.56(1.43)^{ab}	2.00^{abcdefg}	2.00^{defghij}	2.11^{bcdef}	2.67^{defghi}
15	0.00(0.70)^{b}	0.55(1.02)^{abc}	1.22(1.10)^{abcde}	1.78^{bcdefg}	1,56^{hijk}	2.67^{abcde}	3.11^{abcdefghi}
16	0.33(0.89)^{ab}	0.77(1.06)^{ab}	0.88(1.09)^{bcde}	2.33^{abcde}	2.78^{abc}	2.56^{abcdef}	3.11^{abcdefghi}
17	0.33(0.89)^{ab}	0.11(0.70)^{c}	0.11(0.70^{e}	1.00^{g}	1.22^{k}	2.44^{abcdef}	2.78^{cdefghi}
18	0.11(0.71)^{b}	0.44(0.96)^{abc}	0.66(1.05)^{bcde}	1.89^{bcdefg}	1.89^{efghijk}	2.22^{bcdef}	2.55^{efghi}
19	0.11(0.71)^{b}	0.66(1.05)^{abc}	1.44(1.18)^{abcde}	1.89^{bcdefg}	2.11^{cdefghi}	2.45^{abcdef}	3.00^{bcdefghi}
20	0.44(0.96)^{a}	0.44(0.96)^{abc}	0.77(1.06)^{bcde}	1.67^{cdefg}	2.00^{defghij}	2.89^{abcde}	3.33^{abcdefgh}
21	0.11(0.71)^{b}	0.11(0.70)^{c}	0.33(0.94)^{bcde}	1.78^{bcdefg}	1.78^{fghijk}	2.22^{abcdef}	3.00^{bcdefghi}
22	0.11(0.71)^{b}	0.33(0.94)^{abc}	0.77(1.06)^{bcde}	1.67^{cdefg}	1.89^{efghijk}	1.44^{f}	2.56^{efghi}
23	0.11(0.71)^{b}	0.33(0.94)^{abc}	1.11(1.10)^{abcde}	2.44^{abcd}	2.55^{abcde}	3.22^{abc}	4.22^{ab}
24	0.11(0.71)^{b}	0.33(0.94)^{abc}	0.77(1.06)^{bcde}	2.22^{abcdef}	2.00^{defghij}	2.99^{abcd}	3.44^{abcdefgh}
25	0.00(0.70)^{b}	0.55(1.02)^{abc}	0.66(1.05)^{bcde}	2.11^{abcdefg}	2.22^{cdefgh}	2.89^{abcde}	3.55^{abcdefg}
26	0.22(0.83)^{ab}	0.44(0.96)^{abc}	0.77(1.06)^{bcde}	2.00^{abcdefg}	2.00^{defghij}	3.33^{ab}	3.67^{abcdef}
27	0.22(0.83)^{ab}	0.33(0.94)^{abc}	1.33(1.14)^{abcde}	1.67^{cdefg}	1.89^{efghijk}	2.89^{abcde}	3.00^{bcdefghi}
28	0.33(0.89)^{ab}	0.66(1.05)^{abc}	0.88(1.09)^{bcde}	2.33^{abcde}	2.33^{cdefg}	3.22^{abc}	4.22^{ab}
29	0.22(0.83)^{ab}	0.66(1.05)^{abc}	0.88(1.09)^{bcde}	2.22^{abcdef}	2.22^{cdefgh}	2.56^{abcdef}	3.55^{abcdefg}
30	0.11(0.71)^{b}	0.33(0.94)^{abc}	1.22(1.10)^{abcde}	2.11^{abcdefg}	1.56^{hijk}	3.33^{ab}	3.78^{abcde}
31	0.33(0.89)^{ab}	0.44(0.96)^{abc}	0.77(1.06)^{bcde}	1.44^{defg}	1.89^{efghijk}	2.00^{cdef}	2.33^{ghi}
32	0.11(0.71)^{b}	0.55(1.02)^{abc}	0.4(0.96)^{bcde}	2.00^{abcdefg}	1.67^{ghijk}	2.33^{abcdef}	2.56^{efghi}
33	0.22(0.83)^{ab}	0.33(0.89)^{abc}	1.22(1.29)^{abcd}	1.77^{bcdefg}	1.78^{fghijk}	2.56^{abcdef}	3.22^{abcdefgh}
34	0.22(0.83)^{ab}	0.55(1.03)^{abc}	1.11(1.26)^{abcd}	2.22^{abcdef}	2.22^{cdefgh}	2.67^{abcde}	2.99^{bcdefghi}
35	0.11(0.71)^{b}	0.11(0.77)^{bc}	1.11(1.26)^{abcd}	2.67^{abc}	2.67^{abcd}	3.11^{abcd}	3.89^{abcd}
36	0.22(0.83)^{ab}	0.11(0.77)^{bc}	0.66(1.06)^{bcde}	1.22^{efg}	2.56^{abcde}	2.44^{abcdef}	3.33^{abcdefgh}
37	0.33(0.89)^{ab}	0.33(0.89)^{abc}	0.55(1.01)^{bcde}	1.56^{cdefg}	1.44^{ijk}	2.44^{abcdef}	3.11^{abcdefghi}
38	0.44(0.96)^{a}	0.11(0.77)^{bc}	0.88(1.18)^{abcde}	3.11^{a}	3.29^{a}	3.44^{a}	4.33^{a}
39	0.00(0.70)^{b}	0.33(0.89)^{abc}	0.77(1.12)^{abcde}	1.33^{defg}	1.67^{ghijk}	2.67^{abcde}	3.44^{abcdefgh}
40	0.22(0.83)^{ab}	0.66(1.05)^{abc}	1.44(1.39)^{abc}	2.45^{abcd}	2.78^{abc}	2.66^{abcde}	3.44^{abcdefgh}
41	0.11(0.71)^{b}	0.44(0.95)^{abc}	1.56(1.42)^{ab}	2.22^{abcdef}	2.22^{cdefgh}	2.78^{abcde}	3.33^{abcdefgh}
42	0.00(0.70)^{b}	0.22(0.79)^{bc}	1.11(1.26)^{abcd}	2.22^{abcdef}	2.34^{cdefg}	3.00^{abcd}	3.78^{abcde}

Value in parenthesis denotes square root transformation

Table 5. Girth of the shoot (cm) in *Dendrobium* var. Sonia 17 as influenced by different levels of inorganic fertilizers and biofertilizers

Treat-ment	At planting	2 MAP	4 MAP	6 MAP	8 MAP	10 MAP	12 MAP
1	2.40^{abc}	2.99^{defghi}	3.97^{abcd}	4.10^{abc}	4.16^{abcdef}	4.29^{ab}	4.33^{abcdef}
2	2.74^{abc}	$3.09^{cdefghi}$	3.79^{abcde}	4.04^{abc}	4.30^{abc}	4.40^{ab}	4.22^{abcdef}
3	2.67^{abc}	3.53^{bcdefg}	3.80^{abcde}	3.47^{bcdef}	3.62^{bcdefg}	3.77^{abcd}	4.27^{abcdef}
4	2.47^{abc}	$3.09^{cdefghij}$	2.93^{f}	2.98^{f}	3.14^{g}	3.27^{d}	4.21^{abcdef}
5	2.61^{abc}	2.04^{k}	3.49^{bcdef}	3.65^{bcdef}	3.87^{bacefg}	3.98^{abcd}	3.95^{bcdef}
6	2.29^{c}	2.77^{ghijk}	3.77^{abcde}	3.72^{bcdef}	3.92^{bcdefg}	3.96^{abcd}	3.97^{bcdef}
7	2.39^{abc}	3.72^{abcd}	3.90^{abcde}	3.57^{bcdef}	3.81^{bcdefg}	3.91^{abcd}	3.91^{bcdef}
8	2.38^{abc}	3.55^{bcdef}	3.40^{bcdef}	3.60^{bcdef}	3.73^{bcdefg}	3.91^{abcd}	4.13^{abcdef}
9	2.14^{c}	2.62^{jk}	3.28^{cdef}	3.34^{cdef}	3.61^{cdefg}	3.72^{bcd}	3.72^{ef}
10	2.55^{abc}	2.92^{efghij}	3.11^{ef}	3.42^{bcdef}	3.61^{cdefg}	3.67^{bcd}	4.02^{bcdef}
11	2.13^{c}	4.13^{ab}	3.84^{abcde}	3.45^{bcdef}	3.74^{bcdefg}	3.78^{abcd}	4.07^{abcdef}
12	2.62^{abc}	3.84^{abc}	3.78^{abcde}	3.67^{bcdef}	3.89^{bacefg}	4.02^{abc}	3.74^{def}
13	2.25^{c}	2.77^{ghijk}	3.38^{bcdef}	3.49^{bcdef}	3.76^{bcdefg}	3.85^{abcd}	3.90^{bcdef}
14	2.47^{abc}	2.86^{fghij}	3.31^{cdef}	3.82^{abcde}	4.00^{abcdef}	4.08^{abc}	4.11^{abcdef}
15	2.62^{abc}	3.71^{abcd}	3.31^{abcde}	3.51^{bcdef}	3.69^{bcdefg}	3.75^{bcd}	4.13^{abcdef}
16	2.24^{c}	3.68^{abcde}	3.88^{cdef}	3.74^{bcdef}	$3.98^{abcdefg}$	4.10^{abc}	4.18^{abcdef}
17	2.22^{c}	2.72^{ijk}	3.28^{bcdef}	3.76^{abcdef}	3.94^{bcdefg}	4.03^{abc}	4.28^{abcde}
18	2.63^{abc}	$2.99^{defghij}$	3.40^{bcdef}	3.81^{abcdef}	4.00^{abcdef}	4.16^{abc}	4.39^{bcdef}
19	2.25^{c}	$3.43^{bcdefghi}$	3.54^{bcdef}	3.63^{bcdef}	3.76^{bcdefg}	3.90^{abcd}	3.96^{abcdef}
20	2.59^{abc}	2.87^{fghij}	3.98^{abcd}	3.87^{abcde}	4.09^{abcdef}	4.17^{abc}	4.05^{abcdef}
21	2.42^{abc}	4.34^{a}	4.40^{a}	4.60^{a}	4.78^{a}	4.83^{a}	4.88^{a}
22	2.15^{c}	2.60^{jk}	3.56^{bcdef}	4.13^{abc}	4.28^{abcd}	4.34^{ab}	4.50^{abc}
23	2.61^{abc}	4.08^{ab}	3.92^{abcd}	3.93^{abcde}	4.14^{ab}	4.24^{abc}	4.46^{abc}
24	2.41^{abc}	3.54^{bcdef}	3.42^{bcdef}	4.24^{bcdef}	4.46^{ab}	4.22^{abc}	4.41^{abcd}
25	2.81^{ab}	$3.21^{cdefghij}$	3.80^{abcde}	3.70^{bcdef}	3.94^{bcdefg}	4.07^{abc}	4.12^{abcdef}
26	2.59^{abc}	$3.00^{defghij}$	3.31^{cdef}	3.39^{cdef}	3.56^{cdefg}	3.75^{bcd}	3.91^{bcdef}
27	2.12^{c}	2.52^{jk}	3.71^{abcdef}	4.07^{abc}	4.25^{abcd}	4.34^{ab}	4.53^{abc}
28	2.54^{abc}	$2.97^{defghij}$	4.02^{abc}	3.92^{abc}	4.17^{abcdef}	4.21^{abc}	4.37^{abcde}
29	2.34^{bc}	2.75^{hijk}	3.35^{cdef}	3.51^{bcdef}	3.60^{cdefg}	3.69^{bcd}	4.09^{abcef}
30	2.19^{a}	$3.44^{bcdefghi}$	3.39^{bcdef}	3.98^{abcd}	4.13^{abcdef}	4.19^{abc}	4.22^{abcdef}
31	2.22^{c}	2.63^{jk}	3.72^{abcdef}	3.44^{bcdef}	3.62^{bcdefg}	3.80^{abcd}	3.91^{bcdef}
32	2.14^{c}	2.54^{jk}	3.71^{abcdef}	3.79^{abcdef}	$3.98^{abcdefg}$	4.08^{abc}	3.99^{bcdef}
33	2.94^{a}	2.83^{fghij}	3.23^{cdef}	3.11^{ef}	3.33^{fg}	3.86^{abcd}	3.93^{bcdef}
34	2.72^{abc}	2.71^{ijk}	4.16^{ab}	3.88^{abcde}	4.10^{abcdef}	4.21^{abc}	4.07^{abcdef}
35	2.58^{abc}	3.98^{ab}	3.90^{abcde}	3.77^{bcdef}	3.94^{bcdefg}	4.09^{abc}	4.25^{abcdef}
36	2.38^{abc}	$3.51^{bcdefgh}$	3.42^{bcdef}	3.69^{bcdef}	3.83^{bcdefg}	3.94^{abcd}	4.38^{abcde}
37	2.42^{abc}	2.86^{fghij}	3.20^{def}	3.63^{bcdef}	3.86^{bcdefg}	3.97^{abcd}	3.97^{bcdef}
38	2.35^{bc}	2.88^{fghij}	3.30^{cdef}	3.20^{def}	3.37^{efg}	3.48^{cd}	3.73^{def}
39	2.62^{abc}	$3.08^{defghij}$	3.82^{abcde}	4.02^{abcd}	4.19^{abcde}	4.33^{ab}	4.58^{ab}
40	2.43^{abc}	2.81^{fghij}	3.63^{abcdef}	3.75^{bcdef}	3.97^{bcdefg}	4.08^{abc}	4.23^{abcdef}
41	2.52^{abc}	2.94^{efghij}	3.30^{cdef}	3.49^{bcdef}	3.62^{bcdefg}	3.71^{bcd}	3.88^{cdef}
42	2.54^{abc}	2.84^{fghij}	3.88^{abcde}	3.29^{cdef}	3.44^{defg}	3.52^{cd}	3.65^{f}

for the treatment T_4 (2.93 cm). Majority of the treatments were found to be on par with T_{35} (3.90 cm) and the remaining were found to be on par with T_4 (2.93 cm).

