REGULATION OF GROWTH AND FLOWERING IN DENDROBIUM VAR. SONIA 17

By

SWAPNA, S.

THESIS

Submitted in partial fulfillment of the requirement for the degree of

Doctor of Philosophy in Horticulture

Faculty of Agriculture
Kerala Agricultural University

DEPARTMENT OF POMOLOGY AND FLORICULTURE
COLLEGE OF HORTICULTURE
VELLANIKKARA, THRISSUR - 680 656
Kerala, India

2000

DECLARATION

I hereby declare that this thesis entitled ***"Regulation of growth and flowering in dendrobium var. Sonia 17"*** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, fellowship or other similar title, of any other University or Society.

Vellanikkara
08-05-2000

SWAPNA, S.

CERTIFICATE

Certified that this thesis, entitled *"**Regulation of growth and flowering in dendrobium var. Sonia 17**"* is a record of research work done independently by **Ms.Swapna. S.,** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

Dr.P.K. Rajeevan
Chairman, Advisory Committee
Associate Professor and Head
Department of Pomology & Floriculture
College of Horticulture

Vellanikkara
08-05-2000

CERTIFICATE

We, the undersigned members of the Advisory Committee of **Ms.Swapna, S.,** a candidate for the degree of **Doctor of Philosophy in Horticulture** with major in **Pomology and Floriculture**, agree that the thesis entitled *"Regulation of growth and flowering in dendrobium var. Sonia 17"* may be submitted by Ms.Swapna, S., in partial fulfilment of the requirement for the degree.

Dr.P.K. Rajeevan
Associate Professor and Head
Department of Pomology and Floriculture
College of Horticulture, Vellanikkara
(Chairman)

Dr.P.K.Valsalakumari
Associate Professor
Department of Pomology & Floriculture
College of Horticulture
Vellanikkara
(Member)

Dr.C.K. Geetha
Associate Professor
Department of Pomology & Floriculture
College of Horticulture
Vellanikkara
(Member)

Dr.E.K.Lalitha Bai
Associate Professor
Department of Agricultural Meteorology
College of Horticulture
Vellanikkara
(Member)

Dr.V.K.G. Unnithan
Professor
Department of Agricultural Statistics
College of Horticulture
Vellanikkara
(Member)

EXTERNAL EXAMINER
Dr. Devinder Prakash
Senior Scientist, IIHR
Hessarghatta Lake PO
Bangalore 560 080

ACKNOWLEDGEMENT

Thanks from the depth of my heart to

- ***Dr.P.K.Rajeevan**, Associate Professor and Head, Department of Pomology and Floriculture, College of Horticulture and Chairman of my Advisory Committee, whom I regard as the inspiration behind and the leading light in every step of my way.*
- ***Dr.C.K.Geetha**, Associate Professor, Department of Pomology and Floriculture, College of Horticulture and member of my advisory committee for bestowing support and encouragement like someone very own.*
- ***Dr.P.K.Valsalakumari**, Associate Professor, Department of Pomology and Floriculture, College of Horticulture and member of my advisory committee for the wholehearted co-operation and personal interest shown throughout.*
- ***Dr.E.K.Lalitha Bai**, Associate Professor, Department of Agricultural Meteorology and member of my advisory committee for the sincere help and valuable suggestions rendered at various stages of the study.*
- ***Dr.V.K.G.Unnithan**, Professor, Department of Agricultural Statistics and member of my advisory committee for sparing his valuable time, especially during the analysis and interpretation of data.*
- *Sri. Johny Padikkala, Padikkala Orchids, Thrissur for his generosity in permitting me to conduct a portion of my research in his farm. But for his help this probably would have remained a dream.*
- *Dr.N.N.Potty, Professor and Head, Department of Agronomy, Sri.Prasad, Department of Soil Science and Agricultural Chemistry for the facilities and help rendered in the course of chemical analysis..*
- *Staff and students of Department of Pomology and Floriculture. Department of Agronomy and employees of Padikkala Orchids for their wholehearted help.*

- *My friends Lavanya, Rathy, Geetha, Linnett, Deepa, Anu and Leena, who were with me during the hard times.*
- *Sri. Joy who typed out the work with utmost sincerity and accuracy.*
- *My parents and sister for their constant prayers and encouragement.*
- *My husband and little son for bearing all the negligence and monotony throughout.*
- *AICFIP, Vellanikkara Centre for funding my research work.*
- *Kerala Agricultural University for awarding the senior research fellowship.*
- *And above all, the God Almighty for all the unmerited blessings showered.*

Swapna, S.

CONTENTS

LIST OF TABLES

LIST OF PLATES

11 Effect of superior pulsing treatments in control treatment of holding solutions.
From left P_1 (HQ 500 ppm + sucrose 5% for 12 hours), P_2 (HQ 500 ppm + sucrose 5% for 6 hours), P_3 (Hot water treatment at 50-60°C for 10 seconds), P_4 (HQ 250 ppm + sucrose 5% for 12 hours)

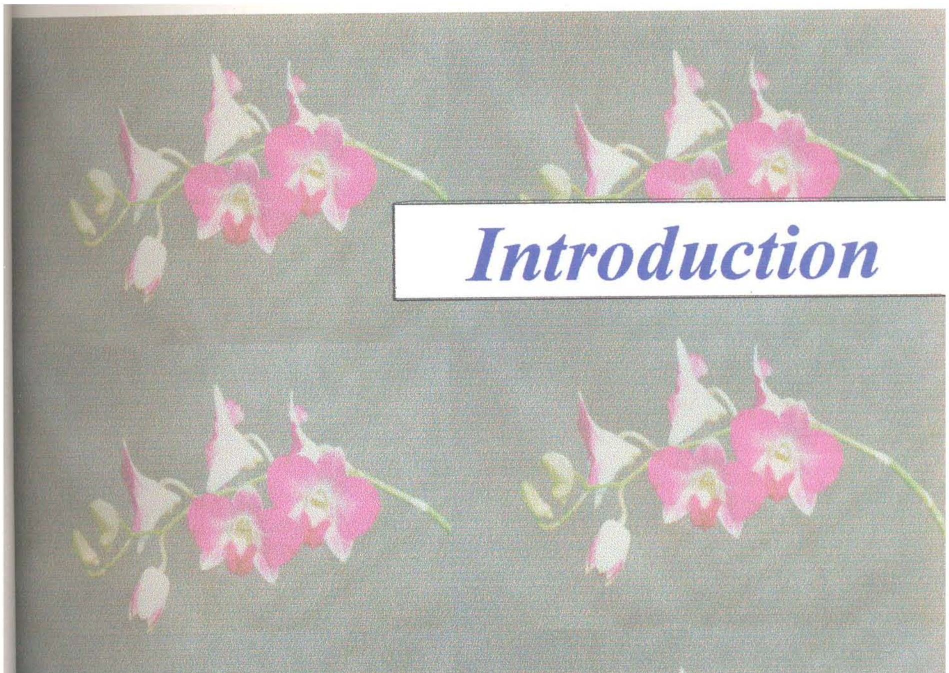
12 Effect of best pulsing treatments (P1 - HQ 500 ppm + sucrose 5% for 12 hours) in superior holding solutions in comparison with holding control.
From left - H_0 (Holding control), H_1 (AgNO3 50 ppm + HQ 400 ppm + sucrose 5%), H_2 ($AgNO_3$ 25 ppm + HQ 400 ppm + sucrose 5%), H_3 ($AgNO_3$ 50 ppm + HQ 200 ppm + sucrose 5%).

13 Effect of best holding treatment (H_1 - $AgNO_3$ 50 ppm + HQ 400 ppm + sucrose 5%) in combination with superior pulsing treatments compared to holding control.
From left - P_1 (HQ 500 ppm + sucrose 5% for 12 hours) with holding control, P_1 with H1, P_2 (HQ 500 ppm + sucrose 5% for 6 hours), P_3 (Hot water treatment at 50-60°C for 10 seconds) with H_1, P_4 (HQ 250 ppm + sucrose 5% for 12 hours) with H_1.

14 Yellowing of stem (left) as influenced by poor pulsing and holding solutions, compared to superior treatments (right)

LIST OF FIGURES

Introduction



INTRODUCTION

Orchids, the most spectacular among flowers, are unique with their versatility in colour, form, size, shape and longer life span of the plant and flower. The small proportion of the total international trade of cut flowers occupied by orchids highlights their potential to take an even greater share of the market. Prospects of an increasing consumer demand and buoyant world market have promoted the status of orchid growing as an industry in many countries, especially in South-East Asia.

Orchids belong to the largest family of flowering plants, Orchidaceae, having over 600 genera and 30,000 species. They have a wide range of growing habit, from terrestrial to epiphytic. India has immense orchid wealth including more than 1300 indigenous types, but their commercial exploitation has been very slow.

In Kerala, cultivation of orchids was started by a few growers in Trivandrum as early as during the late seventies. It is only very recently that commercial cultivation on scientific basis has started in Kerala (Chadha, 1992). There are many commercial growers now in Kerala engaged in orchid cultivation and trade, especially with *Dendrobium, Arachnis* and *Vanda* which have good market potential (Rajeevan *et al.*, 1993). The scenario has significantly improved during the last few years, resulting in significant expansion of area. According to the Federation of Indian Floriculturists Association (1997), about 14 lakh orchids are cultivated in Kerala.

Dendrobium is considered as the second largest genus of orchids. About 900-2000 species are reported in the genus with an estimate of 1340 species (Baker and Baker, 1996). Many of the *Dendrobium* species, viz., *D. aduncum densiflorum, D. moschatum, D. aggregatum, D. farmerii, D. fimbriatum, D. nobile, D. pierardii* etc., were found to perform well under Kerala conditions (Rajeevan and Sobhana, 1993). In view of the easiness in management practices and ready availability of hybrids from private importers, dendrobiums now occupy not less than 90 per cent of the area under orchid cultivation in the state. The hybrids popular here are Sonia 17, Sonia 28 (purple and white flowers), Renappa, Sabine red (pure purple), Emma white, Kasem white, Fairy white, Pravit white (pure white) etc. However, lack of adequate information on management practices, right from planting to handling of harvested blooms, has resulted in low yield and poor quality of spikes. Since information from domestic sources is scanty, the cultural operations and nutrient management followed by the farmers are those adopted in the countries from where the plants are sourced, mainly Thailand, Malaysia and Singapore.

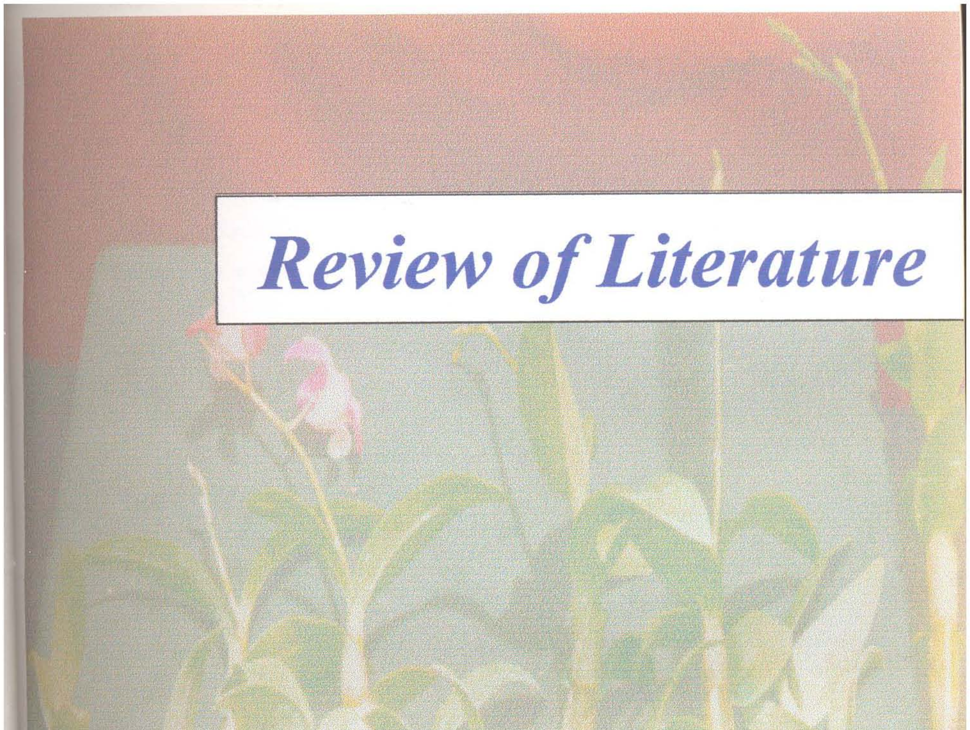
The major constraints encountered in orchid cultivation are long pre-blooming period, susceptibility to pests and diseases, poor health, mixed spikes, inferior quality spikes and short vase life. Most of the above problems emanate out of improper nutrition and hormonal imbalance.

Application of nutrients in optimum proportions, quantities and frequencies is the key factor in regulating growth and flowering in cutflowers. Proper relationship between nutrients and hormones, major and minor nutrients, inorganic and organic forms etc., also play a significant role. Investigation's on these lines are, however, meagre in *Dendrobium*. Being a flower having inherently long vase life, research on enhancing the vase life has also not attracted sufficient attention. Hence it has become imperative to arrive at a package of practices of our own, right from the planting of hardened plants to the cut spikes in vase.

In this context a study was undertaken in *Dendrobium* var. Sonia 17, a popular variety of Kerala, through the use of different combinations of nutrients, growth regulators and other chemicals, with the following major objectives.

1. To enhance the growth of plants and to reduce the pre-blooming period.
2. To improve the size and quality of spikes and to enhance the rate of spike production.
3. To prolong the vase life of spikes.

Review of Literature



2. REVIEW OF LITERATURE

The dawn of nineties had witnessed popularisation of orchids in India, especially in Kerala, with the introduction of a popular tropical genus, *Dendrobium*. This being the second largest genus in the family of orchids with respect to number of species, is the most popular sympodial orchid under commercial cultivation in the tropics. In view of the large number of species available a wide variety of hybrids are evolved in *Dendrobium*, of which 'Sonia 17' is of great demand.

Eventhough orchid cultivation has attained great popularity, many of the cultivation practices followed even now are adopted from other growing countries in the tropics, especially, the South-East Asian countries. Being a crop of relatively recent introduction research work on the aspects of nutrition and post harvest handling in *Dendrobium* is meagre in our country. Hence reports of research, conducted in *Dendrobium* as well as in other orchid genera, done elsewhere, are also reviewed in this chapter, under various heads.

2.1 Reducing pre-blooming period

2.1.1 Effect of nutrients

Like any other crop, in orchids too, nitrogen, phosphorus and potassium are the macronutrients, which are required in considerably large quantities.

Nitrogen is a vitally important plant nutrient and is the most frequently deficient of all nutrients. An adequate supply of nitrogen is associated with high photosynthetic activity and vigorous vegetative growth indicated by dark green leaves. Excess of nitrogen in relation to other nutrients like P and K can improve the vegetative growth. If nitrogen is used properly in conjunction with other major nutrient inputs, it can speed up the maturity of crops. Phosphorus (P) in plants is essential for energy currency. An adequate supply of P early in the life of a plant is important in increased root growth. Phosphorus is also found to promote early maturity of crops.

Potassium, eventhough forms no co-ordinated compounds in the plants, is required for activation of many enzymes, regulation of water status in the plant, translocation of assimilates, N uptake and protein synthesis (Tisdale *et al.*, 1995).

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 that provided by their growing medium (Sandford, 1974). Later it was proved that, like any other ornamental plant, balanced nutrient supply was required for orchids too, for their growth and flowering. Bose (1978) suggested that growth and flowering in orchids are improved by a regular schedule of fertilizers in liquid form. The frequency and dilution of the fertilizing solution is dependent on the type of orchids, their health and stage of growth.

Many workers have reported the beneficial effects of inorganic fertilizers in improving growth and flowering in orchids. Effect of three different levels of nitrogen, viz., 0, 50 and 100 lb/acre, on the growth of *Phalaenopsis* seedlings and *Cattleya* was studied by Sheehan (1960). He reported that there was significant increase in leaf growth with increment of nitrogen. In *Phalaenopsis* 'Pink Chiffon', when nitrogen level was increased from 50 ppm to 1000 ppm, enhancement of vegetative parameters like number of leaves and leaf area were observed (Sheehan, 1966).

Penningsfield and Fast (1962) reported the effect of deficient and excess use of nitrogen. Increased use led to rotting of roots and leaves in cattleya and deficiency resulted in yellowing and wilting of leaves. Potassium deficiency resulted in dwarfness with edges of leaves scorched and dead. Response of *Odontoglossum* to different doses of nitrogen was reported by Gething (1974). The fresh weight recorded was found to be 11, 22 and 43 g, with the treatment of 0, 50 and 100 ppm of nitrogen, respectively. Addition of P_2O_5 along with nitrogen considerably added to increase in the fresh weight. In cattleya, leaf production was increased with the application of K alone and with N and N content increased with the increased level of K (Poole and Sheehan, 1970).

According to Northen (1970) too much of nitrogen produces excess vegetative growth and delays flowering. Bhattacharjee (1977) observed that spraying N, P_2O_5 and K_2O at 100 ppm, each, at fortnightly intervals was beneficial in the case of *Bulbophyllum*. In cymbidium and phalaenopsis seedlings, 100 ppm N together with 50 ppm P and 25 ppm K was found to be optimal (Poole and Seeley, 1978).

In a study conducted in *Aranda* 'Noorah Alsagoff', the nutrient requirement found optimum for enhancing growth parameters was 20.9 mg N, 5.0 mg P and 21.8 mg K, applied at weekly intervals. Along with that, 3.4 mg magnesium was also found to give good results (Khaw and Chew, 1980).

Gomi *et al.* (1980) recommended nutrient solution containing 77.0, 15.5, 39.1, 80.1 and 12.2 ppm N, P, K, Ca and Mg, respectively, for maximum vegetative growth, which was thrice that of standard level of application in four year old *Phalaenopsis* hybrids. Effect of different levels (0, 500 and 1000 ppm) of nitrogen, phosphorus and potassium on the growth of *Dendrobium moschatum* grown in chunks of hardwood charcoal was studied by Bhattacharjee (1981). 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 500 ppm, each, of P_2O_5 and K_2O and an increase above that level had no effect.

Nichols (1982) reported 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 was applied as spray at weekly intervals for a period of six months. Bik and Van der berg (1983) observed that increasing nitrogen rate helped in increasing the shoot production in *Cymbidium* 'Pendragon Sikkim'. Similar findings were obtained in Mini cymbidium where vegetative parameters including number of shoots and leaf area were enhanced by well balanced nitrogen supply (Bik and Van der berg, 1982).

Excess of nutrition along with reduced water supply was suspected to be the reason for leaf drop in *Cymbidium* (Johnson, 1984a). Nutrient solution containing 100 ppm N, 20 ppm P and 75 ppm K was recommended for improving growth in *Cymbidium* and *Cattleya* (Johnson, 1984b).

According to Schenk and Brundert (1983), increased dosage of nitrogen from 60 mg l^{-1} to 240 mg l^{-1} was the reason for delay in flowering in *Phalaenopsis*. Sakai *et al.* (1985) suggested that a higher dose of nitrogen was beneficial under outdoor cultivation of *Dendrobium*. Longer pseudobulbs were produced when nitrogen was applied at 48 mg l^{-1}. Yadav and Bose (1986) found that, in *Aerides multiflorum*, plants with deficient nitrogen showed stunted growth and early maturity. Spraying of 1000 ppm, each, of nitrogen, phosphorus and potassium enhanced the length and number of leaves.

Results of experiment on *Vanda* 'Miss Joaquim' with 150 kg ha^{-1} nitrogen, 200 kg ha^{-1} phosphorus and 275 kg ha^{-1} potash by Higaki and Imamura (1987) showed that height of plants and diameter of stem increased in the field conditions. Banfield (1981) has recommended fertilizers containing high doses of nitrogen for *Paphiopedilum spp.* during growing season. Schum and Fischer (1985) obtained the greatest number of leaves and fresh weight in the plants receiving nitrogen and potassium in the ratio 1:1. Stewart (1988) recommended a combination containing a greater proportion of nitrogen (3:1:1) in the early summer for better vegetative growth and balanced proportion of nutrient with NPK 1:1:1 for sustained growth. The use of Ohio W.P. solution for the growth of most of the cultivated orchids has been suggested by Singh (1986).

In *Dendrobium* `Lim Hepa', increasing nitrogen dose from 50 ppm to 300 ppm and potassium from 25 ppm to 150 ppm showed clear effects on vegetative growth. Nitrogen at 300 ppm delayed flowering and enhanced stem length (Uesato *et al.*, 1987). When doses of nitrogen, phosphorus and potassium were increased from 77.00 ppm, 15.50 ppm and 39.10 ppm to 308 ppm, 62.00 ppm and 156.40 ppm, respectively, earlier flowering and increase in fresh weight and the nitrogen and potassium content of leaves were obtained in the case of *Cattleya* and *Phalaenopsis* (Tanaka *et al.*, 1981, 1988a, 1988b and 1989).

Mukherjee (1990) recommended a formulation containing calcium nitrate, magnesium sulphate, potassium nitrate and ammonium sulphate as major components in addition to trace elements for ideal growth of pot grown orchids. According to Koval'skaya and Zeimenko (1991), one year old *Dendrobium phalaenopsis* seedlings grew better when fed with MS nutrient solution and two year old seedlings grew best when fed with NPK 2:1:1. Seeni and Latha (1990) suggested that a combination of commercial diammonium phosphate and potassium nitrate (20:10:10 NPK) was by far the most effective in terms of rapid leaf and root growth.

NPK 17:17:17 complex sprayed at weekly intervals @ 10 g l^{-1} could increase the number of clumps and leaves in *Cymbidium traceanum* (Sobhana and Rajeevan, 1995). Wadasinghe and Hew (1995) suggested that the leaves of backshoots of *Dendrobium* cv. Jashika Pink were an important source of photosynthates for the growth and flower production. Hence adequate nutrition in the current season becomes beneficial for the succeeding vegetative growth as well as flowering.

Effect of nitrate-nitrogen and ammoniacal nitrogen on the growth and development in *Cymbidium sinense* was studied by Ruichi *et al.* (1994). It was observed that both sources of N enhanced leaf growth at 10 mol l^{-1}, but 50 mol NH_4^+ per litre reduced leaf growth. Wang (1996) 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.

In *Arachnis* Maggie Oei 'Red Ribbon' under trench culture, a nutrient dosage 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 was recommended by Thekkayam (1996). According to her, the beneficial doses in *Dendrobium* 'Sonia 16' was 400 to 500 ppm of N, P and K. Taejung *et al.* (1998) reported that healthy compact plants were produced in *Cymbidium* with NPK combination having high content of K. Leaf analysis showed high N content when 30:10:10 NPK was applied and least when 6:40:6 NPK was given. Nutrient recommendation of 2.0 mg NPK from three to six months, 6:2:2 NPK from six to nine months and 6:2:6 NPK from nine to twelve months was made by Umamaheswari (1999). For more than one year old plants 6:6:2 NPK was the best for maximum vegetative growth.

2.1.2 Effect of plant growth regulators

Promotion of lateral shoot growth in intact stems of orchids using cytokinins is found successful in *Ascocenda* and *Paphiopedilum* (Kunisaki, 1975). In his studies, the plants were sprayed with BA and BAP at 750 mg l^{-1} and 1000 mg l^{-1}, respectively.

Dendrobium sprayed thrice with 0.01 mg/ft² triacontanol flowered earliest (18 months after spraying) followed by 0.01 mg/ft² (21 months after spraying), whereas control plants did not flower by this time (Yee, 1983).

Keithly *et al.* (1991) reported the growth enhancing properties of Dichloro phenoxy triethyl amine (DCPTA) in *Dendrobium* 'Hickam Deb'. Shoot growth, root:shoot ratio and survival of DCPTA treated plants were increased significantly. In another study Pileuk *et al.*, (1992) found that application of BA @ 1000 mg l^{-1} significantly reduced leaf shedding during transit

2.2 Effect of nutrients on flowering

Effect of nutrients like nitrogen, phosphorus and potassium on flowering conforms with those in other flower crops. In *Phalaenopsis* increased nitrogen supply up to 1000 ppm was found to produce longer flower spikes with increased girth of spikes. Vacharotayan and Keetapirom (1975) found improvement in flowering of *Dendrobium* Madame Pompadour with NPK ratio 3:3:2 to 5:5:2.

Sagarik and Siripong (1963) reported beneficial effects by the use of a solution containing potassium nitrate, ammonium sulphate and superphosphate as major ingredients. Bhattacharjee (1982) studied the effect of three levels of nitrogen, viz., 250, 500 and 1000 ppm, in combination with 250 and 500 ppm, each, of P_2O_5 and K_2O in *Rhynchostylis gigantea*. When 500 ppm of N was used with a combination of 500 ppm of P_2O_5 and K_2O, flowering and flower parameters were enhanced. Schenk and Brundert (1983) recommended the use of nitrate and ammoniacal forms of nitrogen in the proportion of 2:1 for obtaining better flowering in phalaenopsis. A spray schedule of NPK 10:30:20 at weekly intervals for flowering plants was recommended by Abraham and Vatsala (1981).

Pradhan (1976) recommended the use of 1:1:1 of NPK mixture for flowering season. Boon (1982) and Merriman (1987) recommended N, P and K in the ratio 11:13:6 at weekly intervals for increased flower production during summer and autumn in *Oncidium* and *Cymbidium*, respectively. Stewart (1988) suggested that use of a high K content combination of NPK 1:1:3 was beneficial for flowering.

Longman (1989) recommended foliar feeding of mature flowering plants using NPK at 18:18:18. However, NPK at 10:30:30 produced more number of spikes per plant per year. Higaki (1989) suggested that it was better to use dilute solution daily rather than concentrated solution monthly. He recommended the use of 22 per cent N, 21 per cent orthophosphoric acid and 17 per cent K_2O for spraying in flowering plants.

A combination of NPK in the ratio 10:12:10 was suggested as the best by Bose and Bhattacharjee (1972), for growth and flowering in large number of hybrids of orchids. Yadav and Bose (1986) reported an enhanced spike length of 30.1 cm and diameter of 4.1 mm, compared to 19.1 cm and 3.0 mm, respectively, in control, when 1000 ppm of nitrogen was applied as spray.

In trials with miniature *Cymbidium* grown for cut flowers, the effects of nitrogen @ 24-120 mg l^{-1} were assessed and it was observed that increasing N rates enhanced number of flower stems per plant but length of spike and number of flowers per spike were found to decline (Bik and van den Berg, 1982).

Ma (1992) reported a competition between the inflorescence and vegetative shoot for assimilates translocated from the leaves of current shoot of *Dendrobium* W. Rong Rong. He has recommended the use of higher concentration of N and P and frequency of 2-3 sprays per week when the plant is in the flowering stage. Clifford *et al.* (1992) reported the role of the leaves of back shoots as a source for development of inflorescence in monopodial orchid *Aranda*.

Wang and Gregg (1994) observed that increasing the fertilizer application from 0.25 to 1.00 g l^{-1}, increased the flower number, stalk diameter and length in *Phalaenopsis*. Wang (1996) reported that fertilizer application using 20.0 N, 8.6 P and 16.6 K @ 1 g l^{-1} constantly resulted in more inflorescence and flowers in *Dendrobium* 'Rinnapa'.

Thekkayam (1996) reported that nitrogen at 500 ppm increased the length of inflorescence, number of florets per inflorescence and span area of the flowers. The number of inflorescences produced was also greater in the plants receiving 400 and 500 ppm N, 400 and 500 ppm K and 500 ppm P in *Dendrobium* 'Sonia 16'.

2.2.2 Effect of growth regulators

Naturally occurring hormones play an important role in the process of flower bud induction in orchids (Vries, 1953). This strengthened the exogenous application of growth regulators. The juvenile stage prior to flowering varies from three to more than even thirteen years in orchid hybrids. Control of flowering by plant growth regulators has attracted attention due to the need in commercial orchid production to resolve problems of flowering periodicity (Koay and Chua, 1981, Lee and Koay, 1986).

A wide range of plant growth regulators including gibberellins, auxins, cytokinins, ethephon and abscissic acid has been tested for their effect on flowering in orchids. Bivins (1968, 1970) reported the effect gibberellin on the flowering of *Cymbidium*. Application of GA_3 at 1000, 5000 and 10000 ppm at an interval of 2, 4 or 6 weeks accelerated flowering. Length of flower spike and size of flower were also increased. Goh and Wan (1974) reported that the flowering intensity in *Vanda* 'Miss Joaquim' was inversely correlated with the auxin level in the shoot apex. Plants exhibiting profuse flowering were found to have lowest level of auxin. Goh and Seetoh (1973) also obtained similar results. Decapitation was found to induce flowering in *Aranda* 'Deborah'. But this response could be inhibited by continuous supply of 10^{-4} M IAA solution. Goh (1977) found that application of cytokinin (BA) caused production of multiple inflorescences. Also antiauxins and growth retardants were effective in stimulting flowering in *Aranda* 'Deborah'. Similar results were obtained in *Arachnis* 'Maggie Oei' and *Aranda* 'Queen of Purples' (Goh, 1976) too.

In *Dendrobium*, application of BAP at 4000 ppm revealed a decrease in flower number, which normally occurs when the plants were forced to flower through light and temperature treatments. It also increased the number of spikes (Higuchi and Sakai, 1977). Goh and Yang (1978) reported that treatment of mature pseudobulbs with BA stimulated flowering. Gibberellic acid was ineffective when applied alone but enhanced the effect when applied in combination with BA.

Spraying with ethrel at 1000-4000 ppm, 1-3 times, at weekly intervals has been found to hasten flower induction in *Oncidium* 'Golden Shower' (Widyastuti and

Soedjone, 1979). In *Dendrobium* 'Lousiae' GA_3 did not stimulate BAP effect (Lee and Koay, 1986) whereas in *Dendrobium noduka,* GA_3 stimulated BAP action.

Aranda was found to produce inflorescences following BAP application just before flowering season (Hew, 1993). But in the case of *Dendrobium,* BAP was found to have no effect (Goh and Arditti, 1985). Paclobutrazol, a triazole growth regulator inhibiting gibberellin biosynthesis, has been reported to promote early flowering of *Dendrobium* although with reduced plant and flower size (Pileuk *et al.*, 1986). Chen *et al.*, (1997), after studying the effect of BA and GA_3 on flowering plants of *Phalaenopsis* 'Leda', found that at concentrations of 1, 3 and 5 μg/shoot, flowers were deformed. The deformity was reduced by BA combination but internodes were reduced.

Frequent reports of bud drop are seen in popular tropical orchids grown for cut flowers like *Aranthera* and *Dendrobium,* which has reduced the cultivation of these crops. There is a report of the application of 2-NOA @ 40 mg l^{-1} preventing bud drop in *Dendrobium bigibbum* (Boyd, 1985). It has also been found that GA_3 at 50 mg l^{-1} prevented ethephon induced bud drop in *Cymbidium* hybrid (Brewer *et al.*, 1989).

2.3 Post harvest studies

A cut flower is a complex organ composed of morphologically and physiologically different units. The regulatory factors, such as, water relations, carbohydrate levels and ethylene production and their inter relationships determine post harvest longevity and quality. The most widely accepted theories on extending vase life of cut flowers are based on the improvement in water relations within the stem. A high level of turgidity is necessary for the development of cut flower buds to full bloom maturity (Bhattacharjee, 1994).

According to Halevy and Mayak (1979), extension of vase-life of cut flowers involves two seemingly conflictive processes; the promotion of growth during the first phase and retardation of senescence process during the second phase. Post harvest life of cut flowers depends on several pre and post harvest factors, such as nutritional status of the growth medium, aerial and root temperature, photoperiod and light intensity during growth period in the green house, conditions during harvesting, grading, packaging, transportation and composition of pulsing and bud opening solutions (Salunkhe *et al.*, 1990).

Two major factors affecting water absorption through conducting vessels are air embolism and the occurrence of vascular occlusion in cut flower stems. Vascular blockage begins at the cut end and moves upwards in the stem with time (Durkin and Kue, 1966). Microbial occlusions are localised at the base of cut flower stems (Linberger and Steponkus, 1976) and gummy exudates of cellular origin found inside the stems, usually above the solution levels, plug the conducting vessels and obstruct water flow. Ethylene induced clogging due to wounding of stem tissue is also believed to be a major factor limiting post harvest life by inducing water stress and senescence (Paull and Goo, 1985).

2.3.1 Post harvest physiology of orchid flowers

Depending on the orchid species, unpollinated orchid flowers may remain fresh for weeks or even months (Arditti, 1979). After pollination, senescence is greatly accelerated. This was observed at a slightly slower rate following emasculation.

Both pollination and emasculation stimulate ethylene production (Burg and Dijkman, 1967). The physiological and biochemical processes associated with pollination (post-pollination phenomena) have been extensively studied. The stigma and rostellum are the primary sites for ethylene production (Chadwik *et al.*, 1980).

Orchid flowers are very sensitive to ethylene (Beyer, 1976; Davidson, 1949) and there are many reports of senescing flowers producing this hormone (Akamine, 1963; Arditti, 1979; Goh *et al.*, 1985; Nair and Tong, 1987 and Nair *et al.*, 1991).

Premature fading of *Cymbidium* flowers was observed when exposed to as little as 0.0002 ppm of ethylene for 24 hours (Davidson, 1949). Van (1997) observed that endogenous ethylene has a role in changing perianth form and colour in addition to signalling the occurrence of pollination. Many chemicals have been used as growth regulators to reduce ethylene damage in cut flowers of non-orchid species (Halevy and Mayak, 1981). The same have also been tried for orchid cut flowers, although to a considerably lesser extent.

To preserve the quality of cut flowers after harvest and to make them resistant to fluctuations in environmental conditions, treatment with floral preservatives, known as pulsing, is recommended. The method of pulsing consists of placing the lower portion of flower stems in solutions containing sugar and germicides for a period ranging from few hours to as long as two days. The cut flowers may be pulsed with flower preservatives containing sugars, anti-microbial substances and antiethylene substances (Bhattacharjee, 1997).

The main ingredient of pulsing solution is, however, sugar, the percentage of which varies with species and cultivars. The sugar concentration of pulsing is much higher than that used in floral preservatives for the continuous treatment of flowers in the vase or holding solution. Hence a strictly curtailed period is necessary in order to avoid the injury caused due to high sugar concentrations. Sucrose replaces the depleted endogenous carbohydrates utilized during the post harvest respiration of flowers. But orchid flower being non-climacteric is harvested only after majority of florets in a spike is open. Hence sugar requirement is less in the case of orchids (Arditti, 1990). Sucrose is however required both in bud opening (Marousky, 1973; Ketsa and Amutiratana, 1986) and in holding solution for increasing vase life (Ketsa, 1986, Hew, 1987 and

Downs *et al.*, 1988). Though sucrose is the sugar most often used in floral preservatives in some formulations glucose and fructose may also be used (Novak and Rudnicki, 1990).

2.3.1.1 Effect of pulsing treatments

Treatment with silver nitrate for 30 minutes at a concentration of 500 mg l^{-1} was found to extend the vase life of *Oncidium* flowers (Ong and Lee, 1983). A significant increase in the vase life of *Aranda* flowers was observed when they were pulsed with 4 mM silver thiosulphate (STS) for 10 minutes (Hew, 1989).

According to Novak and Vacharotayan (1980), the vase life of *Dendrobium* could be extended from 23 days to 30 days following treatments with silver thio sulphate @ 0.01 mM for 30 minutes. However, in cattleya flowers, STS @ 4 mM for 30 minutes did not have any effect on post harvest longevity (Goh *et al.*, 1985). The relatively low concentration and short immersion time needed for the treatment indicate that STS is highly mobile in plants (Hew and Clifford, 1993). Silver is well known as an effective ethylene antagonist. By blocking the receptor site for ethylene, Ag^+ prevents the autocatalytic increase in ethylene production (Nair, 1984).

Foliar application of ammonium chloride at 500 ppm, ammonium molybdate at 100 ppm or boric acid at 1000 ppm lengthened the vase life of *Oncidium* 'Goldiana' (Ong, 1982). Hot water treatment has also been known to help cut stem to recover turgidity and thus extend vase life (Wangkeaw and Techanpiyawat, 1992). Porat *et al.* (1994) reported that exogenous application of methyl ester of jasmonic acid to *Dendrobium* cv. Jaquelyn Thomas flowers accelerated senescence. Hence their inhibitors, viz., salicyl hydroxamic acid and n-propyl gallate could be used to reduce senescence.

A study on the effects of BA pre-treatment on vase life, ethylene production and soluble sugar content of *Cattleya* hybrids by Yamane *et al.* (1997) revealed that

BA upto 3 mM for 24 hours significantly suppressed ethylene production and prolonged vase life of cut florets of *Laeliocattleya* 'Irene Finney' and *Brassolaeliocattleya* Helen Brown cv. Sweet Afton. According to Huang *et al.* (1997), chilling storage of *Phalaenopsis* flowers for 10 days at 7°C reduced its vase life to half due to enhanced ethylene production and electrolyte leakage. In *Arachnis* and *Cattleya*, longevity could be enhanced by a 10 minute treatment of $AgNO_3$ @ 100-200 ppm (Sharma and Kaur, 1994). Jung Nam *et al.* (1998) suggested that treatment of aminoethoxy vinyl glycine (AVG) reduced the rise in ethylene production after harvest. Jomy (1998) reported that the use of a combination of four per cent sucrose and 400 ppm 8-HQ for six hours enhanced the vase life of *Dendrobium* flowers up to 21.0 days.

2.3.2 Effect of holding solutions

Many chemicals have been used in holding solutions to improve vase life, their functions being different, viz., opening of buds after harvest, reducing microbial growth and activity, inhibition of ethylene synthesis and evolution etc. Silver nitrate and silver thiosulphate were reported to inhibit microbial growth in vase water and ethylene synthesis in tissues, resulting in extension of vase life (Halevy and Kofranek, 1977, Mayak *et al.*, 1977). Hydroxyquinoline sulphate (HQS) and Hydroxy quinoline citrate (HQC), bacteriocides commonly included in holding solutions for extension of vase-life of cut flowers (Halevy and Mayak, 1981), have also been used to extend vase life of orchid flowers. Generally, HQS seems to work best for orchid flowers when it is used in combination with sugar (Hew, 1987; Ketsa and Amutiratana, 1986).

Yong and Ong (1979) obtained extension of vase life in *Oncidium* 'Goldiana' with 200 ppm 8-HQ, two per cent sucrose and 100 ppm ascorbic acid. Ong and Lee (1983) found increased shelf life with 25 to 40 ppm silver nitrate, along with 8-HQ in holding solutions for *Oncidium* 'Golden shower'. Hew *et al.* (1987) observed enhancement of vase life of *Aranda* cultivars with sucrose and 8-HQ, two per cent sucrose and 100 ppm ascorbic acid. Ketsa (1989) recommended that the optimum holding solution for cut inflorescence of *Dendrobium* 'Pompadour' was 200 mg 8-HQS l^{-1} + 50 mg $AgNO_3$ l^{-1} + 8 per cent sucrose solution. This combination increased the percentage of bud opening and vase life and decreased the opening time. Ketsa and Boonrote (1990) also reported prolonging vase life with sucrose, glucose, 8-HQ and $AgNO_3$ in *Dendrobium* 'Youppadeewan' and recommended four per cent glucose, 225 mg l^{-1} of 8-HQS and 30 mg l^{-1} of $AgNO_3$ as being the optimum concentration.