Again after sixth month of planting the highest value for shoot girth was recorded by the treatment T_{21} (4.60 cm) followed by the treatments T_{24}, T_{22}, T_1, T_{27} and T_2. All these treatments were found to be statistically on par with T_{21} and the treatment T_4 recorded the minimum girth of shoot (2.98 cm).

Shoot girth at eighth month after planting showed a significant variation due to the influence of treatments. The treatment T_{21} again reported the highest value of 4.78 cm followed by treatments T_{24}, T_2, T_{22} and T_{27}. Majority of the treatments were found to be statistically on par with T_{28} (4.17 cm) and lowest value was recorded by T_4 (3.14 cm).

Even after tenth month of planting treatment T_{21} recorded the maximum shoot girth (4.83 cm) followed by T_2, T_{22}, T_{27}, T_{39} and T_1. Majority of the treatments were on par with the treatment T_{21} and the remaining treatments were on par with the treatment T_4 (3.27 cm) which recorded the lowest value.

Data for twelfth month after planting revealed that there was a progressive increase in shoot girth for treatments T_{21}, T_{39}, T_{27}, T_{22} and T_{23}. Best result was obtained for the treatment T_{21} (4.88 cm) and majority of the treatments were on par with this treatment. The treatment T_{42} recorded the lowest value (3.65 cm) for shoot girth.

4.1.6 Internodal length

Data related to internodal length as influenced by different treatments are presented in Table 6.

During second and fourth month after planting internodal length did not show much effect as influenced by the various treatment combinations. Significant differences were noticed for the length of inter node after sixth month of planting.

Table 6. Internodal length (cm) in *Dendrobium* var. Sonia 17 as influenced by different levels of inorganic fertilizers and biofertilizers

Treat-ment	At planting	2 MAP	4 MAP	6 MAP	8 MAP	10 MAP	12 MAP
1	1.92^{a}	2.77^{abc}	3.29^{abcdef}	3.90^{abc}	3.60^{bcdef}	4.24^{abcde}	4.49^{abc}
2	1.56^{ab}	2.46^{abcdef}	2.82^{bcdef}	3.82^{abcd}	3.56^{bcdefg}	4.29^{abcde}	$4.16^{abcdefg}$
3	1.59^{ab}	2.24^{abcdef}	2.93^{bcdef}	$3.30^{bcdefghijk}$	3.74^{abcde}	4.43^{abcde}	4.57^{abc}
4	1.55^{ab}	2.10^{cdef}	2.56^{cdef}	$2.83^{efghijk}$	$3.29^{bcdefghi}$	4.34^{abcde}	$4.31^{abcdefg}$
5	1.34^{bc}	2.33^{abcdef}	2.38^{def}	2.59^{ijk}	2.57^{ghi}	3.58^{bcdef}	3.52^{fg}
6	1.25^{bc}	2.47^{abcdef}	2.90^{bcdef}	$2.99^{cdefghijk}$	3.44^{bcdefg}	4.49^{abcd}	$4.32^{abcdefg}$
7	1.10^{bc}	2.78^{abc}	2.46^{cdef}	2.64^{hijk}	$3.26^{bcdefghi}$	3.72^{abcdef}	$4.03^{abcdefg}$
8	1.14^{bc}	2.61^{abcdef}	2.88^{bcdef}	$3.31^{bcdefghijk}$	3.65^{abcdef}	4.56^{abcd}	4.44^{abcd}
9	1.34^{bc}	2.50^{abcdef}	2.57^{cdef}	2.65^{hijk}	2.28^{i}	2.89^{f}	3.57^{efg}
10	1.25^{bc}	2.33^{abcdef}	2.79^{bcdef}	$2.87^{efghijk}$	$3.03^{bcdefghi}$	3.98^{abcdef}	$4.13^{abcdefg}$
11	1.49^{ab}	2.77^{abc}	3.00^{bcdef}	$3.51^{abcdefghi}$	3.56^{bcdefg}	4.03^{abcde}	$4.28^{abcdefg}$
12	1.51^{ab}	2.72^{abcd}	2.70^{bcdef}	$3.25^{bcdefghijk}$	3.43^{bcdefg}	4.05^{abcde}	$4.11^{abcdefg}$
13	1.12^{bc}	1.92^{cdef}	2.28^{f}	2.56^{jk}	2.71^{defghi}	3.32^{ef}	$3.91^{abcdefg}$
14	1.24^{bc}	2.67^{abcde}	3.19^{bcdef}	$3.61^{abcdefg}$	$3.27^{bcdefghi}$	4.34^{abcde}	4.47^{abcd}
15	1.25^{bc}	2.14^{bcdef}	2.84^{bcdef}	$3.13^{cdefghijk}$	$3.27^{bcdefghi}$	4.42^{abcde}	$4.16^{abcdefg}$
16	1.34^{bc}	2.16^{bcdef}	3.22^{bcdef}	$3.42^{bcdefghij}$	3.62^{bcdef}	4.39^{abcde}	$4.28^{abcdefg}$
17	1.25^{bc}	1.87^{def}	2.58^{cdef}	2.72^{fhijk}	$2.79^{cdefghi}$	3.54^{def}	$4.20^{abcdefg}$
18	1.32^{bc}	2.27^{abcdef}	3.00^{bcdef}	3.64^{abcdef}	3.44^{bcdefg}	4.48^{abcde}	4.40^{abcde}
19	1.33^{bc}	2.15^{bcdef}	2.62^{bcdef}	$3.10^{cdefghijk}$	$3.14^{bcdefghi}$	4.14^{abcde}	$4.18^{abcdefg}$
20	1.61^{ab}	3.02^{a}	4.33^{a}	4.13^{ab}	4.01^{ab}	4.68^{abc}	4.53^{abc}
21	1.23^{bc}	3.00^{ab}	3.22^{bcdef}	4.36^{a}	4.62^{a}	4.71^{a}	4.77^{a}
22	1.18^{bc}	2.11^{cdef}	2.43^{cdef}	2.69^{ghijk}	$2.99^{bcdefghi}$	3.88^{abcdef}	3.77^{bcdefg}
23	1.40^{bc}	2.35^{abcdef}	2.60^{cdef}	$3.01^{cdefghij}$	2.69^{efghi}	3.55^{def}	3.76^{bcdefg}
24	1.31^{bc}	2.33^{abcdef}	3.73^{ab}	$3.57^{abcdefgh}$	3.67^{abcdef}	4.65^{abcd}	4.39^{abcdef}
25	1.33^{bc}	2.50^{abcdef}	2.63^{bcdef}	$2.88^{efghijk}$	$2.90^{cdefghi}$	3.74^{abcdef}	3.50^{g}
26	1.11^{bc}	2.18^{abcdef}	2.31^{ef}	$2.96^{defghijk}$	2.62^{fghi}	4.04^{abcde}	$4.00^{abcdefg}$
27	1.10^{bc}	1.86^{ef}	2.41^{cdef}	$2.95^{defghijk}$	$2.74^{cdefghi}$	3.96^{abcdef}	3.75^{bcdefg}
28	1.27^{bc}	2.56^{abcdef}	3.42^{abcde}	3.74^{abcde}	3.79^{abc}	3.71^{abcdef}	3.82^{bcdefg}
29	1.40^{bc}	1.92^{cdef}	2.48^{cdef}	2.58^{ijk}	2.70^{efghi}	3.98^{abcdef}	$4.02^{abcdefg}$
30	1.10^{bc}	2.98^{ab}	3.38^{abcdef}	3.65^{abcdef}	3.79^{abc}	4.57^{abcd}	4.50^{abc}
31	1.08^{c}	2.11^{cdef}	2.47^{cdef}	$3.02^{cdefghijk}$	$3.15^{bcdefghi}$	3.58^{bcdef}	$4.11^{abcdefg}$
32	1.15^{bc}	2.03^{cdef}	2.65^{bcdef}	$3.44^{bcdefghij}$	$3.03^{bcdefghi}$	3.76^{abcdef}	3.89^{bcdefg}
33	1.40^{bc}	1.80^{f}	2.37^{def}	$3.49^{abcdefghi}$	3.44^{bcdefg}	3.63^{abcdef}	$3.96^{abcdefg}$
34	1.47^{ab}	2.52^{abcdef}	3.51^{abc}	3.88^{abcd}	3.77^{abcd}	4.69^{ab}	4.71^{ab}
35	1.29^{bc}	2.26^{abcdef}	3.48^{abcd}	$3.55^{abcdefgh}$	3.68^{abcdef}	4.17^{abcde}	4.41^{abcde}
36	1.16^{bc}	2.50^{abcdef}	2.61^{cdef}	$3.29^{bcdefghijk}$	3.38^{bcdefg}	4.13^{abcde}	$4.27^{abcdefg}$
37	1.30^{bc}	2.24^{abcdef}	2.73^{bcdef}	$2.85^{efghijk}$	$2.79^{cdefghi}$	3.57^{cdef}	3.64^{cdefg}
38	1.20^{bc}	2.05^{cdef}	2.42^{cdef}	2.41^{k}	2.38^{hi}	3.50^{def}	3.61^{defg}
39	1.39^{bc}	2.75^{abc}	3.00^{bcdef}	$3.11^{cdefghijk}$	3.70^{abcde}	3.92^{abcdef}	$4.17^{abcdefg}$
40	1.35^{bc}	2.33^{abcdef}	2.81^{bcdef}	$2.97^{defghijk}$	$3.34^{bcdefgh}$	3.79^{abcdef}	$3.97^{abcdefg}$
41	1.19^{bc}	2.61^{abcdef}	2.42^{cdef}	$2.97^{defghijk}$	2.64^{fghi}	3.56^{cdef}	3.61^{defg}
42	1.41^{bc}	2.52^{abcdef}	2.56^{cdef}	2.78^{fghijk}	$2.99^{bcdefghi}$	3.53^{def}	3.77^{bcdefg}

Treatment receiving *Azospirillum* T_{21} recorded the highest internodal length (4.36 cm). The minimum was recorded by the treatment T_{38} (2.41 cm).

Eighth month after planting the internodal length showed marked variations among different treatments and the treatment T_{21} recorded the longest internode (4.62 cm). The treatments T_{20}, T_{28}, T_{30}, T_{34}, T_3, T_{39}, T_{35} and T_8 were found to be statistically on par with T_{21}. But most of the treatments were found to be on par with the treatment T_9 (2.28 cm) which recorded the smallest internodal length.

At tenth month stage the treatments showed significant variation, identifying T_{21} as the best treatment (4.71 cm) and the treatments T_{34} and T_{20} were found to be on par with T_{21}. The least value was recorded by the treatment T_9 (2.89 cm). From the data recorded twelfth month after planting it was clearly evident that all the treatments except T_3, T_{20}, T_{30} and T_1 were statistically on par with the treatment T_{21} which recorded the best result (4.77 cm). Treatment T_{25} expressed the least value (3.50 cm).

4.1.7 Number of roots per plant

Data related to the number of roots per plant as influenced by different treatments are presented in Table 7.

The data corresponding to number of roots per plant revealed that the plants showed significant variation among the treatments due to the influence of various biofertilizers. Highest number of roots (59.67) was produced by the plants which received the treatment T_{36}. The treatments T_{13}, T_{40}, T_{21}, T_{39}, T_9 and T_{17} were found to be statistically on par with T_{36} (59.67).

4.1.8 Root length

Data pertaining to root length are presented in Table 7.

Comparison of data collected to know the effect of treatments on root length indicated that all the treatments had significant influence and the treatment T_{36} recorded the maximum root length (59.00 cm) followed by the treatment T_5

(56.00 cm) and they were statistically on par. The minimum root length (17.33 cm) was observed for the treatment T_{16} which was on par with the treatments T_{24}, T_{20}, T_{22}, T_{15}, T_{42}, T_8 and T_{26}

4.1.9 Root volume

Data related to the effect of biofertilizers on root volume are presented in Table7

The effect of treatments on root volume recorded significant variations. The data revealed that the treatment T_{40} (11.67 ml) which received all the three biofertilizers showed a superior value than other treatments. It was followed by the treatment T_{36} (10.83 ml) and both were found to be on par. Treatment T_{20} recorded the lowest root volume (2.07 ml).

Overall effect of biofertilizers on growth parameters are presented in Plates 3 and 4.

4.1.10 Dry matter production at flowering

Dry matter production expressed in 'g' are presented in Table 7.

The different treatments imposed, significantly influenced the dry matter production at the time of flowering. In this regard the treatment T_{34} (NPK 20:10:10 + *Azospirillum* + phosphobacteria) recorded the highest value of 9.39 g. This was followed by the treatment T_{36} (NPK 20:10:10 + *Azospirillum* + phosphobacteria + AMF) which recorded 9.29 g. Treatments T_1, T_2 and T_{33} were on par with the treatment T_{34}. The lowest weight was noted for the treatment T_{42} (Absolute control) and was on par with T_{41} and both these treatments recorded 3.49 g and 5.36 g respectively.