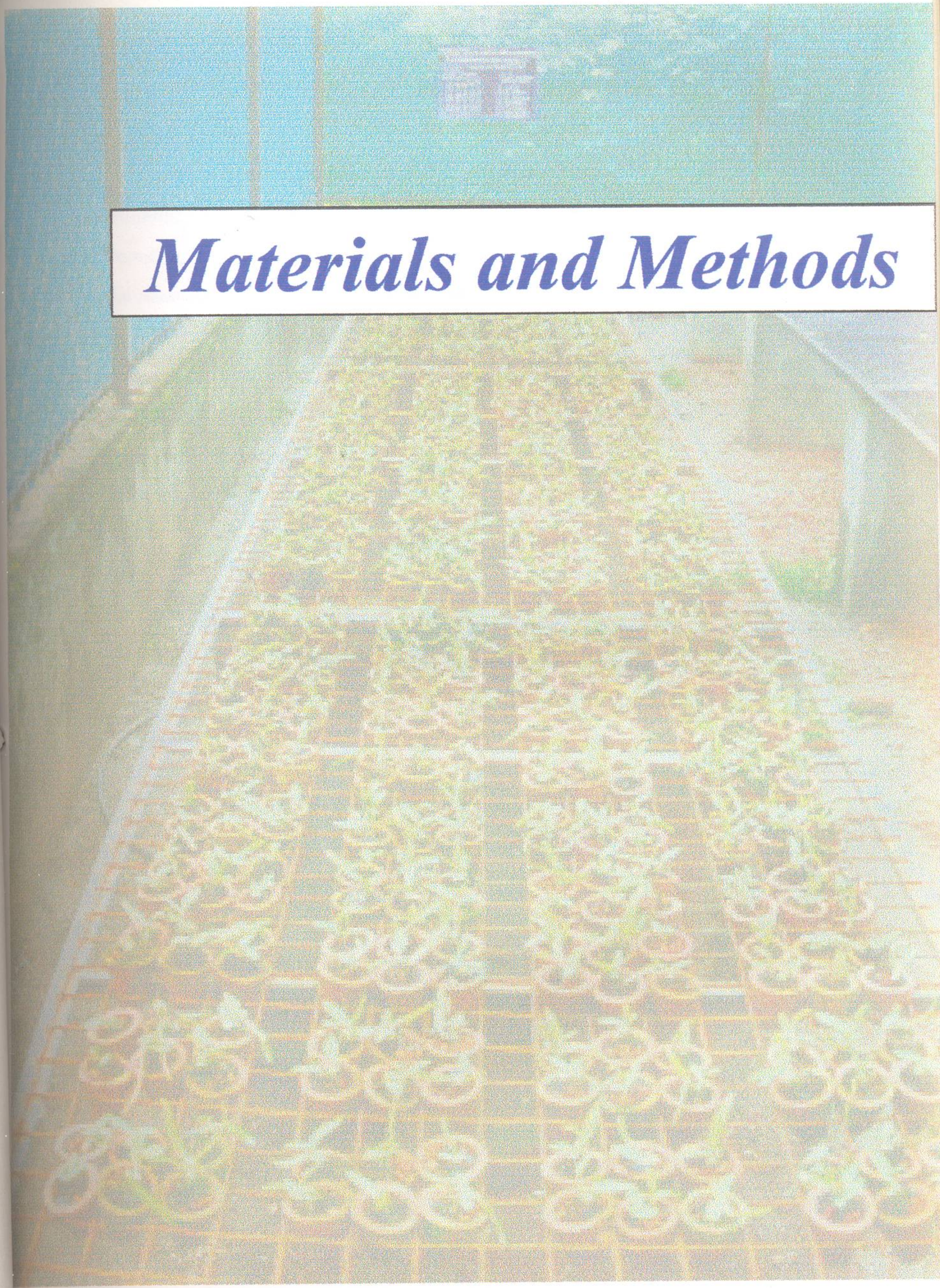
Bhattacharjee (1995) observed that the shelf life of orchid cut flowers was increased by placing the stems in solutions of 250 ppm boric acid or HQC solution or 5 mM KCl and 0.5 mM $CoCl_2$. According to Ketsa *et al.* (1995), inflorescence of *Dendrobium* held in vase solution containing 225 mg l^{-1} HQS + 30 mg l^{-1} $AgNO_3$ + 4 per cent glucose recorded the longest vase life of 51.5 days, while in distilled water it was only 7.25 days. This also had the highest percentage of buds opened (89.46%, compared to 18.82% in control) and lowest bacterial population. Application of $AgNO_3$ at 100-200 mg l^{-1} was useful in delaying senescence in *Cattleya*, *Dendrobium*, *Oncidium* and *Rhynchostylis* and thereby increasing their shelf life (Pathak and Kaur, 1996).

Ketsa *et al.* (1995) reported that vase life of open florets of *Dendrobium* 'Sabine' and 'Sonia Bom' significantly increased when they were held in a solution containing 8-hydroxy quinoline sulphate + glucose, even though ethylene production was not reduced. According to Jomy (1998), vase life of *Dendrobium*, Mary Trowse, Candy Stripe and Walter Oumae was maximum (26 days) in holding solution containing six per cent sucrose, 300 ppm 8-HQ and 20 ppm $AgNO_3$. The mode of action of HQS, silver nitrate and antisalicylic acid is more likely as bactericidal in preventing xylem blockage.

There are also reports that *Vanda* 'Miss Joaquim' could be stored well under hypoboric storage conditions (Burg, 1973).

Although some progress has been made in studies on the post harvest handling of orchids, there are very little reports of application in commercial nurseries. Generally, knowledge regarding the proper handling and storage of cut orchid flowers remains far behind than that for other commercial flowers such as rose, carnation and chrysanthemum.

Materials and Methods



3. MATERIALS AND METHODS

The present studies on the regulation of growth and flowering in dendrobium var. Sonia 17 were carried out in the orchidarium of AICFIP, Department of Pomology and Floriculture, Vellanikkara from June 1998 to September 1999. A part of the research work was carried out at Padikkala Orchids, Thrissur from January 1999 to September 1999. The studies were conducted with an objective to enhance the growth of the plants and to reduce the preblooming period, to improve the size and quality of spikes, to enhance spike production and to prolong the vase life of spikes through the use of different combinations of nutrients and growth regulators. The materials used and the methods adopted for the investigation are dealt with in this chapter.

Vellanikkara is situated at a latitude of 10° 31' N and longitude of 76° 3' E. The area lies 22.25 m above MSL and enjoys the typical warm humid tropical climate of Kerala. The climatological data during the period of investigation are given in Appendix I.

3.1 Planting material

Dendrobium is an epiphytic genus belonging to the family Orchidaceae. This is a commercially important genus widely cultivated in Kerala. Sonia 17 is one of the popular varieties of the genus. The plant shows sympodial growth with club shaped pseudobulbs. Leaves are bright green, broad and acute.

3.2 Treatments

3.2.1 Experiment 1

This experiment was carried out with the objective of reducing the preblooming period. Tissue culture plants of less than 2.5 cm size were used for this experiment. These plants were planted in pots of 5.0 cm size using brick pieces and charcoal bits as growing media (Plate 1).

3.2.1.1 Inorganic nutrients

Major nutrients N, P and K at three different ratios, viz., NPK 10:10:10, 20:10:10 and 30:10:10 were used. These were tried at two concentrations, viz., 0.1 per cent and 0.2 per cent. Two frequencies of application were tried, viz., weekly once and weekly twice.

Nutrient combinations were made using ammonium nitrate, orthophosphoric acid and potassium nitrate.

3.2.1.2 Growth Regulators

Three different growth regulators, viz., Benzyl Adenine (BA), Gibberellic Acid (GA_3) and Indole Acetic Acid (IAA) were used in the trial. These were tried at two different concentrations, each, namely, BA 100 ppm and 200 ppm, GA_3 10 ppm and 20 ppm and IAA 250 ppm and 500 ppm. A set of plants was grown without any growth regulators (control).

Treatment combinations

T_1 - $F_1G_0W_1$ - NPK 10:10:10 - 0.1% Weekly once + No growth regulator

T_2 - $F_1G_1W_1$ - NPK 10:10:10 - 0.1% Weekly once + BA 100 ppm

T_3 - $F_1G_2W_1$ - NPK 10:10:10 - 0.1% Weekly once + BA 200 ppm

T_4 - $F_1G_3W_1$ - NPK 10:10:10 - 0.1% Weekly once + GA_3 10 ppm

T_5 - $F_1G_4W_1$ - NPK 10:10:10 - 0.1% Weekly once + GA_3 20 ppm

T_6 - $F_1G_5W_1$ - NPK 10:10:10 - 0.1% Weekly once + IAA 250 ppm

T_7 - $F_1G_6W_1$ - NPK 10:10:10 - 0.1% Weekly once + IAA 500 ppm

T_8 - $F_2G_0W_1$ - NPK 10:10:10 - 0.2% Weekly once + No growth regulator

T_9 - $F_2G_1W_1$ - NPK 10:10:10 - 0.2% Weekly once + BA 100 ppm

T_{10} - $F_2G_2W_1$ - NPK 10:10:10 - 0.2% Weekly once + BA 200 ppm

T_{11} - $F_2G_3W_1$ - NPK 10:10:10 - 0.2% Weekly once + GA_3 10 ppm

T_{12} - $F_2G_4W_1$ - NPK 10:10:10 - 0.2% Weekly once + GA_3 20 ppm

T_{13} - $F_2G_5W_1$ - NPK 10:10:10 - 0.2% Weekly once + IAA 250 ppm

T_{14} - $F_2G_6W_1$ - NPK 10:10:10 - 0.2% Weekly once + IAA 500 ppm

T_{15} - $F_3G_0W_1$ - NPK 20:10:10 - 0.1% Weekly once + No growth regulator

T_{16} - $F_3G_1W_1$ - NPK 20:10:10 - 0.1% Weekly once + BA 100 ppm

T_{17} - $F_3G_2W_1$ - NPK 20:10:10 - 0.1% Weekly once + BA 200 ppm

T_{18} - $F_3G_3W_1$ - NPK 20:10:10 - 0.1% Weekly once + GA_3 10 ppm

T_{19} - $F_3G_4W_1$ - NPK 20:10:10 - 0.1% Weekly once + GA_3 20 ppm

T_{20} - $F_3G_5W_1$ - NPK 20:10:10 - 0.1% Weekly once + IAA 250 ppm

T_{21} - $F_3G_6W_1$ - NPK 20:10:10 - 0.1% Weekly once + IAA 500 ppm

T_{22} - $F_4G_0W_1$ - NPK 20:10:10 - 0.2% Weekly once + No growth regulator

T_{23} - $F_4G_1W_1$ - NPK 20:10:10 - 0.2% Weekly once + BA 100 ppm

T_{24} - $F_4G_2W_1$ - NPK 20:10:10 - 0.2% Weekly once + BA 200 ppm

T_{25} - $F_4G_3W_1$ - NPK 20:10:10 - 0.2% Weekly once + GA_3 10 ppm

T_{26} - $F_4G_4W_1$ - NPK 20:10:10 - 0.2% Weekly once + GA_3 20 ppm

T_{27} - $F_4G_5W_1$ - NPK 20:10:10 - 0.2% Weekly once + IAA 250 ppm

T_{28} - $F_4G_6W_1$ - NPK 20:10:10 - 0.2% Weekly once + IAA 500 ppm

T_{29} - $F_5G_0W_1$ - NPK 30:10:10 - 0.1% Weekly once + No growth regulator

T_{30} - $F_5G_1W_1$ - NPK 30:10:10 - 0.1% Weekly once + BA 100 ppm

T_{31} - $F_5G_2W_1$ - NPK 30:10:10 - 0.1% Weekly once + BA 200 ppm

T_{32} - $F_5G_3W_1$ - NPK 30:10:10 - 0.1% Weekly once + GA_3 10 ppm

T_{33} - $F_5G_4W_1$ - NPK 30:10:10 - 0.1% Weekly once + GA_3 20 ppm

T_{34} - $F_5G_5W_1$ - NPK 30:10:10 - 0.1% Weekly once + IAA 250 ppm

T_{35} - $F_5G_6W_1$ - NPK 30:10:10 - 0.1% Weekly once + IAA 500 ppm

T_{36} - $F_6G_0W_1$ - NPK 30:10:10 - 0.2% Weekly once + No growth regulator

T_{37} - $F_6G_1W_1$ - NPK 30:10:10 - 0.2% Weekly once + BA 100 ppm

T_{38} - $F_6G_2W_1$ - NPK 30:10:10 - 0.2% Weekly once + BA 200 ppm

T_{39} - $F_6G_3W_1$ - NPK 30:10:10 - 0.2% Weekly once + GA_3 10 ppm

T_{40} - $F_6G_4W_1$ - NPK 30:10:10 - 0.2% Weekly once + GA_3 20 ppm

T_{41} - $F_6G_5W_1$ - NPK 30:10:10 - 0.2% Weekly once + IAA 250 ppm

T_{42} - $F_6G_6W_1$ - NPK 30:10:10 - 0.2% Weekly once + IAA 500 ppm

In another set of treatment combinations, nutrients were also applied twice a week (W_2). The growth regulators were applied only once a month in all the treatments. Each treatment was imposed on twelve plants.

3.2.2 Experiment 2

This part of the trial was conducted to improve the flower yield and quality in the flowering plants of dendrobium var. Sonia 17.

3.2.2.1 Inorganic nutrients

Three different combinations of the major nutrients, viz., NPK 10:10:10, 20:20:20 and 10:20:10 were tried at two different levels, 0.1 per cent and 0.2 per cent, each. Two frequencies of application, weekly once and weekly twice, were tried. Chemicals used to prepare the nutrient combinations were ammonium nitrate, orthophosphoric acid and potassium nitrate.

3.2.2.2 Growth regulators

Two growth regulators and their combinations were used at two levels. The growth regulator treatments were BA 50 ppm and 100 ppm, GA_3 10 ppm and 20 ppm, BA 25 ppm + GA_3 5 ppm and BA 50 ppm + GA_3 10 ppm. A group of plants were grown without any growth regulators (control).

Combination of treatments

T_1 - $F_1G_0W_1$- NPK 10:10:10 - 0.1% Weekly once + No growth regulator

T_2 - $F_1G_1W_1$ - NPK 10:10:10 - 0.1% Weekly once + BA 50 ppm

T_3 - $F_1G_2W_1$ - NPK 10:10:10 - 0.1% Weekly once + BA 100 ppm

T_4 - $F_1G_3W_1$ - NPK 10:10:10 - 0.1% Weekly once + GA_3 10 ppm

T_5 - $F_1G_4W_1$ - NPK 10:10:10 - 0.1% Weekly once + GA_3 20 ppm

T_6 - $F_1G_5W_1$ - NPK 10:10:10 - 0.1% Weekly once + BA 25 ppm + GA_3 5 ppm

T_7 - $F_1G_6W_1$ - NPK 10:10:10 - 0.1% Weekly once + BA 50 ppm + GA_3 10 ppm

T_8 - $F_2G_0W_1$ - NPK 10:10:10 - 0.2% Weekly once + No growth regulator

T_9 - $F_2G_1W_1$ - NPK 10:10:10 - 0.2% Weekly once + BA 50 ppm

T_{10} - $F_2G_2W_1$ - NPK 10:10:10 - 0.2% Weekly once + BA 100 ppm

T_{11} - $F_2G_3W_1$ - NPK 10:10:10 - 0.2% Weekly once + GA_3 10 ppm

T_{12} - $F_2G_4W_1$ - NPK 10:10:10 - 0.2% Weekly once + GA_3 20 ppm

T_{13} - $F_2G_5W_1$ - NPK 10:10:10 - 0.2% Weekly once + BA 25 ppm + GA_3 5 ppm

T_{14} - $F_2G_6W_1$ - NPK 10:10:10 - 0.2% Weekly once + BA 50 ppm + GA_3 10 ppm

T_{15} - $F_3G_0W_1$ - NPK 10:20:20 - 0.1% Weekly once + No growth regulator

T_{16} - $F_3G_1W_1$ - NPK 10:20:20 - 0.1% Weekly once + BA 50 ppm

T_{17} - $F_3G_2W_1$ - NPK 10:20:20 - 0.1% Weekly once + BA 100 ppm

T_{18} - $F_3G_3W_1$ - NPK 10:20:20 - 0.1% Weekly once + GA_3 10 ppm

T_{19} - $F_3G_4W_1$ - NPK 10:20:20 - 0.1% Weekly once + GA_3 20 ppm

T_{20} - $F_3G_5W_1$ - NPK 10:20:20 - 0.1% Weekly once + BA 25 ppm + GA_3 5 ppm

T_{21} - $F_3G_6W_1$ - NPK 10:20:20 - 0.1% Weekly once + BA 50 ppm + GA_3 10 ppm

T_{22} - $F_4G_0W_1$ - NPK 10:20:20 - 0.2% Weekly once + No growth regulator

T_{23} - $F_4G_1W_1$ - NPK 10:20:20 - 0.2% Weekly once + BA 50 ppm

T_{24} - $F_4G_2W_1$ - NPK 10:20:20 - 0.2% Weekly once + BA 100 ppm

T_{25} - $F_4G_3W_1$ - NPK 10:20:20 - 0.2% Weekly once + GA_3 10 ppm

T_{26} - $F_4G_4W_1$ - NPK 10:20:20 - 0.2% Weekly once + GA_3 20 ppm

T_{27} - $F_4G_5W_1$ - NPK 10:20:20 - 0.2% Weekly once + BA 25 ppm + GA_3 5 ppm

T_{28} - $F_4G_6W_1$ - NPK 10:20:20 - 0.2% Weekly once + BA 50 ppm + GA_3 10 ppm

T_{29} - $F_5G_0W_1$ - NPK 10:20:10 - 0.1% Weekly once + No growth regulator

T_{30} - $F_5G_1W_1$ - NPK 10:20:10 - 0.1% Weekly once + BA 50 ppm

T_{31} - $F_5G_2W_1$ - NPK 10:20:10 - 0.1% Weekly once + BA 100 ppm

T_{32} - $F_5G_3W_1$ - NPK 10:20:10 - 0.1% Weekly once + GA_3 10 ppm

T_{33} - $F_5G_4W_1$ - NPK 10:20:10 - 0.1% Weekly once + GA_3 20 ppm

T_{34} - $F_5G_5W_1$ - NPK 10:20:10 - 0.1% Weekly once + BA 25 ppm + GA_3 5 ppm

T_{35} - $F_5G_6W_1$ - NPK 10:20:10 - 0.1% Weekly once + BA 50 ppm + GA_3 10 ppm

T_{36} - $F_6G_0W_1$ - NPK 10:20:10 - 0.2% Weekly once + No growth regulator

T_{37} - $F_6G_1W_1$ - NPK 10:20:10 - 0.2% Weekly once + BA 50 ppm

T_{38} - $F_6G_2W_1$ - NPK 10:20:10 - 0.2% Weekly once + BA 100 ppm

T_{39} - $F_6G_3W_1$ - NPK 10:20:10 - 0.2% Weekly once + GA_3 10 ppm

T_{40} - $F_6G_4W_1$ - NPK 10:20:10 - 0.2% Weekly once + GA_3 20 ppm

T_{41} - $F_6G_5W_1$ - NPK 10:20:10 - 0.2% Weekly once + BA 25 ppm + GA_3 5 ppm

T_{42} - $F_6G_6W_1$ - NPK 10:20:10 - 0.2% Weekly once + BA 50 ppm + GA_3 10 ppm

In another set of treatment combinations, nutrients were also applied twice a week (W_2). The growth regulators were applied only once a month in all the treatments. Each treatment was imposed on six plants.

In the above two experiments, general treatments like cow's urine (1:25 dilution) and coconut water (1:25 dilution) were given uniformly to all plants in alternate weeks. Prophylactic application of plant protection chemicals was also done at regular intervals.

3.2.3 Experiment 3

This consisted of post harvest studies. The objective was to enhance the vase life of cut spikes of dendrobium var. Sonia 17. Spikes were harvested when two third of the flowers were open. Standard spikes having 4-5 open florets and 1-2 buds were used for the study. A slanting cut was given to expose more surface area to the pulsing and holding treatments. Post harvest observations, such as, fresh weight of the spike, number of florets per spike, stalk length of the spike, rachis length and size of open florets were taken initially. The spikes were given different pulsing and holding treatments, the details of which are as follows.

3.2.3.1 Pulsing treatments

P_0 - Control (no pulsing treatment)

P_1 - HQ 500 ppm + Sucrose 5% for 6 hours

P_2 - HQ 500 ppm + Sucrose 5% for 12 hours

P_3 - HQ 250 ppm + Sucrose 5% for 6 hours

P_4 - HQ 250 ppm + Sucrose 5% for 12 hours

P_5 - Precooling at 16-20°C for 6 hours

P_6 - Precooling at 16-20°C for 12 hours

P_7 - Precooling at 10-15°C for 3 hours

P_8 - Precooling at 10-15°C for 6 hours

P_9 - Hot water dip at 60-70°C for 5 seconds

P_{10} - Hot water dip at 60-70°C for 10 seconds

P_{11} - Hot water dip at 50-60°C for 5 seconds

P_{12} - Hot water dip at 50-60°C for 10 seconds

3.2.3.2 Holding solutions

H_0 - Control (distilled water)

H_1 - Triadimephon 10 ppm

H_2 - Triadimephon 20 ppm

H_3 - Benzyl Adenine 10 ppm

H_4 - Benzyl Adenine 20 ppm

H_5 - HQ 200 ppm + Sucrose 5%

H_6 - HQ 400 ppm + Sucrose 5%

H_7 - Silver nitrate 25 ppm + Sucrose 5%

H_8 - Silver nitrate 50 ppm + Sucrose 5%

H_9 - $AgNO_3$ 25 ppm + HQ 200 ppm + Sucrose 5%

H_{10} - $AgNO_3$ 50 ppm + HQ 200 ppm + Sucrose 5%

H_{11} - $AgNO_3$ 25 ppm + HQ 400 ppm + Sucrose 5%

H_{12} - $AgNO_3$ 50 ppm + HQ 400 ppm + Sucrose 5%

All the combinations of pulsing and holding treatments were tried. The spikes were kept in the prepared solution. Each treatment was tried on two spikes which was replicated twice. Every alternate day, a fresh cut of about 0.5 cm was given to the base of the stalk to remove dead tissues so as to facilitate easy absorption of chemicals and free respiration. The pulsing or holding solution was taken in a bottle containing 200 ml of the solution.

3.3 Observations

The following observations were made from six plants in each treatment combination and average values were recorded.

3.3.1 Plant characters

Observations on the following characters of the plants under each treatment were recorded.

3.3.1.1 Plant height

The height of the plant was measured from the base of the tallest shoot to the last node at monthly intervals and expressed in cm.

3.3.1.2 Side shoots

Number of side shoots per plant was counted and recorded.

3.3.1.3 Shoot girth

Girth of the biggest shoot was measured and expressed in cm.

3.3.1.3 Number of leaves

The total number of leaves was counted and recorded at monthly intervals.

3.3.1.4 Length, breadth and area of the leaf

The length and breadth of each leaf was recorded and the area of leaf was computed using the formula,

$a = 2.78 + 0.688\ lb$ (where 'a' is the leaf area in cm^2, 'l' is the length of the leaf in cm and 'b' is the maximum width of the leaf in cm.) (unpublished)

3.3.1.5 Total leaf area

The total leaf area was estimated from individual leaf area obtained at regular intervals over the given period of the experiment.

3.3.1.7 Root characters

Number of roots and length of roots (cm) were recorded from the samples taken from each treatment.

3.3.1.8 Biomass production

Plant samples taken from each treatment was dried in a hot air oven at 70^0C for 2-3 days until constant weight is obtained and the weight was expressed in g.

3.3.1.9 Time taken for spike emergence

The time taken for the emergence of first spike in every treatment was recorded in days.

3.3.1.10 Number of spikes

Number of spikes produced on each plant was noted and number of spikes per plant per year in each treatment was estimated.

3.3.1.11 Number of florets per spike

Number of florets per spike in each treatment was recorded and mean values were worked out.

3.3.1.12 Length of spike, stalk and rachis

Total length of spike, length of flower stalk and length of rachis were recorded separately and expressed as cm.

3.3.1.13 Internodal length

Length between florets was recorded as internodal length and expressed in cm.

3.3.1.14 Spike production per year

Number of spikes produced per plant per year was calculated from the data obtained during the experimental period.

3.3.1.14 Interval of spike production

Interval between emergence of consecutive spikes was recorded in days.

3.3.1.15 Size of floret

Size of individual floret was recorded as length (vertically) and width (across) of the flower and expressed in cm.

3.3.1.16 Fresh weight of the spike

Initial weight of the spike was taken immediately after harvest and recorded in g.

3.3.1.17 Physiological loss in weight (PLW)

Initial and final weights of inflorescence were noted at the beginning and end of the experiment, respectively, and by working out the difference PLW was arrived at and expressed in g.

3.3.1.18 Days to wilt of first floret

Time taken from the harvest of the spike to wilting of first floret was recorded and expressed in days.

3.3.1.20 Electrical conductivity of the vase solution (EC)

EC of the vase solution was recorded initially and after the experiment using conductivity bridge and expressed as mSg^{-1} (milli siemens per gram).

3.3.1.21 Water uptake

The quantity of vase solution remaining at the end of the experiment was recorded and by finding the difference between the initial and final volumes of the vase solution, total uptake was worked out and expressed in ml.

3.3.1.22 Longevity of individual floret

Life of each floret in the spike in vase was recorded in days and average value worked out.

3.4 Uptake studies

3.4.1 Nutrient concentration

The dried plant samples were ground and chemically analysed for macronutrients and micronutrients as detailed below.

One gram of dried plant sample was digested using concentrated sulphuric acid and analysed for estimating nitrogen following the Microkjeldahl method (Jackson, 1958).

Diacid extracts were prepared by digesting 0.5 g of the sample with 15 ml of 2:1 concentrated nitric acid - perchloric acid mixture (Johnson and Ulrich, 1959) and was made up to 100 ml. Aliquots from this solution were taken for analysis of P and K.

Phosphorus was determined colorimetrically by the Vanadomolybdophosphoric yellow colour method (Jackson, 1958). The yellow colour was read in a Spectronic-20 at a wavelength of 470 nm. Potassium was estimated using a flame photometer (EEL). Micronutrients (Ca, Mg, Cu, Fe, Zn, Mn) were estimated by Atomic Absorption Spectrophotometer (Jackson, 1958).

3.4.2 Nutrient uptake

Nutrient uptake was computed from the values of concentration of the nutrients and dry weight of the parts sampled.

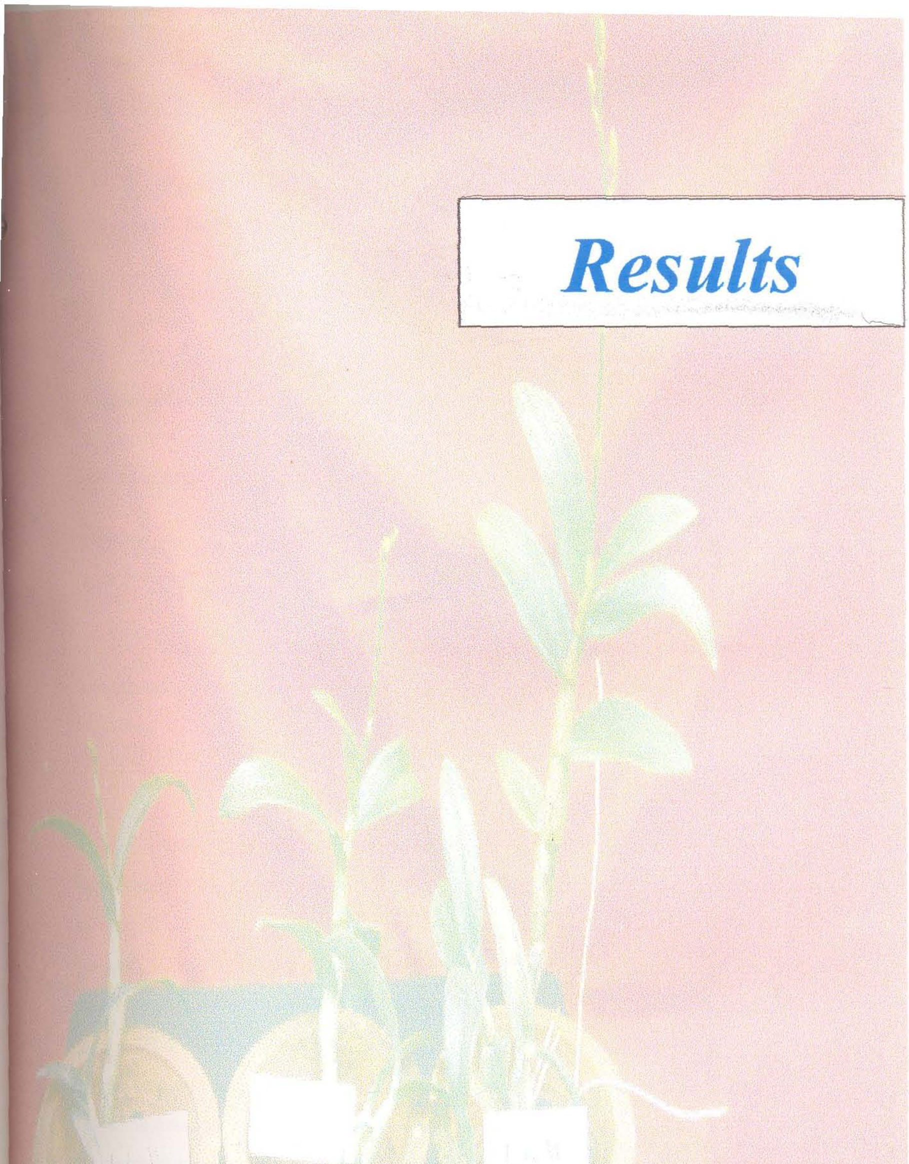
3.5 Statistical Analysis

The recorded data were statistically analysed following the methods suggested by Panse and Sukhatme (1985).

3.6 Cost of cultivation

Cost of cultivation of the best treatment combination was worked out based on the results obtained.

Results



4. RESULTS

Results of the experiments conducted on 'Regulation of growth and flowering in dendrobium var. Sonia 17' are presented in this chapter.

4.1 Reducing pre-blooming period

Data generated from the pot culture experiments to study the growth and nutrient uptake of dendrobium plants as influenced by nutrients (concentration and frequency of application) and growth regulators for 12 months are presented under two main heads, viz., growth parameters and nutrient uptake.

4.1.1 Growth parameters

4.1.1.1 Plant height

The data pertaining to the effect of different treatments individually and in combinations are presented in Tables 1 to 5 and in Plates 1 to 4.

4.1.1.1.1 Main effect of nutrients, frequency of application and growth regulators (Table 1)

Among the nutrient concentrations, NPK 20:10:10 at 0.2 per cent was significantly superior with respect to plant height (1.77 cm) two months after planting. This was on par with the nutrient concentration of 30:10:10 NPK at 0.2 per cent, which produced a height of 1.73 cm. Minimum height of 1.15 cm was shown by plants receiving NPK 10:10:10 at 0.2 per cent which was on par with the same level of NPK at 0.1 per cent. After four months of planting, NPK 30:10:10 at 0.2 per cent was found to be significantly superior (2.97 cm) to all other treatments. The same trend followed there after, except at sixth month, when NPK 20:10:10 at 0.2 per cent was on par with the superior treatment. During six to twelve MAP, NPK 30:10:10 at 0.2 per cent produced the tallest plants (height of 4.76 cm,

Table 1. Plant height (cm) in dendrobium var. Sonia 17 as influenced by nutrients (concentration and frequency of application) and growth regulators

Treatments	Plant height (cm)					
	2 MAP	4 MAP	6 MAP	8 MAP	10 MAP	12 MAP
Nutrients						
NPK 10:10:10 - 0.1%	1.18	1.93	2.82	3.52	5.40	5.62
NPK 10:10:10 - 0.2%	1.15	2.00	3.12	4.27	6.37	6.64
NPK 20:10:10 - 0.1%	1.49	2.70	4.02	5.24	7.41	7.82
NPK 20:10:10 - 0.2%	1.77	2.72	4.47	6.28	8.46	8.86
NPK 30:10:10 - 0.1%	1.43	2.47	3.80	5.31	7.80	8.51
NPK 30:10:10 - 0.2%	1.73	2.97	4.76	6.93	10.09	11.04
CD (0.05)	0.188	0.217	0.303	0.407	1.071	0.434
SEm±	0.068	0.078	0.109	0.146	0.382	0.156
Frequency						
Weekly twice	1.75	3.16	4.61	6.17	7.79	8.98
Weekly once	1.16	1.77	3.06	4.84	6.38	7.19
CD (0.05)	0.108	0.125	0.327	0.236	0.613	0.25
SEm±	0.039	0.045	0.118	0.85	0.221	0.09
Growth regulators						
Control	1.21	1.92	3.03	4.16	5.55	6.28
BA 100 ppm	1.47	2.26	3.44	4.85	6.33	7.37
BA 200 ppm	1.49	2.57	3.73	5.03	6.60	7.66
GA_3 10 ppm	1.59	3.03	4.70	6.54	8.72	10.52
GA_3 20 ppm	1.92	3.35	5.29	7.14	9.86	11.81
IAA 250 ppm	1.31	2.14	3.50	4.77	6.08	6.84
IAA 500 ppm	1.21	2.00	3.13	4.30	5.46	6.10
CD(0.05)	0.203	0.235	0.327	0.440	1.147	0.468
SEm±	0.073	0.084	0.118	0.158	0.413	0.168

MAP - Months after planting

6.93 cm, 10.09 cm and 11.04 cm, respectively). The lowest nutrient level of NPK 10:10:10 at 0.1 per cent produced significantly lowest height of 3.52 cm and 5.62 cm at eight and twelve months after planting, respectively.

When the frequency of application was considered, nutrients applied weekly twice was found to be distinctly superior during the entire period (1.75 cm, 3.16 cm, 4.61 cm, 6.17 cm, 7.79 cm and 8.98 cm at 2, 4, 6, 8, 10 and 12 months after planting, respectively).

Among the growth regulators, GA_3 20 ppm produced the tallest plants throughout the experimental period (1.92 cm, 3.35 cm, 5.29 cm, 7.14 cm, 9.87 cm and 11.81 cm at 2, 4, 6, 8, 10 and 12 months after planting, respectively).

4.1.1.1.2 Interaction effects

Interaction was evident between nutrients and frequency of application (Table 2). Nutrient level of NPK 20:10:10 at 0.1 per cent, applied weekly once was on par with that of NPK 20:10:10 at 0.2 per cent applied at the same frequency. For weekly twice application NPK 30:10:10 at 0.2 per cent produced significantly taller plants compared to all other treatments at two months after planting (2.41 cm).

During 6, 8, 10 and 12 months after planting, NPK 30:10:10 at 0.2 per cent applied weekly twice recorded highest values for height (6.05 cm, 8.76 cm, 11.66 cm and 14.27 cm, respectively). This was closely followed by 20:10:10 NPK 0.2 per cent applied twice weekly (5.56 cm, 7.57 cm, 9.18 cm and 10.09 cm, respectively). Nutrient level of 30:10:10 NPK at 0.1 per cent applied twice weekly was on par with the above during 10 months (7.86 cm) and 12 months (9.35 cm) after planting. The lowest values for height were for 10:10:10 NPK 0.2 per cent up to six months (0.90 cm, 1.31 cm and 2.54 cm, respectively) and 10:10:10 at 0.1 per cent from eight months to 12 months after planting (3.29 cm, 5.12 cm and 5.80 cm, respectively). In general, the lower concentration of nutrients (0.1%) at higher

Table 2. Plant height (cm) in dendrobium var. Sonia 17 as influenced by combinations of nutrient concentrations and frequency of application

Treatments	Plant height (cm)											
	2 MAP		4 MAP		6 MAP		8 MAP		10 MAP		12 MAP	
	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice
NPK 10:10:10 - 0.1%	0.90	1.38	1.31	2.29	2.58	3.06	3.29	3.75	5.12	4.76	5.81	5.43
NPK 10:10:10 - 0 .2%	0.97	1.39	1.56	2.70	2.54	3.71	3.84	4.71	5.28	6.20	6.44	6.85
NPK 20:10:10 - 0 .1%	1.51	1.46	1.96	3.39	3.36	4.69	4.59	5.90	6.82	7.10	7.77	7.87
NPK 20:10:10 - 0 .2%	1.52	2.03	2.01	3.49	3.38	5.56	4.98	7.57	6.96	9.18	7.63	10.09
NPK 30:10:10 - 0 .1%	1.04	1.82	1.81	3.13	3.02	4.57	4.28	6.33	6.22	7.86	7.67	9.35
NPK 30:10:10 - 0 .2%	1.05	2.41	2.24	3.94	3.48	5.05	5.10	8.76	6.86	11.66	7.81	14.27
CD (0.05)	0.266		0.428		0.4283		0.5755		2.81		1.15	
SEm±	0.096		0.154		0.1541		0.2070		1.001		0.413	

frequencies (weekly twice) recorded greater values compared to higher concentration (0.2%) of nutrients at lower frequencies (weekly once).

Interaction was evident between nutrients and growth regulators (Table 3). Highest value recorded for height was 2.53 cm in the case of NPK 30:10:10 at 0.2 per cent with GA_3 20 ppm at two MAP. The treatments GA_3 20 ppm with NPK 20:10:10 at 0.2 per cent and NPK 30:10:10 at 0.1 per cent were found to be on par with the above (plant height of 2.41 cm and 2.42 cm, respectively). The lowest height recorded was 0.98 cm for NPK 10:10:10 at 0.2 per cent with BA 200 ppm. The combination of GA_3 20 ppm with 30:10:10 NPK at 0.2 per cent was found to be significantly higher from four to 12 MAP (4.38 cm, 7.30 cm, 10.16 cm, 14.47 cm and 17.88 cm, respectively from four to 12 MAP). This was closely followed by combination of GA_3 10 ppm and NPK 30:10:10 at 0.2 per cent during eight months (8.52 cm), 10 months (11.56 cm) and 12 months (15.03 cm) after planting. A combination of NPK 20:10:10 at 0.2 per cent and GA_3 20 ppm recorded values which were on par with the above during 8, 10 and 12 months after planting (8.45 cm, 11.24 cm and 12.81 cm, respectively). Significantly inferior values were recorded for NPK 10:10:10 at 0.1 per cent with no growth regulator during six to 12 MAP (2.24 cm, 2.58 cm, 3.24 cm, 4.23 cm, respectively). Interaction was also evident in the case of IAA 500 ppm and higher levels of nutrient concentration. Combination of 20:10:10 NPK at 0.1 and 0.2 per cent and 30:10:10 NPK at both the levels with IAA 500 ppm recorded values of height that were lesser than those in nutrient application alone (5.95cm, 5.51cm, 6.76cm and 7.71 cm, respectively, at 12 MAP). In general, the effect of GA3 20 ppm improved with an increase in the nutrient level, recording the highest value for height with NPK 30:10:10 at 0.2 per cent.

Interaction was evident between frequency of nutrient application and growth regulators during the entire period of observation (Table 4). Plant height was found to be significantly increased in the case of combination of GA_3 20 ppm and

Table 3. Plant height (cm) in dendrobium var. Sonia 17 as influenced by combinations of nutrient concentration and growth regulators

Treatments	Plant height (cm)					
	2 MAP	4 MAP	6 MAP	8 MAP	10 MAP	12 MAP
N_1G_0	1.13	1.82	2.24	2.58	3.24	4.23
N_1G_1	1.03	1.59	2.37	3.15	4.90	5.12
N_1G_2	1.12	1.56	2.41	3.18	4.12	4.98
N_1G_3	1.01	2.48	3.41	4.27	5.33	6.65
N_1G_4	1.41	2.48	3.93	4.80	6.51	7.63
N_1G_5	1.43	1.77	2.51	3.09	4.13	5.30
N_1G_6	1.11	1.80	2.86	3.54	4.81	5.43
N_2G_0	1.04	1.53	2.28	3.15	4.28	4.76
N_2G_1	1.06	1.95	2.89	4.03	5.22	5.79
N_2G_2	0.98	2.25	3.33	4.38	6.03	7.18
N_2G_3	1.03	2.33	3.89	5.35	7.07	8.63
N_2G_4	1.43	2.64	4.19	5.61	7.78	9.29
N_2G_5	1.38	1.84	2.83	3.66	5.01	5.61
N_3G_6	1.10	1.48	2.45	3.73	4.81	5.23
N_3G_0	1.15	1.98	2.90	4.33	5.54	6.07
N_3G_1	1.63	2.53	3.77	4.77	6.25	7.00
N_3G_2	1.71	3.03	3.96	4.96	6.25	7.16
N_3G_3	1.59	3.17	4.81	6.10	8.75	10.26
N_3G_4	1.51	3.54	5.62	6.95	10.02	11.37
N_3G_5	1.49	2.54	3.94	5.38	6.66	6.96
N_3G_6	1.35	2.11	3.16	4.22	5.25	5.95
N_4G_0	1.29	2.22	3.67	4.88	6.43	6.93
N_4G_1	1.98	2.76	4.64	6.78	8.58	9.39
N_4G_2	1.69	2.64	4.63	6.09	7.88	8.46
N_4G_3	2.05	0.21	5.64	8.43	10.88	11.86

Contd.