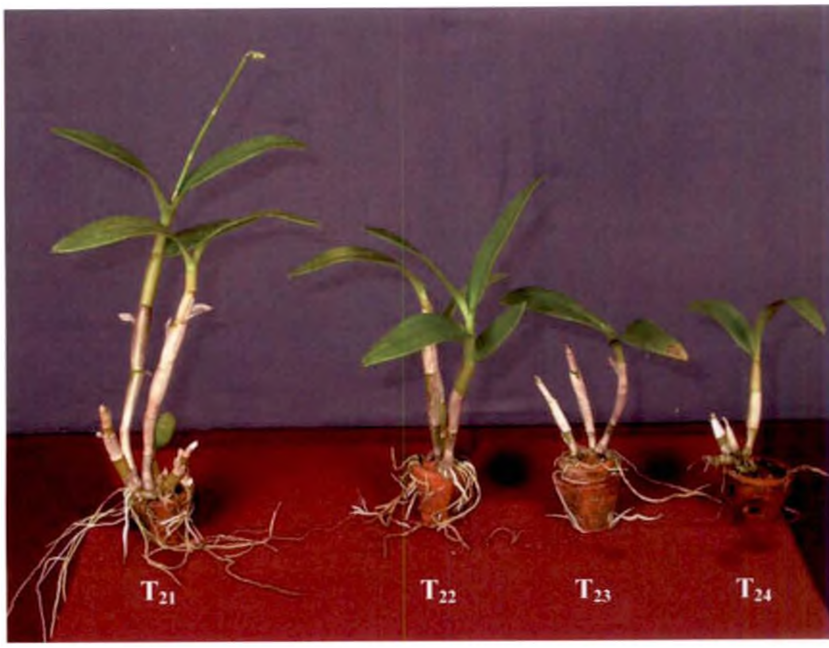
4.2 FLOWER CHARACTERS

4.2.1 Days to first flowering

Data regarding days to first flowering are presented in Table 8.

Table 7. Root parameters and dry matter production at the time of flower in *Dendrobium* var. Sonia 17 as influenced by different levels of inorganic fertilizers and biofertilizers

Treatment	No. of roots/plant	Root length (cm)	Root volume (ml)	Dry matter production at flowering (gm)
1	50.67^{bcd}	31.00^{jklmn}	9.33^{bcd}	9.22^{ab}
2	49.67^{bcde}	51.00^{cd}	7.67^{defghi}	9.15^{abc}
3	34.00^{lm}	29.33^{lmnop}	9.00^{bcde}	8.19^{ghi}
4	22.00^{q}	22.67^{qrst}	3.67^{nopq}	8.19^{ghi}
5	52.00^{b}	56.00^{ab}	10.50^{abc}	8.77^{cde}
6	48.00^{bcdef}	51.00^{cd}	8.83^{bcde}	8.37^{efghi}
7	47.33^{cdef}	47.33^{de}	8.33^{defg}	7.93^{i}
8	31.00^{mno}	22.00^{vstu}	8.33^{defg}	7.92^{i}
9	57.00^{a}	43.33^{efg}	7.50^{defghij}	7.29^{j}
10	38.33^{jkl}	33.67^{jkl}	4.00^{mnopq}	7.33^{j}
11	40.00^{jk}	30.00^{klmno}	9.00^{bcde}	7.24^{j}
12	31.00^{mno}	38.67^{hi}	8.50^{cdef}	7.14^{j}
13	59.00^{a}	44.67^{ef}	8.23^{defgh}	8.91^{bcd}
14	51.67^{bc}	27.00^{nopq}	8.17^{defgh}	8.71^{def}
15	37.00^{kl}	21.00^{stu}	7.17^{efghij}	8.67^{defg}
16	25.33^{pq}	17.33^{u}	4.83^{klmno}	8.58^{defgh}
17	56.67^{a}	43.33^{efg}	7.17^{efghij}	8.45^{defgh}
18	46.67^{defgh}	39.67^{gh}	6.00^{ijklm}	8.59^{defgh}
19	38.33^{jkl}	24.67^{pqrs}	6.33^{ghijkl}	8.41^{efgh}
20	28.67^{mop}	19.00^{tu}	2.07^{q}	8.45^{defgh}
21	58.33^{a}	23.00^{qrst}	8.50^{cdef}	8.57^{defgh}
22	32.33^{mm}	20.00^{stu}	5.83^{ijklm}	8.50^{defgh}
23	52.00^{b}	32.00^{jklm}	5.50^{jklmn}	8.53^{defgh}
24	29.67^{mnop}	18.67^{tu}	3.50^{nopq}	8.52^{defgh}
25	49.67^{bcde}	34.67^{ij}	7.17^{efghij}	8.18^{hi}
26	45.33^{efghi}	22.00^{vstu}	3.50^{nopq}	8.24^{fghi}
27	31.33^{mno}	41.33^{fgh}	4.33^{lmnop}	8.32^{efghi}
28	42.33^{hij}	27.33^{mnopq}	3.67^{nopq}	8.33^{efghi}
29	47.00^{defg}	52.00^{bc}	3.33^{opq}	7.42^{j}
30	39.00^{jk}	27.00^{nopq}	3.17^{opq}	7.44^{j}
31	36.67^{kl}	23.00^{vrst}	4.67^{klmno}	7.39^{j}
32	42.00^{ij}	40.33^{fgh}	2.83^{opq}	7.32^{j}
33	47.00^{defg}	34.33^{jk}	8.90^{bcde}	9.14^{abc}
34	40.00^{jk}	39.33^{gh}	6.17^{hijkl}	9.39^{a}
35	29.67^{mnop}	29.67^{lmno}	8.33^{defg}	8.90^{bcd}
36	59.67^{a}	59.00^{a}	10.83^{ab}	9.29^{ab}
37	42.67^{ghij}	29.00^{mnop}	8.67^{cdef}	8.65^{defgh}
38	42.33^{hij}	26.00^{opqr}	6.67^{fghijk}	8.59^{defgh}
39	57.00^{a}	28.33^{mnop}	6.67^{fghijk}	8.62^{defgh}
40	58.67^{a}	27.33^{mnopq}	11.67^{a}	8.56^{defgh}
41	44.67^{fghi}	23.33^{qrst}	2.33^{pq}	5.36^{j}
42	27.00^{op}	21.0^{stu}	2.33^{pq}	3.49^{j}



T_{21} - 10:5:10 NPK + *Azospirillum*
T_{22} - 10:5:10 NPK + phosphobacteria
T_{23} - 10:5:10 NPK + AMF
T_{24} - 10:5:10 NPK

Plate 3. Effect of biofertilizers on overall growth

T_{36} - NPK 20:10:10 + *Azospirillum* + phosphobacteria + AMF
T_{42} - NPK 20:10:10

Plate 4. Effect of combined inoculation of biofertilizers on root parameters

With respect to various treatments applied, early flowering was obtained for the treatment T_1 (20:10:10 + *Azospirillum* (297.67 days). The highest concentration of inorganic spray along with the biofertilizer treatment had resulted in early flowering. The plants receiving the treatments T_2, T_3, T_4, T_{34}, T_{35} and T_{36} had come to flowering within a period ranging from 315.33 days to 322 days.

4.2.2 Number of spikes per plant

Data presented in Table 8.

The results obtained indicated that the different treatments did not markedly influence the number of spikes per plant. A homogenous result of one spike per plant was obtained during the whole study period.

4.2.3 Size of flowers

Size of individual flowers obtained are presented in Table 8.

Beneficial effect of treatments on the size of flowers were not observed. Almost all the treatments recorded a similar trend in the values. However a maximum size was noticed for the treatment T_1 (7.1 cm x 6.6 cm).

4.2.4 Spike length

The length of the spikes obtained are presented in Table 8.

A marked difference in spike length was observed due to the effect of various treatments. Highest spike length (21.03 cm) was obtained for the treatment T_1 (20:10:10 + *Azospirillum*) and the remaining observations showed that higher values were obtained for higher dose of inorganic spray in combination with biofertilizers.

4.2.5 Number of flowers per spike

Data pertaining to number of flowers per spike as influenced by various treatments are expressed in Table 8 and Plate 5.

T_{21} - **NPK 10:5:10 + *Azospirillum***
T_1 - **NPK 20:10:10 + *Azospirillum***

Plate 5. Effect of biofertilizers on flowering

Biofertilizer treatments along with higher dose of inorganic spray had influenced the number of flowers per spike. Maximum number of flowers per spike were obtained for T_1 (3.67), T_{34} (3.67) and T_{36} (3.67). Lowest numbers were recorded for the treatments T_{31} (1.00) and T_{32} (1.00).

4.2.6 Inter-nodal length

The inter-nodal length observed are presented in Table 8.

The inter-nodal length was not markedly influenced by the treatments, and almost all the treatments showed a similar trend. The length of the internode recorded for the different treatments ranged from 3.16 to 3.22 cm, showing only a slight variation among the treatments.

4.2.7 Flower pedicel length

The length of the flower pedicels obtained are presented in Table 8.

No significant influence of treatments were observed for flower pedicel length. Almost all the treatments showed a similar trend with values ranging from 3.40 to 3.45 cm.

4.2.8 Longevity of spike on the plant

Data pertaining to longevity of spikes on the plant are presented in Table 8.

The different treatments were not found to have much influence on the longevity of spikes on plant. The highest value was obtained for the treatment T_1 (34.67 days).

4.2.9 Vase life in water

Due to the lack of spikes, the study on vase life in water could not be carried out for all the treatments.

Table 8. Flower characters in *Dendrobium* var. Sonia 17 as influenced by different levels of inorganic fertilizers and biofertilizers

Treatment	Days to first flowering	No. of spikes/ plant	Size of flower (cm)	Spike length (cm)	No. of flowers/ spike	Inter-nodal length (cm)	Flower pedicel length (cm)	Longevity of spike on the plant (days)
1	297.67	1	7.1 x 6.6	21.03	3.67	3.20	3.45	34.67
2	315.33	1	7.1 x 6.5	20.75	3.33	3.17	3.43	34.00
3	320.00	1	7.0 x 6.5	20.55	3.00	3.16	3.40	33.00
4	318.00	1	7.0 x 6.5	20.48	3.00	3.17	3.40	33.00
5	322.33	1	7.0 x 6.5	20.82	3.33	3.20	3.45	33.33
6	343.33	1	7.0 x 6.4	20.75	3.00	3.21	3.44	33.00
7	352.00	1	7.0 x 6.5	20.70	2.33	3.21	3.43	32.00
8	351.00	1	7.0 x 6.7	20.69	2.33	3.20	3.44	33.00
9	347.00	1	6.9 x 6.3	18.93	2.33	3.22	3.45	32.00
10	349.00	1	7.0 x 6.5	18.90	2.00	3.21	3.44	31.00
11	359.00	1	7.2 x 6.4	18.75	2.00	3.21	3.44	31.00
12	362.00	1	7.0 x 6.5	18.72	2.00	3.21	3.43	31.00
13	325.67	1	6.9 x 6.2	21.00	3.33	3.19	3.45	33.00
14	334.67	1	7.0 x 6.5	20.87	3.00	3.18	3.43	33.00
15	345.00	1	6.9 x 6.5	20.55	3.00	3.17	3.44	31.00
16	343.00	1	7.0 x 6.3	20.52	3.00	3.19	3.43	30.00
17	353.00	1	7.0 x 6.5	20.35	3.00	3.18	3.44	32.00
18	365.33	1	7.0 x 6.5	20.30	2.00	3.18	3.44	33.00
19	367.67	1	7.0 x 6.3	20.31	2.00	3.19	3.43	33.00
20	344.33	1	7.0 x 6.3	19.92	2.00	3.20	3.44	33.00
21	357.00	1	7.2 x 6.2	19.87	2.33	3.20	3.44	32.00
22	369.00	1	7.0 x 6.4	19.77	2.33	3.19	3.43	32.00
23	365.33	1	6.8 x 6.2	19.53	2.00	3.19	3.44	31.00
24	372.67	1	7.0 x 6.5	19.55	2.00	3.19	3.43	31.00
25	375.33	1	7.0 x 6.4	19.75	2.33	3.19	3.42	31.00
26	384.00	1	7.1 x 6.4	19.70	2.00	3.19	3.44	32.00
27	382.33	1	7.0 x 6.4	19.65	2.00	3.19	3.43	32.00
28	394.33	1	6.9 x 6.5	19.63	2.00	3.19	3.44	31.00
29	428.67	1	7.0 x 6.5	18.54	2.00	3.23	3.42	31.00
30	432.00	1	6.9 x 6.4	18.39	2.00	3.22	3.43	32.00
31	448.33	1	6.8 x 6.2	18.35	1.00	3.22	3.44	31.00
32	445.00	1	6.5 x 6.1	18.37	1.00	3.22	3.43	31.00
33	*	*	*	*	*	*	*	*
34	320.00	1	7.0 x 6.5	20.82	3.67	3.20	3.43	34.00
35	322.00	1	7.0 x 6.4	20.87	3.33	3.18	3.43	33.00
36	321.00	1	7.0 x 6.4	20.85	3.67	3.17	3.43	33.00
37	*	*	*	*	*	*	*	*
38	*	*	*	*	*	*	*	*
39	*	*	*	*	*	*	*	*
40	*	*	*	*	*	*	*	*
41	*	*	*	*	*	*	*	*
42	*	*	*	*	*	*	*	*

* Plants not flowered

4.2.10 **Colour variation**

In the present study no significant variation for the colour of petals was observed. All the flowers were found to have the same shade of colour.

4.3 INCIDENCE OF PEST AND DISEASE

During the entire period of study the commonly noticed pest was snails (*Ariophanta* sp.) and slugs mainly 2 types (*Arion* sp. and *Linox* sp.) which were identified by their colour. The former was black in colour and the later light brown. They fed on tender stem, buds and blossoms. These pests were controlled to the maximum extend using metaldehylde 2.5 per cent pellet (Snail kill). No other pest was noticed during the period of study.

Regarding diseases, the most commonly observed disease was fungal leaf blight which mainly affected the leaves. The affected areas first changed into yellow and later purplish brown and black. This was mainly observed immediately after rains, in a humid weather condition. It was controlled by applying indofil 3g l^{-1} during the initial stages of the disease. Moreover akomin was sprayed 3ml l^{-1} weekly once as a prophylactic measure against fungal pathogen.

Another disease which was noticed during the experiment was bacterial soft rot which was characterised by the yellowing of leaves, later turning to water soaked lesions with a characteristic smell. Streptomycin sulphate was a good remedy for this and was applied at the rate of 0.20 g l^{-1}.

4.4 NUTRIENT ANALYSIS

4.4.1 **Total nitrogen**

Total nitrogen content present in the plant sample expressed in percentage are presented in Table 9.

Analysis of the nitrogen content in the plants revealed that treatment T_{34} (NPK 20:10:10 + *Azospirillum* + phosphobacteria) was significantly superior with higher nitrogen content (1.37%). The treatments T_1, T_3, T_{36} and T_{33} were found to be statistically on par with the treatment T_{34}. The least content of nitrogen (1.15%) was noted for the treatment T_{42} which was the absolute control.

4.4.2 Total phosphorus

Data pertaining to total phosphorus present in the plant sample are presented in Table 9.

Estimation of phosphorus revealed that the treatment T_{34} recorded the highest phosphorus content (0.39%). Treatment T_{36}, T_7 and T_{15} were found to be statistically on par with the treatment T_{34} (NPK 20:10:10 + *Azospirillum* + phosphobacteria). Phosphorus content was the lowest for the treatment T_{42} (absolute control) which recorded a value of (0.27%).

4.4.3 **Total potassium**

Total potassium content in the plant sample expressed as percentage are present in Table 9.

The results of potassium analysis using flame photometer revealed that superior results were obtained for the two treatments namely T_{34} (NPK 20:10:10 + *Azospirillum* + phosphobacteria) and T_{36} (NPK 20:10:10 + *Azospirillum* + phosphobacteria + AMF). The values obtained were around 2.63 per cent and 2.62 per cent respectively. Treatments T_3, T_7, T_1, T_{35}, T_{40}, T_6 and T_{10} were found to be statistically on par with T_{36}. The lowest content of potassium was observed in the treatment T_{42} (2.34%) which represented the absolute control.

4.5 MICROBIAL ANALYSIS

From the post experimental microbial analysis it was found that the microorganism *Azospirillum* and phosphobacteria were present in the root and media even after 12 months of planting. But, AMF was found to be absent in the roots. This is represented in Table 10.

Table 9. Nutrient (NPK) content (%) in plants of *Dendrobium* var. Sonia 17 as influenced by different levels of inorganic fertilizers and biofertilizers

Treatment	Nitrogen content (%)	Phosphorus content (%)	Potassium content (%)
1	1.350^{ab}	0.360^{abcde}	2.603^{ab}
2	1.337^{abcd}	$0.343^{abcdefghi}$	2.590^{abc}
3	1.357^{ab}	0.363^{abcd}	2.600^{ab}
4	1.343^{abcd}	0.353^{abcdef}	2.563^{abcdef}
5	1.287^{defg}	0.357^{abcdef}	2.580^{abcd}
6	1.283^{efgh}	0.357^{abcdef}	2.600^{ab}
7	1.283^{efgh}	0.370^{abc}	2.607^{ab}
8	1.233^{hijkl}	0.357^{abcdef}	2.580^{abcd}
9	1.207^{jklm}	$0.350^{abcdefg}$	$2.487^{abcdefgh}$
10	1.183^{lm}	$0.346^{abcdefgh}$	2.600^{ab}
11	1.190^{klm}	$0.336^{abcdefghij}$	$2.480^{abcdefgh}$
12	1.160^{m}	$0.330^{bcdefghij}$	2.357^{h}
13	1.273^{fghi}	0.360^{abcde}	2.547^{abcdef}
14	1.290^{cdefgh}	0.353^{abcdef}	2.550^{abcdef}
15	1.300^{bcdefg}	0.370^{abc}	$2.457^{bcdefgh}$
16	1.270^{fghij}	$0.350^{abcdefg}$	2.413^{fgh}
17	1.260^{fghij}	$0.310^{cdefghij}$	2.543^{abcdef}
18	1.257^{fghij}	0.297^{efghij}	2.440^{cdefgh}
19	1.253^{fghij}	$0.300^{defghij}$	2.417^{efgh}
20	1.240^{ghijkl}	0.287^{ghij}	2.383^{gh}
21	1.247^{fghijk}	$0.313^{bcdefghij}$	$2.483^{abcdefgh}$
22	1.247^{fghijk}	$0.317^{bcdefghij}$	$2.493^{abcdefgh}$
23	1.250^{fghijk}	$0.320^{bcdefghij}$	$2.493^{abcdefgh}$
24	1.253^{fghij}	$0.303^{defghij}$	2.557^{abcdef}
25	1.253^{fghij}	$0.303^{defghij}$	$2.460^{bcdefgh}$
26	1.263^{fghij}	$0.307^{cdefghij}$	$2.530^{abcdefgh}$
27	1.307^{bcdef}	0.280^{ij}	2.577^{abcd}
28	$1.243^{fghijkl}$	0.297^{efghij}	2.570^{abcde}
29	$1.243^{fghijkl}$	0.283^{hij}	2.363^{h}
30	1.247^{fghijk}	0.287^{ghij}	2.427^{defgh}
31	1.250^{fghijk}	0.293^{fghij}	2.440^{cdefgh}
32	1.233^{hijkl}	0.287^{ghij}	2.360^{h}
33	1.350^{ab}	0.353^{abcdef}	$2.487^{abcdefgh}$
34	1.370^{a}	0.393^{a}	2.630^{a}
35	1.347^{abc}	$0.350^{abcdefg}$	2.603^{ab}
36	1.360^{ab}	0.377^{ab}	2.623^{a}
37	1.280^{efgh}	$0.310^{cdefghij}$	2.573^{abcd}
38	1.260^{fghij}	$0.323^{bcdefghij}$	2.543^{abcdef}
39	1.280^{efgh}	$0.313^{bcdefghij}$	2.493^{abc}
40	1.253^{fghij}	$0.300^{defghij}$	2.600^{ab}
41	1.213^{ijklm}	0.283^{hij}	2.373^{h}
42	1.160^{m}	0.273^{j}	2.343^{h}

4.5.1 *Azospirillum*

As shown in Table 10, population of *Azospirillum* in the roots was the highest in the treatments which received more inorganic nutrients. And the highest value was recorded for the treatments T_1, T_5, T_{17}, T_{21}, T_{33}, T_{34}, T_{36}, T_{37}, T_{38} and T_{40} (0.078×10^4 cfu $root^{-1}$). The least population was found in the treatments T_9 and T_{41} (0.020×10^4 cfu $root^{-1}$). Control had no colonies of *Azospirillum*.

4.5.2 Phosphobacteria

In *Dendrobium* var. Sonia 17, the highest phosphobacteria population of 7.81×10^6 cfu g^{-1} media was obtained for the treatments T_6, T_{34} and T_{38}, which was followed by the treatment T_{22} (7.72×10^6 cfu g^{-1} media). Here, the lowest population was noted for the treatment T_{41} (6.59×10^6 cfu g^{-1}).

4.5.3 Arbuscular Mycorrhizal Fungi (AMF)

The plant did not express any variation due to AMF inoculation. It was found that there was no root colonization of AM fungi when the roots were examined twelve months after planting.

Table 10. Microbial population (*Azospirillum*, phosphobacteria and AMF) at twelve months after planting

Treatment	*Azospirillum* (x10^4 cfu root^{-1})	Treatment	Phosphobacteria (x10^6 cfu g^{-1} media)	Treatment	AMF spore count (spores root^{-1})
T_1	0.078	T_2	49.67(7.69)	T_3	0.00
T_5	0.078	T_6	65.67(7.81)	T_7	0.00
T_9	0.020	T_{10}	39.00(7.59)	T_{11}	0.00
T_{13}	0.045	T_{14}	51.00(7.71)	T_{15}	0.00
T_{17}	0.078	T_{18}	26.33(7.42)	T_{19}	0.00
T_{21}	0.078	T_{22}	52.00(7.72)	T_{23}	0.00
T_{25}	0.045	T_{26}	19.00(7.27)	T_{27}	0.00
T_{29}	0.020	T_{30}	14.33(7.15)	T_{31}	0.00
T_{33}	0.078	T_{34}	65.67(7.81)	T_{33}	0.00
T_{34}	0.078	T_{35}	49.67(7.69)	T_{35}	0.00
T_{36}	0.078	T_{36}	57.00(7.71)	T_{36}	0.00
T_{37}	0.078	T_{38}	65.67(7.81)	T_{37}	0.00
T_{38}	0.078	T_{39}	51.00(7.71)	T_{39}	0.00
T_{40}	0.078	T_{40}	49.67(7.69)	T_{40}	0.00
T_{41}	0.020	T_{41}	4.00(6.59)	T_{41}	0.00
T_{42}	0.000	T_{42}	0.00(0.00)	T_{42}	0.00
Mean	0.058	Mean	7.09	Mean	0.00

Specific biofertilizer treatments are only taken and compared with control
Value in parenthesis denotes logarithmic transformation

Discussion

5. DISCUSSION

The results obtained from the studies regarding supplementary effect of biofertilizers in *Dendrobium* are briefly presented in this chapter.

Orchids, one of the most beautiful flowers with perplexing range of floral structures, fascinating colours and longer vase life have great economic potential as cut bloom.Improving the yield through plant growth and its various parameters are the main objectives in economic crop production. Besides other factors, nutrition plays an important role in increasing the yield. Nowadays the use of biofertilizers had gained momentum in obtaining better yield and also in economising the use of inorganic fertilizers when used in combination.

The present trial conducted on *Dendrobium* var. Sonia 17 clearly revealed the effect of various biofertilizers used, on the growth and development

5.1 EFFECT OF INORGANIC SPRAY AND BIOFERTILIZERSS ON GROWTH PARAMETERS

The influence of biofertilizers on growth was studied by recording data on vegetative characters such as plant height, internodal length, number of leaves, number of leafy shoots , number of pseudobulbs, girth of the shoot, number of roots, length of roots, root volume and dry matter production.

When the affect of biofertilizers on plant characters were considered better response could be observed wherever biofertilizers were included in the treatment. The treatment T_{21} which consisted of *Azospirillum* along with 10:5:10 NPK applied weekly twice at 0.2 per cent concentration recorded superior values for plant height, internodal length, number of leaves, number of leafy shoots and shoot girth. Whereas in the case of number of pseudobulbs, treatment T_{38} which consisted of both *Azospirillum* and phosphobacteria along with 10:5:10 NPK sprayed at 0.2 per cent weekly twice gave significantly superior results.

Plant height and internodal length were significantly influenced by biofertilizers after six months of planting. Results revealed that during the initial four months of plant growth not much influence of biofertilizers was noticed. But later from sixth month onwards biofertilizers were found to have significant influence on plant height and internodal length. Similar observations were noted for the subsequent months (Fig.1 and Fig.6). Hence it is clearly evident that T_{21} (NPK 10:5:10 + *Azospirillum*) was the best treatment among the various treatment combinations.This result is in conformity with the findings of Ravichandran (1991) in crossandra, Mariappan (1992) in African marigold and Gnanasekar (1994) in jathimalli.

From this, it could be concluded that eventhough the rate of action of biofertilizers was slow it had significant influence in the long run. The increase in growth characters like plant height and internodal length was due to *Azospirillum* inoculation which had added nitrogen to crop growth through associative symbiosis and increased production of growth hormones like NAA, GA and cytokinins. These phytohormones might have caused morphological changes in roots thereby causing an increase in uptake of nutrients resulting in better growth. The possible reason for such an effect could be that *Azospirillum* fixes appreciable quantities of atmospheric nitrogen which lead to increase in cell division and cell elongation in the region of axillary buds (Torrey, 1950). Similar findings were reported by Balasubramanian (1989) in French marigold, Preethi (1990) in Edward rose, Mariappan (1992) in marigold and Manonmani (1992) in *Jasminum sambac.*

In the present study, the influence of biofertilizers on leaf production was noticed from sixth month onwards (Fig. 2). Thereafter, a profound influence of biofertilizers was noticed during the entire period of observation. Higher leaf production was noticed in the treatment T_{21} (NPK 10:5:10 + *Azospirillum*).

This may be due to the combined effect of inorganic spray and *Azospirillum* treatment which provided good amounts of nitrogen. Nitrogen being the essential constituent of proteins,it might have resulted in better growth leading to increased production of leaves (Maynard *et al.*, 1962). Similar results have been reported by Swaminathan and Sambandamurthi (2000) in crossandra.