Table 3. Continued

Treatments	Plant height (cm)					
	2 MAP	4 MAP	6 MAP	8 MAP	10 MAP	12 MAP
N_4G_4	2.41	3.68	5.93	8.45	11.24	12.81
N_4G_5	1.52	2.38	3.69	5.12	6.53	7.08
N_4G_6	1.36	2.17	3.08	4.19	4.97	5.51
N_5G_0	1.03	1.79	3.21	4.36	5.90	6.92
N_5G_1	1.34	2.14	3.31	4.97	6.77	8.01
N_5G_2	1.28	2.74	3.72	4.95	6.86	8.23
N_5G_3	1.98	3.29	4.65	6.60	8.71	10.71
N_5G_4	2.42	3.36	4.78	6.88	9.18	11.91
N_5G_5	0.94	1.76	3.58	4.67	5.86	7.03
N_5G_6	1.34	2.28	3.33	4.71	6.04	6.76
N_6G_0	1:63	2.18	3.90	5.64	7.89	8.75
N_6G_1	1.76	2.54	3.69	5.43	7.26	8.92
N_6G_2	2.17	3.19	4.32	6.62	8.50	9.93
N_6G_3	1.86	3.74	5.80	8.52	11.56	15.00
N_6G_4	2.53	4.38	730	10.16	14.47	17.88
N_6G_5	1.12	2.57	4.44	6.72	8.28	9.09
N_6G_6	1.01	2.16	3.89	5.40	6.88	7.71
CD (0.05)	0.498	0.575	0.801	2.241	2.810	1.14
SEm±	0.179	0.207	0.288	0.797	1.01	0.413

N_1 - NPK 10:10:10 - 0.1%
N_2 - NPK 10:10:10 - 0.2%
N_3 - NPK 20:10:10 - 0.1%
N_4 - NPK 20:10:10 - 0.2%
N_5 - NPK 30:10:10 - 0.1%
N_6 - NPK 30:10:10 - 0.2%

G_0 - Control
G_1 - BA 100 ppm
G_2 - BA 200 ppm
G_3 - GA_3 10 ppm
G_4 - GA_3 20 ppm
G_5 - IAA 250 ppm
G_6 - IAA 500 ppm

Table 4. Plant height (cm) in dendrobium var. Sonia 17 as influenced by combinations of growth regulator and frequency of nutrient application

Treatments	Plant height (cm)											
	2 MAP		4 MAP		6 MAP		8 MAP		10 MAP		12 MAP	
	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice
Control	0.94	1.49	1.53	2.31	2.66	3.41	3.74	4.58	5.33	5.77	6.23	6.32
BA 100ppm	1.09	1.85	1.58	2.93	2.79	4.09	3.99	5.71	7.48	7.18	6.42	8.32
BA 200ppm	1.13	1.86	1.76	3.38	2.92	4.54	4.21	5.85	5.91	7.30	6.74	8.58
GA_3 10ppm	1.41	1.76	2.07	3.98	3.52	5.88	5.26	7.83	7.41	10.02	9.07	11.98
GA_3 20ppm	1.45	2.38	2.14	4.56	4.05	6.53	5.61	8.67	8.26	11.46	9.99	13.63
IAA 250 ppm	1.15	1.48	1.69	2.59	2.99	4.01	4.14	5.41	5.62	6.54	6.45	7.24
IAA 500 ppm	1.10	1.43	1.65	2.34	2.48	3.78	3.46	5.13	4.64	6.28	5.42	6.77
CD(0.05)	0.288		0.330		0.461		0.623		1.623		0.662	
SEm±	0.104		0.119		0.166		0.224		0.584		0.238	

weekly twice frequency of application of nutrients twice a week from 2 months to 12 months (2.38cm, 4.56 cm, 6.53 cm, 8.67 cm, 11.46 cm and 13.63 cm, respectively). Height was minimum for combination of control of growth regulator and weekly once application of nutrients in the early months (0.94 cm, 1.53 cm, respectively at 2 and 4 MAP). Later on IAA 500 ppm and weekly once nutrient application recorded the lowest values (2.48 cm, 3.46 cm, 4.64 cm and 5.42 cm, respectively during 6, 8, 10 and 12 MAP). These values were inferior to the combination with no growth regulator (2.66 cm, 3.74 cm, 5.33 cm and 6.23 cm, respectively, during the above stages).

Interaction of nutrients, growth regulators and frequency of application was significant during all the stages of plant growth (Table 5). However, in view of the large volume of data and due to the fact that plants in some of the treatments started flowering during tenth MAP the data pertaining to 10 MAP alone are given. Plant height of 19.50 cm was recorded during 10 MAP for a combination of NPK 30:10:10 at 0.2 per cent applied twice a week + GA_3 20 ppm, which was significantly superior to all other treatment combinations. This was followed by 30:10:10 NPK 0.2 per cent applied twice a week + GA_3 10 ppm (15.00 cm). Application of 20:10:10 NPK at 0.2 per cent twice a week along with both GA_3 20 ppm and GA_3 10 ppm gave values for height on par with the above (14.03 cm and 12.12 cm, respectively). The lowest values for height were recorded in the combination of NPK 10:10:10 at 0.1 per cent applied weekly once with no growth regulator, during initial months of growth (3.30 cm, 3.18 cm, 4.47 cm and 4.08 cm, respectively). Interaction between IAA 500 ppm and weekly once and twice application of nutrients was evident for NPK 20:10:10 at 0.2 per cent, NPK 30:10:10 at 0.1 per cent and NPK 30:10:10 at 0.2 per cent (4.88 cm, 6.05 cm, 5.28 cm, 6.80 cm, 4.63 and 9.13 cm, respectively). This was found to be even inferior to combination having growth regulator control (6.07 cm, 6.78 cm, 5.82 cm, 5.98 cm, 6.55 cm and 9.23 cm, respectively).

Table 5. Plant height (cm) in dendrobium var. Sonia 17 as influenced by combinations of nutrients (concentration and frequency) and growth regulators

Growth regulators	Nutrients											
	N1		N2		N3		N4		N5		N6	
	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice
Control	3.30	3.18	4.47	4.08	5.75	5.33	6.07	6.78	5.82	5.98	6.55	9.23
BA 100 ppm	3.53	4.27	4.17	6.27	5.12	7.38	8.18	8.98	5.85	9.68	6.02	8.52
BA 200 ppm	3.52	4.72	5.68	6.37	5.93	6.57	6.87	8.88	6.88	6.83	6.55	10.45
GA_3 10 ppm	4.72	5.95	5.83	8.30	8.80	8.70	9.63	12.12	7.38	10.03	8.12	15.00
GA_3 20 ppm	6.12	6.90	7.03	8.52	10.60	9.43	8.45	14.03	7.95	10.40	9.43	19.50
IAA 250 ppm	4.85	3.42	4.88	5.13	7.18	6.13	5.65	7.42	4.40	7.32	6.75	9.80
IAA 500 ppm	4.78	4.85	4.88	4.73	4.88	6.12	4.88	6.05	5.28	6.80	4.63	9.13
CD(0.05)	3.08											
SEm±	1.43											

N1 – NPK 10:10:10 – 0.1% N2 – NPK 10:10:10 – 0.2%
N3 – NPK 20:10:10 – 0.1% N4 – NPK 20:10:10 – 0.2%
N5 – NPK 30:10:10 – 0.1% N6 – NPK 30:10:10 – 0.2%

Plate 1. General view of the plot of Experiment I

Plate 2. Effect of lower concentrations of nutrient levels applied weekly once on the growth of plants

$F_1G_0W_1$
$F_3G_0W_1$
$F_5G_0W_1$

Plate 3. Effect of higher concentration of nutrient levels on growth of plants

a) Nutrients applied weekly once
b) Nutrients applied weekly twice

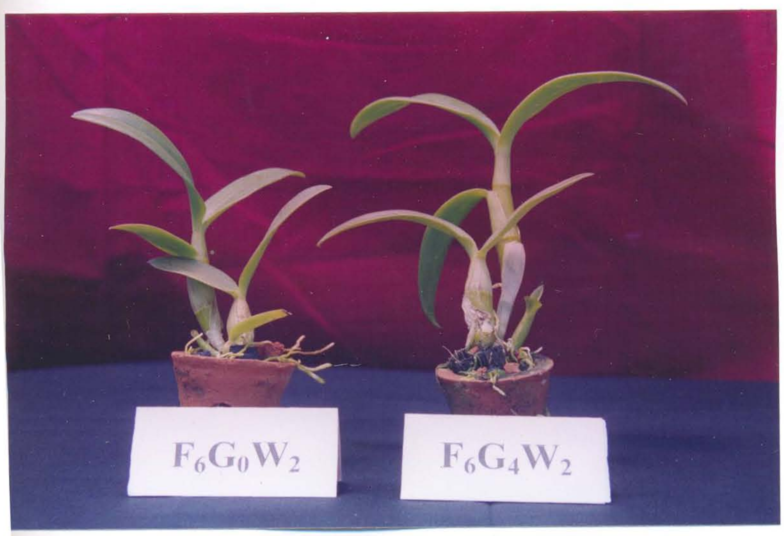

F2G0W1
F4G0W1


F2G0W2
F4G0W2
F6G0W2

Plate 4. Effect of highest level of nutrients + GA_3 20 ppm on the height of the plants

a) Compared with nutrients alone at the lowest level
b) Compared with nutrients alone at the highest level


$F_1G_0W_2$
$F_6G_4W_2$


$F_6G_0W_2$
$F_6G_4W_2$

4.1.1.2 Shoot production

Data relating to shoot number as influenced by different treatments individually and in combinations are presented in Tables 6 to 10.

4.1.1.2.1 Main effect of nutrients, frequency of application and growth regulators (Table 6)

Nutrient concentration had no significant influence on the number of shoots during initial months of growth. After a period of four months from planting highest number of shoots (2.55) was recorded in the case of NPK 20:10:10 at 0.2 per cent. All the treatments, except NPK 10:10:10 at 0.1 per cent, were on par with this. At eight MAP, NPK 30:10:10 at 0.2 per cent produced highest number of shoots (3.91). Values for NPK 20:10:10 at 0.2 per cent and NPK 30:10:10 at 0.1 per cent were on par with the above (3.87 and 3.74, respectively). Number of shoots recorded was significantly higher (4.80 and 5.30, respectively) for NPK 30:10:10 at 0.2 per cent during 10 and 12 months after planting. The lowest number of shoots was recorded in the case of NPK 10:10:10 at 0.1 per cent, which was significantly inferior to all other treatments (2.26, 2.75, 3.23, 3.74 and 4.20 shoots from 4 to 12 MAP, respectively).

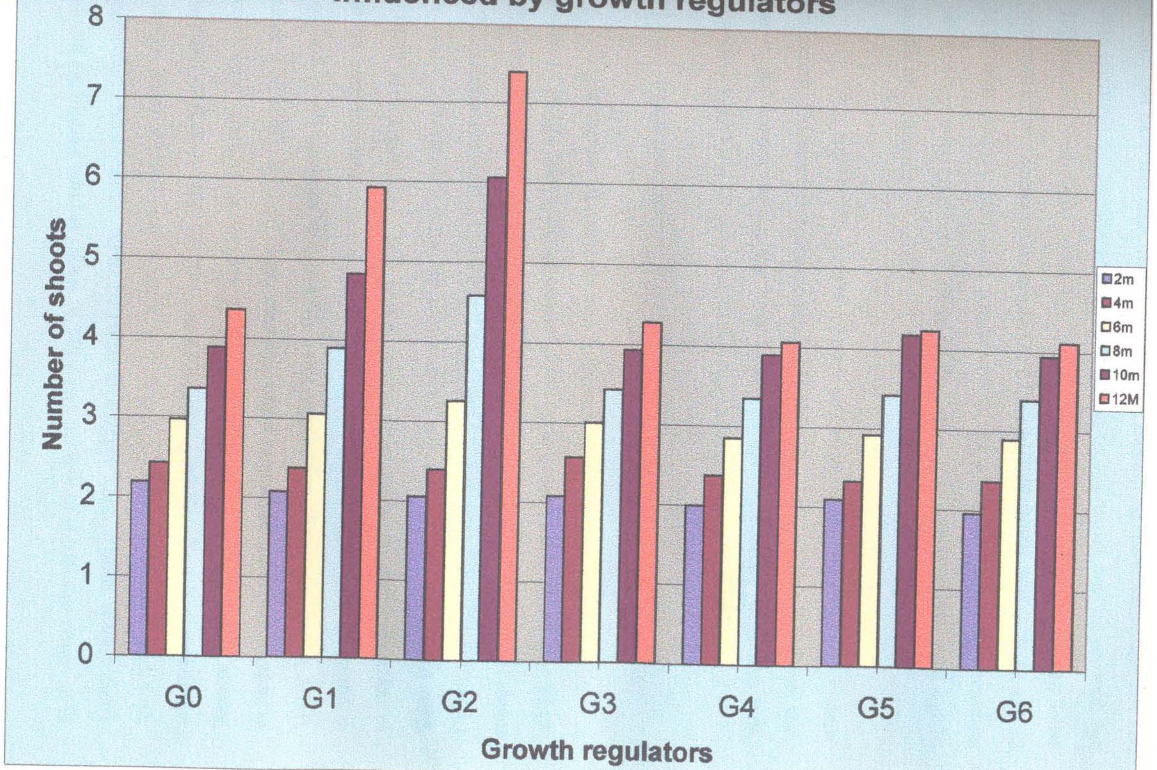
Among the two frequencies of application the superiority of application at weekly twice with regard to the number of shoots was clearly evident from the initial stages to final month of observation. The difference in number of shoots was significant. Application of nutrients weekly twice produced 2.23, 2.65, 3.41, 4.20, 5.24 and 5.92 shoots at 2, 4, 6, 8, 10 and 12 months, respectively, compared to 1.93, 2.16, 2.58, 3.07, 3.54 and 3.89 shoots in the respective months when the nutrients were applied once a week.

Growth regulators produced no marked differences with regard to the number of shoots during early period of study. At four MAP, GA_3 10 ppm produced

Table 6. Shoot production in dendrobium var. Sonia 17 as influenced by nutrients (concentration and frequency of application) and growth regulators

Treatments	Number of shoots					
	2 MAP	4 MAP	6 MAP	8 MAP	10 MAP	12 MAP
Nutrients						
NPK 10:10:10 - 0.1%	2.04	2.26	2.75	3.23	3.74	4.20
NPK 10:10:10 - 0.2%	2.06	2.39	2.93	3.52	4.25	4.74
NPK 20:20:10 - 0.1%	2.16	2.41	3.06	3.54	4.50	4.69
NPK 20:20:10 - 0.2%	2.19	2.55	3.13	3.87	4.55	4.25
NPK 30:10:10 - 0.1%	1.95	2.37	2.93	3.74	4.41	4.96
NPK 30:10:10 - 0.2%	2.08	2.45	3.18	3.91	4.80	5.30
CD (0.05)	0.225	0.19	0.19	0.21	0.24	0.27
SEm±	0.081	0.07	0.07	0.07	0.09	0.10
Frequency						
Weekly twice	2.23	2.65	3.41	4.20	5.24	5.92
Weekly once	1.93	2.16	2.58	3.07	3.54	3.89
CD (0.05)	0.126	0.105	0.105	0.116	0.133	0.151
SEm±	0.047	0.039	0.039	0.043	0.049	0.056
Growth regulators						
Control	2.18	2.42	2.97	3.36	3.88	4.36
BA 100 ppm	2.08	2.38	3.07	3.90	4.83	5.92
BA 200 ppm	2.06	2.40	3.26	4.58	6.06	7.39
GA_3 10 ppm	2.08	2.57	3.01	3.43	3.93	4.28
GA_3 20 ppm	2.00	2.38	2.85	3.35	3.90	4.06
IAA 250 ppm	2.10	2.33	2.92	3.42	4.18	4.24
IAA 500 ppm	1.96	2.36	2.89	3.39	3.94	4.11
CD(0.05)	0.24	0.20	0.20	0.22	0.26	0.29
SEm±	0.09	0.07	0.07	0.08	0.09	0.10

Fig. 1. Shoot production in dendrobium var. Sonia 17, as influenced by growth regulators



2.57 shoots, which was significantly superior to IAA 250 ppm treated plants, (2.33 shoots) and IAA 500 ppm treated plants (2.36 shoots). At six months stage BA 200 ppm produced the maximum number of shoots (3.26), which was on par with BA 100 ppm (3.07 shoots). Later, BA 200 ppm excelled all other growth regulators with respect to number of shoots (4.58, 6.06 and 7.39 shoots during 8, 10 and 12 MAP, respectively). Minimum number of shoots was produced by the treatment having no growth regulators (3.36 and 3.88 shoots, respectively during eight and 10 months after planting).

GA_3 application, both at 10 ppm and 20 ppm, showed reduction in shoot production. The number of shoots produced in the case of GA_3 was even lesser than that in the control during the later period of the experiment (4.28 and 4.06, respectively, for GA_3 10 ppm and 20 ppm and 4.36 in the case of control).

4.1.1.2.2 Interaction effects

Interaction of nutrients and frequency of application was not evident in number of shoots during initial stages of the experiment (Table 7). At four MAP, NPK 10:10:10 at 0.2 per cent, applied weekly twice, gave highest number of shoots (2.79). Treatments NPK 20:10:10 at 0.2 per cent (2.71 shoots), NPK 20:10:10 at 0.1 per cent (2.67 shoots), NPK 30:10:10 at 0.2 per cent (2.60 shoots) and NPK 30:10:10 at 0.1 per cent (2.50 shoots) were found to be on par. Interaction of nutrient concentration with weekly twice application was significant compared to combination of nutrients and weekly once application. From six to 10 MAP, treatment NPK 20:10:10 at 0.1 per cent was found to produce maximum number of shoots when applied at weekly twice interval (3.60, 4.50 and 5.79 shoots, respectively) whereas NPK 20:10:10 at 0.2 per cent gave significantly more number of shoots when applied once a week at 4, 8 and 12 MAP (2.38, 3.43 and 4.62, respectively). At 12 MAP NPK 30:10:10 at 0.2 per cent applied weekly twice produced the highest number shoots (6.34). Least number of shoots was observed in

Table 7. Shoot production in dendrobium var. Sonia 17 as influenced by combinations of nutrient concentration and frequency of application

Treatments	Number of shoots											
	2 MAP		4 MAP		6 MAP		8 MAP		10 MAP		12 MAP	
	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice
NPK10:10:10 - 0.1%	1.79	2.29	1.91	2.62	2.31	3.19	2.74	3.71	3.00	4.48	3.19	5.21
NPK10:10:10 - 0 .2%	1.91	2.21	2.00	2.79	2.52	3.33	2.88	4.17	3.38	5.12	3.67	5.81
NPK20:10:10 - 0 .1%	2.05	2.26	2.14	2.67	2.52	3.60	2.98	4.50	3.41	5.79	3.67	6.01
NPK20:10:10 - 0 .2%	2.05	2.33	2.38	2.71	2.71	3.55	3.43	4.31	3.88	5.21	4.62	5.88
NPK30:10:10 - 0 .1%	1.91	2.00	2.24	2.50	2.69	3.17	3.04	4.00	3.57	5.24	3.86	6.07
NPK30:10:10 - 0 .2%	1.88	2.29	2.31	2.60	2.74	3.62	3.31	4.50	3.98	5.82	4.36	6.34
CD (0.05)	0.32		0.27		0.26		0.29		0.34		0.38	
SEm±	0.11		0.10		0.09		0.11		0.12		0.14	

the case of NPK 10:10:10 at 0.1 per cent sprayed weekly once (1.79, 1.91, 2.31, 2.74, 3.00 and 3.19 shoots, respectively from two 12 MAP). It was observed that the lower concentration of nutrients at higher frequencies (weekly twice) recorded more number of shoots compared to higher concentration of nutrients applied at lower frequencies (weekly once).

Number of shoots showed noticeable differences in accordance with the treatment combinations of nutrients and growth regulators (Table 8). Plants treated with BA 200 ppm and NPK 20:10:10 at 0.1 per cent produced 2.58 shoots at two MAP. At four MAP, maximum number of shoots was observed in plants treated with NPK 30:10:10 at 0.1 per cent and GA_3 10 ppm (3 shoots). Shoot production up to 3.67 was recorded at six MAP when treated with BA 200 ppm and NPK 30:10:10 at 0.2 per cent. Similar trend was recorded at eight, ten and twelve MAP with values 5.25, 6.85 and 8.25, respectively. NPK 20:10:10 at 0.1 and 0.2 per cent and NPK 30:10:10 at 0.1 per cent along with BA 200 ppm recorded values on par with above at 10 and 12 MAP (6.67, 6.25, 6.58, 7.58, 7.83 and 7.83 shoots, respectively). In general the effect of the best growth regulator (BA 200 ppm) improved with an increase in the nutrient level, recording the highest values with NPK 30:10:10 at 0.2 per cent (Plate 5 a and b).

Combination of growth regulators and frequency of application of nutrients had significant influence on the number of shoots produced (Table 9). Effect of growth regulators was not evident during initial stages. At two and four MAP, control for growth regulator and weekly twice application of nutrients gave 2.53 and 2.78 shoots, respectively, which was significantly superior. From six MAP onwards maximum number of shoots was recorded as 3.64, 5.22, 7.11 and 9.03, respectively in plants treated with BA 200 ppm and given nutrients at weekly twice frequency.

Table 8. Shoot production in dendrobium var. Sonia 17 as influenced by combinations of nutrient concentration and growth regulators

Treatments	Number of shoots					
	2 MAP	4 MAP	6 MAP	8 MAP	10 MAP	12 MAP
N_1G_0	2.08	2.25	2.75	2.92	3.08	3.58
N_1G_1	2.08	2.42	2.67	3.33	3.92	4.50
N_1G_2	2.08	2.42	3.08	3.53	4.83	6.08
N_1G_3	1.92	2.50	2.83	3.33	3.58	4.08
N_1G_4	2.17	2.25	2.75	3.08	3.58	3.58
N_1G_5	2.25	2.00	2.67	3.08	3.83	4.00
N_1G_6	1.67	2.00	2.50	3.00	3.33	3.58
N_2G_0	2.08	2.42	2.83	3.25	3.83	4.08
N_2G_1	2.08	2.00	2.75	3.58	4.50	5.42
N_2G_2	2.33	2.50	3.00	4.00	5.17	6.75
N_2G_3	2.23	2.83	3.00	3.50	3.67	4.17
N_2G_4	2.17	2.17	2.67	3.42	4.17	4.17
N_2G_5	2.00	2.50	3.33	3.68	4.33	4.50
N_3G_6	1.92	2.33	2.92	3.33	4.08	4.08
N_3G_0	2.60	2.50	3.00	3.42	3.83	4.33
N_3G_1	2.60	2.50	3.00	4.08	5.08	5.75
N_3G_2	2.58	2.42	3.50	5.00	6.67	7.58
N_3G_3	1.75	2.33	2.92	3.08	3.83	4.00
N_3G_4	1.92	2.17	2.75	3.42	4.08	4.33
N_3G_5	2.00	2.17	2.83	3.25	4.17	4.17
N_3G_6	2.33	2.75	3.42	3.92	4.50	4.75
N_4G_0	2.08	2.50	3.25	3.92	4.42	5.00
N_4G_1	2.00	2.67	3.50	4.25	4.92	6.75
N_4G_2	2.25	2.42	3.17	4.67	6.25	7.83
N_4G_3	2.25	2.58	2.92	3.67	4.17	4.67

Contd.

Table 8. Continued

Treatments	Number of shoots					
	2 MAP	4 MAP	6 MAP	8 MAP	10 MAP	12 MAP
N_4G_4	2.25	2.58	3.08	3.50	4.00	4.17
N_4G_5	2.33	2.67	3.08	3.83	4.33	4.42
N_4G_6	2.17	2.42	2.92	3.25	3.75	3.92
N_5G_0	2.08	2.33	2.75	2.92	3.58	4.33
N_5G_1	2.00	2.42	3.08	3.83	5.00	6.08
N_5G_2	1.75	2.08	3.46	4.75	6.58	7.83
N_5G_3	2.33	3.00	3.20	3.75	4.33	4.50
N_5G_4	1.58	2.25	2.75	3.00	3.50	3.83
N_5G_5	2.08	2.25	2.58	3.25	4.08	4.00
N_5G_6	1.83	2.25	2.67	3.25	3.75	4.17
N_6G_0	2.00	2.33	3.25	3.75	4.50	4.83
N_6G_1	2.08	2.42	3.42	4.33	5.58	7.00
N_6G_2	2.50	2.58	3.67	5.25	6.85	8.25
N_6G_3	1.92	2.17	2.92	3.25	4.00	4.25
N_6G_4	2.33	2.83	3.08	3.67	4.08	4.25
N_6G_5	1.92	2.42	3.00	3.50	4.33	4.33
N_6G_6	1.83	2.42	2.92	3.58	4.25	4.17
CD(0.05)	0.60	0.50	0.49	0.55	0.63	0.71
SEm	0.21	0.18	0.13	0.20	0.23	0.26

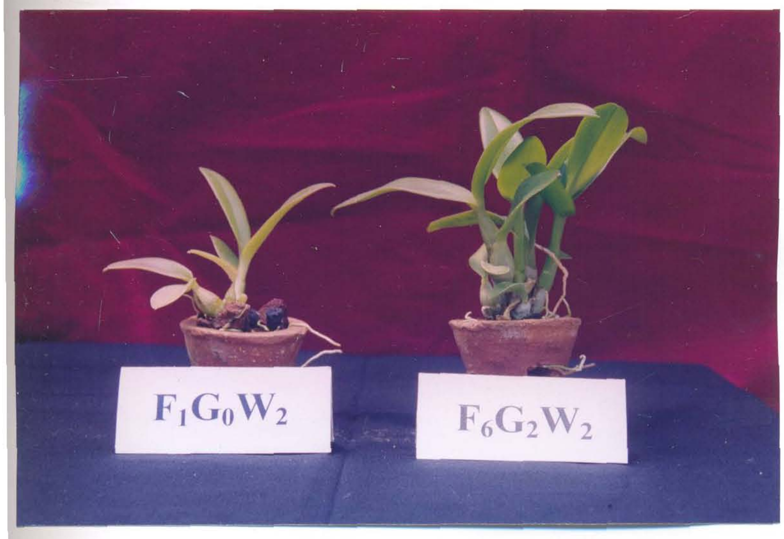
N_1 - NPK 10:10:10 - 0.1% G_0 - Control
N_2 - NPK 10:10:10 - 0.2% G_1 - BA 100 ppm
N_3 - NPK 20:10:10 - 0.1% G_2 - BA 200 ppm
N_4 - NPK 20:10:10 - 0.2% G_3 - GA_3 10 ppm
N_5 - NPK 30:10:10 - 0.1% G_4 - GA_3 20 ppm
N_6 - NPK 30:10:10 - 0.2% G_5 - IAA 250 ppm
G_6 - IAA 500 ppm

Table 9. Shoot production in dendrobium var. Sonia 17 as influenced by combinations of growth regulators and frequency of nutrient application

Growth regulators	Number of shoots											
	2 MAP		4 MAP		6 MAP		8 MAP		10 MAP		12 MAP	
	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice
Control	1.83	2.53	2.06	2.78	2.44	3.50	2.75	3.97	3.06	4.69	3.47	5.25
BA 100ppm	2.27	2.08	2.31	2.44	2.78	3.36	3.39	4.42	3.86	5.81	4.69	7.14
BA 200ppm	1.83	2.28	2.25	2.56	2.89	3.64	3.94	5.22	5.00	7.11	5.75	9.03
GA_3 10ppm	2.08	2.08	2.42	2.72	2.67	3.36	3.03	3.83	3.36	4.50	3.61	4.94
GA_3 20ppm	1.81	2.19	2.08	2.67	2.44	3.25	2.81	3.89	3.14	4.67	3.22	4.89
IAA 250ppm	1.92	2.28	1.97	2.69	2.39	3.44	2.81	4.02	3.25	5.11	3.31	5.17
IAA 500ppm	1.75	2.17	2.06	2.67	2.47	3.31	2.75	4.02	3.08	4.81	3.19	5.03
CD (0.05)	0.34		0.29		0.29		0.32		0.36		0.41	
SEm±	0.12		0.10		0.10		0.11		0.12		0.15	

Plate 5. Effect of highest level of nutrients + BA 200 ppm on shoot production

a) Compared with nutrients alone at the lowest level
b) Compared with nutrients alone at the highest level


$F_1G_0W_2$
$F_6G_2W_2$


$F_6G_0W_2$
$F_6G_2W_2$

Maximum shoot production was observed in plants treated with NPK 30:10:10 at 0.2 per cent, applied weekly twice + BA 200 ppm and NPK 30:10:10 at 0.1 per cent applied weekly twice + BA 200 ppm, recording shoot number of 7.67 at 10 months after planting. This was significantly superior to all other treatment combinations (Table 10). Minimum number of shoots (2.50) was observed in plants receiving NPK 10:10:10 at 0.1 per cent, applied weekly once + growth regulator control. At higher nutrient doses, combination with GA_3 20 ppm and IAA 500 ppm produced lesser shoots, compared to the combination with growth regulator control.

4.1.1.3 Shoot girth

Data pertaining to shoot girth, as influenced by various treatments and their combinations are presented in Tables 11 to 15.

4.1.1.3.1 Main effect of nutrients, frequency of application and growth regulators (Table 11)

Shoot girth was found to be markedly influenced by nutrient application. At two MAP maximum girth of shoot recorded was 2.03 cm, when NPK 30:10:10 at 0.2 per cent was applied. The treatments on par were NPK 30:10:10 at 0.1 per cent (1.98 cm) and NPK 20:10:10 at 0.2 per cent (1.94 cm). Later, at four MAP, NPK 30:10:10 at 0.2 per cent distinctly improved the girth of shoots to 2.78 cm. Significant increase in shoot girth due to application of NPK 30:10:10 at 0.2 per cent was observed throughout the study. Shoot thickness of 3.43 cm, 3.85 cm, 4.47 cm and 4.85 cm, which were significantly superior, was observed at 6, 8, 10 and 12 MAP, respectively. Nutrient dose NPK 20:10:10 at 0.2 per cent closely followed this treatment, producing shoots having thickness of 2.58 cm, 3.27 cm, 3.62 cm, 4.36 cm and 4.60 cm, respectively, from four to 12 MAP. Least thickness for shoots was recorded in the case of NPK 10:10:10 at 0.1 per cent, which was significantly inferior to the next best treatment, viz., 10:10:10 NPK at 0.2 per cent

Table 10. Shoot production in dendrobium var. Sonia 17 as influenced by combinations of nutrients (concentration and frequency) and growth regulators

Growth regulators	Nutrients											
	N1		N2		N3		N4		N5		N6	
	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice
Control	2.50	3.67	3.00	4.67	2.83	4.83	3.50	5.33	3.33	4.33	3.67	5.33
BA 100 ppm	3.33	4.50	3.67	5.33	3.50	6.67	4.50	5.33	3.67	6.33	4.50	6.67
BA 200 ppm	3.83	5.83	4.00	6.33	4.50	5.83	6.17	6.33	5.50	6.67	6.00	7.67
GA_3 10 ppm	2.83	4.33	3.33	4.00	3.33	4.33	3.33	5.00	3.67	5.00	3.67	4.33
GA_3 20 ppm	2.83	4.33	3.00	5.33	3.17	5.00	3.33	4.67	3.00	4.00	3.50	4.67
IAA 250 ppm	3.00	4.67	3.50	5.17	3.17	5.17	3.33	5.33	3.17	5.00	3.33	5.33
IAA 500 ppm	2.67	4.00	3.17	5.00	3.33	5.67	3.00	4.50	3.17	4.33	3.17	5.33
CD(0.05)	0.89											
SEm±	0.32											

N1 – NPK 10:10:10 – 0.1% N2 – NPK 10:10:10 – 0.2%
N3 – NPK 20:10:10 – 0.1% N4 – NPK 20:10:10 – 0.2%
N5 – NPK 30:10:10 – 0.1% N6 – NPK 30:10:10 – 0.2%

Table 11. Shoot girth (cm) in dendrobium var. Sonia 17 as influenced by nutrient (concentration and frequency of application) and growth regulators

Treatments	Shoot girth (cm)					
	2MAP	4 MAP	6 MAP	8 MAP	10 MAP	12 MAP
Nutrients						
NPK 10:10:10 - 0.1%	1.73	2.00	2.38	2.64	3.06	3.31
NPK 10:10:10 - 0.2%	1.76	2.26	2.76	3.07	3.88	4.22
NPK 20:20:10 - 0.1%	1.84	2.43	2.92	3,32	4.13	4.39
NPK 20:20:10 - 0.2%	1.94	2.58	3.27	3,62	4.36	4.60
NPK 30:10:10 - 0.1%	1.98	2.58	3.02	3,42	4.02	4.53
NPK 30:10:10 - 0.2%	2.03	2.78	3.43	3.85	4.47	4.85
CD (0.05)	0.10	0.09	0.15	0.15	0.03	0.15
SEm±	0.03	0.03	0.05	0.05	0.03	0.05
Frequency						
Weekly twice	1.91	2.53	3.08	3.49	4.32	4.74
Weekly once	1.85	2.38	2.85	3.16	3.66	3.90
CD (0.05)	0.055	0.052	0.085	0.085	0.043	0.087
SEm±	0.020	0.019	0.030	0.030	0.016	0.031
Growth regulators						
Control	1.79	2.26	2.69	3.04	3.62	4.01
BA 100 ppm	1.89	2.53	3.07	3.49	4.12	4.57
BA 200 ppm	1.97	2.61	3.19	3.57	4.39	4.68
GA_3 10 ppm	1.88	2.37	2.93	3.19	3.75	3.91
GA_3 20 ppm	1.70	2.11	2.53	2.90	3.43	3.75
IAA 250 ppm	1.93	2.63	3.11	3.46	4.26	4.65
IAA 500 ppm	2.04	2.69	3.21	3.59	4.32	4.65
CD(0.05)	0.10	0.10	0.16	0.16	0.08	0.16
SEm±	0.04	0.03	0.06	0.06	0.03	0.06

(2.00 cm, 2.38 cm, 2.64 cm, 3.06 cm and 3.31 cm, respectively, from four to 12 MAP).

Appreciable difference in shoot girth was recorded with difference in frequency of application of nutrients in all the observations. Nutrients applied weekly twice produced shoots having more girth, viz., 1.91 cm, 2.53 cm, 3.08 cm, 3.49 cm, 4.32 cm and 4.74 cm during two to 12 MAP, respectively, as compared to 1.85 cm, 2.38 cm, 2.85 cm, 3.16 cm, 3.66 cm and 3.90 cm, which were given nutrients weekly once.

Distinguishable difference in shoot girth was recorded with the application of growth regulators. During early stages, the difference in girth was not significant for a single treatment. Maximum thickness of 2.04 cm was produced by IAA 500 ppm, which was significantly superior to the least value of 1.70 cm recorded in the case of GA_3 20 ppm at two MAP. A shoot thickness of 1.97 cm was produced by BA 200 ppm, which was on par with IAA 500 ppm. Similar observations were recorded four months after planting also. At six and eight months of planting IAA 500 ppm gave maximum thickness (3.21 cm and 3.59 cm, respectively). Values on par with this were recorded by BA 200 ppm and 100 ppm as well as IAA 250 ppm. Later, at 10 and 12 MAP, BA 200 ppm showed greater shoot girth (4.39 cm and 4.68 cm, respectively). On par with the above, IAA 500 ppm produced shoots having thickness of 4.32 cm and 4.65 cm, respectively. Lowest values for shoot girth was recorded in the case of GA_3 20 ppm (1.70 cm, 2.11 cm, 2.53 cm, 2.90 cm, 3.43 cm and 3.75 cm, respectively as growth advanced) which was less than values of control for growth regulator.

4.1.1.3.2 Interaction effects

Significant influence of combination of nutrients and frequency of application was present from early stages of growth (Table 12). In the case of

Table 12. Shoot girth (cm) in dendrobium var. Sonia 17 as influenced by combinations of nutrient concentration and frequency of application

Treat-ments	Shoot girth (cm)											
	2 MAP		4 MAP		6 MAP		8 MAP		10 MAP		12 MAP	
	Weekly once	Weekly twice	Weekly Once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice
NPK10:10:10 - 0.1%	1.71	1.75	1.91	2.29	2.15	2.61	2.39	2.90	2.74	3.38	2.84	3.78
NPK10:10:10 - 0 .2%	1.73	1.79	2.24	2.28	2.69	2.83	2.96	3.19	3.51	4.25	3.85	4.59
NPK20:10:10 - 0 .1%	1.82	1.85	2.32	2.53	2.81	3.02	3.16	3.47	3.82	4.43	4.11	4.67
NPK20:10:10 - 0 .2%	1.99	1.88	2.53	2.54	3.20	3.33	3.51	3.73	3.99	4.73	4.15	5.06
NPK30:10:10 - 0 .1%	1.93	2.14	2.45	2.71	2.91	3.14	3.28	3.57	3.81	4.23	4.11	4.96
NPK30:10:10 - 0 .2%	1.91	2.16	2.72	2.85	3.34	3.53	3.64	4.05	4.07	4.87	4.31	5.39
CD(0.05)	0.14		0.13		0.21		0.21		0.11		0.21	
SEm±	0.05		0.05		0.07		0.07		0.04		0.08	

weekly twice application, 30:10:10 NPK at 0.2 per cent gave the highest thickness of shoot (2.16 cm). The effect was significant as the growth of the plant advanced. The maximum shoot girth recorded in succeeding months were 2.85 cm, 3.53 cm, 4.05 cm, 4.87 cm and 5.39 cm, respectively, which was corresponding to 30:10:10 NPK at 0.2 per cent, sprayed weekly twice. Application of NPK 20:10:10 at 0.2 per cent closely followed, giving values of 3.33, 3.73, 4.73 and 5.06 cm for girth during 6, 8, 10 and 12 MAP. In the case of weekly once spray of nutrients also 30:10:10 NPK at 0.2 per cent produced significantly higher values (2.72 cm, 3.34 cm, 3.64 cm, 4.07 cm and 4.31 cm girth, respectively from four to 12 MAP). Application of NPK 20:10:10 at 0.2 per cent produced similar results to that of 30:10:10 NPK at 0.2 per cent in combination with weekly once application (3.20 cm, 3.51 cm, 3.99 cm and 4.15 cm girth from six to 12 MAP, respectively). It was observed that higher frequency of the lower level of nutrients produced more shoot girth at later stages of growth when compared to lower frequency of the higher concentration of nutrients.

Nutrients in combination with growth regulators also recorded distinguishable differences with respect to shoot girth (Table 13). Highest value was recorded in the case of IAA 250 ppm along with NPK 30:10:10 at 0.2 per cent (2.25 cm). Higher concentration of IAA in the same combination recorded girth of 2.21 cm on par with the former. In combination with NPK 20:10:10 and NPK 30:10:10, at both the levels (0.1 and 0.2 per cent) BA 100 ppm and 200 ppm produced plants with pseudo-bulb thickness on par with the above (1.96 cm, 1.99 cm, 2.06 cm and 2.05 cm for BA 200 ppm and 1.85 cm, 1.99 cm, 1.90 cm and 2.03 cm for BA 200 ppm, respectively). In the combination with NPK 30:10:10 at 0.1 per cent and NPK 20:10:10 at 0.2 per cent, IAA 500 ppm also showed values for girth on par with IAA 250 ppm (2.19 cm and 2.14 cm, respectively). Similar trends followed with advance in plant growth. After 12 months of treatment, IAA 250 ppm, in combination with NPK 30:10:10 at 0.2 per cent, produced shoots

Table 13. Shoot girth (cm) in dendrobium var. Sonia 17 as influenced by combinations of nutrient concentration and growth regulators

Treatments	Shoot girth (cm)					
	2 MAP	4 MAP	6 MAP	8 MAP	10 MAP	12 MAP
N_1G_0	1.61	1.79	2.01	2.21	2.72	2.87
N_1G_1	1.83	2.20	2.58	2.99	3.32	3.53
N_1G_2	1.83	2.47	2.65	2.85	3.36	3.64
N_1G_3	1.77	1.95	2.22	2.46	2.83	3.00
N_1G_4	1.56	1.83	2.02	2.19	2.51	2.65
N_1G_5	1.72	2.20	2.59	2.89	3.37	3.67
N_1G_6	1.79	2.26	2.61	2.91	3.31	3.77
N_2G_0	1.52	2.16	2.65	2.99	3.46	3.81
N_2G_1	1.77	2.24	2.80	3.16	4.12	4.51
N_2G_2	1.89	2.39	2.90	3.20	4.13	4.55
N_2G_3	1.79	2.06	2.43	2.81	3.49	3.73
N_2G_4	1.66	1.99	2.24	2.59	3.19	3.48
N_2G_5	1.61	2.42	3.10	3.14	4.26	4.61
N_3G_6	2.00	2.59	3.22	3.61	4.49	4.87
N_3G_0	1.82	2.31	2.65	2.90	3.90	4.08
N_3G_1	1.85	2.52	3.05	3.56	4.28	4.67
N_3G_2	1.96	2.66	3.40	3.88	4.59	5.01
N_3G_3	1.86	2.39	2.83	3.21	4.04	4.05
N_3G_4	1.65	2.07	2.49	3.80	3.75	3.96
N_3G_5	1.83	2.54	2.96	3.39	4.24	4.54
N_3G_6	1.89	2.49	3.04	3.50	4.10	4.46
N_4G_0	1.88	2.33	2.94	3.29	4.15	4.44
N_4G_1	1.99	2.78	3.56	3.99	4.48	4.80
N_4G_2	1.99	2.74	3.52	3.99	4.82	4.91
N_4G_3	1.78	2.46	3.61	3.40	4.10	4.18

Contd.