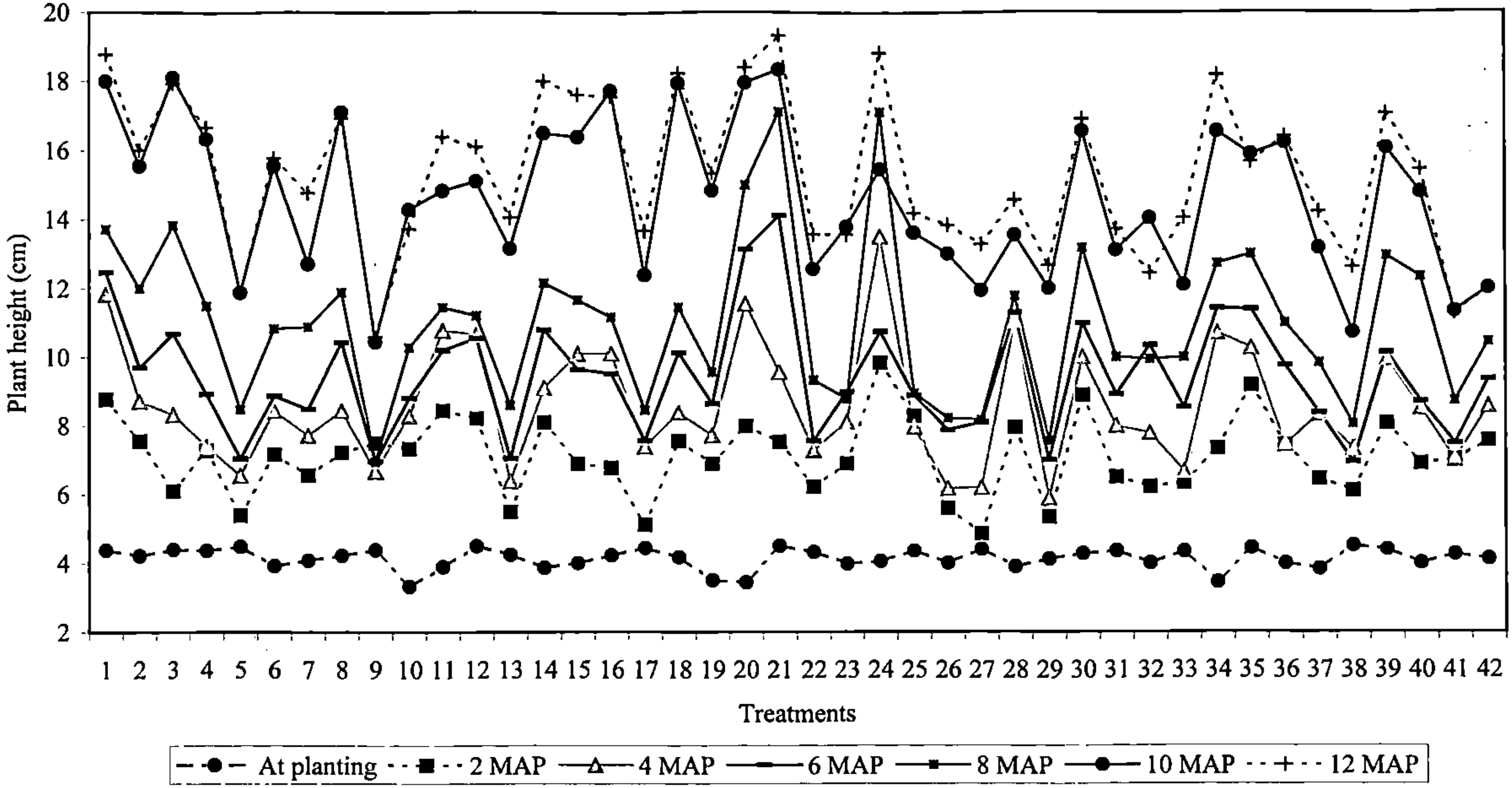


Fig. 1. Plant height (cm) in *Dendrobium* var. Sonia 17 as influenced by different levels of inorganic fertilizers and biofertilizers

The number of shoots with leaves produced per plant indicated that there was a significant influence on shoot production from second month of planting onwards where the treatment T_{21} (NPK 10:5:10 + *Azospirillum*) gave the best results (Fig.3). But during later stages, that is, during tenth and twelfth month after planting not much significant difference was observed, eventhough a progressive increase in number of shoots with leaves was observed for the treatment T_{21}.

The girth of shoot produced per plant throughout the experimental period seemed to be significantly influenced by the biofertilizers. A profound influence of the biofertilizer *Azospirillum* was noticed during the entire period of observation (Fig.5). Higher shoot girth was observed in the treatment T_{21} (NPK 10:5:10 + *Azospirillum*). The possible reason for this acceleration might be due to the influence of nitrogen, chief constituent of protein, essential for the formation of protoplasm which leads to cell division and cell enlargement. Moreover, nitrogen is an important component of amino acids and co-enzymes which are of considerable biological importance (Bakly, 1974). Similar views were expressed by Rathore *et al.* (1985) in marigold, Vedanayagam (1985) and Yassin (1987) in chrysanthemum.

Based on the data derived from the study conducted it was obserrved that biofertilizers have significant influence on pseudobulb production in orchids. It was found that treatment T_{38} (10:5:10 + *Azospirillum* + phosphobacteria) reported statistically superior values from sixth month after planting (Fig.4). The better performance may be attributed to the effective functioning of *Azospirillum* and phosphobacterium which produced bio-active substances having similar effect as that of growth regulators. The combination of *Azospirillum* and phosphobacteria has shown a synergestic effect on crop growth due to enhanced cell division and cell enlargement besides the effect of growth hormone production. The cell enlargement occurred as a result of increased plasticity of cell wall. This increased plasticity decreased the wall pressure around the cell wall. The turgor pressure caused by osmotic forces in the vascular sap leading to entry of water and nutrients into the cell result in cell enlargement and thereby increased pseudobulb production, which is considered to be the store house of reserved nutrients. The results obtained were in

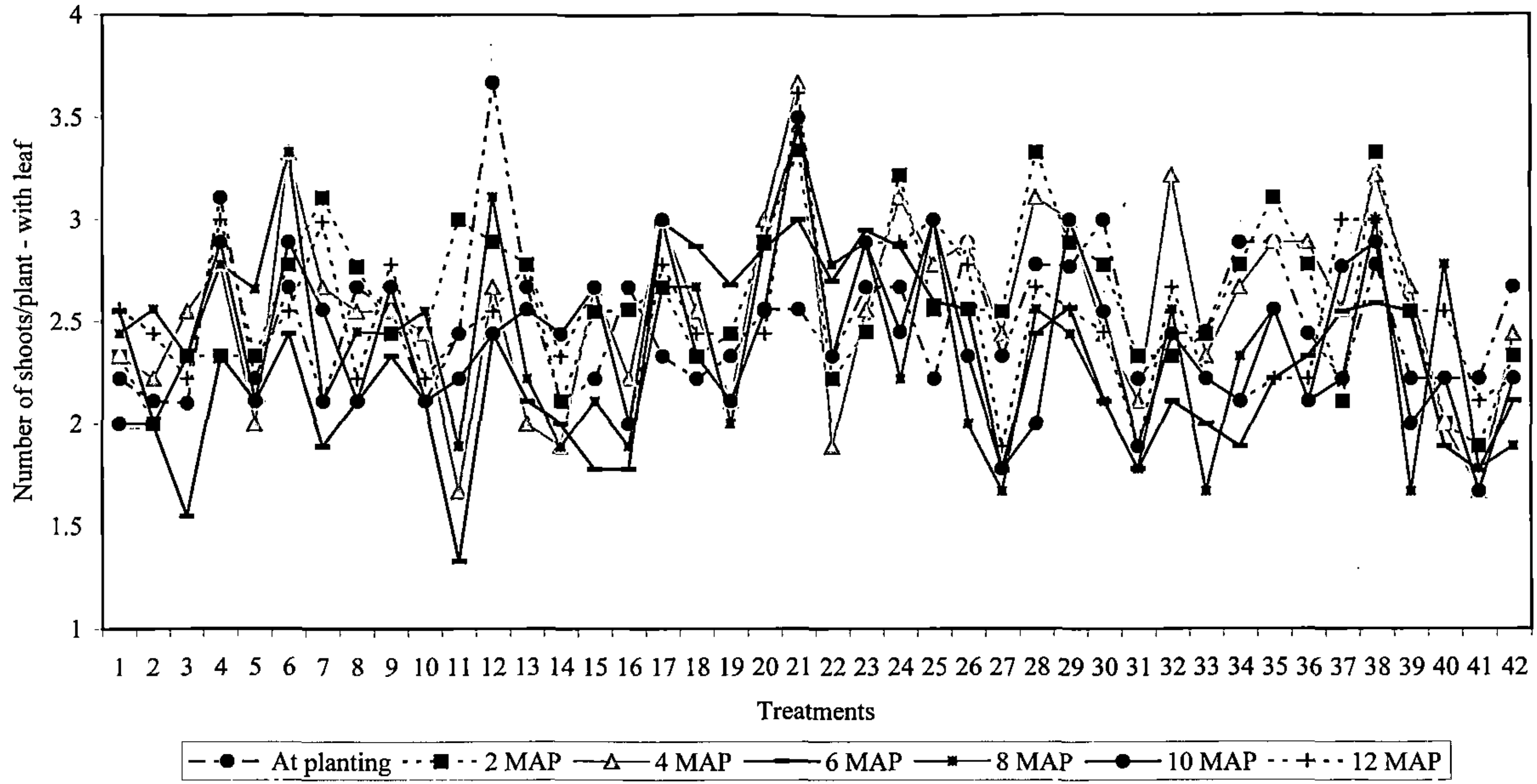


Fig. 3. Number of leafy shoots per plant in *Dendrobium* var. Sonia 17 as influenced by different levels of inorganic fertilizers and biofertilizers

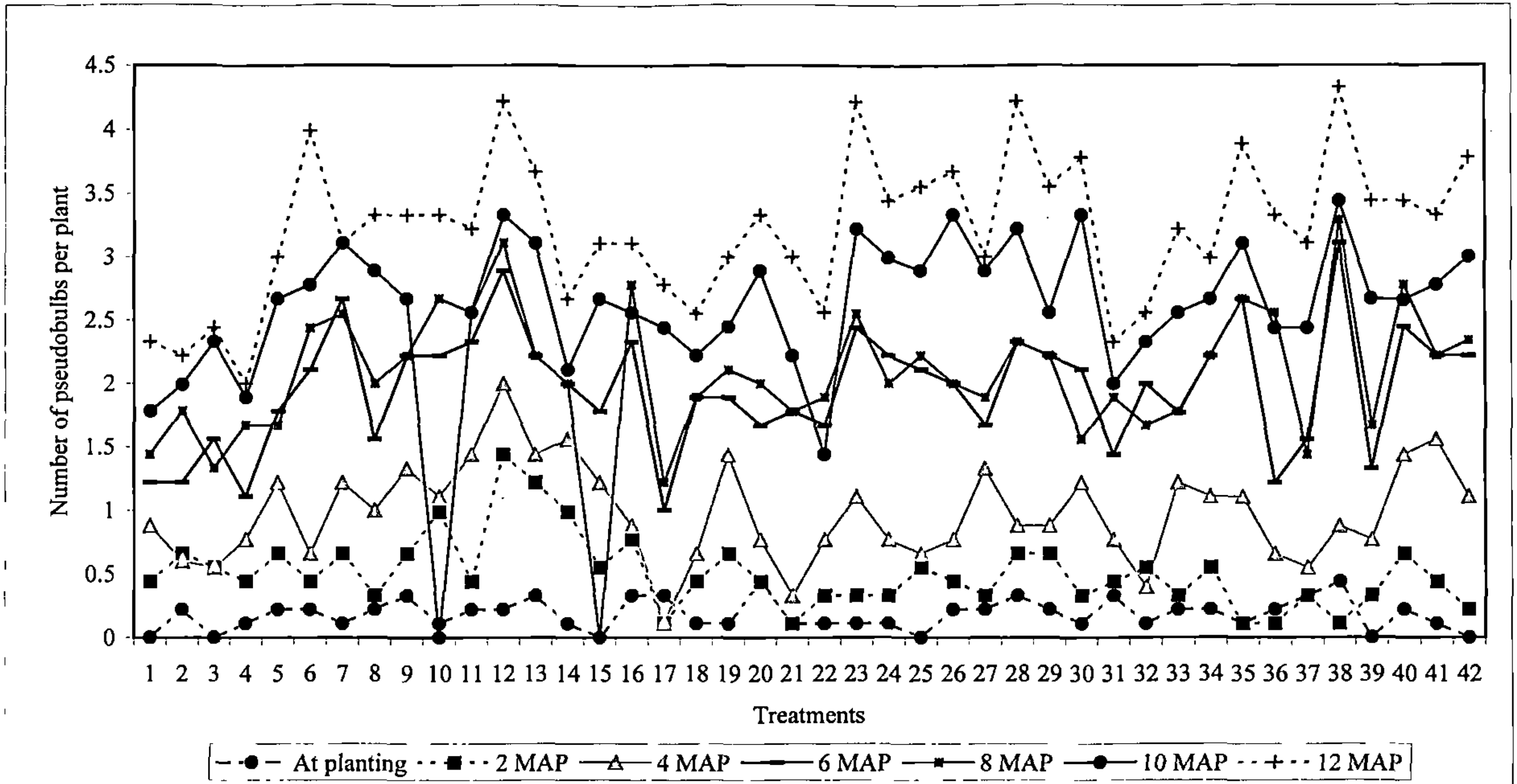


Fig. 4. Number of pseudobulbs per plant in *Dendrobium* var. Sonia 17 as influenced by different levels of inorganic fertilizers and biofertilizers

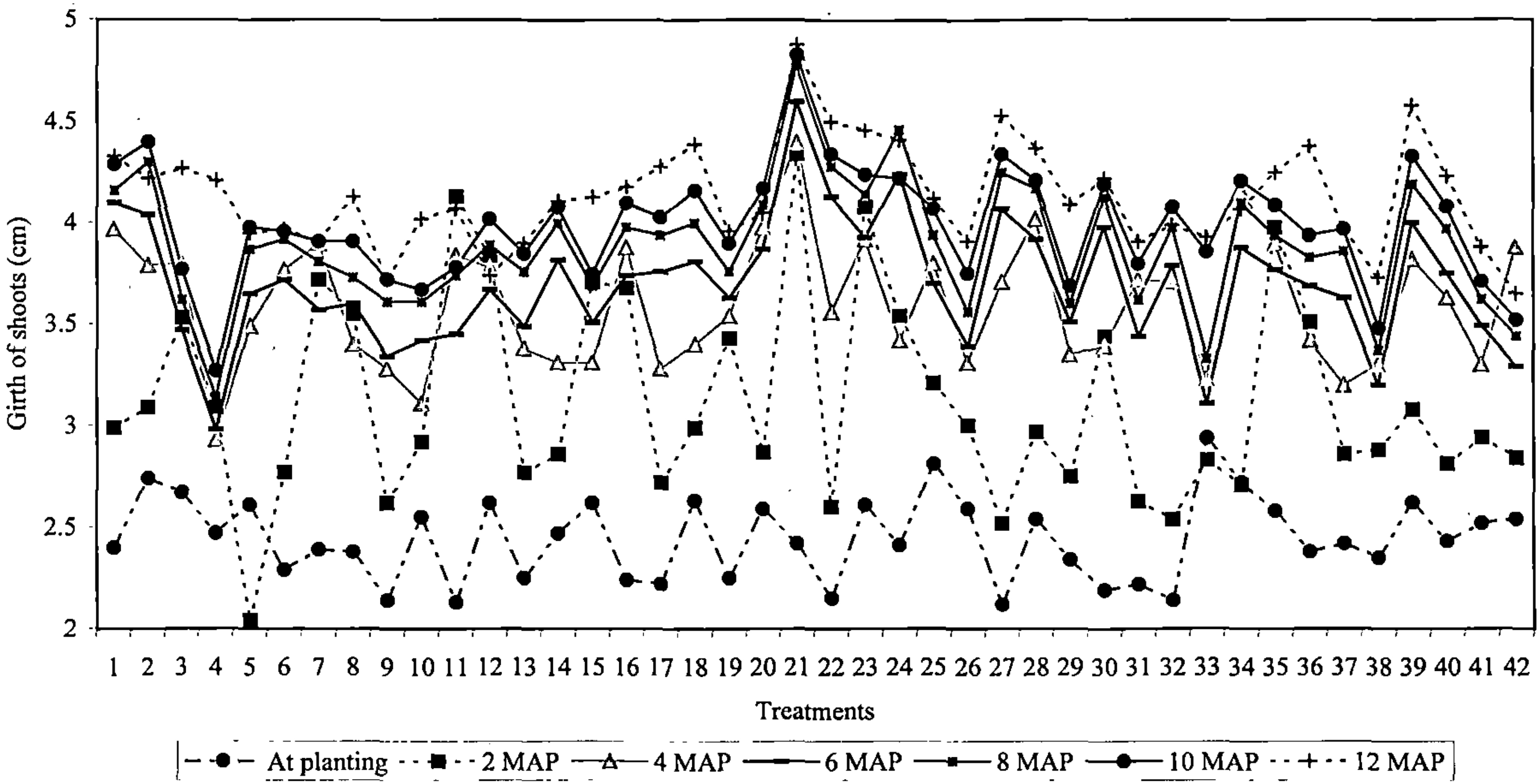


Fig. 5. Girth of shoots (cm) in *Dendrobium* var. Sonia 17 as influenced by different levels of inorganic fertilizers and biofertilizers

consonance with the findings of Ravichandran (1991) in crossandra, Manonmani (1992) in jasmine, Gnanasekar (1994) in jathimalli and Subramanian (1997) in carnation.

5.2 EFFECT OF INORGANIC SPRAY AND BIOFERTILIZERS ON ROOT PARAMETERS AND DRY MATTER PRODUCTION AT FLOWERING

The study revealed that the maximum root length was produced by the treatment T_{36} (NPK 20:10:10 *Azospirillum*+ AMF + phosphobacteria) which gave a statistically superior result. Similar result were obtained in the case of number of roots (Fig.7). Here also, treatment T_{36} was found to be significantly superior than other treatment combinations. This can be concluded as due to the increased fixation of nitrogen by *Azospirillum* and increased phosphorus uptake by inoculation of phosphobacterium. The synergistic effect of AMF and phosphobacteria has been reported by Azcon *et al.* (1976) in field crops, Wang and Ling (1997) in petunia and Stalin *et al.* (1993) in silver oak.

The biofertilizer treatments had a direct influence on the root volume of the crop. Best treatment was found to be T_{40} (NPK 10:5:10 + *Azospirillum* + phosphobacteria + AMF). Even the second highest value was observed for the treatment T_{36} (NPK 20:10:10 + *Azospirillum* + phosphobacteria + AMF). This clearly shows that combined inoculation of all the three biofertilizers has a highly significant effect on the volume of roots produced (Fig.7). This may be due to the combined influence of *Azospirillum*, phosphobacteria and AMF in enhancing the N availability, improving the phosphorus solublization and enhancement of phosphorus uptake. Similar results have been reported by Stalin *et al.* (1993).

In the case of dry matter production it was observed that treatments which received higher concentration of N, P and K along with biofertilizers had significant effect (Fig.7). This may be due to the application of higher quantities of inorganic spray along with the supplementation of biofertilizers, viz., *Azospirillum* and phosphobacteria. Similar finding has been reported by Gnanasekar (1994) in jathimalli.

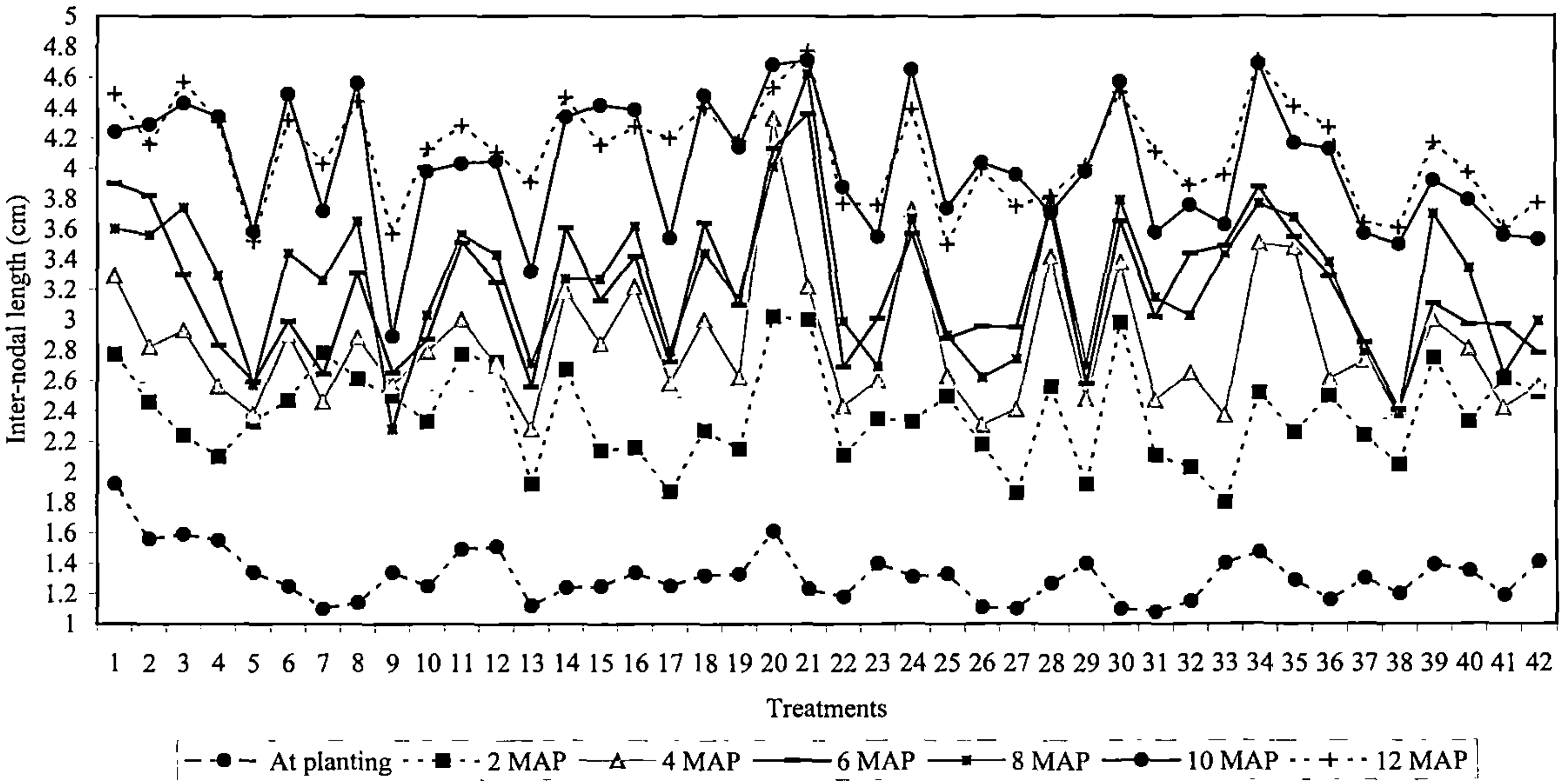


Fig. 6. Inter-nodal length (cm) in *Dendrobium* var. Sonia 17 as influenced by different levels of inorganic fertilizers and biofertilizers

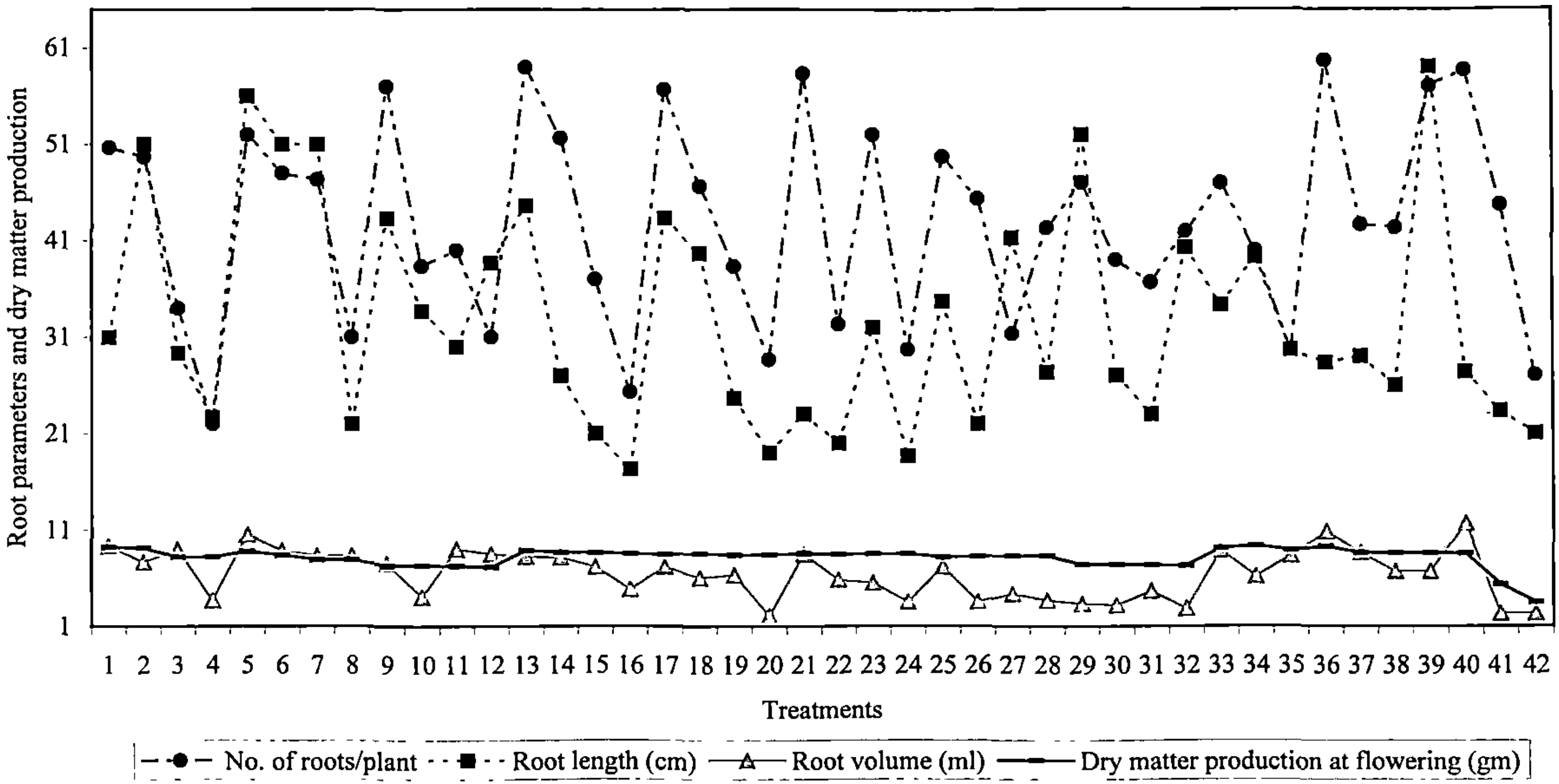


Fig. 7. Root parameters and dry matter production at the time of flowering in *Dendrobium* var. Sonia 17 as influenced by different levels of inorganic fertilizers and biofertilizers

5.3 EFFECT OF BIOFERTILIZERS ON FLOWER CHARACTERS

In floriculture crops, the economic part is the cut bloom and the ultimate aim of the research was to obtain early flowering and increased yield. In orchids results regarding early flowering, number of spikes, size of flowers, number of flowers per spike, internodal length, flower pedicel length and longevity of spike on the plant are reported. In the present trial, all the plants did not come to flowering during the period of study and using the available blooms, maximum characters have been studied.