Table 13. Continued

Treatments	Shoot girth (cm)					
	2 MAP	4 MAP	6 MAP	8 MAP	10 MAP	12 MAP
N_4G_4	1.73	2.18	2.63	3.16	3.82	4.26
N_4G_5	2.04	2.77	3.28	3.80	4.63	4.83
N_4G_6	2.14	2.84	3.33	3.70	4.56	4.81
N_5G_0	1.96	2.40	2.76	3.13	3.25	4.20
N_5G_1	1.90	2.44	2.95	3.36	4.13	4.81
N_5G_2	2.06	2.49	3.12	3.62	4.52	4.73
N_5G_3	1.94	2.50	2.98	3.37	3.86	3.99
N_5G_4	2.02	2.42	2.77	3.10	3.53	3.98
N_5G_5	2.15	2.79	3.10	3.41	4.07	4.97
N_5G_6	2.19	3.01	3.49	3.99	4.79	5.04
N_6G_0	1.94	2.55	3.15	3.74	4.25	4.68
N_6G_1	2.03	2.98	3.51	3.88	4.42	5.10
N_6G_2	2.05	2.91	3.53	3.86	4.92	5.25
N_6G_3	1.82	2.84	3.54	3.90	4.21	4.53
N_6G_4	1.58	2.19	3.06	3.54	3.81	4.16
N_6G_5	2.25	3.06	3.66	4.15	4.99	5.28
N_6G_6	2.21	2.96	3.60	3.86	4.70	4.97
CD (0.05)	0.26	0.24	0.39	0.39	0.20	0.40
SEm±	0.09	0.09	0.14	0.14	0.07	0.14

N_1 - NPK 10:10:10 - 0.1%
N_2 - NPK 10:10:10 - 0.2%
N_3 - NPK 20:10:10 - 0.1%
N_4 - NPK 20:10:10 - 0.2%
N_5 - NPK 30:10:10 - 0.1%
N_6 - NPK 30:10:10 - 0.2%

G_0 - Control
G_1 - BA 100 ppm
G_2 - BA 200 ppm
G_3 - GA_3 10 ppm
G_4 - GA_3 20 ppm
G_5 - IAA 250 ppm
G_6 - IAA 500 ppm

having girth of 5.28 cm, which was the highest value recorded. With the same nutrient concentration, a girth of 5.25 cm produced by BA 200 ppm closely followed the above. This was on par with NPK 30:10:10 at 0.2 per cent in combination with BA 100 ppm and IAA 500 ppm (girth of 5.10 cm and 4.97 cm, respectively) and NPK 30:10:10 at 0.1 per cent in combination with IAA 250 ppm and 500 ppm (girth of 4.97 cm and 5.04 cm, respectively). In combination with NPK 20:10:10, both at 0.1 and 0.2 per cent, BA 200 ppm produced shoots with maximum girth of 5.01 and 4.91 cm, respectively, which were on with the above. In general, the effect of IAA in enhancing the shoot girth was not significantly different with the increase in nutrient concentration.

Interaction was present in the case of growth regulators and frequency of nutrient application (Table 14). For weekly twice nutrient application, IAA 500 ppm producing a girth of 5.36 cm was found to be the best combination which was significantly superior to all other treatment combinations, except that with BA 200 ppm (5.21 cm girth at 12 MAP). But in the case of weekly once application, IAA 250 ppm recorded the highest value for girth (4.19 cm). Least value for girth was observed in the growth regulator control in the early months of study (1.79 cm and 2.22 cm at two and four MAP, respectively). Later, the girth was found to decrease appreciably in the case of GA_3 20 ppm (2.53 cm, 2.77 cm, 3.25 cm and 3.58 cm, respectively, from sixth month onwards).

Interaction was evident in the case of nutrients, growth regulators and frequency of application (Table 15). Plants with thickest pseudo-bulbs (5.80 cm) was produced by IAA 500 ppm + NPK 30:10:10 at 0.2 per cent, applied weekly twice, which was significantly superior to all other treatment combinations 10 MAP. The Lowest value for girth (2.55 cm) was recorded in the combination of GA_3 20 ppm with NPK 10:10:10 at 0.1 per cent, applied weekly once.

Table 14. Shoot girth (cm) in dendrobium var. Sonia 17 as influenced by combinations of growth regulators and frequency of nutrient application

Treatments	Shoot girth (cm)											
	2 MAP		4 MAP		6 MAP		8 MAP		10 MAP		12 MAP	
	Weekly Once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice
Control	1.79	1.80	2.22	2.29	2.59	2.80	2.87	3.22	3.38	3.87	4.35	3.67
BA 100 ppm	1.88	1.91	2.46	2.59	2.95	3.20	3.33	3.65	3.78	4.46	4.98	4.16
BA 200 ppm	1.92	2.01	2.51	2.71	3.08	3.29	3.44	3.69	4.04	4.74	5.21	4.15
GA_3 10 ppm	1.86	1.80	2.41	2.32	2.87	3.00	3.13	3.25	3.50	4.00	4.26	3.57
GA_3 20 ppm	1.73	1.68	2.12	2.10	2.53	2.54	2.77	3.02	3.25	3.61	3.91	3.58
IAA 250 ppm	1.80	2.07	2.45	2.80	2.95	3.28	3.27	3.66	3.91	4.61	5.11	4.19
IAA 500 ppm	1.95	2.12	2.48	2.90	2.98	3.44	3.29	3.90	3.75	4.90	5.36	3.95
CD(0.05)	0.15		0.14		0.23		0.23		0.11		0.23	
SEm±	0.05		0.05		0.08		0.08		0.04		0.08	

Table 15. Shoot girth (cm) in dendrobium var. Sonia 17 as influenced by combinations of nutrients (concentration and frequency) and growth regulators

Growth regulators	Nutrients											
	N1		N2		N3		N4		N5		N6	
	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice
Control	2.61	2.84	3.31	3.68	3.45	4.34	3.64	4.65	3.22	3.29	4.05	4.45
BA 100 ppm	2.83	3.81	3.81	4.43	4.01	4.55	4.07	4.89	3.97	4.29	4.02	4.82
BA 200 ppm	2.86	3.85	3.72	4.55	4.41	4.78	4.36	5.27	4.22	4.66	4.66	5.19
GA_3 10 ppm	2.62	3.04	2.90	4.08	3.91	4.17	3.82	4.39	3.66	4.12	4.12	4.30
GA_3 20 ppm	2.55	2.47	2.87	3.50	3.73	3.78	3.64	4.00	3.26	3.47	3.47	4.14
IAA 250 ppm	2.87	3.88	3.80	4.73	3.96	4.51	4.44	4.82	3.81	4.56	4.56	5.43
IAA 500 ppm	2.87	3.75	4.19	4.79	3.28	4.92	4.00	5.12	4.57	3.59	3.59	5.80
CD(0.05)	0.28											
SEm±	0.10											

N1 – NPK 10:10:10 – 0.1% N2 – NPK 10:10:10 – 0.2%
N3 – NPK 20:10:10 – 0.1% N4 – NPK 20:10:10 – 0.2%
N5 – NPK 30:10:10 – 0.1% N6 – NPK 30:10:10 – 0.2%

4.1.1.4 Number of leaves

Data pertaining to the number of leaves as influenced by various treatments individually and in combination are presented in Tables 16 to 20.

4.1.1.4.1 Main effect of nutrients, frequency of application and growth regulators (Table 16)

Number of leaves was found to be influenced by nutrient concentrations. Maximum number of leaves was observed in the case of NPK 30:10:10 at 0.2 per cent from two months to final month of observation (4.34, 5.10, 6.42, 7.77, 8.79, 10.3 leaves, respectively). A similar trend was shown by NPK 20:10:10 at 0.2 per cent during initial months (4.33 and 4.92 leaves, during second and fourth month, respectively). The effect of NPK 30:10:10 at 0.2 per cent was significant later. This was closely followed by NPK 20:10:10 at 0.2 per cent.(5.61, 6.51, 7.88 and 9.01 leaves, respectively, from 6 months to 12 months after planting). Nutrient dosage of NPK 10:10:10 at 0.1 per cent produced the least number of leaves (4.07, 4.80, 5.55 and 7.75 leaves respectively) which was significantly inferior to all other treatments.

Frequency of application of nutrients markedly influenced leaf production. Significant increase in the number of leaves was noticed with applications twice a week (4.27, 5.03, 5.92, 6.99, 8.83, 11.27 leaves, respectively, from two to 12 months after planting), while weekly once application produced 3.63, 3.83, 4.69, 5.43, 5.95 and 6.89 leaves.

Noticeable effect of growth regulator treatments on leaf production was absent during initial months of observation. Detectable differences appeared later in the case of BA, both at lower and higher levels. Application of BA 200 ppm resulted in 4.88 and 6.25 leaves during four and six months after planting, respectively, whereas BA 100 ppm gave 4.94 and 6.17 leaves, respectively, which were on par. Application of BA 200 ppm significantly enhanced leaf production

Table 16. Number of leaves in dendrobium var. Sonia 17 as influenced by nutrients (concentration and frequency of application) and growth regulators

Treatments	Number of leaves					
	2 MAP	4 MAP	6 MAP	8 MAP	10 MAP	12 MAP
Nutrients						
NPK 10:10:10 - 0.1%	3.51	3.59	4.01	4.80	5.55	7.75
NPK 10:10:10 - 0.2%	3.76	4.08	5.08	5.98	7.38	8.77
NPK 20:20:10 - 0.1%	3.99	4.70	5.37	6.09	7.51	9.07
NPK 20:20:10 - 0.2%	4.33	4.92	5.61	6.51	7.88	9.01
NPK 30:10:10 - 0.1%	3.87	4.20	5.36	6.22	7.24	8.77
NPK 30:10:10 - 0.2%	4.34	5.10	6.42	7.77	8.79	10.30
CD (0.05)	0.437	0.438	0.526	0.631	0.688	0.682
SEm±	0.157	0.157	0.189	0.227	0.248	0.245
Frequency						
Weekly twice	4.27	5.03	5.92	6.99	8.83	11.27
Weekly once	3.63	3.83	4.69	5.43	5.95	6.89
CD (0.05)	0.253	0.253	0.303	0.364	0.398	0.395
SEm±	0.091	0.091	0.109	0.131	0.143	0.142
Growth regulators						
Control	3.96	4.32	4.94	5.64	6.33	7.76
BA 100 ppm	4.19	4.94	6.17	7.15	9.38	12.69
BA 200 ppm	3.86	4.88	6.25	7.81	10.57	15.40
GA_3 10 ppm	3.90	4.26	5.11	5.61	6.13	7.19
GA_3 20 ppm	3.89	3.85	4.49	5.35	5.82	6.26
IAA 250 ppm	3.89	4.44	5.03	6.04	6.63	7.13
IAA 500 ppm	3.96	4.33	5.17	5.89	5.89	7.26
CD(0.05)	0.472	0.473	0.568	0.682	0.744	0.736
SEm±	0.170	0.170	0.204	0.245	0.268	0.265

from six months onwards, producing 6.25, 7.81, 10.57 and 15.4 leaves, respectively. Least number of leaves was produced by GA_3 20 ppm, which was lesser than the treatment with no growth regulator (3.89, 4.49, 5.35, 5.82 and 6.26 leaves, respectively, from two months to 12 months). The same trend followed for lower doses of GA_3, i.e., 10 ppm, during later stages of investigation.

4.1.1.4.2 Interaction effects

Interaction of nutrients and frequency of application was significant from early months of treatment (Table 17). NPK 30:10:10 at 0.2 per cent was found to produce maximum number of leaves when applied weekly twice; 4.91, 5.83, 7.38, 9.10, 10.83 and 13.07 leaves were observed from two months to 12 months, respectively, which was significantly superior to all other treatment combinations from six MAP. This was followed by NPK 20:10:10 at 0.2 per cent, which recorded 4.81 and 5.67 leaves at two and four MAP and was on par with the superior treatment. Weekly once application of NPK 20:10:10 at 0.2 per cent was found to produce more number of leaves at two (3.86) and four (4.47) MAP. But from six months onwards, NPK 30:10:10 at 0.2 per cent was found to be significantly superior for weekly once application, producing 5.45, 6.30 and 6.74 leaves during six, eight and 10 MAP, respectively. At 12 MAP maximum leaves (7.52) was recorded for NPK 30:10:10 at 0.2 per cent. Values on par with this was recorded by NPK 20:10:10 at 0.2 per cent also (7.33 leaves). In general, higher frequency of lower level of nutrients produced more number of leaves compared to lower frequency of higher concentration of nutrients.

Interaction of nutrients and growth regulators was evident in the study (Table 18). At two and four MAP maximum number of leaves was recorded in the case of NPK 30:10:10 at 0.2 per cent, in combination with BA 100 ppm (4.83 and 6.17 leaves, respectively). At two months after planting, GA_3 20 ppm was found to be on par (4.75 leaves) for NPK 30:10:10 at 0.2 per cent. At four MAP,

Table 17. Number of leaves in dendrobium var. Sonia 17 as influenced by combinations of nutrient concentration and frequency of application

Treat-ments	Number of leaves											
	2 MAP		4 MAP		6 MAP		8 MAP		10 MAP		12 MAP	
	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice
NPK10:10:10 - 0.1%	3.17	3.86	3.52	3.67	3.91	4.24	4.43	5.17	4.88	6.21	6.19	9.31
NPK10:10:10 - 0 .2%	3.67	3.86	3.64	4.52	4.31	5.86	5.14	6.81	6.05	8.71	6.86	10.69
NPK20:10:10 - 0 .1%	3.83	4.14	3.81	5.60	4.60	6.14	5.26	6.93	5.76	9.26	6.86	11.29
NPK20:10:10 - 0 .2%	3.86	4.81	4.17	5.67	5.12	6.10	6.24	6.79	6.43	9.33	7.33	12.29
NPK30:10:10 - 0 .1%	3.69	4.05	3.50	4.91	4.79	5.81	5.19	7.05	5.83	8.65	6.60	10.95
NPK30:10:10 - 0 .2%	3.57	4.91	4.36	5.83	5.45	7.38	6.30	9.10	6.74	10.83	7.52	13.07
CD(0.05)	0.618		0.619		0.744		0.892		0.974		0.964	
SEm±	0.222		0.223		0.268		0.321		0.350		0.347	

Table 18. Number of leaves in dendrobium var. Sonia 17 as influenced by combinations of nutrient concentration and growth regulators

Treatments	Number of leaves					
	2 MAP	4 MAP	6 MAP	8 MAP	10 MAP	12 MAP
N_1G_0	4.00	4.17	4.58	4.67	5.33	7.00
N_1G_1	3.58	4.08	4.83	4.58	5.50	9.00
N_1G_2	3.58	3.58	4.68	6.17	7.58	14.25
N_1G_3	3.42	3.50	3.50	4.25	4.58	6.00
N_1G_4	3.42	2.92	3.42	4.50	5.00	5.08
N_1G_5	3.33	3.83	3.67	4.42	4.67	5.92
N_1G_6	3.25	3.08	4.42	5.00	6.17	6.92
N_2G_0	3.67	4.58	4.75	5.25	6.17	7.17
N_2G_1	3.83	4.17	5.83	6.17	7.75	10.67
N_2G_2	4.00	4.75	6.67	8.00	11.17	14.92
N_2G_3	3.67	0.42	4.75	5.33	6.33	7.58
N_2G_4	3.25	3.33	4.50	5.75	6.67	6.83
N_2G_5	4.00	3.83	4.58	5.67	6.83	7.42
N_3G_6	3.92	4.50	4.50	5.67	6.75	6.83
N_3G_0	4.00	4.17	4.92	5.17	6.42	7.17
N_3G_1	4.50	5.25	6.08	6.92	10.00	12.83
N_3G_2	3.92	5.33	5.83	7.75	11.17	15.67
N_3G_3	3.25	5.42	5.42	5.67	6.08	6.92
N_3G_4	3.92	4.50	4.92	4.83	5.08	6.08
N_3G_5	3.83	4.42	4.83	6.25	6.42	7.00
N_3G_6	4.50	4.83	6.08	6.08	7.42	7.83
N_4G_0	3.92	4.58	4.83	6.00	6.58	8.50
N_4G_1	4.33	5.00	6.77	7.08	10.08	14.42
N_4G_2	4.25	4.83	5.83	7.00	9.58	15.42
N_4G_3	4.50	5.33	6.08	6.92	7.33	8.08

Contd.

Table 18. Continued

Treatments	Number of leaves					
	2 MAP	4 MAP	6 MAP	8 MAP	10 MAP	12 MAP
N_4G_4	4.50	4.08	4.33	5.75	6.50	6.83
N_4G_5	4.33	5.58	6.50	6.50	7.75	7.92
N_4G_6	4.50	5.00	5.50	6.33	7.33	7.50
N_5G_0	4.23	3.83	5.25	5.83	6.00	7.58
N_5G_1	4.08	5.00	6.75	7.92	10.42	12.92
N_5G_2	3.50	4.75	6.58	8.00	11.25	14.83
N_5G_3	4.00	4.17	5.00	4.92	5.67	6.67
N_5G_4	3.50	3.83	4.33	4.92	5.25	5.92
N_5G_5	3.83	4.00	4.42	5.50	6.17	6.58
N_5G_6	3.83	3.83	4.75	5.75	5.92	6.92
N_6G_0	3.83	4.58	5.33	6.92	7.50	9.17
N_6G_1	4.83	6.17	7.83	10.25	12.50	16.25
N_6G_2	3.92	6.00	8.50	9.92	12.67	17.33
N_6G_3	4.58	4.75	5.92	6.58	6.75	7.33
N_6G_4	4.75	4.42	5.42	6.33	6.42	6.83
N_6G_5	4.00	5.00	6.17	7.92	7.92	7.92
N_6G_6	3.75	4.75	5.75	6.50	7.75	7.25
CD (0.05)	1.16	1.16	1.39	1.67	1.82	1.803
SEm±	0.416	0.416	0.501	0.601	0.655	0.649

N_1 - NPK 10:10:10 - 0.1%
N_2 - NPK 10:10:10 - 0.2%
N_3 - NPK 20:10:10 - 0.1%
N_4 - NPK 20:10:10 - 0.2%
N_5 - NPK 30:10:10 - 0.1%
N_6 - NPK 30:10:10 - 0.2%

G_0 - Control
G_1 - BA 100 ppm
G_2 - BA 200 ppm
G_3 - GA_3 10 ppm
G_4 - GA_3 20 ppm
G_5 - IAA 250 ppm
G_6 - IAA 500 ppm

BA 200 ppm produced more number of leaves when NPK 10:10:10 at 0.2 per cent and NPK 20:10:10 at 0.1 per cent were applied (4.75 and 5.33 leaves, respectively).

At six MAP, leaf production was more when BA 200 ppm was used along with NPK 30:10:10 at 0.2 per cent (8.50) and NPK 10:10:10 at 0.2 per cent (6.67). Along with NPK 30:10:10, BA 100 ppm gave value on par with this (7.83). But in the case of NPK 30:10:10 at 0.1 per cent, NPK 20:10:10 at 0.1 and 0.2 per cent and NPK 10:10:10 at 0.1 per cent, number of leaves was maximum when BA 100 ppm was also applied (6.75, 6.08, 6.77 and 4.83 leaves, respectively).

Similar observations were recorded in subsequent months also. Maximum number of leaves was produced by BA 200 ppm in combination with NPK 10:10:10 at 0.1 and 0.2 per cent (7.58 and 11.17 leaves, respectively), NPK 20:20:10 at 0.1 per cent (11.17 leaves) and NPK 30:10:10 at 0.1 and 0.2 per cent (11.25 and 12.67 leaves, respectively). For NPK 20:10:10, BA 100 ppm was found to be more effective (10.08 leaves) at 10 MAP.

At 12 MAP, BA 200 ppm was observed to produce maximum number of leaves when combined with all nutrient doses (14.25, 14.92, 15.67, 15.42, 14.83 and 17.33 leaves, with increasing nutrient doses). This was found to be significantly superior in the case of NPK 10:10:10 at 0.1 and 0.2 per cent, NPK 20:10:10 and 30:10:10 at 0.1 per cent used in the combination. The treatments NPK 20:10:10 and 30:10:10 at 0.2 per cent, in combination with BA 100 ppm, produced 14.42 and 16.25 leaves, respectively, which was on par with the superior combination. Minimum number of leaves was recorded in the case of IAA 250 and 500 ppm for all nutrient doses (5.92, 7.42, 7.00, 7.92, 6.58, 7.92 and 6.92, 6.83, 7.83, 7.50, 6.92 and 7.25 leaves, respectively with increasing nutrient doses). This, was inferior compared to control of growth regulators (7.00, 7.17, 7.17, 8.50, 7.58, 9.17 leaves, respectively, with increase in nutrient doses). In general, the effect of BA 200 ppm in producing more number of leaves was similar at different nutrient concentrations, except at the highest nutrient concentration of NPK 30:10:10 at 0.2 per cent.

Interaction was evident in the case of growth regulators and frequency of application of nutrients too (Table 19). Combination of weekly once application and growth regulators was distinctly inferior compared to growth regulators and weekly twice application of nutrients. For weekly twice application of nutrients BA 200 ppm was found to produce more leaves during all stages of the experiment (4.39, 6.08, 7.61, 9.67, 14.89 and 21.31 leaves, respectively, with progress in month). This combination was significantly superior in the later months of study; but BA 100 ppm in the combination was on par during early stages (4.25, 5.50 and 7.08 leaves, respectively, in 2, 4 and 6 months). With the nutrients applied weekly once, BA 100 ppm produced 4.14, 4.39, 5.42, 5.92 and 6.94 leaves at 2 months to 10 months of study, respectively. In the above combination of nutrients, BA 200 ppm was on par (4.72,5.84 and 6.25 leaves at 6, 8 and 10 months, respectively). At 12 MAP, BA 200 ppm in combination with weekly once application of nutrients produced 9.50 leaves and BA 100 ppm in the combination produced 8.83 leaves, which was on par with the former. Gibberellic acid, both at 10 and 20 ppm, produced minimum number of leaves in both the application frequencies (8.30 and 7.44 leaves for weekly twice application and 5.81, 5.08 for weekly once application, respectively) which was lesser than control.

Nutrients, growth regulators and frequency of application had significant interactions (Table 20). For the higher doses of all the three nutrient ratios, BA 200 ppm applied weekly twice gave the maximum number of leaves, which was significantly superior to other treatment combinations (15.67, 12.17 and 19.83 leaves, respectively, with increase in nutrient ratios). For NPK 30:10:10 at 0.1 per cent also similar trend was observed (15.67 leaves). BA 100 ppm in the same combination was on par in the case of NPK 20:10:10 at 0.2 per cent and NPK 30:10:10 at 0.1 per cent (10.50 and 13.67 leaves, respectively). In the case of

Table 19. Number of leaves in dendrobium var. Sonia 17 as influenced by combinations of growth regulators and frequency of nutrient application

Treatments	Number of leaves											
	2 MAP		4 MAP		6 MAP		8 MAP		10 MAP		12 MAP	
	Weekly Once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice
Control	3.67	4.25	3.78	4.86	4.75	5.14	5.83	5.44	5.97	6.69	6.67	8.86
BA 100ppm	4.14	4.25	4.39	5.50	5.42	7.08	5.92	8.39	6.94	11.81	8.83	16.56
BA 200ppm	3.33	4.39	3.67	6.08	4.72	7.61	5.84	9.67	6.25	14.89	9.50	21.31
GA_3 10ppm	3.61	4.19	3.92	4.61	4.64	5.58	5.25	5.97	5.44	6.81	5.81	8.39
GA_3 20ppm	3.42	4.36	3.19	4.50	3.89	5.08	4.89	6.31	4.78	6.86	5.08	7.44
IAA 250 ppm	3.64	4.14	3.97	4.92	4.44	5.61	5.58	6.50	5.72	7.53	6.06	8.19
IAA 500 ppm	3.61	4.31	3.92	4.75	5.00	5.32	4.11	6.67	6.53	7.25	6.31	8.11
CD(0.05)	0.667		0.668		0.803		0.964		1.052		1.04	
SEm±	0.240		0.240		0.289		0.347		0.378		0.375	

Table 20. Number of leaves in dendrobium var. Sonia 17 as influenced by combinations of nutrients (concentration and frequency) and growth regulators

Growth regulators	Nutrients											
	N1		N2		N3		N4		N5		N6	
	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice
Control	4.67	6.00	7.33	5.00	5.67	7.17	5.50	7.67	6.67	5.33	6.00	9.00
BA 100 ppm	4.67	6.33	6.50	9.00	7.17	12.83	7.67	10.50	7.17	13.67	8.50	16.50
BA 200 ppm	5.67	9.50	6.67	15.67	5.83	16.50	7.00	12.17	6.83	15.67	5.50	19.83
GA_3 10 ppm	4.17	5.00	5.67	7.00	5.50	6.67	6.67	8.00	4.50	6.83	6.17	7.33
GA_3 20 ppm	5.00	5.00	5.00	8.33	3.83	6.33	5.00	8.00	4.67	5.83	5.17	7.67
IAA 250 ppm	4.00	5.33	5.67	8.00	5.83	7.00	5.83	9.67	5.33	7.00	7.67	8.17
IAA 500 ppm	6.00	6.33	5.50	8.00	6.50	8.33	7.33	7.33	5.67	6.17	8.17	7.33
CD(0.05)	2.580											
SEm±	0.927											

N1 – NPK 10:10:10 – 0.1% N2 – NPK 10:10:10 – 0.2%
N3 – NPK 20:10:10 – 0.1% N4 – NPK 20:10:10 – 0.2%
N5 – NPK 30:10:10 – 0.1% N6 – NPK 30:10:10 – 0.2%

weekly once application of NPK 20:10:10 at 0.1 and 0.2 per cent and NPK 30:10:10 at 0.1 and 0.2 per cent, BA 100 ppm in the combination gave better results (7.17, 7.67, 6.83 and 8.50 leaves, respectively).

4.1.1.5 Total leaf area

Data on total leaf area of dendrobium var. Sonia 17 as influenced by different treatments, individually and in combination, are presented in Tables 21 to 24.

4.1.1.5.1 Main effect of nutrients, frequency of application and growth regulators (Table 21)

Nutrient concentrations showed detectable differences in total leaf area throughout the experimental period. Nutrient dose 30:10:10 at 0.2 per cent recorded the maximum leaf area of 29.74 cm^2, 41.00 cm^2, 58.80 cm^2, 99.10 cm^2, 139.92 cm^2 and 198.65 cm^2, respectively, from two to 12 MAP. Least values for leaf area were recorded in the case of NPK 10:10:10 at 0.1 per cent (16.43 cm^2, 27.35 cm^2, 33.58 cm^2, 59.00 cm^2, 70.83 cm^2 and 91.00 cm^2, respectively, from two to 12 MAP.

Application of nutrients in two different frequencies recorded detectable differences throughout the experiment. Application of nutrients weekly twice produced plants with significantly better leaf area (25.6 cm^2, 40.0 cm^2, 56.35 cm^2, 89.98 cm^2, 100.57 cm^2 and 158.25 cm^2, respectively, from two to 12 months after planting) as compared to those produced by application of nutrients weekly once (19.24 cm^2, 23.85 cm^2, 31.30 cm^2, 42.60 cm^2, 64.28 cm^2, and 99.33 cm^2, respectively, from two to 12 months after planting).

Total leaf area was found to vary significantly with differences in growth regulators and doses. The highest values for leaf area was recorded by IAA 500 ppm (26.00 cm^2), closely followed by BA 200 ppm and IAA 250 ppm (24.36 cm^2 and

Table 21. Leaf area (cm^2) in dendrobium var. Sonia 17 as influenced by nutrients (concentration and frequency of application) and growth regulators

Treatments	Leaf area (cm^2)					
	2 MAP	4 MAP	6 MAP	8 MAP	10 MAP	12 MAP
Nutrients						
NPK 10:10:10 - 0.1%	16.43	27.35	33.58	59.00	70.83	91.00
NPK 10:10:10 - 0.2%	19.35	31.30	40.21	66.73	89.00	124.71
NPK 20:20:10 - 0.1%	21.20	29.45	43.85	74.08	94.68	149.32
NPK 20:20:10 - 0.2%	24.65	34.50	47.63	78.99	101.00	167.20
NPK 30:10:10 - 0.1%	24.30	35.85	49.06	81.35	119.33	184.00
NPK 30:10:10 - 0.2%	29.74	41.00	58.80	99.10	139.92	198.65
CD (0.05)	2.860					
SEm±	1.031					
Frequency						
Weekly twice	25.60	40.00	56.35	89.98	100.57	158.25
Weekly once	19.24	23.85	31.30	42.60	64.28	99.3
CD (0.05)	4.654					
SEm±	1.674					
Growth regulators						
Control	20.87	32.00	47.25	71.00	79.80	98.25
BA 100 ppm	21.22	37.54	50.22	89.97	138.88	196.35
BA 200 ppm	24.36	39.08	59.68	123.17	174.60	223.00
GA_3 10 ppm	20.48	29.96	47.23	62.77	80.38	94.32
GA_3 20 ppm	19.67	28.25	44.31	60.39	82.61	87.60
IAA 250 ppm	24.28	38.00	49.00	65.67	87.02	98.17
IAA 500 ppm	26.00	38.62	44.36	69.97	90.33	104.68
CD(0.05)	5.290					
SEm±	1.903					

24.28 cm^2, respectively) at two MAP. At four MAP, maximum leaf area of 39.08 cm^2 was recorded in the case of BA 200 ppm; IAA 500 ppm and 250 ppm recording values on par with this (38.62 cm^2 and 38.00 cm^2, respectively). Later, BA 200 ppm was found to produce significant increase in leaf area; 123.17 cm^2, 174.60 cm^2 and 223.00 cm^2, respectively, with progress in growth. Least values for leaf area were seen in plants treated with GA_3 20 ppm (19.67 cm^2, 28.25 cm^2, 44.31 cm^2, 60.39 cm^2 and 87.60 cm^2, respectively, at two, four, six, eight and 12 MAP).

4.1.1.5.2 Interaction effects

Nutrient concentration along with frequency of application had no significant influence during initial stages of study (Table 22). From four months onwards highest values were recorded for NPK 30:10:10 at 0.1 per cent applied twice a week (41.20 cm^2 and 58.98 cm^2 at 4 and 6 MAP, respectively). Significantly superior treatment combination with respect to total leaf area was NPK 30:10:10 at 0.2 per cent along with weekly twice application (100.84, 148.30 and 203.33 cm^2, respectively at 8, 10 and 12 MAP). Total leaf area produced by higher frequency (weekly twice) of lower concentration (0.1%) of nutrients was in general higher than the higher nutrient concentration at lower frequency (weekly once).

In the combinations of nutrients and growth regulators, detectable differences were not observed in the early stages of plant growth (Table 23). From fourth MAP, BA 200 ppm along with 30:10:10 NPK at 0.2 per cent produced plants with highest leaf area (48.98 cm^2). Benzyl adenine 100 ppm and IAA 500 ppm substituted in the combination gave 45.75 cm^2 and 44.45 cm^2 area, which was on par with the former combination. Similar trend was seen with progress in plant growth. BA 200 ppm combined with 30:10:10 at 0.2 per cent NPK gave maximum leaf area of 175.23 cm^2, 203.41 cm^2 at 10 and 12 MAP. BA 100 ppm in the combination was found to be on par with leaf area of 169.00 cm^2 and 195.90 cm^2,

Table 22. Total leaf area (cm^2) in dendrobium var. Sonia 17 as influenced by combinations of nutrient concentration and frequency of application

Treatments	Total leaf area (cm^2)											
	2 MAP		4 MAP		6 MAP		8 MAP		10 MAP		12 MAP	
	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice
NPK 10:10:10 - 0.1%	18.12	18.20	20.20	24.32	26.62	40.30	36.68	64.18	37.20	77.80	50.10	100.60
NPK 10:10:10 - 0 .2%	18.16	18.65	19.86	25.83	26.99	46.66	39.25	68.00	42.30	84.60	54.36	112.32
NPK 20:10:10 - 0 .1%	18.24	18.99	21.48	28.36	27.41	47.92	41.31	69.25	44.50	89.98	57.60	117.61
NPK 20:10:10 - 0 .2%	18.28	19.13	22.31	33.20	28.63	49.00	47.00	74.66	49.90	95.72	59.00	128.42
NPK 30:10:10 - 0 .1%	18.26	19.20	25.00	38.68	29.98	53.10	46.65	82.91	49.88	118.31	68.86	149.88
NPK 30:10:10 - 0 .2%	18.28	19.36	25.32	41.20	33.00	58.98	52.11	100.84	57.36	148.30	74.66	203.33
CD(0.05)	5.524		5.663		8.098		11.164		19.018		20.377	
SEm±	1.987		2.037		2.913		4.016		6.841		9.830	

Table 23. Total leaf area (cm²) in dendrobium var. Sonia 17 as influenced by combinations of nutrients and growth regulators.

Treatments	Total leaf area (cm²)					
	2 MAP	4 MAP	6 MAP	8 MAP	10 MAP	12 MAP
N_1G_0	19.35	23.98	29.92	36.75	51.36	56.39
N_1G_1	19.47	24.07	31.60	40.15	55.21	61.20
N_1G_2	19.62	24.90	33.33	42.06	59.00	63.67
N_1G_3	19.25	24.02	28.60	39.98	48.62	56.37
N_1G_4	19.80	23.95	29.83	38.63	50.16	53.12
N_1G_5	19.00	23.88	31.37	37.50	51.21	55.79
N_1G_6	19.42	23.96	31.90	38.36	50.77	59.92
N_2G_0	20.41	29.65	31.34	38.35	60.22	69.99
N_2G_1	20.65	33.00	33.03	41.22	64.32	78.20
N_2G_2	11.35	34.25	38.51	42.67	69.48	89.00
N_2G_3	20.22	29.90	35.06	40.05	50.07	68.29
N_2G_4	20.31	29.87	33.17	39.96	48.96	64.02
N_2G_5	19.65	30.25	32.25	40.25	51.35	70.10
N_3G_6	19.48	31.99	32.17	41.33	57.00	72.35
N_3G_0	10.42	33.00	37.67	44.67	88.95	97.23
N_3G_1	21.00	39.87	40.68	47.95	91.32	100.35
N_3G_2	20.85	40.25	42.26	49.83	94.65	111.79
N_3G_3	20.96	37.63	40.20	42.43	78.20	87.67
N_3G_4	21.20	36.96	39.31	40.68	72.31	81.35
N_3G_5	20.65	36.99	37.64	44.65	79.68	98.62
N_3G_6	20.48	37.12	38.43	45.99	84.25	109.20
N_4G_0	20.68	36.20	40.45	58.95	101.31	149.38
N_4G_1	20.89	41.60	43.99	65.91	112.25	154.98
N_4G_2	21.00	45.91	47.20	72.63	119.17	167.20
N_4G_3	21.02	40.21	41.60	50.31	31.96	101.30

Contd.

Table 23. Continued

Treatments	Total leaf area (cm^2)					
	2 MAP	4 MAP	6 MAP	8 MAP	10 MAP	12 MAP
N_4G_4	20.97	38.63	40.07	49.18	88.35	97.78
N_4G_5	20.86	39.17	40.18	49.96	95.02	137.63
N_4G_6	20.91	39.45	41.24	54.20	103.25	151.00
N_5G_0	20.12	35.87	44.21	63.40	118.92	140.20
N_5G_1	20.45	41.86	43.67	70.31	131.03	151.25
N_5G_2	20.63	44.95	46.95	74.20	142.27	168.04
N_5G_3	20.95	40.48	41.55	54.21	102.35	103.50
N_5G_4	21.05	40.02	42.07	50.18	100.07	92.69
N_5G_5	20.99	37.87	39.96	51.45	120.98	120.29
N_5G_6	20.95	38.33	42.21	64.05	122.42	141.35
N_6G_0	20.49	38.61	49.67	76.25	156.20	185.20
N_6G_1	22.00	45.75	53.41	84.00	169.00	195.90
N_6G_2	21.86	48.98	55.75	89.36	175.23	203.41
N_6G_3	20.98	44.32	45.00	59.96	135.31	127.62
N_6G_4	21.35	42.61	44.43	56.25	127.62	108.60
N_6G_5	21.07	40.48	42.71	60.12	149.98	132.44
N_6G_6	21.33	44.45	45.65	68.33	163.00	180.18
CD(0.05)	3.987	5.285	5.885	6.155	7.284	7.765
SEm	1.434	1.901	2.117	2.214	2.620	2.793

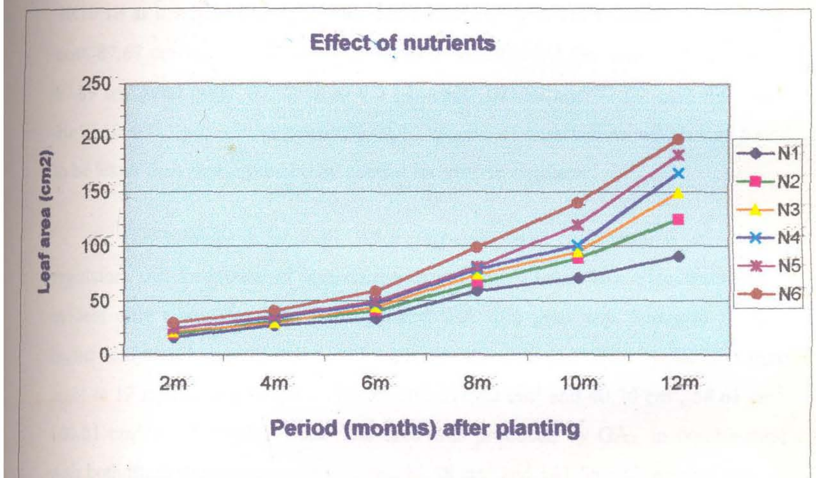
N_1 - NPK 10:10:10 - 0.1%
N_2 - NPK 10:10:10 - 0.2%
N_3 - NPK 20:10:10 - 0.1%
N_4 - NPK 20:10:10 - 0.2%
N_5 - NPK 30:10:10 - 0.1%
N_6 - NPK 30:10:10 - 0.2%

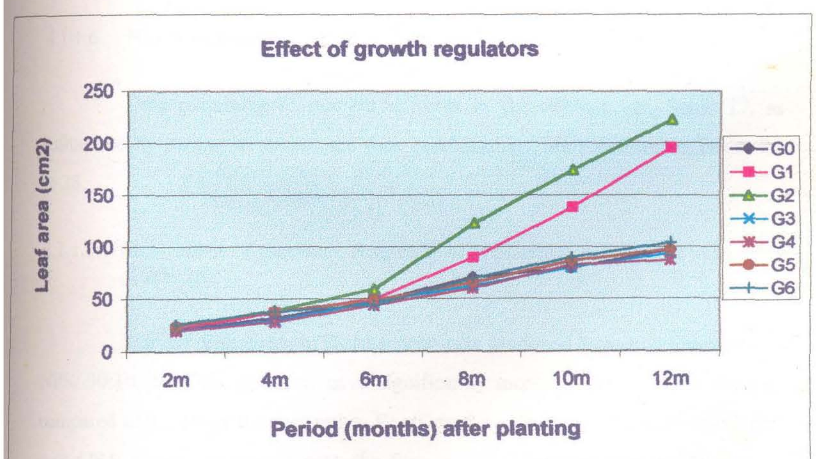
G_0 - Control
G_1 - BA 100 ppm
G_2 - BA 200 ppm
G_3 - GA_3 10 ppm
G_4 - GA_3 20 ppm
G_5 - IAA 250 ppm
G_6 - IAA 500 ppm

Table 24. Total leaf area (cm^2) in dendrobium var. Sonia 17 as influenced by combinations of growth regulators and frequency of nutrient application

Growth regulators	Total leaf area (cm^2)											
	2 MAP		4 MAP		6 MAP		8 MAP		10 MAP		12 MAP	
	Weekly Once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice
Control	18.98	22.60	22.10	32.61	26.00	44.31	38.16	70.36	48.26	87.26	61.20	128.24
BA 100ppm	20.20	24.31	22.72	36.80	26.74	46.97	39.98	92.69	49.90	150.32	89.33	197.66
BA 200ppm	20.67	26.25	23.45	39.95	28.12	48.20	40.70	98.00	58.61	170.00	100.51	210.12
GA_3 10ppm	21.00	26.95	21.92	37.26	26.60	44.32	40.01	62.36	44.72	93.62	60.88	160.24
GA_3 20ppm	20.48	25.33	21.67	36.00	24.30	44.01	33.44	68.85	44.98	81.48	64.68	141.66
IAA 250ppm	21.22	27.00	23.31	38.22	29.44	49.60	38.66	81.00	50.00	164.81	58.00	170.20
IAA 500ppm	21.90	24.60	22.91	38.17	30.26	48.31	38.24	84.10	59.00	166.62	6.00	175.67
CD(0.05)	5.969		6.013		8.593		13.211		20.00		21.77	
SEm±	2.147		2.163		3.091		4.752		7.216		7.831	

Fig. 2. Leaf area in dendrobium var. Sonia 17, as influenced by nutrients and growth regulators





respectively. When lower concentration of nutrients were used, IAA 500 ppm also was found to be on par. Least leaf area was observed in the case of GA_3 10 and 20 ppm with all nutrient combinations - 56.37 cm² and 53.12 cm² with NPK 10:10:10 at 0.1 per cent, 68.29 cm²and 64.02 cm² with NPK 10:10:10 at 0.1 per cent, 87.67 cm² and 81.35 cm² with NPK 20:10:10 at 0.1 per cent, 101.30 cm²and 97.89 cm² with NPK 20:10:10 at 0.2 per cent, 103.50 and 92.69 cm² with NPK 30:10:10 at 0.1 per cent respectively, at 12 months of observation, which was found to be lesser than that produced by control for growth regulator.

Detectable differences were observed with combination of growth regulators and frequency of application of nutrients (Table 24). Significance was evident only when the growth progressed. BA 200 ppm was found to produce higher leaf area in combination with both weekly once and twice application from eight to 12 months (98.00 cm², 170.00 cm², 210.12 cm² and 40.70 cm², 58.61 cm², 100.51 cm², respectively). Least leaf area was produced by GA_3, in combination with both the frequencies of application (60.88 cm² and 141.66 cm², respectively) at 12 MAP.

4.1.1.6 Number of roots

Data pertaining to number of roots in dendrobium var. Sonia 17, as influenced by various treatment and their combinations, are presented in Tables 25 to 28.

4.1.1.6.1 Main effect of nutrients, frequency of application and growth regulators (Table 25)

Marked differences in root number were produced by nutrient application NPK 30:10:10 at 0.2 per cent gave significantly more number of roots (33.14) compared to the lower nutrient ratios. Roots produced by NPK 20:10:10 at 0.2 per cent (29.9 roots) was on par with the former. Least number of roots (20.5) was

Table 25. Biomass production (g) and root characters in dendrobium var. Sonia 17as influenced by nutrients (concentration and frequency of application) and growth regulators

Treatments	Dry matter	Root length (cm)	No. of roots
Nutrients			
NPK 10:10:10 - 0.1%	2.53	16.21	20.50
NPK 10:10:10 - 0.2%	2.93	15.30	24.71
NPK 20:20:10 - 0.1%	3.66	17.84	24.54
NPK 20:20:10 - 0.2%	4.26	17.28	29.86
NPK 30:10:10 - 0.1%	4.81	18.31	26.82
NPK 30:10:10 - 0.2%	6.09	18.92	33.14
CD(0.05)	0.053	3.84	5.55
SEm±	0.019	1.37	1.97
Frequency			
Weekly twice	3.203	16.83	29.19
Weekly once	2.89	2.21	24.00
CD (0.05)	0.025	2.21	3.19
SEm±	0.011	0.789	1.139
Growth regulators			
Control	3.68	20.15	24.38
BA 100 ppm	4.27	15.28	26.00
BA 200 ppm	4.46	14.07	26.58
GA_3 10 ppm	3.92	18.39	23.38
GA_3 20 ppm	3.78	21.22	24.29
IAA 250 ppm	4.06	16.70	29.54
IAA 500 ppm	4.16	15.37	32.00
CD(0.05)	0.057	4.15	5.98
SEm±	0.020	1.48	2.13

produced by NPK 10:10:10 at 0.1 per cent, which was on par with NPK 20:10:10 at 0.1 per cent (24.5 roots) and NPK 10:10:10 at 0.2 per cent (24.7 roots).

Nutrients applied weekly twice excelled the weekly once application in terms of root numbers (29.19 and 24.00 roots, respectively).

Among growth regulators applied IAA 500 ppm produced 32 roots, which was the highest root number recorded and was on par with IAA 250 ppm, BA 200 ppm and BA 100 ppm, which recorded 29.5, 26.6 and 26.0 roots, respectively.

4.1.1.6.2 Interaction effects

Treatment combinations of NPK 30:10:10 at 0.2 per cent, sprayed twice weekly, were superior, producing 38.9 roots which was significantly superior to all other treatments. This was closely followed by 31.6 roots in the case of NPK 20:10:10 at 0.2 per cent sprayed weekly twice (31.6) (Table 28). Root number produced was in general higher in the case of higher frequency (weekly twice) of lower concentration of nutrients compared to lower frequency (weekly once) of higher concentration of nutrients.

BA 200 ppm in combination with NPK 30:10:10 at 0.2 per cent produced significantly highest root number (42.0) followed by 37.3 and 36.5 roots, respectively, in the plants treated with IAA 250 ppm and 500 ppmcombined with the same nutrient dose (Table 30). Minimum root number was observed (16.5) when BA 200 ppm was applied along with NPK 10:10:10 at 0.1 per cent.

Maximum number of roots (33.2) produced by combination of growth regulators and frequency of nutrient application was in the case of BA 100 ppm (Table 29) followed by IAA 500 ppm (33.1 roots) in the case of weekly twice application. GA_3 20 ppm and BA 200 ppm when applied in combination with weekly once nutrient application gave least number of roots (20.5 and 20.0 roots, respectively).

4.1.1.7 Biomass production

Data pertaining to the total biomass production in dendrobium var. Sonia 17, as influenced by treatments and their combinations, are presented in Tables 25 to 27 and 29.

4.1.1.7.1 Main effect of nutrients, frequency of application and growth regulators (Table 25)

Maximum biomass was recorded in plants fertilized using NPK 30:10:10 at 0.2 per cent (6.09 g), which excelled all other nutrient doses significantly. NPK 30:10:10 at 0.1 per cent followed this (4.81 g) and least biomass production (2.53 g) was observed in plants fed with NPK 10:10:10 at 0.1 per cent. In general, biomass production was significantly superior for higher frequency (weekly twice) of lower concentration of nutrients compared to lower frequency (weekly once) of higher concentration of nutrients.

Weekly twice application of nutrients produced 5.20 g biomass which was distinctly superior to 2.89 g in plants fed with nutrients weekly once.

Growth regulator application was found to have marked influence on dry matter production. 4.46 g of dry matter was obtained in plants treated with BA 200 ppm, which was significantly superior to all other growth regulators. Growth regulator control treatment accumulated 3.68 g biomass, which was on par with dry matter produced by plants treated with GA_3 (3.92 g and 3.78 g, respectively for GA_3 10 ppm and 20 ppm).

4.1.1.7.2 Interaction effects

Nutrient doses had effective interaction with frequency of application with respect to biomass production (Table 26). Maximum biomass production (7.40 g) was recorded in plants treated weekly twice using 30:10:10 NPK 0.2 per cent. Least dry matter production was obtained in the case of weekly once application with NPK 10:10:10 at 0.1 per cent (1.67 g).

Highest dry matter (5.66 g) was produced in plants treated with BA 200 ppm fertilized twice weekly (Table 27). BA 100 ppm in the above combination produced 5.45 g. Minimum value for dry matter is recorded in plants which were treated with no growth regulator.

In the case of combinations of nutrients and growth regulators, maximum dry matter accumulation was observed in the case of BA 200 ppm along with NPK 30:10:10 at 0.2 per cent (6.94 g), which was significantly superior compared to all other treatment combinations (Table 29). This was followed by BA 100 ppm in the same nutrient combination, which produced 6.51 g of dry matter. Nutrients in combination with GA_3 20 ppm was found to produce significantly lower dry matter content (2.36 g, 2.64 g, 3.36 g, 4.09 g, 4.45 g and 5.70 g, respectively), which were on par (2.28 g) with treatments having no growth regulators. In general, biomass production due to BA 200 ppm was found to increase with increase in nutrient concentration.

4.1.2 Nutrient content

4.1.2.1 Nitrogen content

Data pertaining to the concentration of nitrogen in dendrobium var. Sonia 17, as influenced by different treatments, are presented in Tables 30 to 36.

Table 26. Biomass production (g) and number of roots in dendrobium var. Sonia 17 as influenced by combination of nutrient concentration and frequency of application

Treatments	Dry weight (g)		Number of roots	
	Weekly once	Weekly twice	Weekly once	Weekly twice
NPK10:10:10 - 0.1%	1.67	3.39	18.71	22.29
NPK10:10:10 - 0 .2%	2.07	3.79	23.21	26.21
NPK20:10:10 - 0 .1%	2.54	4.79	21.71	27.36
NPK20:10:10 - 0 .2%	2.89	5.62	28.07	31.64
NPK30:10:10 - 0 .1%	3.37	6.24	24.93	28.,71
NPK30:10:10 - 0 .2%	4.79	7.40	36.88	38.93
CD (0.05)	0.075		0.785	
SEm±	0.027		0.279	

Table 27. Biomass production (g) and number of roots in dendrobium var. Sonia 17 as influenced by combinations of growth regulators and frequency of nutrient application

Treatments	Dry weight (g)		Number of roots	
	Weekly Once	Weekly twice	Weekly once	Weekly twice
Control	2.50	4.86	22.75	26.00
BA 100ppm	3.10	5.45	23.50	28.50
BA 200ppm	3.26	5.66	20.00	33.17
GA_3 10ppm	2.81	5.04	21.83	24.92
GA_3 20ppm	2.72	4.83	20.50	28.08
IAA 250ppm	2.86	5.25	28.50	30.58
IAA 500ppm	2.98	5.34	30.92	33.08
CD (0.05)	0.082		0.848	
SEm±	0.028		0.302	

Table 28. Number of roots in dendrobium var. Sonia 17 as influenced by combinations of nutrient concentration and growth regulators

Treatments	Number of roots					
	N1	N2	N3	N4	N5	N6
Control	21.00	18.00	17.50	20.50	25.00	31.50
BA 100ppm	21.00	14.50	28.00	23.50	29.75	29.00
BA 200ppm	19.00	14.00	23.00	19.00	21.50	42.00
GA_3 10ppm	16.00	21.50	24.00	20.50	28.25	20.25
GA_3 20ppm	18.50	17.00	26.00	26.00	19.00	35.50
IAA 250ppm	29.00	22.50	29.50	29.50	32.50	37.25
IAA 500ppm	31.50	23.50	35.50	31.00	32.50	36.50
CD(0.05)	1.469					
SEm±	0.522					

Table 29. Biomass production (g) in dendrobium var. Sonia 17 as influenced by combinations of nutrient concentration and growth regulators

Treatments	Dry weight (g)					
	N1	N2	N3	N4	N5	N6
Control	2.28	2.75	3.37	4.04	4.52	5.12
BA 100ppm	2.69	3.11	3.95	4.36	5.04	6.51
BA 200ppm	2.75	3.22	4.05	4.61	5.18	6.94
GA_3 10ppm	2.51	2.83	3.45	4.12	4.65	5.95
GA_3 20ppm	2.36	2.64	3.36	4.09	4.45	5.76
IAA 250ppm	2.54	2.90	3.69	4.23	4.84	6.13
IAA 500ppm	2.60	3.05	3.77	4.34	4.07	6.25
CD(0.05)	0.140					
SEm±	0.050					

N1 - NPK10:10:10 - 0.1% N2 - NPK10:10:10 - 0 .2%
N3 - NPK20:10:10 - 0 .1% N4 - NPK20:10:10 - 0 .2%
N5 - NPK30:10:10 - 0 .1% N6 - NPK30:10:10 - 0 .2%

4.1.2.1.1 Main effect of nutrients, frequency and growth regulators (Table 30)

Nutrient doses applied were found to influence the nitrogen content. Maximum nitrogen content of 1.58 per cent was found in plants receiving NPK 30:10:10 at 0.2 per cent, which was closely followed by NPK 30:10:10 at 0.1 per cent (1.44%). Nitrogen concentration was found to reduce with reduction in nutrient dose applied. Minimum nitrogen concentration of 1.11 per cent was found in the case of NPK 10:10:10 at 0.1 per cent.

Frequency of application was found to significantly influence nitrogen concentration. Application twice a week produced 1.91 per cent nitrogen, which was significantly above 0.73 per cent, seen in the case of weekly once application.

Nitrogen concentration in plant parts showed difference in response to different growth regulators. Highest nitrogen concentration was observed in the case of BA 200 ppm (1.39%) closely followed by 1.37 per cent in the case of BA 100 ppm, IAA 250 ppm and IAA 500 ppm. The lowest nitrogen concentration was detected in the case of GA_3 20 ppm (1.22%).

4.1.2.1.2 Interaction effects

Effect of interaction of nutrient doses and frequency of application was significant with respect to nitrogen concentration in plant parts. (Table 31). Highest nitrogen (2.23 %) was observed when NPK 30:10:10 at 0.2 per cent, combined with weekly twice application frequency, which was significantly superior compared to all the other treatments (Fig.3). In the case of weekly once application also NPK 30:10:10 at 0.2 per cent gave the highest nitrogen (0.93%) and lower level of the same nutrient ratio applied gave value on par with this (0.85%). Least nitrogen was observed in the case of NPK 10:10:10 at 0.1 per cent, combined with weekly once application (0.56%). In general, higher frequency (weekly twice) of application of lower nutrient concentration showed higher nitrogen content compared to lower frequency (weekly once) of higher concentration of nutrients.

Nitrogen concentration in aerial parts showed detectable differences in response to combination of nutrients and growth regulators applied (Table 32). Highest nitrogen content of 1.72 per cent was observed when IAA 250 ppm was applied in combination with 30:10:10 NPK at 0.2 per cent. BA 200 ppm, IAA 500 ppm and BA 100 ppm substituted in the same combination gave nitrogen content on par with the highest value (1.69%, 1.69% and 1.66%, respectively). When applied with lower ratio of nutrients NPK 10:10:10 at 0.1 and 0.2 per cent, none of the growth regulators had any significant influence with the nutrients applied. In the case of NPK 20:10:10, at both the levels, IAA 250 ppm gave the highest nitrogen content of 1.31 and 1.43 per cent, respectively. BA 200 ppm, BA 100 ppm and IAA 500 ppm substituted in the above combination produced results on par with it (1.30%, 1.30%, 1.25%, 1.43%, 1.37% and 1.38%, respectively). In the case of NPK 30:10:10 at 0.1 per cent, significant interactions were noticed with BA 200 ppm (1.57%) and IAA 500 ppm (1.53%), respectively. BA 100 ppm (1.48% N) and IAA 250 ppm (1.47% N) were on par with the above when applied along with the same nutrient dose.

Growth regulators in combination with frequency of nutrient application gave detectable differences in the case of nitrogen content (Table 33). Highest value was recorded in the combination with BA 200 ppm and weekly twice application of nutrients (2.04%). For weekly once application, IAA 500 ppm was found to produce more nitrogen (0.76%) in the plant. But significant differences did not exist between growth regulators in the combination.

Marked differences were observed in the combination of nutrients, frequency of application and growth regulators (Table 34). Highest value for nitrogen was obtained in the plants applied weekly twice with NPK 30:10:10 at 0.2

per cent and IAA 250 ppm (2.47%). When BA 200 ppm and BA 100 ppm were substituted in the above combination, nitrogen content observed in the plant was on par with the highest value. BA 100 ppm and BA 200 ppm combined with NPK 30:10:10 at 0.1 per cent and NPK 20:10:10 at 0.2 per cent applied weekly twice gave higher nitrogen in plant parts (2.27% and 2.09%, respectively). For weekly twice application, higher nitrogen was observed in combination with BA 100 ppm in the case of NPK 10:10:10 at 0.1 per cent and 0.2 per cent spray (1.77% and 1.82% N, respectively). For weekly once application of the same nutrient dose, marked difference due to growth regulators was not observed.

4.1.2.2 Phosphorus

Data on phosphorus concentration in the aerial parts of dendrobium in response to various treatments are presented in Tables 30 to 33 and 35.

4.1.2.2.1 Main effect of nutrients, frequency of application and growth regulators (Table 30)

Phosphorus concentration recorded in the aerial parts of dendrobium var. Sonia 17 differed markedly with nutrients applied. Highest content of phosphorus was recorded in NPK 10:10:10 at 0.1 per cent (0.38%) and NPK 30:10:10 at 0.2 per cent. NPK 20:10:10 at 0.2 per cent gave phosphorus (0.37%) on par with the highest. Minimum content recorded was 0.28 per cent in the case of NPK 20:10:10 at 0.1 per cent.

Frequency of application had significant effect on P content. Weekly twice application of nutrients gave distinctly superior P content of 0.46 per cent, compared to 0.14 per cent of weekly once application.

Growth regulators showed difference in influence on P content. BA 100 ppm showed the highest value of 0.39 per cent, which was significantly superior to all other growth regulator treatments. This was followed by IAA 500 ppm, which gave 0.35 per cent P. Least P content was recorded in the case of GA_3 20 ppm (0.26%). Plants, which were not treated with growth regulators, had 0.28 per cent P, which was similar to that observed in the case of GA_3 10 ppm.

4.1.2.2.2 Interaction effects

Detectable differences could be seen in P content of dendrobium due to nutrient concentrations combined with frequency of application (Table 31). In the case of weekly twice application of nutrients, nutrient level that gave maximum value for P (0.60%) was NPK 10:10:10 at 0.2 per cent (Fig.3). This was followed by NPK 30:10:10 at 0.1 per cent and 30:10:10 at 0.2 per cent (0.59% and 0.57%, respectively). For weekly once application NPK 20:10:10 at 0.2 per cent gave the highest P (0.24%). NPK 10:10:10 at 0.2 per cent and 0.1 per cent closely followed this (0.22% and 0.21%, respectively). Least P content was recorded in the case of NPK 20:10:10 at 0.1 per cent and NPK 30:10:10 at 0.1 per cent (0.13% and 0.15%, respectively). In general, higher frequency (weekly twice) of lower nutrient concentration produced higher P content compared to lower frequency (weekly once) at higher nutrient concentration.

Nutrients in combination with growth regulators gave significant differences in P content (Table 32). Highest P content was recorded in the case of IAA 500 ppm in combination with NPK 10:10:10 at 0.1 per cent (0.47%). NPK 30:10:10 at 0.2 per cent substituted in the combination gave P content on par with the above (0.43%). For NPK 20:10:10 at 0.2 per cent, IAA 250 ppm was found to produce more P (0.43%). Similar trend was present in the case of NPK 10:10:10 at 0.2 per cent also (0.40%). Least values (0.20%) were recorded in the case of GA_3 20 ppm, which was less than the combination of nutrients with no growth regulators used (NPK 10:10:10 at 0.1 and 0.2%).

In the combination of growth regulators and frequency of nutrient application marked influence could be observed (Table 33). IAA 500 ppm along with weekly twice nutrient application gave highest values for P (0.54%). For weekly once application of nutrients, that with no growth regulators gave highest P content (0.22%), which was closely followed by BA 100 ppm applied in combination (0.18%). Least recorded P was in the case of GA_3 10 and 20 ppm applied in combination with weekly once application of nutrients.

Interaction of nutrients, frequency and growth regulators was found significant in the case of P content (Table 35). Highest P was recorded in the combination of NPK 30:10:10 at 0.2 per cent with IAA 250 ppm sprayed weekly twice (0.66%), which was significantly superior to all other treatments. Least P was recorded in the case of combination with GA_3 10 and 20 ppm along with NPK 10:10:10 0.2 per cent applied weekly once (0.11%).

4.1.2.3 Potassium content

Data pertaining to potassium content in dendrobium var. Sonia 17 is presented in Tables 30 to 33 and 36.

4.1.2.3.1 Main effect of nutrients, application frequency and growth regulators (Table 30)

Potassium content showed detectable differences in response to nutrient doses applied. Highest concentration of K was recorded in the case of NPK 10:10:10 at 0.2 per cent (2.71%), closely followed by NPK 30:10:10 at 0.2 per cent (2.60%). Least concentration of K (2.04%) was recorded in the case of NPK 20:10:10 at 0.1 per cent.

Frequency of nutrient application had significant influence on K content. As the frequency increased, K content was found to increase (2.51%, as compared to 1.68% in the case of weekly once application).

Among the growth regulator treatments, highest K content was recorded in the case of IAA 250 ppm (2.62%), which was significantly superior to all other treatments. BA 100 ppm recorded 2.47 per cent K, which closely followed the superior one. Least K content was recorded in the case of treatment with no growth regulator (1.71%).

4.1.2.3.2 Interaction effects

Interaction was evident for nutrients and application frequencies with respect to K content in dendrobium (Table 31 and Fig.3). Highest concentration of K was recorded when NPK 30:10:10 at 0.1 per cent was applied twice weekly (3.11%), which was significantly superior compared to other combinations. NPK 10:10:10 at 0.2 per cent applied twice weekly closely followed (2.81%) the above. In the case of weekly once application, the K content was found to increase when 30:10:10 NPK at 0.2 per cent was applied (1.79%). Lowest K content of 1.51% was recorded in the case of NPK 10:10:10 at 0.1%, applied weekly once.

In general, the K content was higher for higher frequency (weekly twice) of lower concentration of nutrients compared to lower frequency (weekly once) of higher concentration of nutrients.

Combinations of nutrients and growth regulators were also found to influence the K content in dendrobium var. Sonia 17 (Table 32). Maximum K content was produced when IAA 500 ppm was used in combination with NPK 30:10:10 at 0.2 per cent (2.96%). IAA 250 ppm, BA 100 ppm and BA 200 ppm substituted in the combination gave K content on par with this (2.93%, 2.93% and

2.81%, respectively). Lowest K content of 1.40 per cent was recorded in plants that received NPK 10:10:10 at 0.1 per cent and no growth regulators.

Detectable differences were observed in response to different combinations of growth regulators and frequencies of application of nutrients in K content. (Table 33). In general growth regulator effect was more pronounced in the case of plants fed with nutrients twice weekly. Maximum K content of 2.99 per cent was observed when IAA 500 ppm was applied. IAA 250 ppm, BA 200 ppm and BA 100 ppm recorded 2.88 per cent, 2.74 per cent and 2.69 per cent potassium, respectively, which were on par with the highest content. Least K content of 1.25 per cent was observed in the case of weekly once fertilized plants supplied with GA_3 at 20 ppm and GA_3 at 10 ppm (1.60% and 1.61%, respectively).

Interaction was evident in the case of nutrients, growth regulators and frequency of application (Table 36). Maximum values for K recorded was 4.00 per cent when IAA 250 ppm along with NPK 30:10:10 at 0.2 per cent was applied weekly twice. IAA 500 ppm substituted in the above combination gave 3.98 per cent K, which was on par with the above.

4.1.2.4 Calcium content

Data pertaining to content of calcium in dendrobium var. Sonia 17 as influenced by various treatments and their combinations are presented in Tables 30 to 33

4.1.2.4.1 Main effect of nutrients, frequency of application and growth regulators (Table 30)

Among the nutrients applied, highest content was recorded in the case of NPK 30:10:10 at 0.2 per cent (2.83%) followed by 2.63 per cent observed in NPK 20:10:10 at 0.2 per cent. NPK 30:10:10 at 0.1 per cent also recorded 2.52 per cent

Ca, which was on par with the above. Least calcium content was seen in plants treated with NPK 10:10:10 at 0.1 per cent (1.67%).

Calcium content was also found to increase with increase in frequency of application of nutrients. A calcium content of 3.66 per cent was recorded when nutrients were given twice a week, which was significantly superior to 0.78 per cent observed when application was done only once a week.

Among the growth regulators tried, BA 200 ppm treated plants contained 2.86 per cent calcium, which was significantly superior to all other treatments. Least content of Ca was recorded in the case of GA_3 20 ppm (1.84%).

4.1.2.4.2 Interaction effects

Highest Ca content was detected when NPK 30:10:10 at 0.2 per cent was applied twice a week (4.74%), which was significantly superior to all other combinations (Table 31 and Fig.3). In the case of weekly once application also NPK 30:10:10 at 0.2 per cent gave the highest content of 0.93 per cent.

In combination with 30:10:10 NPK at 0.2 per cent, IAA 500 ppm gave the highest Ca content of 3.63 per cent, which was closely followed by 3.58 per cent when IAA 250 ppm was used (Table 32). Similar effects were recorded by IAA 500 and 250 ppm with other nutrient ratios also (3.41%, 3.31%, 1.92% and 1.87%, respectively, with NPK 20:10:10 and 10:10:10 at 0.2 per cent). In general, Ca content was higher for higher frequency (weekly twice) of lower concentration of nutrients compared to lower frequency (weekly once) of higher concentration of nutrients.

Combination of IAA with weekly twice application of nutrients excelled all other combinations (4.42% and 4.35%, respectively, for IAA 500 and 250 ppm) for Ca content (Table 33). In the case of weekly once application of nutrients IAA

500 ppm recorded highest Ca content of 0.87 per cent. Lowest Ca content of 0.69 per cent was observed in plants which received weekly once application of nutrients and no growth regulators.

4.1.2.5 Magnesium content

Data pertaining to Magnesium concentration in dendrobium var. Sonia 17 as influenced by various treatments and treatment combinations are presented in Tables 30 to 33

4.1.2.5.1 Main effect of nutrients, frequency of application and growth regulators (Table 30)

Magnesium content showed detectable differences with nutrients, their frequencies and growth regulators applied.

Highest content of 0.85 per cent was recorded in the case of NPK 30:10:10 at 0.2 per cent, which was significantly superior, compared to other nutrient concentrations. Least Mg content was observed in the case of NPK 10:10:10 at 0.1 per cent (0.59%).

Magnesium content was significantly high (1.10%) when nutrients were applied twice weekly, compared to 0.31 per cent when application was done only once a week.

Response of dendrobium to different growth regulator treatments was detectably different in terms of Mg content. IAA 250 ppm recorded highest Magnesium content of 0.96 per cent, which was significantly superior to other treatments. BA 200 ppm gave the next best Mg content of 0.86 per cent. Mg content was least (0.55%) in treatment having no growth regulator.

4.1.2.5.2 Interaction effects

Mg content was found to be significantly different with different treatment combinations of nutrients and frequency of application (Table 30). For weekly twice application, NPK 30:10:10 at 0.1 per cent was found to be superior(Ca content of 1.42%). Weekly once application of NPK 30:10:10 at 0.2 per cent gave highest Mg content of 0.39 per cent. In general, the Mg content was higher for higher frequency (weekly twice) of lower concentration of nutrients compared to lower frequency (weekly once) of higher concentration of nutrients.

In the case of combinations of nutrients and growth regulators highest Mg content of 1.06 per cent was recorded in the combined influence of BA 200 ppm and NPK 30:10:10 at 0.2 per cent (Table 32). Combination of NPK 20:10:10 at 0.2 per cent also gave high value for Mg when treated with BA 200 ppm (1.04%). In the case of combinations with lower nutrient concentrations, viz., NPK 10:10:10 at 0.1 and 0.2 per cent and NPK 20:10:10 at 0.1 per cent along with IAA 500 ppm gave the highest content of Mg (0.67%, 0.76% and 0.79%, respectively).

Plants showed greatest response in the case of Mg content (1.37%) for weekly twice application of nutrients and BA 200 ppm (Table 33), whereas least content was observed in the case of control for growth regulator.

4.1.2.6 Copper content

Data pertaining to concentration of copper in the aerial parts of dendrobium var. Sonia 17 as influenced by various treatments and their combinations are presented in Tables 37 to 40

Table 30. Concentration of major nutrients (%) in dendrobium var. Sonia 17 as influenced by nutrients (concentration and frequency of application) and growth regulators

Treatments	N	P	K	Ca	Mg
Nutrients					
NPK 10:10:10 - 0.1%	1.11	0.38	2.59	1.67	0.59
NPK 10:10:10 - 0.2%	1.18	0.36	2.71	1.78	0.63
NPK 20:20:10 - 0.1%	1.24	0.28	2.04	1.88	0.67
NPK 20:20:10 - 0.2%	1.34	0.37	2.17	2.63	0.76
NPK 30:10:10 - 0.1%	1.44	0.34	2.42	2.52	0.73
NPK 30:10:10 - 0.2%	1.58	0.38	2.60	2.83	0.85
CD(0.05)	0.029	0.03	0.084	0.693	0.050
SEm ±	0.010	0.01	0.029	0.025	0.018
Frequency					
Weekly twice	1.91	0.46	2.51	3.66	1.10
Weekly once	0.73	0.14	1.68	0.78	0.31
CD (0.05)	0.168	0.02	0.048	0.039	0.031
SEm ±	0.006	0.01	0.017	0.014	0.011
Growth regulators					
Control	1.25	0.28	1.71	1.87	0.55
BA 100 ppm	1.37	0.39	2.47	2.34	0.80
BA 200 ppm	1.39	0.31	2.23	2.86	0.86
GA_3 10 ppm	1.25	0.28	1.89	1.89	0.58
GA_3 20 ppm	1.22	0.26	1.93	1.84	0.63
IAA 250 ppm	1.37	0.33	2.62	2.59	0.96
IAA 500 ppm	1.37	0.35	2.40	2.65	0.75
CD (0.05)	0.031	0.03	0.091	0.075	0.054
SEm ±	0.011	0.01	0.032	0.027	0.019

Table 31. Concentration of major nutrients (%) in dendrobium var. Sonia 17 as influenced by combinations of nutrient concentration and frequency of application

Treatments	N		P		K		Ca		Mg	
	W1	W2	W1	W2	W1	W2	W1	W2	W1	W2
NPK10:10:10 - 0.1%	0.56	1.66	0.21	0.35	1.57	1.61	0.63	2.71	0.22	0.96
NPK10:10:10 - 0 .2%	0.60	1.76	0.22	0.60	1.62	2.81	0.70	2.86	0.24	1.01
NPK20:10:10 - 0 .1%	0.67	1.81	0.13	0.43	1.66	2.41	0.74	3.01	0.29	1.05
NPK20:10:10 - 0 .2%	0.76	1.92	0.24	0.48	1.70	2.64	0.78	4.48	0.36	1.16
NPK30:10:10 - 0 .1%	0.85	2.04	0.15	0.59	1.73	3.11	0.88	4.15	0.34	1.42
NPK30:10:10 - 0 .2%	0.93	2.23	0.18	0.57	1.79	2.45	0.93	4.74	0.39	1.31
CD(0.05)	0.041		0.041		0.119		0.098		0.071	
SEm ±	0.015		0.014		0.042		0.035		0.025	

W1 - Weekly once
W2 - Weekly twice

Table 32. Concentration of major nutrients (%) in dendrobium var. Sonia 17 as influenced by combinations of nutrient concentration and growth regulators

Treatments	Concentration of nutrients (%)				
	N	P	K	Ca	Mg
N_1G_0	1.08	0.21	1.40	1.29	0.43
N_1G_1	1.16	0.27	1.73	1.71	0.65
N_1G_2	1.15	0.35	1.50	1.81	0.67
N_1G_3	1.09	0.22	1.53	1.55	0.51
N_1G_4	1.07	0.20	1.55	1.48	0.53
N_1G_5	1.11	0.30	1.64	1.89	0.66
N_1G_6	1.14	0.47	1.81	1.98	0.67
N_2G_0	1.14	0.23	1.55	1.81	0.49
N_2G_1	1.21	0.26	1.66	1.79	0.70
N_2G_2	1.21	0.27	1.80	1.78	0.73
N_2G_3	1.20	0.23	1.57	1.69	0.62
N_2G_4	1.12	0.20	1.62	1.63	0.56
N_2G_5	1.20	0.40	1.84	1.87	0.60
N_3G_6	1.19	0.39	1.94	1.92	0.76
N_3G_0	1.17	0.27	1.64	1.84	0.55
N_3G_1	1.30	0.28	2.10	1.91	0.76
N_3G_2	1.30	0.38	2.22	1.97	0.78
N_3G_3	1.20	0.26	1.78	1.79	0.57
N_3G_4	1.15	0.24	1.85	1.79	0.56
N_3G_5	1.31	0.29	2.30	1.91	0.73
N_3G_6	1.25	0.32	2.38	1.95	0.79
N_4G_0	1.28	0.37	1.72	1.92	0.58
N_4G_1	1.37	0.30	2.35	2.93	0.88
N_4G_2	1.43	0.32	2.43	2.90	1.04
N_4G_3	1.25	0.27	1.82	1.95	0.61

Contd.

Table 32. Continued

Treatments	N	P	K	Ca	Mg
N_4G_4	1.25	0.28	1.94	1.98	0.63
N_4G_5	1.43	0.43	2.44	3.31	0.76
N_4G_6	1.38	0.36	2.52	3.41	0.78
N_5G_0	1.36	0.32	1.90	2.14	0.60
N_5G_1	1.48	0.38	2.46	2.62	0.88
N_5G_2	1.57	0.36	2.63	2.65	0.88
N_5G_3	1.34	0.29	2.25	2.12	0.62
N_5G_4	1.34	0.32	2.18	2.09	0.65
N_5G_5	1.47	0.39	2.76	3.00	0.75
N_5G_6	1.53	0.40	2.78	2.99	0.77
N_6G_0	1.46	0.36	2.67	2.21	0.62
N_6G_1	1.66	0.39	2.93	3.05	0.98
N_6G_2	1.69	0.39	2.81	3.07	1.06
N_6G_3	1.42	0.32	2.38	2.24	0.64
N_6G_4	1.43	0.32	2.46	2.06	0.86
N_6G_5	1.72	0.43	2.93	3.58	0.96
N_6G_6	1.69	0.43	2.96	3.63	0.81
CD(0.05)	0.077	0.077	0.222	0.183	0.133
SEm	0.027	0.027	0.079	0.065	0.047

N_1 - NPK 10:10:10 - 0.1%
N_2 - NPK 10:10:10 - 0.2%
N_3 - NPK 20:10:10 - 0.1%
N_4 - NPK 20:10:10 - 0.2%
N_5 - NPK 30:10:10 - 0.1%
N_6 - NPK 30:10:10 - 0.2%

G_0 - Control
G_1 - BA 100 ppm
G_2 - BA 200 ppm
G_3 - GA_3 10 ppm
G_4 - GA_3 20 ppm
G_5 - IAA 250 ppm
G_6 - IAA 500 ppm

Table 33. Concentration of major nutrients (%) in dendrobium var. Sonia 17 as influenced by combinations of growth regulators and frequency of nutrient application

Treatments	N		P		K		Ca		Mg	
	W1	W2	W1	W2	W1	W2	W1	W2	W1	W2
Control	0.70	1.80	1.60	0.44	1.60	1.82	0.69	3.04	0.24	1.85
BA 100ppm	0.73	2.00	1.66	0.45	1.66	2.69	0.77	3.90	0.30	1.30
BA 200ppm	0.74	2.04	1.72	0.50	1.72	2.74	0.80	3.93	0.36	1.37
GA_3 10ppm	0.72	1.79	1.61	0.40	1.61	2.17	0.73	3.05	0.26	0.90
GA_3 20ppm	0.70	1.74	1.60	0.39	1.60	2.26	0.73	2.94	0.27	1.00
IAA 250ppm	0.75	2.00	1.76	0.52	1.76	2.88	0.83	4.35	0.38	1.14
IAA 500ppm	0.76	1.97	1.80	0.54	1.80	2.99	0.87	4.42	0.34	1.15
CD(0.05)	0.445		0.044		0.128		0.106		0.077	
SEm ±	0.015		0.016		0.046		0.038		0.027	

W1 - Weekly once
W2 - Weekly twice

Table 34. Nitrogen content (%) in dendrobium var. Sonia 17 as influenced by combinations of nutrients (concentration and frequency) and growth regulators

Growth regulators	Nutrients											
	N1		N2		N3		N4		N5		N6	
	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice
Control	0.56	1.61	0.59	1.68	0.63	1.71	0.71	1.84	0.79	1.93	0.88	2.04
BA 100 ppm	0.56	1.77	0.60	1.82	0.68	1.93	0.77	1.98	0.86	2.11	0.92	2.40
BA 200 ppm	0.58	1.73	0.61	1.82	0.69	1.91	0.78	2.09	0.87	2.27	0.93	2.45
GA_3 10 ppm	0.56	1.62	0.59	1.81	0.65	1.74	0.75	1.75	0.83	1.86	0.91	1.94
GA_3 20 ppm	0.55	1.58	0.59	1.65	0.63	1.67	0.74	1.77	0.81	1.87	0.90	1.93
IAA 250 ppm	0.57	1.65	0.62	1.79	0.69	1.94	0.78	2.07	0.87	2.09	0.96	2.47
IAA 500 ppm	0.57	1.71	0.62	1.77	0.70	1.84	0.79	1.98	0.92	2.15	0.98	2.41
CD(0.05)	0.109											
SEm±	0.039											

N1 – NPK 10:10:10 – 0.1%   N2 – NPK 10:10:10 – 0.2%
N3 – NPK 20:10:10 – 0.1%   N4 – NPK 20:10:10 – 0.2%
N5 – NPK 30:10:10 – 0.1%   N6 – NPK 30:10:10 – 0.2%

Table 35. Phosphorus content (%) in dendrobium var. Sonia 17 as influenced by combinations of nutrients (concentration and frequency) and growth regulators

Growth regulators	Nutrients											
	N1		N2		N3		N4		N5		N6	
	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice
Control	0.41	0.31	0.41	0.36	0.12	0.42	0.13	0.49	0.13	0.52	0.15	0.57
BA 100 ppm	0.41	0.52	0.92	0.40	0.43	0.43	0.44	0.46	0.15	0.52	0.17	0.60
BA 200 ppm	0.42	0.58	0.42	0.41	0.43	0.44	0.14	0.51	0.45	0.57	0.52	0.56
GA_3 10 ppm	0.41	0.33	0.11	0.36	0.42	0.40	0.12	0.42	0.14	0.44	0.16	0.48
GA_3 20 ppm	0.42	0.58	0.11	0.28	0.42	0.37	0.13	0.44	0.13	0.50	0.16	0.49
IAA 250 ppm	0.42	0.43	0.43	0.47	0.14	0.45	0.45	0.51	0.47	0.61	0.46	0.66
IAA 500 ppm	0.42	0.41	0.43	0.52	0.14	0.49	0.16	0.57	0.48	0.62	0.52	0.69
CD(0.05)	0.109											
SEm±	0.039											

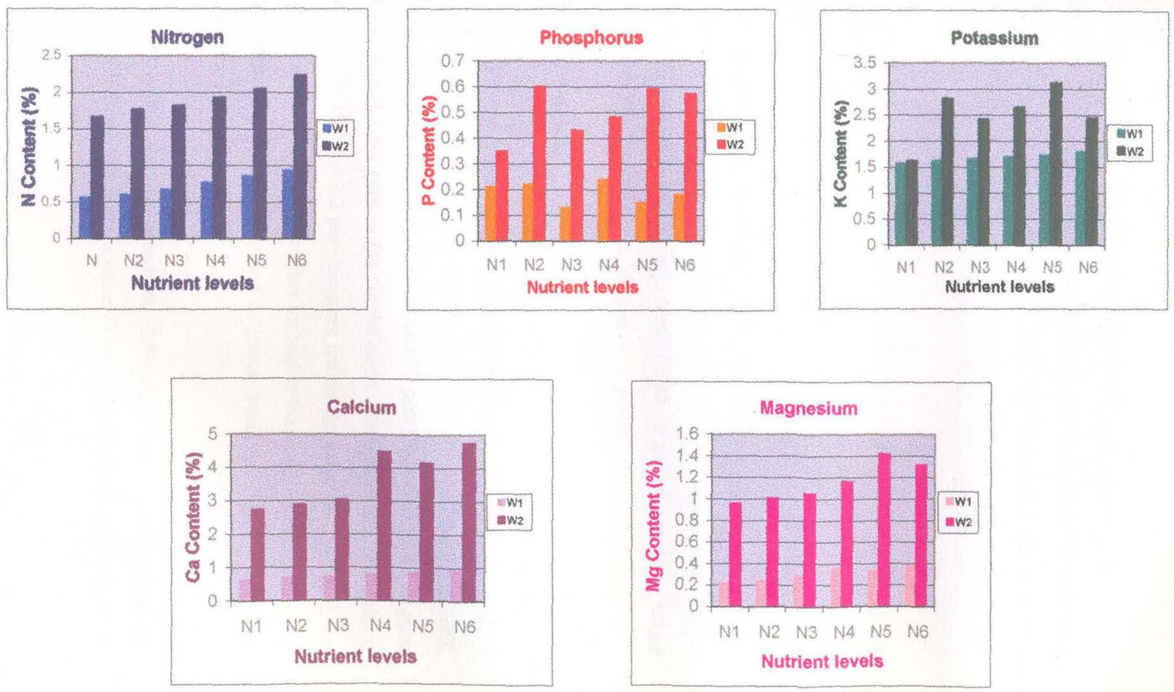
N1 – NPK 10:10:10 – 0.1% N2 – NPK 10:10:10 – 0.2%
N3 – NPK 20:10:10 – 0.1% N4 – NPK 20:10:10 – 0.2%
N5 – NPK 30:10:10 – 0.1% N6 – NPK 30:10:10 – 0.2%

Table 36. Potassium content (%) in dendrobium var. Sonia 17 as influenced by combinations of nutrients (concentration and frequency) and growth regulators

Growth regulators	Nutrients											
	N1		N2		N3		N4		N5		N6	
	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice
Control	1.52	1.29	1.58	1.52	1.59	1.68	1.61	1.82	1.65	2.15	1.68	2.46
BA 100 ppm	1.54	1.92	1.61	1.72	1.62	2.58	1.68	3.02	1.74	3.19	1.76	3.70
BA 200 ppm	1.61	1.38	1.68	1.92	1.65	2.78	1.76	3.10	1.77	3.50	1.84	3.78
GA_3 10 ppm	1.51	1.55	1.53	1.62	1.61	1.95	1.62	2.02	1.68	2.82	1.71	3.04
GA_3 20 ppm	1.52	1.54	1.52	1.72	1.61	2.08	1.60	2.28	1.66	2.70	1.71	3.22
IAA 250 ppm	1.64	1.64	1.68	2.00	1.75	2.85	1.80	3.08	1.80	3.72	1.87	4.00
IAA 500 ppm	1.66	1.96	1.75	2.14	1.78	2.98	1.84	3.19	1.86	3.70	1.95	3.98
CD(0.05)	0.314											
SEm±	0.111											

N1 – NPK 10:10:10 – 0.1% N2 – NPK 10:10:10 – 0.2%
N3 – NPK 20:10:10 – 0.1% N4 – NPK 20:10:10 – 0.2%
N5 – NPK 30:10:10 – 0.1% N6 – NPK 30:10:10 – 0.2%

Fig. 3. Content of major nutrients (%) in dendrobium var. Sonia 17 as influenced by nutrient levels and frequency of application



4.1.2.6.1 Main effect of nutrients, frequency of application and growth regulators (Table 37)

Among the nutrients applied, NPK 20:10:10 at 0.2 per cent was found to be superior in terms of copper content (16.68 ppm), closely followed by a content of 15.54 ppm detected in plants sprayed with NPK 10:10:10 at 0.2 per cent. Least recorded value for copper was 8.29 ppm in plants sprayed with NPK 20:10:10 at 0.1 per cent.