The plants which received higher dose of inorganic nutrients and *Azospirillum* inoculation came to flowering earlier in the variety *Dendrobium* Sonia 17. Earliness in flowering so observed may be due to the combined effect of inorganic nutrients and the biofertilizer *Azospirillum.* The possibility of an increase in the synthesis of cytokinin as induced by *Azospirillum* in the root tissue and its simultaneous transport to axillary buds would have resulted in a better sink for mobilisation of photoassimilates at a rapid rate. This *Azospirillum* induced cytokinin synthesis and rapid assimilation of photosynthates would have possibly helped in the early transformation of the axillary buds from vegetative to reproductive phase as reported by Fisher (1959) and Bakly (1974). Similar results were obtained by Balasubramanian (1989) in French marigold, Preethi (1990) in Edward rose and Ravichandran (1991) in crossandra.

In the case of the number of spikes produced per plant the biofertilizer application coupled with inorganic spray were found to have no influence on the number of spikes produced by the plants during the period of the present study.

In the case of size of florets, spike length and number of flowers per spike it was noted that biofertilizer treated plants which received high doses of inorganic spray had a favourable effect on these characters. This favourable effect might be due to the translocation of sugars and narrowing down of the C:N ratio, production of auxins, gibberellins and cytokinins at the crop root zones induced by the biofertilizer *Azospirillum* ultimately leading to increased yields (Nagarajaih and Reddy, 1986;

Faber and White, 1977). Similar reports were obtained by Wang and Gregg (1994) in *Phalaenopsis* orchid. When the influence of the different treatments on the length of the flower pedicel and internode were studied, all the treatments showed a similar trend and not much variation was observed among the treatments.

Regarding longevity of the spike on plants, almost all the treatments showed a similar trend without much variation among the treatments.

Regarding the vase life of the flowers, due to the lack of sufficient number of spikes during the present period of study, the superiority of the different treatments could not be assessed.

5.4 EFFECT OF INORGANIC SPRAY AND BIOFERTILIZERS ON INCIDENCE OF PESTS AND DISEASES

During the entire period of study, there was not much incidence of pests and diseases. But snails and slugs were common during rainy season which is a common phenomenon in orchids cultivated in Kerala. Fungal and bacterial diseases were also observed which were controlled timely using right prophyllactic measures.

5.5 EFFECT OF INORGANIC SPRAY AND BIOFERTILIZERS ON NUTRIENT CONTENT OF THE CROP

Nutrient analysis was carried out to estimate the total nitrogen, phosphorus and potassium content in plants. Results revealed that there is a slight increase in nutrient content in treatments receiving higher dose of inorganic fertilizers along with biofertilizers. The increase in nutrient content of the plant might be attributed to the multiplication of micro-organisms and these micro-organisms inturn fix the atmospheric nitrogen and produce certain growth promoting substances like gibberellins and auxins (Rao and Venkateswaralu, 1985).

Nitrogen estimation revealed that nitrogen content was more in plants receiving 20:10:10 NPK along with *Azospirillum* and phosphobacteria (Fig.8). This may be due to the higher nitrogen content in the inorganic spray as well as due to the fixation of nitrogen and easy translocation of nutrients by biofertilizers. This is well

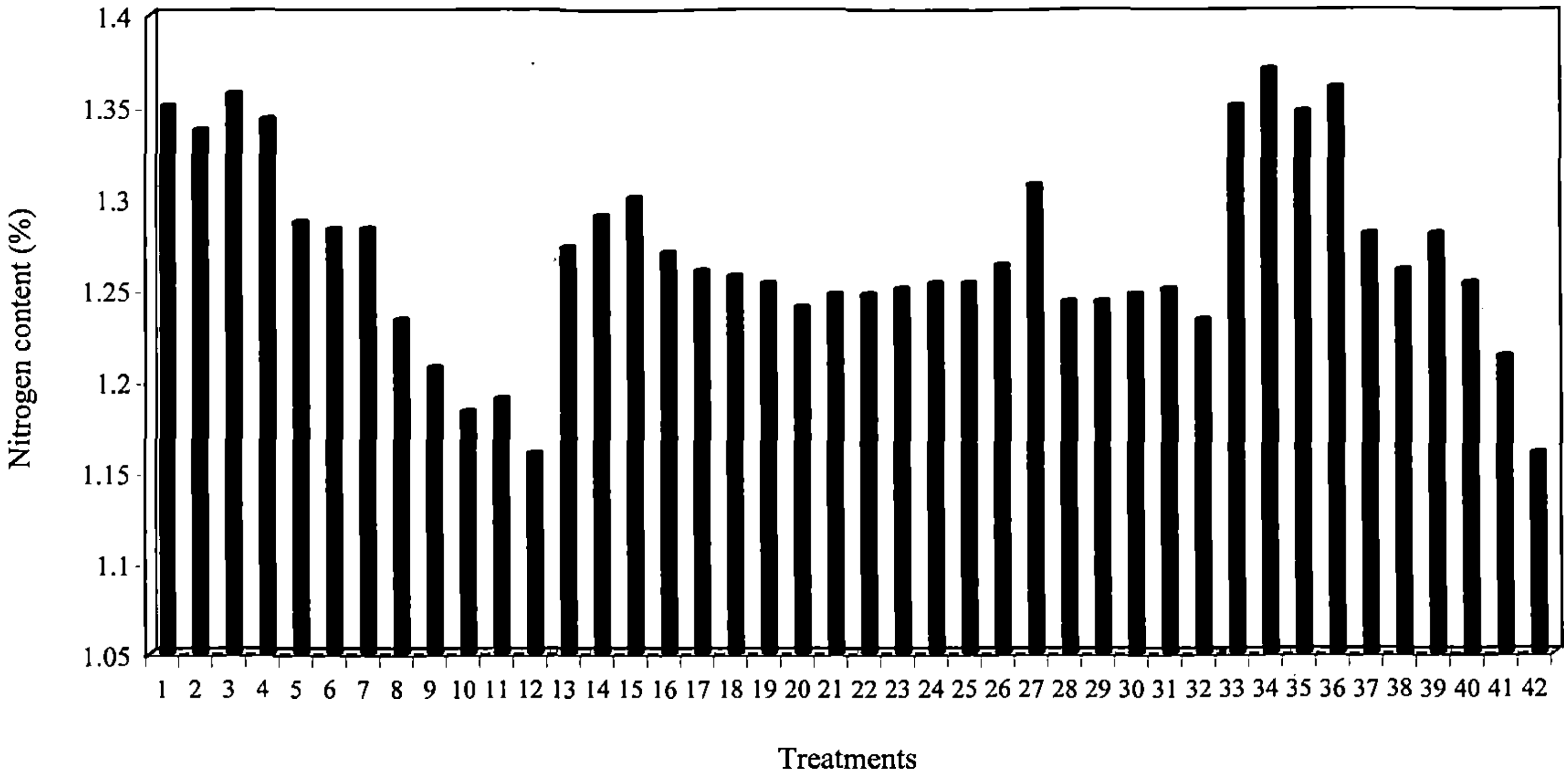


Fig. 8. Nitrogen content (%) in plants of *Dendrobium* variety Sonia 17 as influenced by different levels of inorganic fertilizers and biofertilizers

supported by the findings of Balasubramanian (1989) in French marigold and Gnanasekar (1994) in *Jasminum grandiflorum.*

The highest content of phosphorus was obtained for the same treatment T_{34} which was a combination of *Azospirillum* and phosphobacteria along with 20:10:10 NPK spray applied @ 0.2 per cent weekly twice (Fig. 9). This could be attributed to the synergestic effect of phosphobacteria which resulted in faster rate of phosphorus solubilization. Similar findings were observed by Hakkeem (1998) in chrysanthemum.

Estimation of potassium also revealed that there is a significant role for biofertilizers in increasing the nutrient content in plants (Fig.10). This may be due to the reason that *Azospirillum* and phosphobacterium treated plants absorb nutrients at a faster rate than uninoculated plants (Okon *et al.,* 1983). The results are in confirmation with the results of the studies undertaken by Preethi (1990) in Edward rose, Ravichandran (1991) in crossandra and Mariappan (1992) in marigold.

5.6 EFFECT OF INORGANIC SPRAY AND BIOFERTILIZERS ON POST-EXPERIMENTAL MICROBIAL COUNT

Plants were inoculated with *Azospirillum* and phosphobacteria (40%) and AMF was applied as (50 g kg^{-1} media) at the time of planting and the post-experimental microbial count showed varying results after 12 months of planting.

From the study, it was observed that *Azospirillum* was present in the roots even after twelve months of planting. Under acidic conditions, the bacteria was found to proliferate within the roots (Dobereiner *et al.,* 1976). This might be the reason for the occurance of *Azospirillum* in all the treatments inoculated with the bacteria.

When the count of phosphobacteria was taken,the treatments receiving higher dose of inorganic nutrients and inoculated with both *Azospirillum* and phosphobacteria recorded the highest value. This might be due to the combination effect of the inorganic nutrients and the bacteria. The count was lowest for the treatment which received only biofertilizers

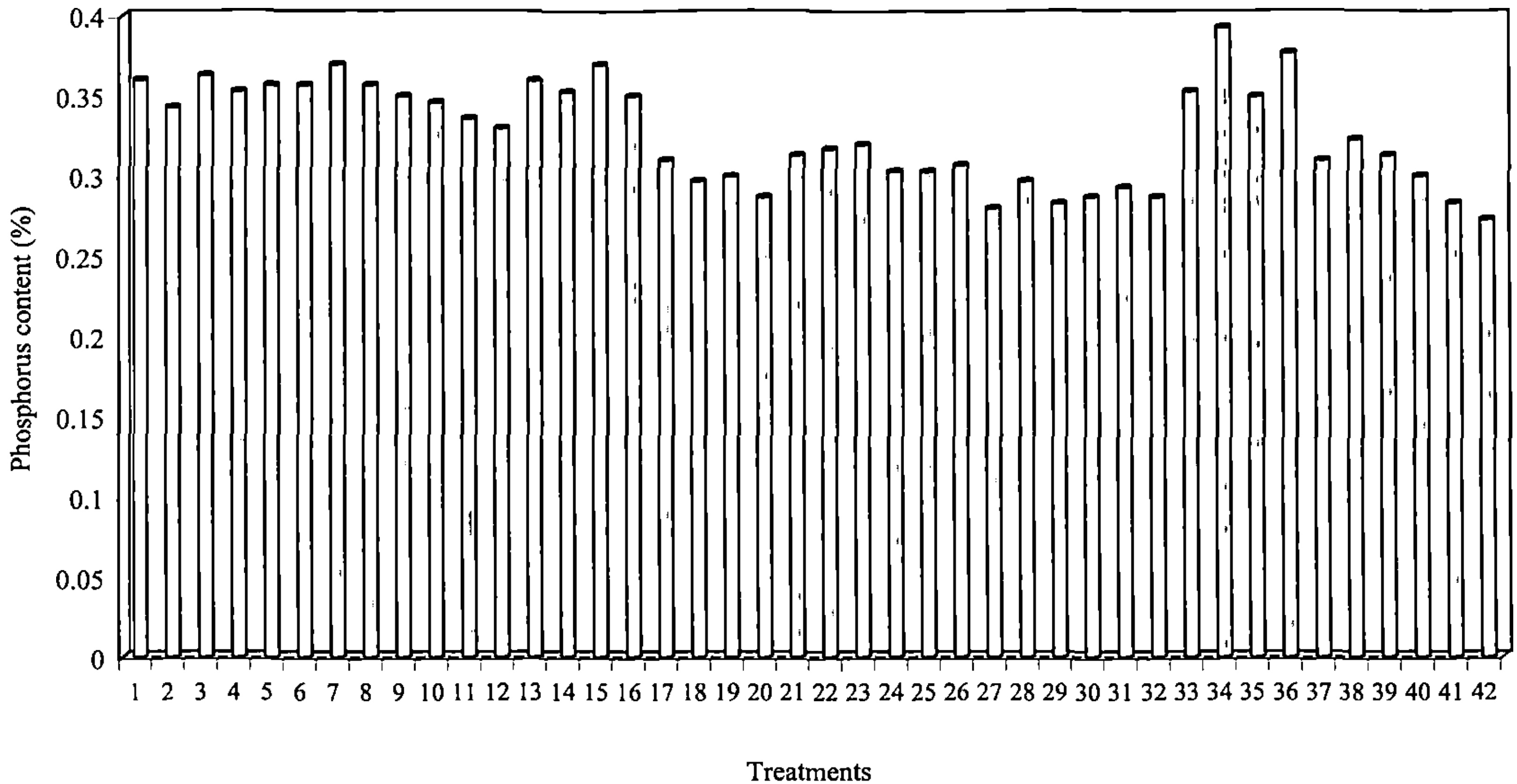


Fig. 9. Phosphorus content (%) in plants of *Dendrobium* variety Sonia 17 as influenced by different levels of inorganic fertilizers and biofertilizers