Copper was found in appreciably higher quantities in the case of plants sprayed twice a week (15.17 ppm) compared to 6.94 ppm recorded in the weekly once application.

Among growth regulators IAA 500 ppm treated plants had the highest content of copper (16.42 ppm) followed by 250 ppm IAA (13.8 ppm). Least copper content (7.88 ppm) was recorded in plants treated with no growth regulator, which was also recorded in the case of GA_3 at 20 ppm (7.92 ppm).

4.1.2.6.2 Interaction effects

Interaction was evident between nutrients and frequency of application (Table 38). Maximum value for copper content was seen in the combination of NPK 30:10:10 at 0.1 per cent applied weekly twice (20.57 ppm) followed by 13.40 ppm for NPK 20:10:10 at 0.2 per cent in the combination. For application of nutrients weekly once, NPK 30:10:10 at 0.2 per cent gave maximum value of 12.43 ppm for copper. In general the Cu content was higher for higher frequency (weekly twice) of lower concentration of nutrients compared to lower frequency (weekly once) of higher concentration of nutrients.

Copper content showed detectable differences when combinations of nutrients and growth regulators were applied (Table 39). Highest value recorded was 25.50 ppm for BA 200 ppm, applied along with NPK 30:10:10 at 0.2 per cent. Copper content observed in the plants given IAA 250 ppm, IAA 500 ppm and BA 100 ppm in the combination gave 25.00 ppm, 24.00 ppm and 23.50 ppm copper, which were on par with the former. Least copper content of 3.00 ppm was observed when combination of NPK 10:10:10 at 0.1 per cent with BA 100 ppm, GA 20 ppm and growth regulator control was applied. Highest copper content of 23.17 ppm was recorded in plants, which received nutrients weekly twice and IAA 500 ppm. Lowest content of 5.08 ppm was observed in the case of weekly once application nutrients and growth regulator control (Table 40).

4.1.2.7 Iron content

Data pertaining to iron content in aerial parts of dendrobium var. Sonia 17 as influenced by treatments and their combinations are presented in Tables 37 to 40

4.1.2.7.1 Main effect of nutrients, frequency of application and growth regulators (Table 37)

Iron content was found to vary with varying nutrient concentrations applied. NPK 10:10:10 at 0.1 per cent gave maximum iron content of 882 ppm which was significantly superior to other nutrient doses. Minimum iron content 422 ppm was recorded in the case of NPK 10:10:10 at 0.2 per cent.

Weekly twice application of nutrients gave noticeably higher amounts of Fe (520 ppm) compared to weekly once treatment (428 ppm).

Among the growth regulators tried, IAA 500 ppm gave the highest iron content (610 ppm). Least quantity of Fe was reported in treatment with no growth regulator (386 ppm).

4.1.2.7.2 Effect of treatment combinations

Highest iron content of 574 ppm was observed when NPK 30:10:10 at 0.1 per cent was applied twice a week (Table 38 and Fig. 4). In general, the Fe content was higher for higher frequency (weekly twice) of lower concentration of nutrients, compared to lower frequency (weekly once) of higher concentration of nutrients.

For nutrients and growth regulators in combination, iron content observed was highest (872 ppm) for IAA 500 ppm, applied with NPK 30:10:10 at 0.2 per cent, followed by IAA 250 with the same nutrient concentration giving 809 ppm iron (Table 39). Least content of iron (323 ppm) was observed in the case of NPK 10:10:10 at 0.1 per cent without growth regulators. GA_3, both at 10 ppm and 20 ppm, were not found to enhance iron content with any of the nutrient concentrations applied.

Iron content was found to vary with growth regulator when applied along with different frequencies of nutrient application (Table 40). Highest iron was recorded in IAA 500 ppm applied plants (659 ppm) in the case of weekly twice application of nutrients, followed by 632 ppm in the case of IAA 250 ppm in the above combination, which were on par. In the case of weekly once application of nutrients, highest iron content (418 ppm) was observed in the case of BA 200 ppm, followed by 397 ppm in the case of BA 100 ppm. Least iron content was recorded when IAA 250 ppm was combined with weekly once application of nutrients (338 ppm).

4.1.2.8 Zinc content

Data pertaining to zinc content in the aerial parts of dendrobium var. Sonia 17 are presented in Tables 37 to 40.

4.1.2.8.1 Main effect of nutrients, growth regulators and frequency of application

Among the different nutrient doses studied NPK 10:10:10 at 0.1 per cent was observed to give maximum zinc content of 482 ppm, followed by NPK 30:10:10 at 0.1 per cent recording 389 ppm. Minimum zinc content (210 ppm) was recorded in the plant fertilized with NPK 20:10:10 at 0.2 per cent.

Zinc content was found in significantly higher levels of 281 ppm when nutrient application was twice a week compared to 232 ppm when application was once a week.

Among the different growth regulators tried, maximum zinc (291 ppm) was found to be recorded in the case of IAA 500 ppm, closely followed by BA 200 ppm (289 ppm Zn) and IAA 250 ppm (283 ppm Zn). Least recorded value was in plants supplied with GA_3 20 ppm (222 ppm).

4.1.2.8.2 Effect of treatment combinations

In the combination of nutrients and frequency of application, weekly twice application with NPK 30:10:10 at 0.2 per cent excelled in terms of Zn content (371 ppm) which was significantly superior to other treatments (Table 38 and Fig. 4). Least value was recorded in plants fertilized weekly once using NPK 20:10:10 at 0.2 per cent (189 ppm). In the combination of nutrients and growth regulators, BA 200 ppm combined with NPK 30:10:10 at 0.2 per cent gave maximum Zn concentration of 416 ppm (Table 39). Significant differences were seen only when lower concentration of nutrients were applied in the combination. Minimum Zn content of 107 ppm was recorded in the case of NPK 10:10:10 0.1 per cent, applied with no growth regulator. Effect of growth regulators was significantly different when applied with different frequencies of nutrient application (Table 40). With weekly twice application of nutrients IAA 500 ppm gave 313 ppm Zn, which was the maximum recorded value followed by 312 ppm in the case of BA 200 ppm in the combination. For weekly once spraying GA_3 20 ppm recorded the maximum Zn content of 281 ppm. Lowest Zn content (175 ppm) was observed in the case of growth regulator control.

4.1.2.9 Manganese content

Data pertaining to content of Mn in the plant parts of dendrobium var. Sonia 17 are presented in Table 37 to 40

4.1.2.9.1 Main effect of nutrients, frequency of application and growth regulators (Table 37)

Manganese content was found to increase with the increase in nutrient dose applied. Maximum content of 801 ppm was recorded in plants which received NPK 30:10:10 at 0.2 per cent which was significantly superior to all other treatments. NPK 10:10:10 at 0.1 per cent recorded the lowest Mn content of 148 ppm.

Weekly twice application of nutrients recorded significantly higher Mn content of 700 ppm, compared to 110 ppm detected in plants receiving nutrients weekly once.

Among the growth regulators tried, IAA 500 ppm gave the highest Mn content of 479 ppm. IAA 250 ppm and BA 200 ppm recorded values on par with it (477 ppm and 439 ppm, respectively).

4.1.2.9.2 Interaction effects

NPK 30:10:10 at 0.2 per cent applied weekly twice recorded highest Mn content of 956 ppm (Table 38 and Fig. 4). NPK 30:10:10 at 0.1 per cent recorded 927 ppm Mn, which was on par with the above. Lowest Mn content of 76 ppm was recorded in the case of NPK 10:10:10 at 0.1 per cent, applied weekly once. In general, the Mn content was higher for higher frequency (weekly twice) of lower concentration of nutrients, compared to lower frequency (weekly once) of higher concentration of nutrients. Plants, which received IAA 250 ppm and nutrients weekly twice, were found to have the highest Mn content of 837 ppm. IAA 500 ppm substituted in the above combination recorded 830 ppm of Mn which was on par with the above.

Among the combination of nutrients and growth regulators, maximum Mn content observed was 983 ppm in the plants which received NPK 30:10:10 at 0.2 per cent and IAA 500 ppm (Table 39). IAA 250 ppm and BA 200 ppm along with the same nutrient concentration gave values for Mn content on par with the superior one (948 ppm and 821 ppm, respectively).

4.1.3 Uptake of major nutrients

4.1.3.1 Uptake of Nitrogen

Data pertaining to nitrogen uptake as influenced by various treatments and their combinations are presented in Table 41 to 44.

4.1.3.1.1 Main effect of nutrients, frequency and growth regulators

Nitrogen uptake was found to be influenced significantly by nutrient doses applied. With increase in nitrogen applied uptake was found to increase significantly. NPK 30:10:10 at 0.2 per cent excelled all other treatments with respect to nitrogen uptake (9.62 g).

Nitrogen uptake in plants applied twice weekly with nutrients recorded an uptake of 9.93 g, which was significantly superior to that in plants applied with nutrients weekly once (2.11 g).

Among the growth regulator treatments also significant differences were recorded with respect to nitrogen uptake. Highest value recorded was 6.20 g for BA

Table 37. Concentration of micronutrients (ppm) in dendrobium var. Sonia 17 as influenced by nutrients (concentration and frequency of application) and growth regulators

Treatments	Cu	Fe	Zn	Mn
Nutrients				
NPK 10:10:10 - 0.1%	13.92	882	482	148
NPK 10:10:10 - 0.2%	15.54	422	235	238
NPK 20:10:10 - 0.1%	8.29	431	258	285
NPK 20:10:10 - 0.2%	16.68	476	210	426
NPK 30:10:10 - 0.1%	15.39	524	389	523
NPK 30:10:10 - 0.2%	12.50	608	344	801
CD(0.05	0.708	13.95	13.90	6.7
SEm ±	0.273	4.96	4.94	2.4
Frequency				
Weekly twice	15.17	520	281	700
Weekly once	6.94	428	232	110
CD(0.05)	0.442	8.01	7.98	3.9
SEm ±	0.158	2.86	2.85	1.4
Growth regulators				
Control	7.88	386	268	270
BA 100 ppm	10.58	443	270	405
BA 200 ppm	12.08	464	289	439
GA_3 10 ppm	8.75	424	233	355
GA_3 20 ppm	7.92	405	222	401
IAA 250 ppm	13.75	585	283	477
IAA 500 ppm	16.42	610	291	479
CD(0.05)	0.830	15.1	15.02	7.3
SEm ±	0.295	5.4	5.34	2.6

Table 38. Concentration of micronutrients (ppm) in dendrobium var. Sonia 17 as influenced by combinations of nutrient concentration and frequency of application

Treatments	Cu		Fe		Zn		Mn	
	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice
NPK10:10:10 - 0.1%	2.29	5.57	335	429	256	208	76	221
NPK10:10:10 - 0 .2%	3.50	7.57	383	460	271	260	133	344
NPK20:10:10 - 0 .1%	5.20	11.29	380	483	232	285	94	475
NPK20:10:10 - 0 .2%	7.93	13.40	425	526	189	231	105	747
NPK30:10:10 - 0 .1%	10.21	20.57	474	574	284	334	119	927
NPK30:10:10 - 0 .2%	12.43	12.57	547	547	347	371	146	956
CD(0.05)	1.086		49.73		19.66		0.095	
SEm±	0.386		17.02		6.99		0.034	

Table 39. Concentration of micronutrients (ppm) in dendrobium var. Sonia 17 as influenced by combinations of nutrient concentration and growth regulators

Treatments	Concentration of nutrients (ppm)			
	Cu	Fe	Zn	Mn
N_1G_0	3.00	323	107	103
N_1G_1	3.00	349	194	140
N_1G_2	4.25	364	206	159
N_1G_3	3.50	359	166	096
N_1G_4	3.00	349	151	176
N_1G_5	5.00	465	219	178
N_1G_6	5.75	466	233	189
N_2G_0	4.50	352	153	184
N_2G_1	5.25	425	212	201
N_2G_2	5.75	424	237	373
N_2G_3	4.50	388	229	182
N_2G_4	4.25	369	205	217
N_2G_5	6.50	490	301	250
N_3G_6	8.00	505	312	260
N_3G_0	7.25	355	192	207
N_3G_1	7.75	395	260	249
N_3G_2	8.50	489	279	256
N_3G_3	6.75	396	271	251
N_3G_4	5.75	380	281	320
N_3G_5	10.50	522	251	391
N_3G_6	11.50	533	273	319
N_4G_0	8.00	384	240	243
N_4G_1	10.00	434	252	489
N_4G_2	11.50	466	265	489
N_4G_3	8.50	431	171	362

Contd

Table 39. Continued

Treatments	Cu	Fe	Zn	Mn
N_4G_4	7.50	414	170	373
N_4G_5	13.50	587	185	514
N_4G_6	15.75	614	190	514
N_5G_0	10.50	406	252	287
N_5G_1	14.00	502	324	575
N_5G_2	17.00	516	329	536
N_5G_3	12.25	478	293	465
N_5G_4	11.50	459	269	662
N_5G_5	9.00	637	350	580
N_5G_6	23.50	670	345	558
N_6G_0	14.00	494	302	594
N_6G_1	23.50	552	378	779
N_6G_2	25.50	476	416	821
N_6G_3	17.00	493	371	775
N_6G_4	15.50	461	358	660
N_6G_5	28.00	809	391	948
N_6G_6	24.00	872	394	983
CD(0.05)	2.032	36.9	36.78	17.8
SEm	0.723	13.1	13.08	6.3

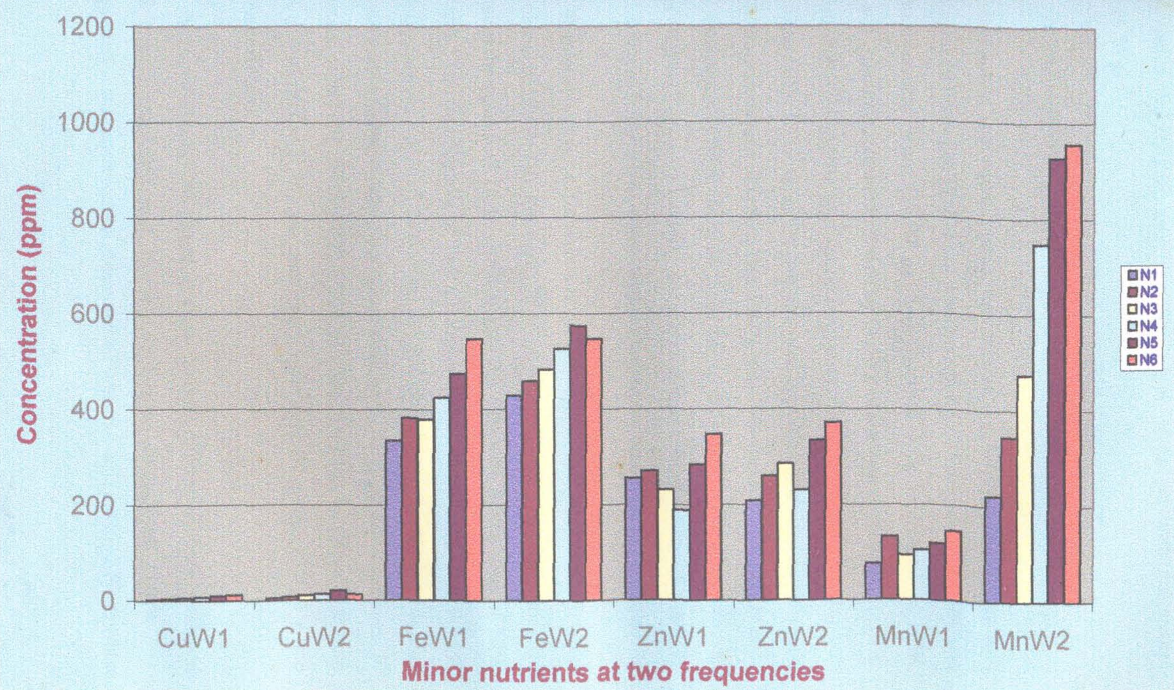
N_1 - NPK 10:10:10 - 0.1%
N_2 - NPK 10:10:10 - 0.2%
N_3 - NPK 20:10:10 - 0.1%
N_4 - NPK 20:10:10 - 0.2%
N_5 - NPK 30:10:10 - 0.1%
N_6 - NPK 30:10:10 - 0.2%

G_0 - Control
G_1 - BA 100 ppm
G_2 - BA 200 ppm
G_3 - GA_3 10 ppm
G_4 - GA_3 20 ppm
G_5 - IAA 250 ppm
G_6 - IAA 500 ppm

Table 40. Concentration of micronutrients (ppm) in dendrobium var. Sonia 17 as influenced by combinations of growth regulators and frequency of nutrient application

Treatments	Cu		Fe		Zn		Mn	
	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice
Control	5.08	10.67	348	423	175	240	91	448
BA 100ppm	6.67	14.50	397	488	249	292	100	710
BA 200ppm	7.33	16.83	418	570	266	312	166	712
GA_3 10ppm	5.83	11.67	376	472	263	263	92	618
GA_3 20ppm	5.67	10.17	356	454	281	243	92	711
IAA 250ppm	8.33	19.17	338	632	258	308	116	837
IAA 500ppm	9.67	23.17	360	659	269	313	127	830
CD(0.05)	1.173		21.30		21.20		0.103	
SEm±	0.417		7.60		7.60		0.037	

Fig. 4. Concentration of minor nutrients (ppm) in dendrobium var. Sonia 17, as influenced by nutrients and frequency of application



200 ppm, followed by BA 100 ppm, which gave an uptake of 5.86 g. Minimum value was shown by GA_3 20 ppm (4.61 g) which is on par with the control treatment (4.56 g).

4.1.3.1.2 Interaction effects

Interaction was significant in nutrients and application frequencies with respect to uptake of nitrogen (Table 42). Highest uptake of nitrogen, when nutrients were applied weekly twice (16.79 g), was observed with application of NPK 20:10:10 at 0.2 per cent, closely followed by 16.50 g in the case of NPK 30:10:10 at 0.2 per cent. For weekly once application frequency, nitrogen uptake of 4.45 g was recorded when NPK 30:10:10 at 0.2 per cent was applied, which was significantly superior. Minimum uptake of 0.94 g and 5.63 g was recorded for both weekly once and twice application of NPK 10:10:10 at 0.1 per cent. In general, the N uptake was higher for higher frequency (weekly twice) of lower concentration of nutrients compared to lower frequency (weekly once) of higher concentration of nutrients.

For combination of nutrients and growth regulators significant differences could be observed (Table 44). For NPK 10:10:10 at 0.1 per cent, BA 100 ppm gave highest value for uptake (3.15 g) while it was BA 200 ppm in the case of NPK 10:10:10 at 0.2 per cent (uptake of 3.90 g). In the case of NPK 20:10:10 at 0.1 per cent, N uptake was as high as 5.27 g when BA 200 ppm was sprayed, where as IAA 250 ppm was more effective when combined with NPK 20:10:10 at 0.2 per cent. In plants sprayed with NPK 30:10:10, BA 200 ppm was found to be effective at both the levels of nutrients, viz., 0.1 per cent and 0.2 per cent (N uptake of 8.13 g and 11.73 g, respectively).

Nitrogen uptake was found to show marked differences with combined effect of growth regulators and nutrient application frequencies (Table 43). Maximum uptake was observed for plants treated with BA 200 ppm (11.55 g) when nutrients were applied weekly twice. Minimum uptake was recorded for growth regulator control for weekly once application (1.75g).

4.1.3.2 Phosphorus uptake

Plant showed differential responses to different treatments and their combinations with respect to phosphorus uptake. Data pertaining to uptake of phosphorus are presented in Table 41 to 43 and 45

4.1.3.2.1 Main effect of nutrients, frequency of application and growth regulators (Table 41)

Uptake of phosphorus was found to increase with increase in the nutrient concentration applied. Highest value of 2.31 g was recorded when NPK 30:10:10 at 0.2 per cent was applied, which was significantly superior to all other treatments. Lowest P uptake of 0.58 g was observed in plants fertilized with NPK 10:10:10 at 0.1 per cent.

Significant increase in P uptake was obtained when nutrients were applied twice a week (2.39 g), compared to weekly once application (0.40 g).

Different growth regulator treatments had significant influence on P uptake in dendrobium var. Sonia 17. Maximum value was 1.46 g recorded for IAA 500 ppm, which was significantly superior to all other treatments. This was followed by BA 200 ppm, which recorded an uptake of 1.38 g. Lowest P uptake of 0.98 g was observed for GA_3 20 ppm.

4.1.3.2.2 Effect of treatment combinations

Combination of nutrient concentrations and frequency of application significantly influenced the P uptake in the plants (Table 42). Highest value (4.22 g) was recorded in the plants treated with combination of NPK 30:10:10 at 0.2 per cent, applied weekly twice. Minimum uptake of 0.18 g was observed when NPK 10:10:10 at 0.1 per cent was applied weekly once. In general, the P uptake was higher for higher frequency (weekly twice) of lower concentration of nutrients, compared to lower frequency (weekly once) of higher concentration of nutrients.

The combination of BA 200 ppm gave highest P uptake when nutrient concentrations of NPK 30:10:10 at 0.2 per cent was applied, which was significantly superior (2.71 g) to all other combinations (Table 45). For all other nutrient concentrations, combination of IAA 500 ppm gave highest P uptake of 0.71 g, 0.98 g, 1.21 g, 1.56 and 1.99 g, respectively, with increase in nutrient dose. Lowest P uptake was seen for GA_3 20 ppm with all nutrient doses, having values 0.47 g, 0.50 g, 0.81 g, 1.15 g, 1.42 g and 1.84 g, respectively, with increase in nutrient dose applied.

Interaction was evident between growth regulators and frequency of nutrient application (Table 43). Maximum P uptake was recorded when IAA 500 ppm was applied for plants treated with nutrients, weekly twice (2.88 g). For weekly once application of nutrients BA 200 ppm was found to give maximum P uptake of 0.49 g. Minimum P uptake (0.30 g) was recorded for growth regulator control.

4.1.3.3 Uptake of potassium

Data pertaining to the uptake of potassium as influenced by various treatments and their combinations are presented in Tables 41 to 43 and 46.

4.1.3.3.1 Main effect of nutrients, frequency of application and growth regulators (Table 41)

Potassium uptake was found to increase with increase in the nutrient concentration applied. Highest value recorded was 15.98 g in plants treated with

NPK 30:10:10 at 0.2 per cent, followed by NPK 30:10:10 at 0.1 per cent (11.64 g). Least value recorded was 4.02 g corresponding to NPK 10:10:10 at 0.1 per cent.

Frequency of nutrient application produced distinguishable differences in K uptake. 13.05 g of K was the uptake recorded for weekly twice application of nutrients whereas weekly once application recorded an uptake of 4.89 g of K.

Among the growth regulators applied, maximum K uptake of 9.98 g was observed in plants treated with IAA 500 ppm. BA 200 ppm recorded a value of 9.95 g which was on par with the above. Lowest uptake was 7.30 g for GA_3 20 ppm and it was 6.29 g in the case of plants which were not supplied with any growth regulators.

4.1.3.3.2 Interaction effects

Nutrient concentrations and frequency of application produced significant effect on K uptake (Table 42). Maximum uptake of 25.53 g was recorded for NPK 30:10:10 at 0.2 per cent, applied weekly twice. For weekly once application also NPK 30:10:10 at 0.2 per cent was found to be the best combination, recording 8.57 g K uptake. In general, the K uptake was higher for higher frequency (weekly twice) of lower concentration of nutrients compared to lower frequency (weekly once) of higher concentration of nutrients.

Combination of BA 200 ppm with NPK 30:10:10 at 0.2 per cent was significantly superior to all other combinations with respect to K uptake, which recorded 19.50 g (Table 46). Lowest K uptake (3.19 g) was observed in plants which received a combination of NPK 10:10:10 at 0.2 per cent without any growth regulator. For NPK 10:10:10, at both lower and higher levels, better combination effect was observed with IAA 500 ppm recording the values 4.71 g and 5.92 g, respectively. However, in plants fertilized with NPK 20:10:10 at both lower and

Table 41. Uptake of major nutrients (g/plant) in dendrobium var. Sonia 17 as influenced by nutrients (concentration and frequency of application) and growth regulators

Treatments	Nutrient uptake (g/plant)		
	N	P	K
Nutrients			
NPK10:10:10 - 0.1%	2.81	0.58	4.02
NPK10:10:10 - 0 .2%	3.46	0.79	5.01
NPK20:10:10 - 0 .1%	4.54	1.02	7.47
NPK20:10:10 - 0 .2%	5.71	1.32	9.24
NPK30:10:10 - 0 .1%	6.93	1.63	11.64
NPK30:10:10 - 0 .2%	9.62	2.31	15.98
CD(0.05)	0.194	0.019	0.037
SEm±	0.069	0.007	0.013
Frequency			
Weekly twice	9.93	2.39	13.05
Weekly once	2.11	0.40	4.89
CD (0.05)	0.194	0.034	0.059
SEm±	0.069	0.012	0.021
Growth regulators			
Control	4.56	1.03	6.29
BA 100ppm	5.86	1.24	9.29
BA 200ppm	6.20	1.38	9.95
GA_3 10ppm	4.90	1.02	7.47
GA_3 20ppm	4.61	0.98	7.30
IAA 250ppm	5.56	1.34	9.42
IAA 500ppm	5.67	1.46	9.78
CD(0.05)	0.056	0.020	0.039
SEm±	0.02	0.007	0.014

Table 42. Uptake of major nutrients (g/plant) in dendrobium var. Sonia 17 as influenced by combinations of nutrient concentration and frequency of application

Treatment	Nutrient uptake (g/plant)					
	N		P		K	
	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice
NPK10:10:10 - 0.1%	0.94	5.63	0.18	1.19	2.62	5.46
NPK10:10:10 - 0 .2%	1.24	6.67	0.25	1.52	3.35	6.86
NPK20:10:10 - 0 .1%	1.70	8.67	0.33	2.06	4.22	11.54
NPK20:10:10 - 0 .2%	2.20	16.79	0.40	2.70	4.91	14.84
NPK30:10:10 - 0 .1%	2.86	12.73	0.51	3.37	5.83	19.41
NPK30:10:10 - 0 .2%	4.45	16.50	0.86	4.22	8.57	25.53
CD(0.05)	0.039		0.042		0.047	
SEm±	0.014		0.015		0.017	

Table 43. Uptake of major nutrients (g/plant) in dendrobium var. Sonia 17 as influenced by combinations of growth regulators and frequency of nutrient application

Treatment	Nutrient uptake (g/plant)					
	N		P		K	
	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice
Control	1.75	8.75	0.30	2.14	4.00	8.85
BA 100ppm	2.26	10.90	0.40	2.45	5.15	14.66
BA 200ppm	2.41	11.55	0.49	2.72	5.61	15.51
GA_3 10ppm	2.02	9.02	0.37	2.02	4.52	10.87
GA_3 20ppm	1.90	8.40	0.35	1.88	4.35	10.92
IAA 250ppm	2.45	10.50	0.43	2.73	5.03	15.12
IAA 500ppm	2.26	10.52	0.48	2.88	5.36	15.97
CD(0.05)	0.39		0.022		0.674	
SEm±	0.14		0.008		0.240	

Table 44. Uptake of nitrogen (g/plant) in dendrobium var. Sonia 17 as influenced by combinations of nutrient concentration and growth regulators

Treatment	Uptake of nitrogen (g/plant)					
	N1	N2	N3	N4	N5	N6
Control	2.46	3.14	3.94	5.17	6.15	7.47
BA 100ppm	3.15	3.76	5.14	5.97	7.46	10.81
BA 200ppm	3.06	3.90	5.27	6.64	8.13	11.73
GA_3 10ppm	2.74	3.40	4.14	5.15	6.23	8.45
GA_3 20ppm	2.53	2.96	3.86	5.11	5.96	8.12
IAA 250ppm	2.97	3.48	4.83	6.65	7.16	10.54
IAA 500ppm	2.96	3.63	4.71	5.99	7.60	10.56
CD(0.05)	0.702					
SEm±	0.250					

Table 45. Uptake of phosphorus (g/plant) in dendrobium var. Sonia 17 as influenced by combinations of nutrient concentration and growth regulators

Treatment	Uptake of phosphorus (g/plant)					
	N1	N2	N3	N4	N5	N6
Control	0.40	0.70	0.91	1.25	1.45	1.84
BA 100ppm	0.48	0.63	1.11	1.31	1.66	2.54
BA 200ppm	0.56	0.81	1.13	1.47	1.86	2.71
GA_3 10ppm	0.69	0.65	0.90	1.11	1.35	1.90
GA_3 20ppm	0.55	0.50	0.81	1.15	1.42	1.84
IAA 250ppm	0.47	0.87	1.07	1.40	1.89	2.64
IAA 500ppm	0.71	0.98	1.21	1.56	1.99	2.69
CD(0.05)	0.028					
SEm±	0.011					

N1 - NPK10:10:10 - 0.1% N2 - NPK10:10:10 - 0 .2%
N3 - NPK20:10:10 - 0 .1% N4 - NPK20:10:10 - 0 .2%
N5 - NPK30:10:10 - 0 .1% N6 - NPK30:10:10 - 0 .2%

Table 46. Uptake of Potassium (g/plant) in dendrobium var. Sonia 17 as influenced by combinations of nutrient concentration and growth regulators

Treatment	Uptake of potassium (g/plant)					
	N1	N2	N3	N4	N5	N6
Control	3.19	4.26	5.53	6.95	8.59	10.60
BA 100ppm	4.65	5.16	8.30	10.25	12.40	17.77
BA 200ppm	4.13	5.80	8.99	11.20	13.62	19.50
GA_3 10ppm	3.84	4.44	6.14	7.50	10.46	14.16
GA_3 20ppm	3.61	4.28	6.22	7.93	9.70	14.17
IAA 250ppm	4.17	5.34	8.49	10.32	13.36	17.96
IAA 500ppm	4.71	5.92	8.97	10.93	13.82	18.50
CD(0.05)	0.731					
SEm±	0.260					

N1 - NPK10:10:10 - 0.1% N2 - NPK10:10:10 - 0 .2%
N3 - NPK20:10:10 - 0 .1% N4 - NPK20:10:10 - 0 .2%
N5 - NPK30:10:10 - 0 .1% N6 - NPK30:10:10 - 0 .2%

higher levels BA 200 ppm was found to be a better combination with uptake of 8.99 g and 11.20 g, respectively.

Influence of combination of frequency of application of nutrients and growth regulators was significant for K uptake (Table 43). Highest value of 15.97 g was observed when plants were treated with IAA 500 ppm and nutrient application frequency was weekly twice. BA 200 ppm with the same application frequency recorded an uptake of 15.51 g, which was on par with the above. Lowest K uptake was recorded when plants fertilized weekly once was given no growth regulator (4.0 g).

4.1.4 Days to flowering

Data on the effect of various nutrients and growth regulators in reducing the preblooming period in dendrobium var. Sonia 17 are presented in Table 47.

4.1.4.1 Main effect of combination of nutrients, frequency of application and growth regulators

Among the treatment combinations earliest flowering was observed in plants which received NPK 30:10:10 at 0.2 per cent applied weekly twice + BA 200 ppm (Plates 6a and 6b). These plants flowered in 300 days after planting. Plants which received NPK 20:10:10 at 0.2 per cent applied weekly twice + BA 200 ppm flowered 308 days after planting. This was followed by NPK 30:10:10 at 0.1 per cent, applied weekly twice + BA 100 ppm. NPK 20:10:10 at 0.1 per cent, applied weekly twice + BA 200 ppm recorded flowering 313 days after planting (DAP).

In the plants that received NPK 30:10:10 at 0.2 per cent at weekly twice frequency, IAA 250 ppm spray recorded flowering 406 DAP and IAA 200 ppm recorded flowering 448 DAP. In the case of NPK 30:10:10 at 0.1 per cent applied weekly twice, IAA 250 ppm and 500 ppm recorded flowering 412 and 450 DAP. In

Table 47. Days to flowering in dendrobium var. Sonia 17 as influenced by combinations of nutrients (concentration and frequency) and growth regulators

Growth regulators	Nutrients											
	N1		N2		N3		N4		N5		N6	
	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice
Control	-	-	-	521	-	503	-	462	-	474	-	449
BA 100 ppm	-	470	494	415	490	394	474	402	486	313	472	321
BA 200 ppm	-	479	428	376	403	313	393	308	401	341	386	300
GA_3 10 ppm	-	-	-	483	-	455	-	478	-	446	-	468
GA_3 20 ppm	-	-	-	479	-	481	-	466	-	466	-	458
IAA 250 ppm	-	-	-	424	-	443	517	414	-	412	503	406
IAA 500 ppm	-	-	-	474	-	461	-	454	-	450	-	448

N1 – NPK 10:10:10 – 0.1% N2 – NPK 10:10:10 – 0.2%
N3 – NPK 20:10:10 – 0.1% N4 – NPK 20:10:10 – 0.2%
N5 – NPK 30:10:10 – 0.1% N6 – NPK 30:10:10 – 0.2%

Plate 6. Effect of highest level of nutrients + BA 200 ppm on flowering

a) Compared with nutrients alone at the lowest level
b) Compared with nutrients alone at the highest level

Plate 7. Effect of highest level of nutrients + growth regulators on flowering.
From left - IAA 500 ppm, GA_3 20 ppm, BA 200 ppm

Plate 8. Effect of higher levels of nutrients and BA 200 ppm on flowering.
From left (NPK 10:10:10, NPK 20:10:10 and NPK 30:10:10 at 0.2 per cent applied weekly twice)

Plate 9. Effect of BA 200 ppm on flowering.
From left (NPK 10:10:10 - 0.1%, NPK 10:10:10 - 0.2%, NPK 20:10:10 - 0.1%, NPK 20:10:10 - 0.2%, NPK 30:10:10 - 0.1%, NPK 30:10:10 - 0.2%)

the case of NPK 20:10:10 at 0.1 and 0.2 per cent applied weekly intervals and NPK 10:10:10 at 0.2 per cent too, the combination with IAA 250 ppm and 500 ppm, respectively, flowered next to the combination with BA 200 ppm and 100 ppm. The effect of highest level of nutrients + growth regulators on flowering can be seen from the Plate 7.

In plants which received NPK 30:10:10 at 0.2 per cent and 0.1 per cent, NPK 20:10:10 at 0.2 percent and 0.1 per cent and NPK 10:10:10 at 0.2 per cent, which did not receive any growth regulator, (growth regulator control) flowering was recorded 449, 474, 462, 503 and 521 DAP, respectively.

Flowering was not observed in plants that received nutrients weekly once, except a few. Flowering was observed in plants which received NPK 10:10:10 at 0.2 per cent, NPK 20:10:10 at 0.1 per cent and 0.2 per cent and NPK 30:10:10 at 0.1 per cent and 0.2 per cent which also received BA 100 ppm or BA 200 ppm (Plate 8 and 9). In plants which received NPK 30:10:10 at 0.2 per cent and NPK 20:10:10 at 0.2 per cent at weekly once frequency IAA 250 ppm in combination also induced flowering.

4.2 Improvement of flower yield and quality

Data generated from the experiments conducted to study the effect of nutrients and growth regulators on flower yield and quality of dendrobium var. Sonia 17 are presented in this chapter.

4.2.1 Number of spikes per plant

Data pertaining to number of spikes produced per plant in dendrobium var. Sonia 17 as influenced by various treatments and their combinations are presented in Tables 48 to 51

4.2.1.1 Main effect of nutrients, frequency of application and growth regulators

Nutrients and their concentrations markedly influenced the number of spikes produced in dendrobium var. Sonia 17. During the period of seven months after the initiation of the trial, 5.62 spikes were produced corresponding to the application of NPK 10:20:20 at 0.2 per cent, which was significantly superior to all other nutrient levels. NPK 10:20:10 at 0.2 per cent closely followed, producing 5.51 spikes per plant. Least number of spikes was observed in the plants supplied with NPK 10:10:10 at 0.1 per cent (4.07 spikes).

Nutrients applied weekly twice produced 5.21 spikes, which was significantly superior to weekly once application (4.00 spike per plant).

Among the growth regulator treatments, significantly higher number of spikes (5.26) was recorded in plants which received BA 100 ppm. This was followed by BA 50 ppm, which produced 4.90 spikes per plant. Lowest number of spikes was produced by GA_3 10 ppm (0.85).

4.2.1.2 Interaction effects

Nutrient concentration in combination with frequency of application produced distinguishable differences in spike production.(Table 49). Maximum number of spikes (5.61) was recorded in plants that received NPK 10:20:10 at 0.2 per cent weekly twice. NPK 10:20:20 at 0.2 per cent and NPK 10:20:10 at 0.1 per cent, both applied weekly twice, recorded values on par with the above (5.56 and 5.40, respectively). Least value recorded was 4.18, in the case of NPK 10:10:10 at 0.1 per cent, applied weekly once.

Number of spikes per plant showed detectable differences in response to combination of growth regulators and frequency of nutrient application. Maximum number of spikes (5.59) was observed in the case of BA 100 ppm applied in plants, which received nutrients twice weekly. This was closely followed by 5.22 spikes corresponding to BA 50 ppm in the case of plants, which received nutrients weekly twice. Lowest value (3.91) for number of spikes was produced for GA3 20 ppm + weekly twice application of nutrients.

In the combination of nutrients and growth regulators NPK 10:20:10 at 0.2 per cent applied weekly twice + BA 100 ppm produced 6.49 spikes, which was significantly superior to other treatment combinations. This was followed by 6.29 spikes produced by the treatment the combination of NPK 10:20:10 at 0.1 per cent + BA 100 ppm. Least number of spikes (4.34) was produced by NPK 10:10:10 at 0.1 per cent, applied weekly once + growth regulator control.

4.2.2 Number of florets

Data pertaining to number of florets per spike in dendrobium var. Sonia 17, as influenced by various treatments and their combinations are presented in Tables 48 to 52.

4.2.1.1 Main effect of nutrients, frequency of application and growth regulators (Table 48)

Nutrients showed differential influences on the number of florets per spike. Maximum number of florets (7.63) was obtained in plants treated with NPK 10:20:20 at 0.2 per cent. Minimum number of florets (6.94) was recorded in plants which received NPK 10:10:10 at 0.1 per cent. After seven months of treatment 7.53 florets were recorded when plants were fertilized twice a week, which was reduced to 6.90 florets when fertilizer application was done only once a week.

Number of florets was found to differ with growth regulator treatments. Increase in number of florets was observed in plants treated with BA at 50 and 100 ppm, being more pronounced in the case of BA 100 ppm. Maximum number of florets was recorded in plants, which received BA 100 ppm (8.46). This was followed by 7.95 florets in plants, which received BA 50 ppm. The combination of BA 50 ppm + GA 10 ppm was on par with this.(7.76 florets after seven months of treatment). Minimum number of florets (6.39) was recorded in the case of GA 20 ppm. The control treatment produced 6.80 florets.

4.2.1.2 Effect of treatment combinations

Combination of nutrients and frequency of application significantly improved the number of florets in during the period of seven months after the initiation of the trial. NPK 10:20:20 at 0.2 per cent was produced maximum number of florets (8.29), closely followed by 8.19 florets produced by NPK 10:20:10 at 0.2 per cent and NPK 10:20:20 at 0.1 per cent. For weekly once spraying of nutrients NPK 10:20:10 at 0.2 per cent gave maximum number of florets (7.10) which was on par with other treatments, except NPK 10:10:10 at 0.1 and 0.2 per cent (6.82 and 6.80 florets, respectively).

Combination of growth regulators with nutrients gave significant difference in number of florets per spike. It was observed that BA 100 ppm gave significantly higher number of florets (9.75) when combined with NPK 10:20:10 at 0.2 per cent. NPK 10:20:20 at 0.2 per cent gave 8.96 florets. Number of florets was less in plants treated with GA_3 20 ppm in combination with all the nutrient doses (6.42, 6.54, 6.33, 6.29, 6.59 and 6.17 florets, respectively, with increase in nutrient doses).

The effect of growth regulators differed significantly with the frequency of nutrient application. More number of florets was produced (9.25) when plants were supplied with BA 100 ppm combined with the application of nutrients twice weekly. BA 50 ppm substituted in the above combination gave 8.50 florets.

4.2.3 Spike length

Data pertaining to length of flower spikes in dendrobium var. Sonia 17 as influenced by treatments individually and combinations are presented in Tables 48 to 51 and 53.

4.2.3.1 Main effect of nutrients, frequency of application and growth regulators (Table 48)

Nutrient doses of NPK 10:20:10 at 0.2 per cent gave maximum spike length (45.05 cm) after seven months of nutrient application. NPK 10:20:20 at 0.2 per cent produced spikes of length 44.49 cm, which was on par with the above. Minimum spike length of 43.66 cm was recorded in plants receiving NPK 10:10:10 at 0.1 per cent.

Application of nutrients weekly twice showed an increase in spike length, which was significantly superior to weekly once application (46.32 cm).

Among the growth regulators tried, maximum length of spike (48.89 cm) was recorded in response to GA_3 20 ppm at seven months after treatment. Gibberellic acid at 10 ppm produced spikes having length of 47.51 cm. Spike length was minimum (41.05 cm) in plants which received no growth regulator treatment.

4.2.3.2 Interaction effects

Combination of nutrients and their frequency of application showed significant influence on spike length in dendrobium (Table 49). Maximum value for spike length was recorded in NPK 10:20:10 applied weekly twice (47.33 cm). This was followed by NPK 10:20:20 at 0.2 per cent, which gave a spike length of 46.70 cm when sprayed weekly twice, which was on par with the above. Weekly once spraying gave maximum spike length of 42.77 cm when NPK 10:20:10 at 0.2 per cent was used.

Interaction of nutrients and growth regulators was evident with respect to spike length (Table 50). Longest spikes were observed in combination of NPK 10:20:20 at 0.2 per cent with GA_3 20 ppm (50.30 cm). GA_3 20 ppm with NPK 10:20:10 at 0.2 per cent closely followed producing spikes of length 50.10 cm and GA_3 10 ppm + NPK 10:20:20 at 0.2 per cent gave 49.65 cm which were on par with the above. Growth regulators control gave spikes of length 40.50 cm, 41.10 cm, 40.95 cm, 41.30 cm, 40.55 cm and 41.90 cm, respectively with ratios NPK 10:10:10, 10:20:20 and 10:20:10 at 0.1 and 0.2 per cent, respectively. Minimum spike length (40.20 cm) was observed in combination of BA 25 ppm + GA_3 5 ppm with NPK 10:20:10 at 0.1 per cent.

Significant differences were present in the combination of growth regulators and frequency of application of nutrients (Table 51). Spike length was maximum (52.37 cm) in plants applied with nutrients weekly twice and treated with GA_3 20 ppm and 45.52 cm in plants applied with nutrients weekly once. Least values for spike length was obtained for BA 25 ppm + GA_3 5 ppm in the case of plants applied with nutrients weekly once (40.78 cm). For plants applied with nutrients weekly twice, least spike length was recorded when treated with BA 50 ppm + GA_3 10 ppm (41.97 cm).

Interaction of nutrients, frequency of application and growth regulators was evident for spike length (Table 53). Maximum spike length was recorded for NPK 10:20:20 at 0.2 per cent aplied weekly twice along with GA_3 20 ppm (55.40), which was on par with NPK 10:20:20 at 0.2 per cent weekly twice + GA_3 10 ppm (54.90). For NPK 10:10:10 at 0.1 per cent and 0.2 per cent applied weekly once, BA 50 ppm gave the least spike length (41.10 cm and 39.80 cm, respectively). For weekly twice application of the same nutrient dose minimum spike length was recorded for BA 50 ppm + GA_3 5 ppm (42.40 cm and 40.20 cm, respectively). Similar trend followed in the case of NPK 10:20:20 at 0.1 per cent also. For weekly twice application, BA 25 ppm + GA_3 5 ppm produced the least spike length

(43.10 cm). When BA 50 ppm + GA_3 10 ppm substituted in the above combination, the spike length was 40.80 cm. In NPK 10:20:10 at 0.1 per cent applied weekly once, the effect of BA 50 ppm + GA_3 10 ppm was the least (spike length of 40.70 cm). For the same nutrient concentration applied weekly twice 39.70 cm was the spike length recorded when BA 25 ppm + GA_3 5 ppm was applied.

4.2.4 Stalk length

Data pertaining to stalk length of flower spikes in dendrobium var. Sonia 17 as influenced by treatments individually and combinations are presented in Tables 48 to 51 and 54

4.2.4.1 Main effect of nutrients, frequency of application and growth regulators (Table 48)

Significant differences in stalk length were not observed among nutrient treatments.

Weekly twice application of nutrients excelled weekly once application (24.02 cm) compared to a stalk lenth of 18.98 cm observed in plants sprayed with nutrients once weekly.

Among the growth regulators applied, BA 100 ppm was observed to be distinctly superior to all other treatments (26.02 cm). BA 50 ppm produced spikes with stalk length on par with it (24.80 cm). Least value for stalk length (18.80 cm) was observed for BA 50 ppm + GA_3 10 ppm.

4.2.4.2 Effect of treatment combinations

Significant influence of combination of nutrient concentration and frequency of application was observed after seven months of treatment (Table 49). Maximum stalk length of 25.14 cm was recorded for NPK 10:10:10 at 0.2 per cent applied weekly twice. Least stalk length of 18.81 cm was for NPK 10:20:10 at 0.2 per cent applied weekly once.

When combination of nutrients and growth regulators were tried interaction was evident (Table 50). Maximum stalk length of 26.45 cm was recorded in plants that received BA 100 ppm + NPK 10:20:20 at 0.2 per cent, which was significantly superior. Least stalk length of 18.45 cm was observed in the case of BA 25 ppm + GA_3 5 ppm + NPK 10:20:10 at 0.1 per cent.

In the case of interaction of growth regulators and frequency of nutrient application (Table 51), highest value for stalk length (29.52 cm) was recorded in the combination of weekly twice application of nutrients with BA 100 ppm.

Interaction of nutrient concentrations, frequency of application and growth regulators was evident (Table 52). Maximum stalk length of 30.10 cm was recorded in weekly twice application of NPK 10:20:20 at 0.2 per cent treated with BA 100 ppm, followed by 29.90 cm recorded corresponding to NPK 10:10:10 at 0.1 per cent applied weekly twice and treated with BA 100 ppm. Least stalk length of 17.30 was observed in plants applied with NPK 10:20:10 at 0.2 per cent weekly once and sprayed with GA_3 20 ppm.

4.2.5 Rachis length

Data pertaining to length of rachis in spikes of dendrobium var. Sonia 17 as influenced by various treatments individually and in combination are presented in Tables 48 to 51 and 55.

4.2.5.1 Main effect of nutrients, frequency of application and growth regulators (Table 48)

Among the nutrient doses tried, highest rachis length was recorded in plants treated with NPK 10:20:10 at 0.2 per cent (23.91 cm). Rachis length of

23.39 cm corresponding to NPK 10:20:20 at 0.1 per cent was on par with this. Least length of rachis (21.59 cm) was observed in plants treated with NPK 10:10:10 at 0.2 per cent, which was distinctly inferior to rest of the treatments.

Nutrient applied weekly twice significantly increased rachis length up to 23.05 cm during seven months of application. Rachis length corresponding to weekly twice application was 23.05 cm.

Among the growth regulators tried rachis length of 25.17 cm was produced corresponding to BA 50 ppm + GA_3 10 ppm. GA_3 20 ppm producing a rachis length of 24.91 cm and GA_3 10 ppm producing a rachis length of 24.31 cm were on par with this.

4.2.5.2 Interaction effects

Maximum rachis length of 23.92 cm was observed in plants treated weekly once with NPK 10:20:10 at 0.2 per cent (Table 49). NPK 10:20:10 at 0.2 per cent applied weekly twice produced a rachis length of 23.91 cm, which was on par with the above.

Combination of nutrient concentration and growth regulators was found to significantly influence rachis length (Table 50). Maximum value for rachis length was recorded as much as 27.51 cm, corresponding to NPK 10:20:10 at 0.2 per cent + GA_3 20 ppm. Minimum value was as low as 17.75 cm for NPK 10:10:10 at 0.1 per cent + BA 100 ppm.

NPK 10:10:10 at 0.1 per cent with BA 50 ppm + GA_3 10 ppm gave a rachis length of 26.05 cm, which was on par with the superior treatment.

Combination of growth regulators and frequency of nutrient application also had significant interactions (Table 51). Maximum rachis length was recorded as 27.00 cm corresponding to combination of weekly twice application of nutrients and BA 50 ppm + GA_3 10 ppm. For weekly once nutrient application, growth regulator, which produced maximum rachis length of 27.56 cm was GA_3 20 ppm. GA_3 10 ppm was found to produce rachis length on par with this (26.58 cm).

Interaction of three factors was found significant at seven months after treatment (Table 52). A maximum rachis length of 30.15 cm was produced by NPK 10:20:10 at 0.2 per cent applied weekly twice + BA 50 ppm + GA_3 10 ppm. This was closely followed by NPK 10:20:10 at 0.2 per cent sprayed weekly once + GA_3 20 ppm, which gave a rachis length 30.16 cm. Several treatments were on par with this.

4.2.6 Internodal length

Data pertaining to internodal length of spikes in dendrobium var. Sonia 17 as influenced by various treatments and their combinations are presented in Tables 48 to 52 and 56.

4.2.6.1 Main effect of nutrients, frequency of application and growth regulators (Table 48)

Nutrient concentration of NPK 10:20:10 at 0.2 per cent recorded the highest internodal length of 3.44 cm. NPK 10:10:10 at 0.1 per cent was on par with the above producing a stalk length of 3.42 cm.

Internodal length was found to increase with increase in frequency of nutrient application. Internodal length of 3.40 cm was observed in weekly twice fertilized plants compared to 3.28 cm in the case of weekly once fertilized plants.

Among growth the regulators tried, highest internodal length was recorded as 4.10 cm for GA_3 20 ppm treatment, which was significantly superior to all other treatments. Internodal length was found to decrease significantly with continuous BA treatment. BA 100 ppm recorded the least internodal length of 2.40 cm, followed by 2.65 cm for BA 50 ppm treatment.

4.2.6.2 Interaction effects

Combined effect of nutrients and frequency of application was distinct in the case of internodal length (Table 49). Maximum values of 3.58 cm was recorded for weekly once application of NPK 10:20:10 at 0.2 per cent. NPK 10:20:10 at 0.1 per cent applied weekly once gave a length of 3.50 cm at seven months after treatment, which was on par with the superior one.

Combination of growth regulators and nutrient concentration had significant influence on internodal length of spikes (Table 50). Highest value recorded was 4.62 cm, which was significantly superior corresponding to combination of GA_3 20 ppm + NPK 10:20:10 at 0.2 per cent. Combination of BA and nutrients were found to reduce internodal length significantly. Least internodal length recorded was 2.18 cm for BA 100 ppm + NPK 10:20:20 at 0.2 per cent.

Highest value for internodal length (4.50 cm) was recorded for GA_3 20 ppm and weekly once nutrient application (Table 51). Least value was recorded as 2.19 cm for combination of BA 100 ppm and weekly twice application of nutrients.

Interaction of all the three factors was significant with respect to the internodal length (Table 52). Significantly superior internodal length of 5.14 cm was recorded for the combination of GA_3 20 ppm with NPK 10:20:10 at 0.2 per cent applied weekly once. Minimum value of 1.93 cm was recorded for BA 50 ppm + NPK 10:20:20 at 0.2 per cent, applied weekly twice.

4.2.7 Spike girth

Data pertaining to girth of the stalk of spikes in dendrobium var.Sonia 17 as influenced by various treatments and their combinations are presented in Tables 48 to 52 and 57.

4.2.7.1 Main effect of nutrients, frequency of application and growth regulators (Table 48)

Nutrient doses significantly influenced the spike girth in dendrobium. Girth was as high as 1.74 cm corresponding to 10:20:20 NPK at 0.2 per cent, which was significantly superior. Minimum girth of the spike (1.51cm) was observed in 10:10:10 NPK at 0.1 per cent.

Significant difference was observed with respect to frequency of nutrient application in the stalk of dendrobium spikes. Girth as high as 1.61 cm was recorded when nutrients were applied weekly twice. This was superior to girth observed in weekly once application (1.58 cm).

Among the growth regulator treatments, significant difference in stalk girth was noticed immediately after the treatments were imposed. BA was found to enhance girth of stalk distinctly. Girth as high as 1.97 cm was recorded when the plants were treated with the BA 100 ppm. This was closely followed by 1.93 cm for BA 50 ppm spray which was on par with the above. Stalk girth was minimum (1.37 cm) for GA_3 20 ppm application.

4.2.7.2 Interaction effects

Combination of nutrients and frequency of application influenced girth of stalk significantly (Table 49). Highest value was recorded in the plants which received NPK 10:20:20 at 0.2 per cent weekly once (1.80 cm). Least girth recorded

Table 48. Floral characters in dendrobium var. Sonia 17 as influenced by nutrients (concentration and frequency of application) and growth regulators (7th month after treatment)

Treatments	No. of spikes	No. of florets	Spike length (cm)	Stalk length (cm)	Rachis length (cm)	Internodal length (cm)	Girth of spike (cm)
Nutrients							
NPK 10:10:10 - 0.1%	4.07	7.04	43.66	21.03	22.58	3.42	1.51
NPK 10:10:10 - 0.2%	5.08	6.94	43.67	22.03	21.59	3.31	1.52
NPK 10:20:20 - 0.1%	5.05	7.60	44.16	20.90	23.39	3.28	1.60
NPK 10:20:20 - 0.2%	5.62	7.63	44.49	21.91	22.08	3.22	1.74
NPK 10:20:10 - 0.1%	5.18	7.22	43.53	21.38	22.39	3.29	1.61
NPK 10:20:10 - 0.2%	5.51	7.60	45.05	21.09	23.91	3.44	1.59
CD(0.05)	0.09	0.267	0.782	NS	0.902	0.067	0.065
SEm ±	0.32	0.095	0.278		0.31	0.024	0.023
Frequency							
Weekly twice	5.21	7.53	46.32	24.02	23.05	3.40	1.61
Weekly once	4.00	6.90	42.04	18.98	22.26	3.28	1.58
CD(0.05)	0.104	0.155	0.452	0.711	0.615	0.640	0.017
SEm ±	0.037	0.055	0.161	0.253	0.219	0.228	0.006
Growth regulators							
Control	4.08	6.80	42.05	19.05	21.88	3.37	1.58
BA 50 ppm	4.90	7.95	43.53	24.80	19.45	2.65	1.93
BA 100 ppm	5.26	8.46	44.29	26.02	18.87	2.40	1.97
GA_3 10 ppm	3.76	6.60	47.51	20.91	24.31	3.83	1.39
GA_3 20 ppm	3.69	6.39	48.89	20.99	24.91	4.10	1.37
BA 25 ppm + GA_3 5 ppm	4.38	7.41	41.69	19.16	24.01	3.45	1.45
BA 50 ppm + GA_3 10 ppm	4.54	7.76	41.70	18.80	25.01	3.49	1.46
CD(0.05)	0.104	0.288	0.845	1.329	0.974	0.073	0.070
SEm ±	0.037	0.103	0.300	0.473	0.347	0.026	0.025

Table 49. Floral characters in dendrobium var. Sonia 17 as influenced by combinations of nutrient concentration and frequency of application

Treat-ments	No. of spikes		No. of florets		Spike length (cm)		Stalk length (cm)		Rachis length (cm)		Internodal length (cm)		Stalk girth (cm)	
	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice
N1	4.18	4.42	6.82	7.26	41.31	46.01	18.83	23.23	22.34	22.81	3.42	3.43	1.48	1.54
N2	4.38	4.95	6.90	7.07	41.14	46.20	18.91	25.14	22.23	20.94	3.40	3.22	1.44	1.59
N3	4.64	5.20	7.00	8.19	41.79	46.53	18.96	22.84	23.22	23.56	3.47	3.09	1.58	1.63
N4	4.83	5.56	6.96	8.29	42.29	46.70	19.06	24.77	23.18	20.98	3.48	2.96	1.80	1.68
N5	4.85	5.40	6.94	7.50	42.56	44.50	19.10	23.66	23.41	21.37	3.50	3.08	1.60	1.62
N6	5.18	5.61	7.10	8.19	42.77	47.33	18.81	23.37	23.92	23.91	3.58	3.29	1.57	1.61
CD(0.05)	0.276		0.377		1.110		1.740		1.280		0.095		0.092	
SEm ±	0.098		0.134		0.391		0.619		0.321		0.034		0.033	

N1 – NPK 10:10:10 – 0.1% N2 – NPK 10:10:10 – 0.2%;
N3 – NPK 10:20:20 – 0.1% N4 – NPK 10:20:20 – 0.2%
N5 – NPK 10:20:10 – 0.1% N6 – NPK 10:20:10 – 0.2%

Table 50. Floral characters in dendrobium var. Sonia 17 as influenced by combinations of nutrient concentration and growth regulators

Treatments	Number of spikes	No. of florets	Spike length (cm)	Stalk length (cm)	Rachis length (cm)	Internodal length (cm)	Stalk girth (cm)
N_1G_0	4.34	6.71	40.50	19.38	20.98	3.29	1.58
N_1G_1	4.81	7.25	42.90	23.95	20.33	3.04	1.61
N_1G_2	5.25	7.84	43.65	25.75	17.75	2.64	1.86
N_1G_3	4.45	6.88	46.15	20.30	23.98	3.66	1.36
N_1G_4	4.44	6.42	47.90	20.40	23.88	3.92	1.36
N_1G_5	4.83	7.38	42.80	19.00	25.08	3.55	1.39
N_1G_6	4.83	6.89	41.75	18.65	26.05	3.86	1.44
N_2G_0	4.59	6.67	41.10	19.25	21.83	3.41	1.63
N_2G_1	5.14	7.34	43.90	25.45	18.68	2.78	1.82
N_2G_2	5.40	7.38	44.25	26.10	18.33	2.64	1.69
N_2G_3	4.72	6.59	46.45	23.85	23.55	3.71	1.35
N_2G_4	4.59	6.54	47.95	22.00	23.65	3.80	1.35
N_2G_5	4.97	6.84	41.20	18.90	21.13	3.21	1.41
N_3G_6	5.18	7.21	40.85	18.65	23.95	3.62	1.41
N_3G_0	5.06	7.54	40.95	18.75	22.05	3.33	1.54
N_3G_1	5.54	7.75	44.50	24.00	21.64	2.86	1.95
N_3G_2	5.88	8.13	43.90	26.20	18.13	2.30	2.04
N_3G_3	4.90	6.67	46.95	19.05	24.88	3.85	1.40
N_3G_4	4.84	6.33	48.90	20.80	26.18	4.34	1.39
N_3G_5	5.33	8.00	41.70	19.00	25.23	3.23	1.47
N_3G_6	5.48	8.75	42.20	18.50	25.65	3.03	1.44
N_4G_0	5.30	6.60	41.30	19.00	22.20	3.49	1.54
N_4G_1	5.82	8.50	43.55	25.40	18.00	2.36	2.40
N_4G_2	6.15	8.96	44.60	26.45	21.25	2.18	2.41
N_4G_3	5.14	6.54	49.65	21.35	22.98	3.74	1.41

Contd.

Table 50. Continued

Treatments	Number of spikes	No. of florets	Spike length (cm)	Stalk length (cm)	Rachis length (cm)	Internodal length (cm)	Stalk girth (cm)
N_4G_4	5.13	6.29	50.30	21.30	23.38	4.04	1.38
N_4G_5	5.74	7.63	41.00	20.15	22.83	3.43	1.46
N_4G_6	5.74	8.88	41.05	19.75	23.93	3.31	1.57
N_5G_0	5.41	6.67	40.55	19.30	21.20	3.30	1.69
N_5G_1	6.08	8.17	43.00	25.60	19.35	2.53	1.88
N_5G_2	6.29	8.71	44.30	25.45	18.80	2.33	1.92
N_5G_3	5.32	6.42	47.45	20.55	23.90	3.80	1.43
N_5G_4	5.21	6.59	48.20	21.50	24.85	3.91	1.38
N_5G_5	5.76	6.88	40.20	18.70	24.40	3.67	1.52
N_5G_6	5.86	7.13	41.00	18.45	24.23	3.51	1.44
N_6G_0	5.61	6.59	41.90	18.85	23.00	3.40	1.54
N_6G_1	6.14	8.71	43.30	24.55	18.70	2.34	1.94
N_6G_2	6.49	9.75	45.05	26.05	18.98	2.28	1.92
N_6G_3	5.43	6.50	48.40	20.35	26.60	4.20	1.42
N_6G_4	5.38	6.17	50.10	19.85	27.51	4.62	1.38
N_6G_5	5.89	7.75	43.25	19.20	25.40	3.61	1.46
N_6G_6	6.00	7.75	43.35	18.80	27.20	3.62	1.47
CD(0.05)	0.145	0.706	2.070	3.255	2.387	0.178	0.170
SEm	0.052	0.252	0.736	1.157	0.849	0.063	0.061

N_1 - NPK 10:10:10 - 0.1%
N_2 - NPK 10:10:10 - 0.2%
N_3 - NPK 10:20:20 - 0.1%
N_4 - NPK 10:20:20 - 0.2%
N_5 - NPK 10:20:10 - 0.1%
N_6 - NPK 10:20:10 - 0.2%

G_0 - Control
G_1 - BA 50 ppm
G_2 - BA 100 ppm
G_3 - GA_3 10 ppm
G_4 - GA_3 20 ppm
G_5 - BA 25 ppm + GA_3 5 ppm
G_6 - BA 50 ppm + GA_3 10 ppm

Table 51. Floral characters in dendrobium var. Sonia 17 as influenced by combinations of growth regulators and frequency of nutrient application

Treatments	No. of spikes		No. of florets		Spike length (cm)		Stalk length (cm)		Rachis length (cm)		Internodal length (cm)		Stalk girth (cm)	
	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice
Control	4.38	4.94	6.67	6.92	39.27	42.83	17.78	20.32	21.40	22.35	3.33	3.41	1.47	1.70
BA 50 ppm	4.93	5.22	7.40	8.50	40.93	46.12	21.10	27.50	20.03	18.86	2.80	2.50	1.98	1.88
BA 100 ppm	5.18	5.59	7.67	9.25	41.78	46.80	22.53	29.52	19.62	18.13	2.60	2.19	1.20	1.75
GA_3 10 ppm	4.02	4.18	6.64	6.56	44.22	50.80	17.58	24.23	26.58	22.04	4.11	3.54	1.35	1.44
GA_3 20 ppm	3.91	4.10	6.39	6.39	45.42	52.37	17.65	24.33	27.56	22.25	4.50	3.71	1.28	1.45
BA 25 ppm+ GA_3 5 ppm	4.59	4.77	6.82	8.00	40.78	42.60	17.92	20.40	22.82	25.20	3.46	3.43	1.38	1.52
BA 50 ppm+ GA_3 10 ppm	4.63	4.74	6.88	8.64	41.43	41.97	18.05	19.55	23.33	27.00	3.51	3.47	1.38	1.54
CD(0.05)	0.103		0.408		1.194		1.879		1.380		0.103		0.099	
SEm	0.037		0.145		0.425		0.668		0.490		0.037		0.035	

Table 52. Number of florets in dendrobium var. Sonia 17 as influenced by combinations of nutrients (concentration and frequency) and growth regulators

Growth regulators	Nutrients											
	N1		N2		N3		N4		N5		N6	
	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice
Control	6.75	6.67	6.67	6.67	6.75	8.33	6.50	6.70	6.67	8.67	6.67	6.50
BA 50 ppm	7.00	7.50	7.00	7.67	7.50	8.00	7.50	9.50	7.67	9.67	7.75	9.67
BA 100 ppm	7.00	8.67	7.25	7.50	7.75	8.50	8.25	9.67	7.75	6.33	8.00	11.50
GA_3 10 ppm	6.75	7.00	6.50	6.67	6.67	6.67	6.75	6.33	6.50	6.67	6.67	6.33
GA_3 20 ppm	6.50	6.38	6.75	6.33	6.33	6.33	6.25	6.33	6.50	7.00	6.00	6.33
BA 25 ppm + GA_3 5 ppm	6.75	8.00	6.67	7.00	7.00	9.00	6.75	8.50	6.75	6.67	7.00	8.50
BA 50 ppm + GA_3 10 ppm	7.00	6.67	6.75	7.67	7.00	10.50	6.75	11.00	6.75	7.50	7.00	8.50
CD(0.05)	0.998											
SEm±	0.355											

N1 – NPK 10:10:10 – 0.1% N2 – NPK 10:10:10 – 0.2%
N3 – NPK 10:20:20 – 0.1% N4 – NPK 10:20:20 – 0.2%
N5 – NPK 10:20:10 – 0.1% N6 – NPK 10:20:10 – 0.2%

Table 53. Spike length (cm) in dendrobium var. Sonia 17as influenced by combinations of nutrients (concentration and frequency) and growth regulators

Growth regulators	Nutrients											
	N1		N2		N3		N4		N5		N6	
	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice
Control	38.00	43.00	38.90	43.30	39.50	42.40	40.10	42.85	39.30	41.80	39.80	44.00
BA 50 ppm	41.10	44.70	39.80	48.00	40.50	48.50	41.70	45.60	41.80	44.20	40.70	45.90
BA 100 ppm	41.50	45.80	40.10	48.40	41.80	46.00	42.50	40.70	43.00	45.60	41.80	48.30
GA_3 10 ppm	42.40	49.90	42.90	50.00	44.10	49.80	44.40	54.90	45.30	49.60	46.20	50.60
GA_3 20 ppm	43.70	52.10	44.80	51.10	45.20	52.60	45.20	55.40	46.20	50.20	47.40	52.80
BA 25 ppm + GA_3 5 ppm	41.40	44.20	40.00	42.40	40.30	43.10	40.80	41.20	40.70	39.70	41.50	45.00
BA 50 ppm + GA_3 10 ppm	41.10	42.40	41.50	40.20	41.10	43.30	41.30	40.80	41.60	40.40	42.00	44.70
CD(0.05)	2.925											
SEm±	1.040											

N1 – NPK 10:10:10 – 0.1%
N3 – NPK 10:20:20 – 0.1%
N5 – NPK 10:20:10 – 0.1%

N2 – NPK 10:10:10 – 0.2%
N4 – NPK 10:20:20 – 0.2%
N6 – NPK 10:20:10 – 0.2%

Table 54. Stalk length (cm) in dendrobium var. Sonia 17 as influenced by combinations of nutrient (concentration and frequency) and growth regulators

Growth regulators	Nutrients											
	N1		N2		N3		N4		N5		N6	
	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice
Control	18.30	20.00	17.50	21.00	19.40	20.10	17.80	20.30	18.30	20.40	17.55	20.10
BA 50 ppm	20.10	27.50	21.10	29.80	21.50	26.80	21.30	29.60	21.70	27.40	21.10	27.85
BA 100 ppm	21.90	29.90	22.60	29.60	20.15	29.60	22.55	30.10	22.90	28.00	22.45	29.80
GA_3 10 ppm	17.60	23.00	17.90	29.80	17.55	23.30	17.75	23.80	17.50	21.60	17.50	21.80
GA_3 20 ppm	18.20	22.60	17.60	26.40	17.30	22.20	18.20	23.20	17.40	22.50	17.30	21.15
BA 25 ppm + GA_3 5 ppm	17.80	20.20	17.70	20.10	18.30	23.25	18.30	23.75	17.80	21.90	18.30	21.90
BA 50 ppm + GA_3 10 ppm	17.90	19.40	18.00	19.30	18.50	24.05	18.20	23.05	17.90	22.40	17.80	21.15
CD(0.05)	0.980											
SEm±	0.349											

N1 – NPK 10:10:10 – 0.1% N2 – NPK 10:10:10 – 0.2%
N3 – NPK 10:20:20 – 0.1% N4 – NPK 10:20:20 – 0.2%
N5 – NPK 10:20:10 – 0.1% N6 – NPK 10:20:10 – 0.2%

Table 55. Rachis length (cm) in dendrobium var. Sonia 17 as influenced by combinations of nutrients (concentration and and frequency) and growth regulators

Growth regulators	Nutrients											
	N1		N2		N3		N4		N5		N6	
	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice
Control	19.45	22.50	21.35	22.30	22.65	22.05	22.25	22.15	21.25	21.15	22.05	23.95
BA 50 ppm	20.45	20.20	18.65	18.70	21.25	22.02	20.45	15.55	19.95	18.75	19.45	17.95
BA 100 ppm	20.05	15.45	18.30	18.35	20.05	16.20	19.75	22.75	20.05	17.55	19.50	18.45
GA_3 10 ppm	24.75	23.20	24.95	22.15	26.55	23.20	26.85	19.10	27.75	20.05	28.65	24.55
GA_3 20 ppm	25.00	22.75	26.65	20.65	27.85	24.50	27.35	19.40	28.35	24.35	30.16	24.86
BA 25 ppm + GA_3 5 ppm	23.55	26.60	22.25	20.00	22.25	28.20	22.55	23.10	22.85	20.95	23.45	27.35
BA 50 ppm + GA_3 10 ppm	23.15	28.95	23.45	24.45	22.55	28.75	23.05	24.80	23.65	24.35	24.15	30.25
CD(0.05)	3.38											
SEm±	1.20											

N1 – NPK 10:10:10 – 0.1%　　N2 – NPK 10:10:10 – 0.2%
N3 – NPK 10:20:20 – 0.1%　　N4 – NPK 10:20:20 – 0.2%
N5 – NPK 10:20:10 – 0.1%　　N6 – NPK 10:20:10 – 0.2%

Table 56. Internodal length (cm) in dendrobium var. Sonia 17 as influenced by combinations of nutrients (concentration and frequency) and growth regulators

Growth regulators	Nutrients											
	N1		N2		N3		N4		N5		N6	
	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice
Control	3.03	3.56	3.31	3.50	3.38	3.28	3.54	3.43	3.29	3.31	3.42	3.37
BA 50 ppm	3.08	3.01	2.74	2.81	2.91	2.81	2.80	1.93	2.66	2.39	2.60	2.07
BA 100 ppm	2.95	2.32	2.55	2.73	2.63	1.98	2.36	2.01	2.64	2.02	2.48	2.08
GA_3 10 ppm	3.79	3.53	3.97	3.45	4.12	3.58	4.12	3.35	4.29	3.30	4.35	4.05
GA_3 20 ppm	4.06	3.78	4.17	3.43	4.60	4.08	4.55	3.52	4.49	3.33	5.14	4.10
BA 25 ppm + GA_3 5 ppm	3.61	3.49	3.45	2.96	3.28	3.17	3.45	3.40	3.50	3.83	3.46	3.76
BA 50 ppm + GA_3 10 ppm	3.41	4.32	3.60	3.64	3.34	2.72	3.53	3.09	3.62	3.39	3.53	3.65
CD(0.05)	0.252											
SEm±	0.089											

N1 – NPK 10:10:10 – 0.1% N2 – NPK 10:10:10 – 0.2%
N3 – NPK 10:20:20 – 0.1% N4 – NPK 10:20:20 – 0.2%
N5 – NPK 10:20:10 – 0.1% N6 – NPK 10:20:10 – 0.2%

Table 57. Girth of spike (cm) in dendrobium var. Sonia 17 as influenced by combinations of nutrients (concentration and frequency) and growth regulators

Growth regulators	Nutrients											
	N1		N2		N3		N4		N5		N6	
	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice
Control	1.53	1.63	1.83	1.44	1.65	1.44	1.63	1.45	1.93	1.45	1.65	1.42
BA 50 ppm	1.60	1.62	1.94	1.69	1.95	1.96	2.07	2.73	1.81	1.95	1.92	1.95
BA 100 ppm	1.92	1.80	1.65	1.73	1.75	2.33	1.88	2.95	1.50	2.36	1.71	2.30
GA_3 10 ppm	1.34	1.38	1.40	1.30	1.47	1.34	1.47	1.35	1.50	1.36	1.46	1.38
GA_3 20 ppm	1.40	1.33	1.39	1.24	1.53	1.25	1.48	1.28	1.48	1.29	1.46	1.30
BA 25 ppm + GA_3 5 ppm	1.49	1.29	1.44	1.38	1.59	1.36	1.53	1.39	1.56	1.48	1.53	1.40
BA 50 ppm + GA_3 10 ppm	1.55	1.34	1.49	1.33	1.47	1.40	1.42	1.42	1.49	1.39	1.52	1.42
CD(0.05)	0.244											
SEm±	0.087											

N1 – NPK 10:10:10 – 0.1%　　N2 – NPK 10:10:10 – 0.2%
N3 – NPK 10:20:20 – 0.1%　　N4 – NPK 10:20:20 – 0.2%
N5 – NPK 10:20:10 – 0.1%　　N6 – NPK 10:20:10 – 0.2%

was 1.44 cm in plants that received NPK 10:10:10 at 0.2 per cent applied weekly once.

Combined effect of nutrients and growth regulators was significant in producing stalks of markedly different girths (Table 50). Stalk girth of 2.41 cm was recorded corresponding to combination of NPK 10:20:20 at 0.2 per cent and BA 100 ppm. Minimum girth was 1.31 cm when NPK 10:10:10 at 0.2 per cent was applied with GA_3 20 ppm.

Maximum stalk girth of 2.20 cm was observed corresponding to BA 100 ppm applied in plants treated weekly twice with the nutrients (Table 51). Least girth (1.28 cm) was recorded in weekly twice application of nutrients + GA_3 20 ppm.

Three factor interaction was found significant in the case of spike girth (Table 52). Maximum girth recorded was 2.95 cm corresponding to NPK 10:20:20 at 0.2 per cent applied weekly twice + BA 100 ppm. Spike girth of 2.73 cm in the case of BA 50 ppm substituting in the above combination was on par with the highest value. Minimum girth was 1.24 cm observed when NPK 10:10:10 at 0.2 per cent was applied weekly twice + GA_3 20 ppm.

4.2.8 Annual spike production

Data pertaining to the annual spike production per plant in dendrobium var. Sonia 17 are presented in Tables 58 and 59.

4.2.8.1 Main effect of nutrients, frequency of application and growth regulators (Table 58)

Nutrient levels and their concentrations influenced the annual spike production significantly. Maximum number of spikes per plant per year (11.14) was observed in plants which received NPK 10:20:20 at 0.2 per cent, followed by 11.02

Table 58. Annual spike production (per plant) in dendrobium var. Sonia 17 as influenced by nutrient concentration, frequency of application, growth regulators and their combinations

Frequency	Nutrients						Growth regulators							
	N1	N2	N3	N4	N5	N6	G0	G1	G2	G3	G4	G5	G6	
Weekly twice	8.84	9.90	10.40	11.12	10.80	11.22	9.88	10.44	11.18	8.36	8.20	9.54	9.48	10.42
Weekly once	8.36	8.76	9.28	9.66	9.86	10.36	8.76	9.86	10.36	8.04	7.82	9.18	9.26	8.00
Main effect	8.14	10.16	10.10	11.14	10.36	11.02	8.16	9.80	10.52	7.52	7.38	8.76	9.08	

N1 – NPK 10:10:10 – 0.1%
N2 – NPK 10:10:10 – 0.2%
N3 – NPK 10:20:20 – 0.1%
N4 – NPK 10:20:20 – 0.2%
N5 – NPK 10:20:10 – 0.1%
N6 – NPK 10:20:10 – 0.2%

G0 - Control
G1 - BA 50 ppm
G2 - BA 100 ppm
G3 - GA_3 10 ppm
G4 - GA_3 20 ppm
G5 - BA 25 ppm + GA_3 5 ppm
G6 - BA 50 ppm + GA_3 10 ppm

spikes in plants receiving NPK 10:20:10 at 0.2 per cent. Significantly low number of spikes was recorded for NPK 10:10:10 at 0.1 per cent (8.14).

Among the frequencies tried, application of nutrients weekly twice produced 10.42 spikes, which was distinctly superior to weekly once application producing 8.00 spikes.

Growth regulators also influenced spike production. Maximum of 10.52 spikes per year was recorded when BA 100 ppm was applied, which excelled all other treatments. BA 50 ppm recorded 9.80 spikes per year and least number of spikes (7.38) was observed for GA_3 20 ppm, which inferior even to the control (8.16).

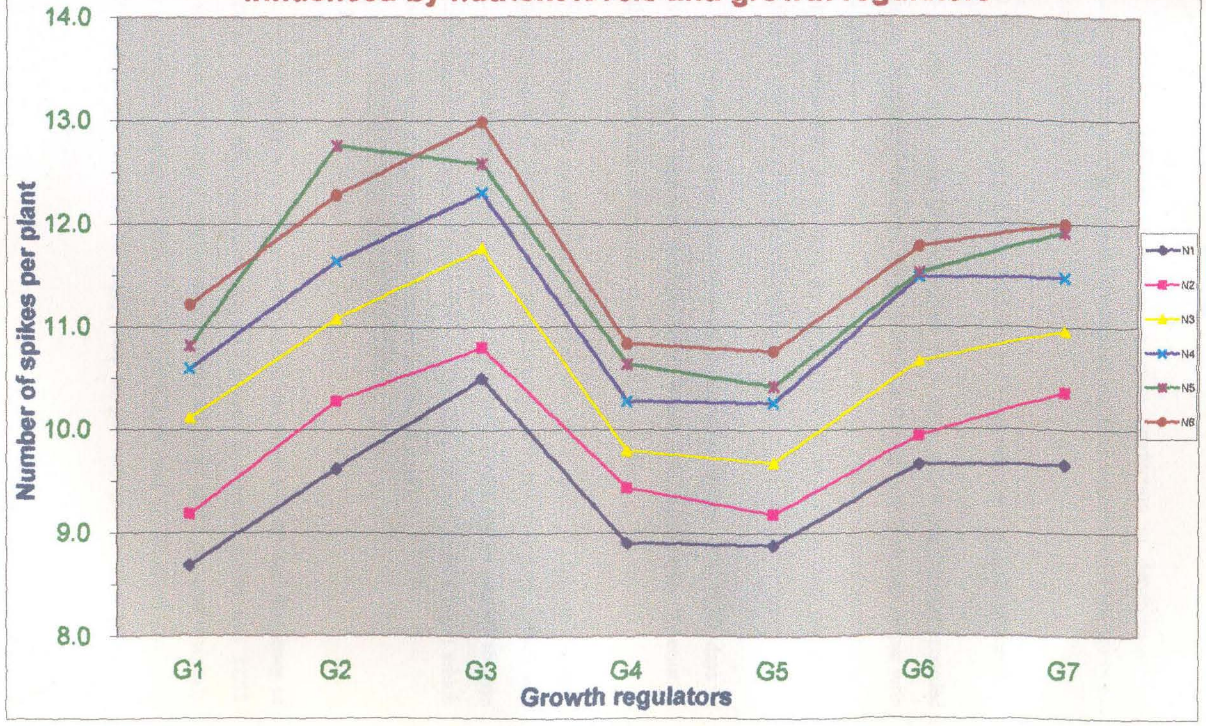
4.2.8.2 Interaction effects

A combined effect of nutrient concentration of NPK 10:20:10 at 0.2 per cent and weekly twice application frequency produced higher annual spike production of 11.22 spikes per plant, followed by 11.12 spikes corresponding to NPK 10:20:20 at 0.2 per cent, applied weekly twice. Least recorded value for annual spike production was 8.36 for NPK 10:10:10 at 0.1 per cent, applied weekly once.

A combination of NPK 10:20:10 at 0.2 per cent and BA 100 ppm gave 12.98 spikes (Table 59 and Fig.5). This was on par with NPK 10:20:10 at 0.1 per cent + BA 50 ppm producing 12.76 spikes. Least spike production of 8.68 was observed for NPK 10:10:10 at 0.1 per cent + growth regulator control.

BA 100 ppm favoured highest spike production (11.18) when applied in plants, which received nutrients weekly twice, followed by BA 50 ppm for the same nutrient application frequency (10.44). Least number of spikes (7.82) was observed in the case of GA_3 20 ppm applied in plants which received nutrients weekly once.