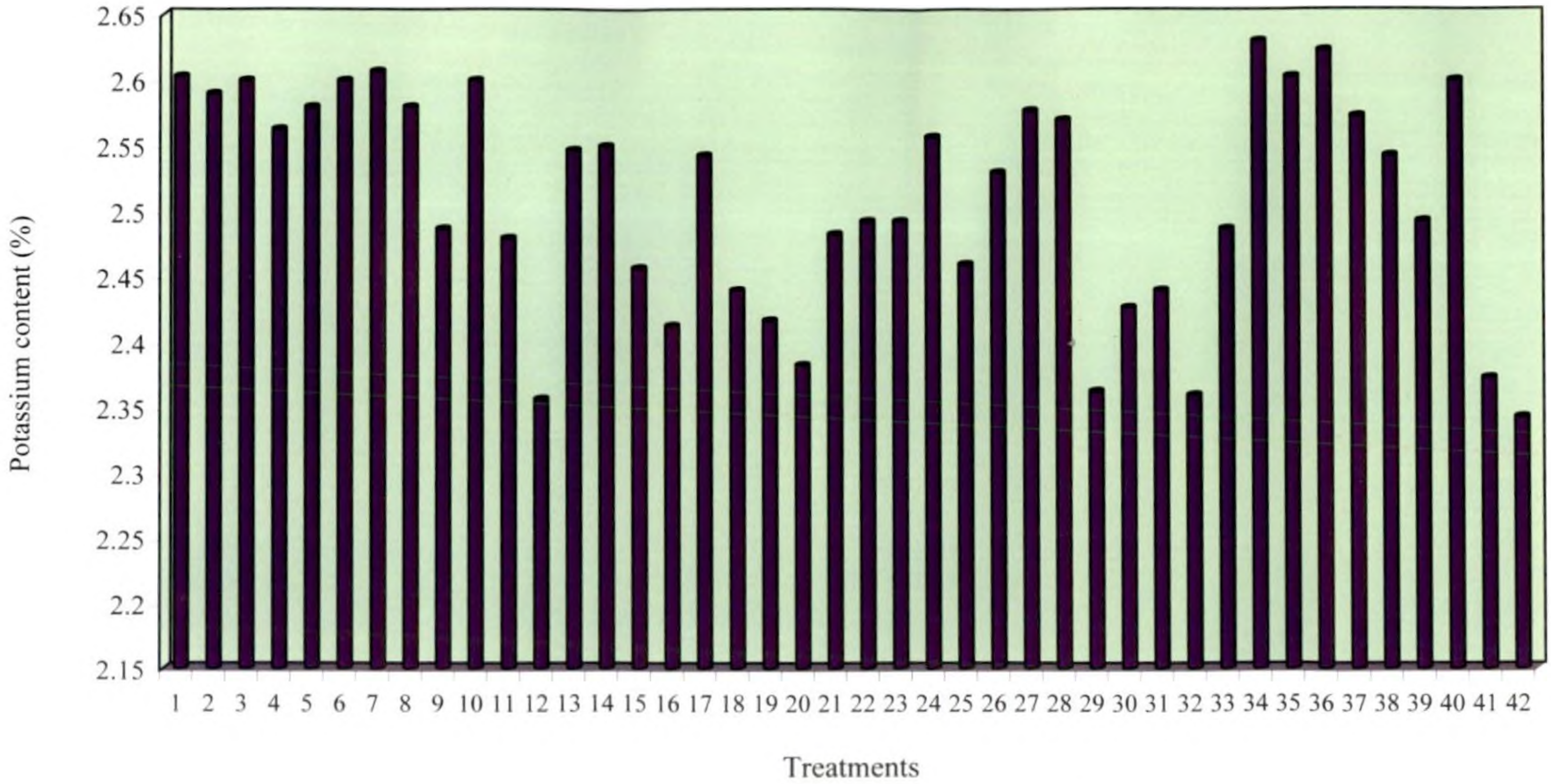


Fig. 10. Potassium content (%) in plants of *Dendrobium* variety Sonia 17 as influenced by different levels of inorganic fertilizers and biofertilizers

Results clearly indicated that AMF spores were not present in root tissue at twelve months after planting. The occurrence of AMF is largely maintained by soil factors such as pH, moisture content, nutrient rich media, organic matter etc. Since, the media consisted of only brick and charcoal pieces and coconut husk, the AMF spores might not have been able to survive in such a media, resulting in zero count of the spores.

Summary

6. SUMMARY

An experiment was conducted during July 2002 to August 2003 in the orchidarium of All India Co-ordinated Floriculture Improvement Project in the Department of Pomology and Floriculture, College of Horticulture, Kerala Agricultural University, Thrissur to determine the effect of biofertilizers along with inorganic fertilizers on growth and flowering in *Dendrobium*. The study was undertaken using the commercial hybrid variety Sonia 17 belonging to the genus *Dendrobium.* Biofertilizers were applied as treatments on the day of planting. The biofertilizers used were *Azospirillum*, phosphobacteria and Arbuscular Mycorrhizal Fungi (AMF). The inorganic nutrients consisted of various levels of NPK at different combinations applied as 0.2 per cent spray twice a week. The salient findings of the study are summarized below.

The growth parameters like height and internodal length of the plants were significantly influenced by biofertilizers, which was pronounced from sixth month of planting. Maximum plant height (19.83 cm) and internodal length (4.77 cm) were obtained for the treatment which received 10:5:10 NPK spray weekly twice at 0.2 per cent level and inoculated with *Azospirillum* at the time of planting.

The number of leaves produced per plant throughout the experimental period were not found to be influenced by biofertilizers. The effect of treatments on leaf production showed a progressive increase only after eighth month of planting. However, among the treatments higher rate of leaf production (8.60) was observed for the treatment receiving *Azospirillum* and 10:5:10 NPK spray at 0.2 per cent concentration twice a week.

The biofertilizer treatments had a direct influence on number of leafy shoots from second month of planting onwards. The treatment receiving 10:5:10 NPK spray at 0.2 per cent concentration along with *Azospirillum* inoculation recorded the highest value of 3.62, after twelth month of planting.

Pseudobulb production was significantly increased by the influence of biofertilizers from sixth month of planting. The maximum pseudobulbs (4.33) were obtained for the treatment receiving the biofertilizer combination of *Azospirillum* and phosphobacteria along with 10:5:10 NPK spray at 0.2 per cent concentration weekly twice.

Significant superiority in girth of shoot (4.88 cm) was observed for treatments provided with 10:5:10 NPK at 0.2 per cent concentration along with *Azospirillum.* A significant influence of this treatment was observed on plants over the entire time frame of study.

Number of roots produced by the plants and the root length were significantly influenced by biofertilizers. Remarkable increase was noticed in plants receiving 20:10:10 NPK at 0.2 per cent applied weekly twice along with a combination of *Azospirillum*, phosphobacteria and AMF. The highest value recorded for root number was 59.67 and that for root length was 59.00 cm.

Biofertilizers had a significant role in improving the root volume of plants. Plants receiving *Azospirillum,* phosphobacteria and AMF along with 10:5:10 NPK at 0.2 per cent applied weekly twice recorded the highest root volume.

Dry matter production differed markedly with the treatments. At the time of flowering, treatments receiving 20:10:10 NPK at 0.2 per cent concentration along with the biofertilizers *Azospirillum* and phosphobacteria recorded the highest dry matter of 9.39 g, whereas the treatment receiving the same inorganic nutrients inoculated with *Azospirillum* alone recorded 9.22 g of dry matter.

Earliest flowering (298 DAP) was recorded in plants receiving highest concentration of NPK 20:10:10 at 0.2 per cent applied weekly twice along with *Azospirillum* treatments. This was followed by 20:10:10 NPK along with phosphobacteria inoculation.

Nutrients, inorganic as well as biofertilizers, in various combinations did not show any improvement in the production of spikes per plant. Only single spike was observed in almost all plants at 12 MAP.

Floral characters like flower size (7.1 cm x 6.6 cm), spike length (21.03 cm) and number of flowers per spike (3.67) were the highest for the treatment combination of NPK 20:10:10 at 0.2 per cent concentration applied twice a week along with the inoculation of biofertilizer *Azospirillum* at planting.

Significant influence of treatments were not observed for internodal length of spike, pedicel length and longevity of spike on plant.

Application of NPK 20:10:10 at 0.2 per cent along with *Azospirillum* and phosphobacteria resulted in maximum N (1.37%), phosphorus (0.39%) and potassium (2.63%) content in plants.

Twelth month after planting, when the microbial population was estimated, *Azospirillum* and phosphobacteria were found to be present in the root and the media, but no trace of AMF spores was there in the roots. This gave an indication that *Azospirillum* and phosphobacteria could survive even in a soil less media but AMF cannot.

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Appendices

APPENDIX-I

Monthly distribution of weather parameters during the experiment (July 2002 to August 2003)

Month	Temperature (°C)		Relative humidity (%)		Rainfall (mm)
	Maximum	Minimum	Morning	Evening	
July (2002)	29.8	21.4	94	74	354.2
August	31.4	21.0	94	78	506.6
September	33.3	21.6	92	62	124.0
October	33.4	22.5	91	74	387.7
November	33.2	22.3	83	60	22.1
December	33.4	16.8	72	45	0.0
January (2003)	35.3	19.5	66	34	0.0
February	36.8	21.6	83	43	162.1
March	36.0	20.4	86	37	94.8
April	37.8	23.4	86	58	23.8
May	35.6	23.5	88	56	40.3
June	30.9	23.8	91	68	570.6
July	29.5	22.2	93	74	492.6
August	30.0	23.4	93	73	490.1

APPENDIX-II

Okon's semi solid malic acid medium

Malic acid	5 g
$K_2H\ PO_4$	0.5 g
KOH	4.0 g
$MgSO_4$	0.1 g
NaCl	0.02 g
$CaCl_2$	0.01 g
$FeSO_4$	0.05 g
$Na_2\ Mo\ O_4$	0.002 g
$Mn\ SO_4$	0.01 g
Bromothymol blue (0.5% alcoholic solution)	2.0 ml
Agar	1.8 g
Distilled water	1.0 l
pH	6.9 - 7.3

APPENDIX-III

Pikovskaya's medium

Glucose	10 g
Yeast extract	0.5 g
$(NH_4)_2 SO_4$	0.5 g
KCl	0.2 g
NaCl	0.2 g
$Mg SO_4.7 H_2O$	0.1 g
$Fe SO_4. 7 H_2O$	Traces
$MnSO_4$	Traces
$Ca_3 (PO_4)_2$	5.0 g
Distilled water	1.0 l
pH	7.0 - 7.2

SUPPLEMENTARY EFFECT OF BIOFERTILIZERS IN *Dendrobium*

By

S. BINISHA

ABSTRACT OF THE THESIS

Submitted in partial fulfilment of the
requirement for the degree of

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ABSTRACT

Studies on "Supplementary effect of biofertilizers in *Dendrobium*" were carried out in the orchidarium of All India Co-ordinated Floriculture Improvement Project, Department of Pomology and Floriculture, College of Horticulture, Vellanikkara during the period from July 2002 to August 2003. The study was conducted using *Dendrobium* var. Sonia 17, with the main objective of determinjng the effect of biofertilizers on growth and flowering of *Dendrobium* in combination with inorganic fertilizers.

Results revealed that, different treatments involving combinations of biofertilizers and inorganic fertilizers highly influenced the growth characters of the plant. The plant height obtained was the highest for NPK 10:5:10 along with *Azospirillum*. This treatment also improved vegetative characters like number of leaves per plant, number of leafy shoots, girth of shoot and internodal length. Maximum number of pseudobulbs was obtained for the treatment receiving NPK 10:5:10 inoculated with *Azospirillum* and phosphobacteria at the time of planting.

Root characters and dry matter production were markedly influenced by biofertilizer treatments. Root length and root number were found to be the highest for the treatment receiving 20:10:10 NPK along with *Azospirillum*, phosphobacteria and Arbuscular Mycorrhizal Fungi. These three biofertilizers along with 10:5:10 NPK yielded the highest root volume. Dry matter production at the time of flowering was markedly influenced by biofertilizer application. Treatment receiving 20:10:10 NPK along with *Azospirillum* and phosphobacteria recorded the highest value for dry matter production.

Plants which were inoculated with *Azospirillum* at the time of planting and sprayed with 20:10:10 NPK at 0.2 per cent concentration, came to flowering early, produced larger flowers, lengthy spikes and more number of flowers per spike.

Number of spikes per plant, colour variation, spike internodal length, pedicel length and longevity of spike on the plant were not found to be influenced by

biofertilizer application. Significant incidence of pests and diseases were not noticed during the period under study.

Nutrient content in the plant was found to be influenced by the biofertilizers applied. The plants inoculated with, both the biofertilizers, *Azospirillum* and phosphobacteria and sprayed with 20:10:10 NPK at 0.2 per cent concentration recorded higher values for the nutrients analysed.

The microbial population estimated at the post-experimental stage recorded the presence of *Azospirillum* and phosphobacteria even after 12 MAP in soil less media but AMF spores were found to be absent.

From this trial conducted, an indication is obtained that, *Azospirillum* and phosphobacteria can survive in a soil less media and these biofertilizers in combination with inorganic nutrients can improve both vegetative and flowering characters in orchid. This piece of information can be very well utilized for carrying out further studies in this line, so that an economically feasible and eco-friendly nutrient formulation can be developed for the benefit of the orchid growers.