Fig. 5. Annual spike production in dendrobium var. Sonia 17, as influenced by nutrient levels and growth regulators



4.2.9 Interval of spike production

Data pertaining to interval of spike production in dendrobium var. Sonia 17 as influenced by various treatments and their combinations are presented in Tables 60 and 61.

4.2.9.1 Main effect of nutrients, frequency of application and growth regulators

Interval of spike production was 32.62 days, which was the least recorded values, in plants which received NPK 10:20:10 at 0.2 per cent. This was on par with 32.12 days recorded for NPK 10:20:10 at 0.2 per cent. Spike production occurred at maximum interval of 44.84 days for NPK 10:10:10 at 0.1 per cent which was significantly inferior to all other treatments.

Interval between production of consecutive spikes was 35.03 days in plants sprayed with nutrients weekly twice, which was significantly superior to weekly once application of nutrients (interval of 45.63 days).

Among the growth regulators tried, interval of spike production recorded a minimum value of 34.70 days in plants treated with BA 100 ppm, which was detectably superior. Maximum interval between consecutive spikes was 49.46 days in plants treated with GA_3 20 ppm, followed by GA_3 10 ppm (48.54 days) which was more than that for growth regulator control (44.73 days).

4.2.9.2 Interaction effects

Interaction was evident between nutrient concentration and frequency of application (Table 68). Minimum interval between successive spikes was 32.53 days for plants receiving a combination of NPK 10:20:10 at 0.2 per cent + weekly twice application frequency. NPK 10:20:20 at 0.2 per cent (32.82 days) and NPK 10:20:10 at 0.1 per cent (33.80 days) were on par with the superior treatment.

Table 60. Interval of spike production (days) in dendrobium var. Sonia 17 as influenced by nutrient concentration, frequency of application, growth regulators and their combinations

Frequency	Nutrients						Growth regulators							
	N_1	N_2	N_3	N_4	N_5	N_6	G_0	G_1	G_2	G_3	G_4	G_5	G_6	
Weekly twice	41.29	36.87	35.70	32.82	33.80	32.53	36.94	34.96	32.65	43.66	44.51	38.26	38.50	35.03
Weekly once	43.66	41.67	39.33	37.78	37.02	35.23	41.67	37.02	35.23	45.40	46.68	39.76	39.42	45.63
Main effect	44.84	35.93	36.14	32.76	35.23	33.12	44.73	37.24	34.70	48.54	49.46	41.67	40.20	

CD(0.05) (Nutrients and frequency) 1.412
(Growth regulator and frequency) 1.117
(Nutrients) 0.302
(Growth regulator) 0.302
(Frequency) 1.821

N1 – NPK 10:10:10 – 0.1%
N2 – NPK 10:10:10 – 0.2%
N3 – NPK 10:20:20 – 0.1%
N4 – NPK 10:20:20 – 0.2%
N5 – NPK 10:20:10 – 0.1%
N6 – NPK 10:20:10 – 0.2%

G0 - Control
G1 - BA 50 ppm
G2 - BA 100 ppm
G3 - GA_3 10 ppm
G4 - GA_3 20 ppm
G5 - BA 25 ppm + GA_3 5 ppm
G6 - BA 50 ppm + GA_3 10 ppm

Table 61. Interval of spike production (days) in dendrobium var. Sonia 17 as influenced by combinations of nutrient concentration and growth regulators

Treatments	Nutrient concentration					
	N_1	N_2	N_3	N_4	N_5	N_6
Control	42.05	39.76	36.07	34.43	33.23	32.53
BA 50 ppm	37.94	35.51	32.94	31.36	28.61	29.72
BA 100 ppm	34.76	33.80	31.04	29.67	29.01	28.12
GA_3 10 ppm	41.01	38.67	37.24	35.51	34.30	33.67
GA_3 20 ppm	41.10	39.76	37.71	35.58	35.03	33.92
BA 25 ppm + GA_3 5 ppm	38.02	36.72	34.24	31.79	31.68	30.98
BA 50 ppm + GA_3 10 ppm	38.02	35.23	33.30	31.79	30.62	30.42
CD(0.05)	1.613					
SEm	0.574					

N1 – NPK 10:10:10 – 0.1% N2 – NPK 10:10:10 – 0.2%
N3 – NPK 10:20:20 – 0.1% N4 – NPK 10:20:20 – 0.2%
N5 – NPK 10:20:10 – 0.1% N6 – NPK 10:20:10 – 0.2%

Maximum interval recorded was 43.66 days for NPK 10:10:10 at 0.1 per cent treated plants, receiving nutrients weekly once.

Combination of weekly twice application of nutrients with BA 100 ppm reduced the spike production interval as low as 32.65 days, which was significantly superior to other treatment combinations. Maximum interval between two consecutive spikes was 46.68 days for combination of weekly once application of nutrients and GA_3 20 ppm.

Combination of NPK 10:20:10 at 0.2 per cent with BA 100 ppm recorded the minimum value for interval of spike production (28.12 days). This was on par with many other treatments. Highest interval recorded was 42.05 days for plants which received a combination of NPK 10:10:10 at 0.1 per cent + growth regulator control.

4.2.10 Size of floret

Data pertaining to size of floret in dendrobium var.Sonia 17 as influenced by various treatments and their combinations are presented in Table 62.

4.2.10.1 Main effect of nutrients, frequency of application and growth regulators

Floret size in dendrobium var. Sonia 17 showed detectable differences due to the treatments. Floret size was reduced to 6.0 cm x 6.0 cm in plants which received a combination of NPK 10:10:10 at 0.1 and 0.2 per cent applied weekly once + BA 100 ppm and NPK 10:20:20 at 0.1 per cent weekly once + BA 100 ppm. Floret size was 6.0 cm x 6.5 cm in plants receiving NPK 10:20:10 at 0.1 per cent weekly once + BA 100 ppm. BA application showed a general reduction in size of floret. This reduction in size was prominent when concentration of BA increased. Floret size was increased to 8.0 cm x 8.5 cm in plants which received a combination

Table 62. Floret size (cm x cm) in dendrobium var. Sonia 17 as influenced by combinations of nutrients (concentration and frequency) and growth regulators

Growth regulators	Nutrients											
	N1		N2		N3		N4		N5		N6	
	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice	Weekly once	Weekly twice
Control	7.0x7.5	7.0x7.5	7.5x7.5	7.5x7.5	7.5x7.5	7.5x7.5	7.5x7.5	7.5x7.5	7.5x7.5	7.5x7.5	7.5x8.0	7.5x8.0
BA 50 ppm	7.0x7.0	6.5x7.0	7.0x7.0	7.0x7.0	7.0x7.0	6.5x6.5	7.5x7.0	6.5x6.5	6.5x6.5	6.5x6.5	7.0x6.5	7.0x6.5
BA 100 ppm	6.0x6.0	6.0x6.0	6.0x6.0	7.0x6.5	7.0x6.5	7.0x6.5	7.0x6.5	7.0x6.5	6.0x6.5	6.5x6.5	7.0x6.5	6.5x6.5
GA_3 10 ppm	7.0x7.0	7.0x7.0	7.0x7.0	7.0x7.0	7.0x7.5	7.0x7.5	7.0x7.5	7.0x7.5	7.0x7.0	7.5x7.5	7.5x7.5	7.5x7.5
GA_3 20 ppm	7.5x7.5	7.5x7.5	7.5x7.5	8.0x7.5	7.5x7.5	7.5x7.5	7.5x7.5	8.0x7.5	8.0x8.0	8.0x8.5	8.0x8.0	8.0x8.5
BA 25 ppm + GA_3 5 ppm	7.0x7.5	7.0x7.5	7.0x7.5	7.5x7.6	7.0x7.5	7.5x7.5	7.0x7.5	7.5x7.5	7.0x7.5	7.5x7.5	7.5x7.5	7.5x7.5
BA 50 ppm + GA_3 10 ppm	7.0x7.0	7.0x7.0	7.0x7.0	7.0x7.0	7.0x7.5	7.0x7.5	7.0x7.5	7.5x7.5	7.5x7.5	8.0x7.5	7.5x7.5	8.0x7.5

N1 – NPK 10:10:10 – 0.1% N2 – NPK 10:10:10 – 0.2%
N3 – NPK 10:20:20 – 0.1% N4 – NPK 10:20:20 – 0.2%
N5 – NPK 10:20:10 – 0.1% N6 – NPK 10:20:10 – 0.2%

of NPK 10:20:10 at 0.1 per cent applied weekly twice + GA_3 20 ppm, NPK 10:20:10 at 0.2 per cent applied weekly twice + GA_3 20 ppm.

4.3 Post-harvest studies

Effect of various pulsing and holding treatments was studied to evaluate their influence on enhancement of vase life in dendrobium var. Sonia 17 (Plate 10). From the results obtained the superior holding and pulsing treatments responsible were selected and analysed. The results of these treatments are presented hereunder.

4.3.1 Effect of pulsing treatments

Data pertaining to the effect of various pulsing treatments are presented in Table 63.

4.3.1.1 Days to wilt of one floret

Spikes remained fresh for a maximum period of 19.92 days when given a pulsing of HQ 500 ppm + sucrose 5 per cent for 12 hours. This was followed by 18.31 days in the case of HQ 500 ppm + sucrose 5 per cent for 6 hours. Minimum vase life was 14.35 days for spikes, which did not receive any pulsing treatment.

4.3.1.2 Days to wilt of last floret

Spikes showed different life spans depending on the pulsing treatment they received (Fig.6). Maximum longevity of 25.00 days was recorded when spikes were pulsed in HQ 500 ppm + sucrose 5 per cent for 12 hours, followed by HQ 250 ppm + sucrose 5 per cent for 6 hours (24.00 days). Minimum longevity of 16.50 days was recorded in spikes, which did not receive any pulsing treatment.

Table 63. Effect of pulsing treatments on post harvest characters in dendrobium var. Sonia 17

Treatment	Days to wilt of one floret	Days to wilt of last floret	Final EC* (mS g^{-1})	Water uptake (ml)	Weight loss (g)
P_0	14.35	16.50	0.14	16.54	1.07
P_1	18.31	21.00	0.16	17.34	0.93
P_2	19.92	25.00	0.10	17.21	0.95
P_3	16.96	24.50	0.12	17.45	1.00
P_4	16.39	24.00	0.18	17.26	1.00
P_5	15.73	21.50	0.24	18.93	0.99
P_6	16.65	21.00	0.33	18.57	1.01
P_7	14.96	20.00	0.32	19.49	1.01
P_8	15.85	20.50	0.24	18.96	0.94
P_9	16.65	20.00	0.39	19.96	0.99
P_{10}	14.46	19.00	0.25	19.70	1.03
P_{11}	17.69	23.00	2.07	19.83	1.00
P_{12}	18.27	21.50	2.13	19.99	1.00
CD(0.05)	1.09	0.916	0.08	1.43	0.02
SEm±	0.39	0.329	0.03	0.51	0.009

* The EC of the distilled water was 0.04 mS g^{-1}

4.3.1.3 Final EC

Pulsing treatment showed varying influence on final electrical conductivity of holding solution. Maximum EC of 2.13 mS g^{-1} was recorded in the case of hot water dip at 50-60°C for 10 seconds. This was followed by 2.07 mS g^{-1} for hot water dip at 50-60°C for 5 seconds. Minimum EC recorded was 0.10 mS g^{-1} for pulsing with HQ 500 ppm + sucrose 5 per cent for 12 hours.

4.3.1.4 Water uptake

Maximum quantity of water (19.99 ml) was absorbed by spikes dipped in hot water at 50-60°C for 10 seconds, followed by 19.96 ml by spikes dipped in hot water of 60-70°C for 5 seconds. Minimum water uptake of 16.54 ml was observed when no pulsing treatment was given to spikes.

4.3.1.5 Loss of weight of spikes

Weight loss was maximum for spikes, which were not given any pulsing treatment (1.07 g). This was markedly high compared to all other treatments. This was followed by 1.03 g weight loss in the case of hot water dip at 60-70°C for 10 seconds. Loss of weight was minimum (0.93 g) for spikes pulsed with HQ 500 ppm + sucrose 5 per cent for 6 hours.

4.3.2 Effect of holding treatments

Data pertaining to the effect of holding treatments on enhancement of vase life are presented in Table 64.

4.3.2.1 Days to wilt of one floret

Among the different holding solutions, maximum life of spike cent (24.73 days) was observed for solution containing $AgNO_3$ 50 ppm, HQ 400 ppm and

Table 64. Effect of holding solutions on the post harvest characters in dendrobium var. Sonia 17

Treatment	Days to wilt of one floret	Days to wilt of last floret	Initial EC (mS g^{-1})	Final EC (mS g^{-1})	Difference in EC (mS g^{-1})	Water uptake (ml)	Weight loss (g)
H_0	8.85	11.00	0.08	0.07	-0.01	16.30	3.42
H_1	9.19	11.50	0.05	0.07	0.02	19.46	1.86
H_2	9.89	13.00	0.15	0.17	0.02	12.50	1.64
H_3	11.88	18.50	1.23	1.32	-0.02	18.55	1.34
H_4	11.77	18.00	2.71	3.75	0.03	19.40	1.07
H_5	17.54	24.00	0.13	0.16	0.02	17.50	0.68
H_6	19.39	22.50	0.13	0.19	0.05	16.45	0.53
H_7	19.85	22.50	0.18	0.15	-0.03	19.50	0.69
H_8	21.38	26.00	0.08	0.13	-0.05	16.25	0.46
H_9	20.42	25.50	0.09	0.14	0.05	18.30	0.43
H_{10}	20.65	23.00	0.13	0.16	0.02	18.65	0.36
H_{11}	22.85	28.50	0.07	0.14	0.07	19.00	0.27
H_{12}	24.73	30.50	0.11	0.22	0.11	19.25	0.13
CD(0.05)	1.09	0.987	0.08	0.08	0.01	1.43	0.02
SEm±	0.39	0.337	0.03	0.03	0.004	0.51	0.009

sucrose 5 per, spikes kept in $AgNO_3$ 25 ppm + HQ 400 ppm + sucrose 5 per cent remained without wilting for 22.85 days. Minimum life was recorded for control, i.e., distilled water (8.85 days). BA 10 ppm and BA 20 ppm were on par with this, in which spikes remained fresh only for 9.19 and 9.89 days, respectively.

4.3.2.2 Days to wilt of last floret

Spike showed different life spans depending on the treatments imposed (Fig.6). Maximum life of 30.50 days was recorded in spikes kept in $AgNO_3$ 50 ppm + HQ 400 ppm + sucrose 5 per cent, which was significantly higher than all other treatments, followed by 28.50 days in $AgNO_3$ 25 ppm + HQ 400 ppm + sucrose 5 per cent. Control treatment exhibited minimum life of spike (11.00 days).

4.3.2.3 Final electrical conductivity of solutions

Electrical conductivity was significantly influenced by the holding solutions. Maximum EC was observed (3.75 mS g^{-1}) in the case of Triadimefon 20 ppm, followed by 1.32 mS g^{-1} for Triadimefon 10 ppm. Minimum EC recorded was 0.07 mS g^{-1} the control and BA 10 ppm.

4.3.2.4 Difference in Electrical Conductivity

Difference between initial and final EC values was minimum (-0.05 mS g^{-1}) in the case of $AgNO_3$ 50 ppm. Highest difference in value was 0.11 mS g^{-1} for $AgNO_3$ 50 ppm + HQ 400 ppm + sucrose 5 per cent.

4.3.2.5 Water uptake

Maximum uptake of water (19.50 ml) was recorded in spikes kept in $AgNO_3$ 25 ppm + sucrose 5 per cent, which was closely followed by 19.46 ml for BA 10 ppm and 19.40 ml for Triadimefon 20 ppm. Minimum uptake of water (12.50 ml) was recorded for BA 20 ppm.

4.3.2.6. Loss of weight

Treatments showed distinct influence on the loss of weight of spikes. Maximum weight loss of 3.42 g was observed in spikes kept in distilled water (control), followed by 1.86 g loss in BA 10 ppm and 1.64 g in BA 20 ppm. Minimum loss of weight of 0.13 g was recorded in the case of spikes kept in solution containing $AgNO_3$ 50 ppm + HQ 400 ppm + sucrose 5 per cent, followed by 0.27 g loss in $AgNO_3$ 25 ppm + HQ 400 ppm + sucrose 5 per cent.

4.3.3 Effect of pulsing and holding treatments

Data pertaining to the effect of various pulsing and holding treatments in combination on the post harvest characters of dendrobium var. Sonia 17 are presented in Table 65.

Due to large volume of data on the effect of combination of pulsing and holding treatments, data on the combination of best pulsing and holding treatments alone are presented here (Plates 11 to 13). The selected combinations of are:

P_0H_0 - Absolute control

P_1H_0 - Pulsing HQ 500 ppm + Sucrose 5% for 12 hours + Holding control

P_1H_1 - Pulsing HQ 500 ppm + Holding $AgNO_3$ 50 ppm + HQ 400 ppm + Sucrose 5%

P_1H_2 - Pulsing HQ 500 ppm + Holding $AgNO_3$ 25 ppm + HQ 400 ppm + Sucrose 5%

P_1H_3 - Pulsing HQ 500 ppm + Holding $AgNO_3$ 25 ppm + HQ 200 ppm + Sucrose 5%

P_1H_4 - Pulsing HQ 500 ppm + Holding $AgNO_3$ 50 ppm + HQ 200 ppm + Sucrose 5%

P_1H_5 - Pulsing HQ 500 ppm + Holding $AgNO_3$ 50 ppm + Sucrose 5%

P_2H_0 - Pulsing HQ 500 ppm + Sucrose 5% for 6 hours + Holding control

P_2H_1 - Pulsing HQ 500 ppm + Holding $AgNO_3$ 50 ppm + HQ 400 ppm + Sucrose 5%

P_2H_2 - Pulsing HQ 500 ppm + Holding $AgNO_3$ 25 ppm + HQ 400 ppm + Sucrose 5%

P_2H_3 - Pulsing HQ 500 ppm + Holding $AgNO_3$ 25 ppm + HQ 200 ppm + Sucrose 5%

P_2H_4 - Pulsing HQ 500 ppm + Holding $AgNO_3$ 50 ppm + HQ 200 ppm + Sucrose 5%

P_2H_5 - Pulsing HQ 500 ppm + Holding $AgNO_3$ 50 ppm + Sucrose 5%

Table 65. Effect of pulsing and holding treatments on the post harvest characters in dendrobium var. Sonia 17

Treatment	Days to wilt of one floret	Days to wilt of last floret	Initial EC ($mS\ g^{-1}$)	Final EC ($mS\ g^{-1}$)	Difference in EC ($mS\ g^{-1}$)	Water uptake (ml)	Weight loss (g)
P_0H_0	6.50	9.50	0.10	0.08	-0.02	7.80	3.85
P_1H_0	11.50	15.00	0.03	0.02	-0.01	21.90	3.21
P_1H_1	27.50	31.50	0.13	0.16	0.03	28.20	0.10
P_1H_2	25.50	28.50	9,15	0.18	0.03	24.20	0.23
P_1H_3	17.50	20.50	0.07	0.09	0.02	21.40	0.44
P_1H_4	23.00	26.50	0.20	0.26	0.06	22.70	0.35
P_1H_5	21.00	24.00	0.18	0.22	0.04	16.90	0.42
P_2H_0	11.50	14.00	0.05	0.03	-0.02	22.80	3.13
P_2H_1	28.50	32.00	0.10	0.12	0.02	21.10	0.07
P_2H_2	25.00	28.50	0.15	0.16	0.01	23.10	0.21
P_2H_3	19.00	22.50	0.14	0.16	0.02	18.40	0.44
P_2H_4	22.00	25.50	0.26	0.28	0.02	21.40	0.33
P_2H_5	21.50	23.00	0.18	0.20	0.02	18.70	0.41
P_3H_0	9.50	12.00	0.04	0.02	-0.02	18.10	3.36
P_3H_1	26.00	29.50	0.03	0.07	0.04	18.80	0.12
P_3H_2	24.00	27.50	0.05	0.08	0.03	21.00	0.25
P_3H_3	22.00	27.00	0.05	0.07	0.02	21.70	0.46
P_3H_4	24.50	27.50	0.04	0.08	0.04	19.50	0.32
P_3H_5	21.50	26.00	0.06	0.08	0.03	20.10	0.46
P_4H_0	11.50	16.00	0.07	0.05	0.02	16.10	3.37
P_4H_1	25.50	29.50	0.05	0.08	0.03	18.30	0.11
P_4H_2	24.00	28.00	0.05	0.08	0.03	18.30	0.25
P_4H_3	21.50	26.00	0.09	0.10	0.01	20.10	0.46
P_4H_4	22.50	26.00	0.04	0.08	0.04	20.30	0.37
P_4H_5	24.00	29.50	0.03	0.08	0.05	17.90	0.37
CD(0.05)	3.91	1.318	0.306	0.027	0.027	5.15	1.09
SEm±	1.40	0.47	0.110	0.009	0.009	1.84	0.30

P_3H_0 - Pulsing HQ 250 ppm + Sucrose 5% for 12 hours + Holding control

P_3H_1 - Pulsing HQ 250 ppm + Holding $AgNO_3$ 50 ppm + HQ 400 ppm + Sucrose 5%

P_3H_2 - Pulsing HQ 250 ppm + Holding $AgNO_3$ 25 ppm + HQ 400 ppm + Sucrose 5%

P_3H_3 - Pulsing HQ 250 ppm + Holding $AgNO_3$ 25 ppm + HQ 200 ppm + Sucrose 5%

P_3H_4 - Pulsing HQ 250 ppm + Holding $AgNO_3$ 50 ppm + HQ 200 ppm + Sucrose 5%

P_3H_5 - Pulsing HQ 250 ppm + Holding $AgNO_3$ 50 ppm + Sucrose 5%

P_4H_0 - Hot water dip at 50-60°C + Holding control for 10 seconds

P_4H_1 - Hot water dip at 50-60°C + Holding $AgNO_3$ 50 ppm + HQ 400 ppm + Sucrose 5%

P_4H_2 - Hot water dip at 50-60°C + Holding $AgNO_3$ 25 ppm + HQ 400 ppm + Sucrose 5%

P_4H_3 - Hot water dip at 50-60°C + Holding $AgNO_3$ 25 ppm + HQ 200 ppm + Sucrose 5%

P_4H_4 - Hot water dip at 50-60°C + Holding $AgNO_3$ 50 ppm + HQ 200 ppm + Sucrose 5%

P_4H_5 - Hot water dip at 50-60°C + Holding $AgNO_3$ 50 ppm + Sucrose 5%

4.3.3.1 Days to wilt of one floret

Spikes pulsed with HQ 500 ppm and sucrose 5 per cent for 6 hours and kept in holding solution containing $AgNO_3$ 50 ppm + HQ 400 ppm + sucrose 5 per cent recorded maximum vase life of 28.50 days. Spikes which did not receive any pulsing or holding stayed fresh for a period of 6.50 days only. In such plants, including those in the inferior treatments, yellowing of the stalk could be noticed (Plate 14).

4.3.3.2 Days to wilt of last floret

Days to wilt of the last floret showed marked differences depending on the treatment combination received (Fig.6). Maximum longevity of 32.00 days was recorded in spikes pulsed with HQ 500 ppm + sucrose 5 per cent for 12 hours and kept in holding solution containing $AgNO_3$ 50 ppm + HQ 400 ppm + sucrose 5 per cent. This was followed by spikes pulsed with HQ 500 ppm + sucrose 5 per cent for 6 hours and kept in holding solution containing $AgNO_3$ 50 ppm + HQ 400 ppm +

sucrose 5 per cent (31.50 days), which was on par with above. Minimum longevity of 9.50 days was observed for absolute control treatment.

4.3.3.3 Final EC

EC recorded after experiment was maximum for combination of pulsing treatment of HQ 500 ppm + sucrose 5 per cent for 6 hours and holding treatment of $AgNO_3$ 50 ppm + HQ 200 ppm + sucrose 5 per cent (0.28 mS g^{-1}). Minimum EC recorded was 0.02 mS g^{-1} for combination of pulsing with HQ 500 ppm + sucrose 5 per cent for 12 hours and kept in distilled water and treatment combination of hot water dip at 50-60°C for 5 seconds and kept in distilled water.

4.3.3.4 Difference in EC

Difference in EC at the beginning and end of the experiment showed distinguishable difference with varying combinations of pulsing and holding solutions. Maximum value was recorded (0.06 mS g^{-1}) for a combination of pulsing treatment with HQ 500 ppm + sucrose 5 per cent for 12 hours and holding solution containing $AgNO_3$ 50 ppm + HQ 200 ppm + sucrose 5 per cent. Minimum difference was recorded in the combination with neither pulsing nor holding treatment, which recorded value of -0.02 mS g^{-1}.

4.3.3.5 Water uptake

Maximum quantity of water (28.20 ml) was absorbed by spikes which were pulsed with HQ 500 ppm + sucrose 5 per cent for 12 hours and kept in holding solution contained $AgNO_3$ 50 ppm + HQ 400 ppm + sucrose 5 per cent which was significantly higher compared to all other treatment combinations. Minimum uptake of water was 7.80 ml recorded in the case of absolute control.

Fig. 6. Effect of pulsing and holding solutions on the longevity of cut spikes in dendrobium var. Sonia 17

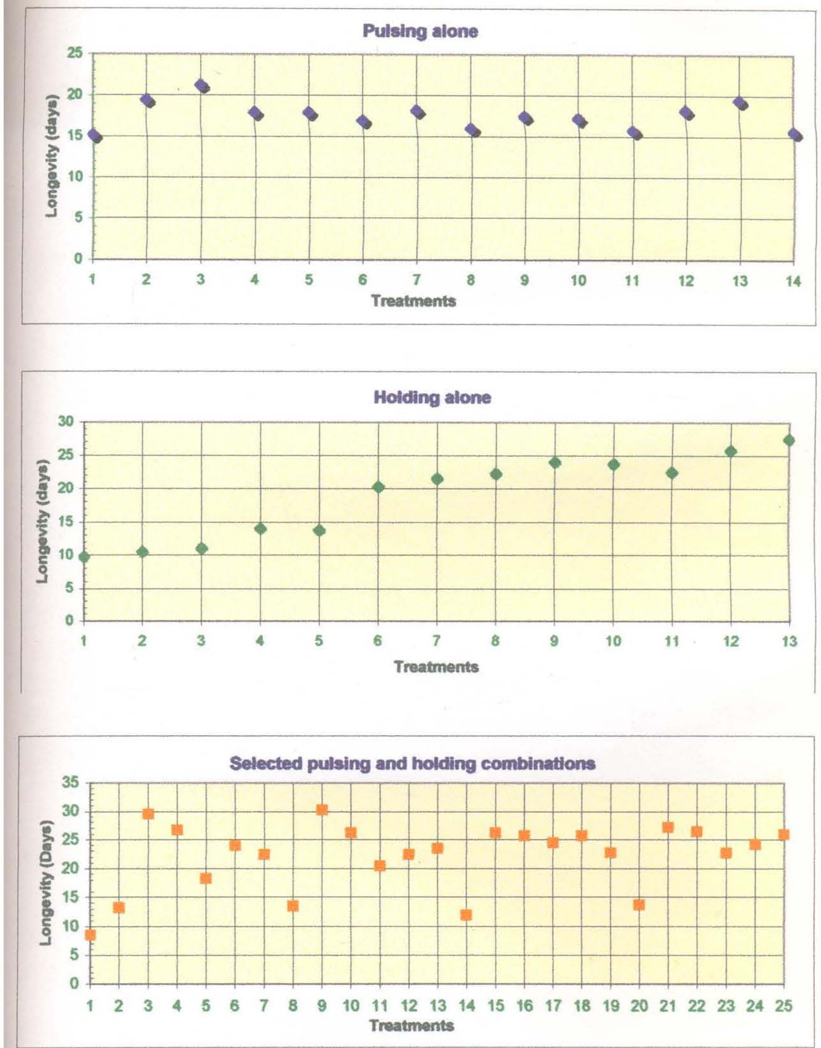


Plate 10. General view of Experiment 3

Plate 11. Effect of superior pulsing treatments in control treatment of holding solutions.
From left P_1 (HQ 500 ppm + sucrose 5% for 12 hours), P_2 (HQ 500 ppm + sucrose 5% for 6 hours), P_3 (Hot water treatment at 50-60°C for 10 seconds), P_4 (HQ 250 ppm + sucrose 5% for 12 hours)

Plate 12. Effect of best pulsing treatments (P1 - HQ 500 ppm + sucrose 5% for 12 hours) in superior holding solutions in comparison with holding control.
From left - H_0 (Holding control), H_1 (AgNO3 50 ppm + HQ 400 ppm + sucrose 5%), H_2 ($AgNO_3$ 25 ppm + HQ 400 ppm + sucrose 5%), H_3 ($AgNO_3$ 50 ppm + HQ 200 ppm + sucrose 5%).


P1H0
P2H0
P3H0
P4H0

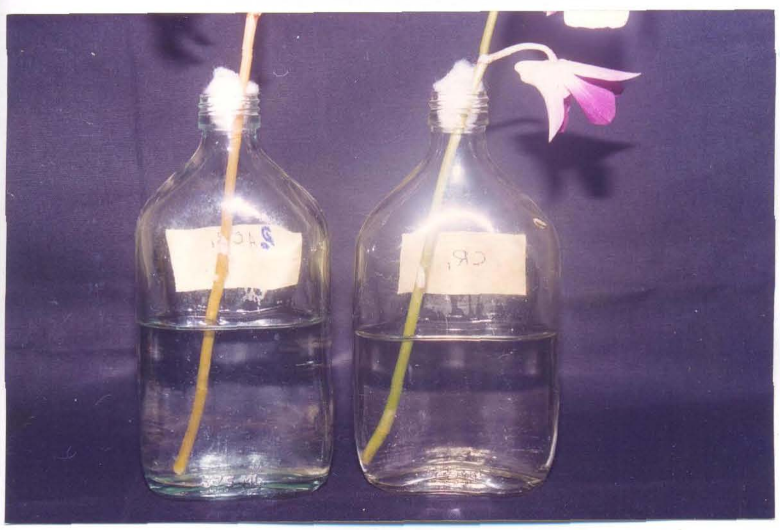

P1H0
P1H1
P1H2
P1H3

Plate 13. Effect of best holding treatment (H_1 - $AgNO_3$ 50 ppm + HQ 400 ppm + sucrose 5%) in combination with superior pulsing treatments compared to holding control.

From left - P_1 (HQ 500 ppm + sucrose 5% for 12 hours) with holding control, P_1 with H1, P_2 (HQ 500 ppm + sucrose 5% for 6 hours), P_3 (Hot water treatment at 50-60°C for 10 seconds) with H_1, P_4 (HQ 250 ppm + sucrose 5% for 12 hours) with H_1.

Plate 14. Yellowing of stem (left) as influenced by poor pulsing and holding solutions, compared to superior treatments (right)

P_1H_0
P_1H_1
P_2H_1
P_3H_1
P_4H_1



4.3.3.6 Loss of weight

Maximum weight loss of 3.85 g was observed in spikes, which received neither pulsing nor holding treatment. This was followed by spikes, which were dipped in hot water at 50-60°C for 10 seconds and kept in distilled water (3.37 g). Minimum loss of weight of spike (0.10 g) was corresponding to a combination of pulsing with HQ 500 ppm + sucrose 5 per cent for six hours and kept in holding solution containing $AgNO_3$ 50 ppm + HQ 400 ppm + sucrose 5 per cent.

4.4 Cost of chemicals for the best treatment

Cost of chemicals for best treatment was calculated up to flowering in experiment I and for one year in experiment II (Table 66). For reducing pre-blooming period the treatment containing NPK 30:10:10 at 0.2 per cent applied weekly twice + BA 200 ppm applied monthly once was the best. The cost for nutrients per plant per year was 20 paise and for growth regulator was Rs.2.60.

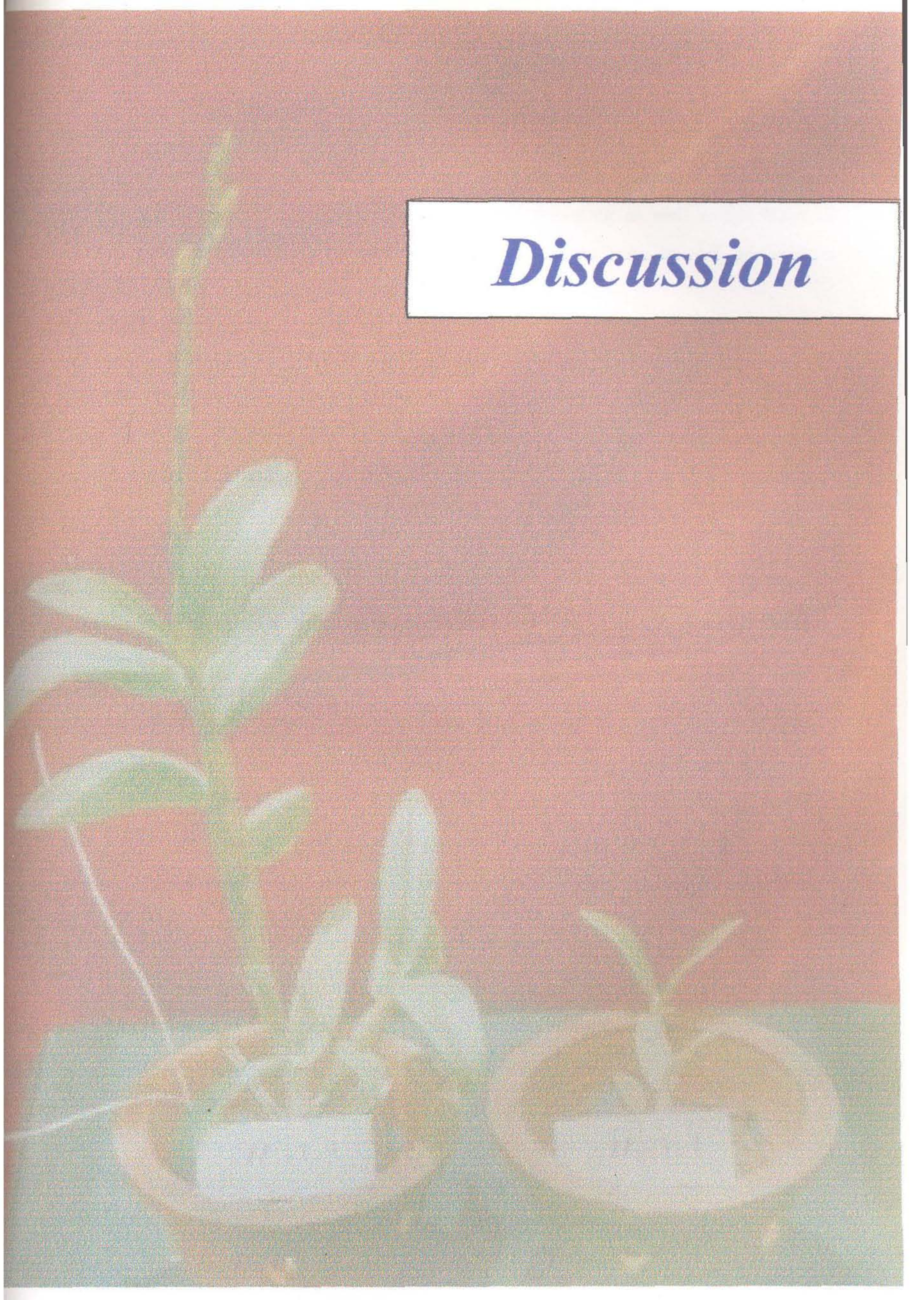
For improving flower yield and quality NPK 10:20:10 at 0.2 per cent applied weekly twice and BA 50 ppm + GA_3 10 ppm applied monthly once was found superior. The cost of nutrients per plant per year was Rs.0.69 and for growth regulators it was Rs.1.86.

Table 66. Cost of chemicals for the best treatments

Treatment details	Cost of chemical (Rs.)	Cost / litre spray solution (Rs.)	Cost/plant /year (Rs.)
Experiment I (Till flowering)			
NPK 30:10:10 - 0.2% weekly twice + BA 200 ppm - monthly once			
a) Ammonium nitrate	79.00/500 g	0.24	0.10
b) Orthophosphoric acid	185.00/500 ml	0.14	0.06
c) Potassium nitrate	92.00/500 g	0.10	0.04
BA	262.00 / g	52.40	2.60
		Total	2.80
Experiment II (per year)			
NPK 10:20:10-0.2% weekly twice + BA 50 ppm + GA_3 10 ppm (monthly)			
a) Ammonium nitrate	79.00/500 g	0.58	0.06
b) Orthophosphoric acid	185.00/500 ml	0.468	0.52
c) Potassium nitrate	92.00/500 g	0.095	0.11
BA	262.00 / g	13.10	1.67
GA_3	149.00 / g	1.49	0.19
		Total	2.55

Note: 1. Average number of plants covered by a litre of spray solution = 200
2. For experiment I the cost was accounted up to 10 months after hardening

Discussion



5. DISCUSSION

The results generated from the studies on the influence of nutrients and growth regulators on the regulation of growth and flowering as well as the effect of various pulsing and holding treatments on the post harvest behaviour of dendrobium var. Sonia 17 are briefly discussed here under.

Dendrobium is a sympodial orchid grown mostly in the tropical region. Reported to be the second largest genus, 1340 species are included under *Dendrobium* (Baker and Baker, 1996), belonging to both tropical and subtropical regions. The hybrids produced from these species also show a wide range of variability with respect to shoot, leaf and floral characters and response to climatic conditions.

In sympodial orchids, like *Dendrobium*, the true stem has a horizontal growth and creeps over the media throwing aerial shoots occasionally giving the characteristic clustered appearance for the plant.

During the growth and development of any plant, the type of nutrients, quantity and their frequency of application play a major role. This is more so in an epiphytic orchid like dendrobium, where all the nutrients are applied through foliage. Such plants are virtually deprived of receiving any nutrient from any other source. Another interesting factor is the significant difference in the requirement of nutrients between growth and developmental stages.

The role of growth regulators in improving growth parameters in different ornamental crops has been reported by many workers. The beneficial effects of various bioregulators are commercially exploited in commercial flowers too, to a very large extent. Chemicals also play a major role during the postharvest handling of flower spikes. Hence a comprehensive information on the rǒle of various nutrients and other chemicals in the commercial culture of dendrobium hybrids, the most popular group of orchids in Kerala and in the South-East Asian countries is very much needed.

5.1 Reducing pre-blooming period

Long pre-blooming period is considered as a drawback in the commercial cultivation of orchids. In *Dendrobium*, the hardened plants take about 15 months to attain flowering stage. Reducing the pre-blooming period has thus an added advantage.

5.1.1 Growth parameters

Height, in general, is an indication of the overall growth of the plant. In dendrobium, progress in height is in a different pattern. Unlike monopodial orchids, which have a continuous vertical growth, in which, the flowers are produced from leaf axils of the main stem, in the sympodial orchids, the flowers are produced on the pseudostem. The growth habit of a sympodial orchid like dendrobium, is such that the new shoots (pseudostems) produced initially grow and bloom after attaining sufficient growth and maturity. Hence, the external treatments which can favour this character can be considered beneficial.

In the present study height was found to be significantly influenced by nutrient doses, right from the initial stage of the experiment. The nutrient concentration NPK 30:10:10 at 0.2 per cent, which was the highest ratio of N tried in the experiment, produced the tallest (11.04 cm) plants. The characteristic of nitrogen to increase vegetative characters is evident in this result also. Minimum height recorded was 5.62 cm in response to the lowest nutrient concentration, ie., NPK 10:10:10 at 0.1 per cent. Similar observations were recorded by Sakai *et al.* (1985) in *Dendrobium*, Banfield (1981) in *Paphiopedilum* and Stewart (1988) in many monopodial and sympodial orchids.

The frequency of application of nutrients is indirectly availability of more nutrients. Plants treated twice weekly with a nutrient dose is receiving double the nutrients received by those treated once a week with the same nutrients. Increase in frequency was found to increase height in *Cymbidium traceanum* by Sobhana and Rajeevan (1995) also.

Among the growth regulators tried, GA_3 20 ppm gave tallest plants, compared to all other growth regulators. This effect was evident right from the initial months of the treatment application. The functional effect of GA_3 on the elongation of cell may be the basic reason for increased height in GA_3 applied plants (Randhawa, 1981). Lower dose of GA_3, i.e., 10 ppm, was also found to increase height, but to a lesser extent, compared to GA_3 20 ppm. This is in conformation with the results obtained by Pirone (1958), Burovac and Wittwer (1956), in different plants.

Nutrients play an important role in the number of shoots produced in a plant. In the variety Sonia 17, the shoots, which are pseudobulbs, are cane like on which the leaves are arranged in two rows. The flower spikes arise from the end of the pseudobulb or from the lateral buds. Hence in dendrobium, the number of new shoots produced by the plant determines the extent of flower production.

In the present trial more number of shoots was produced in plants sprayed with the nutrient dose of NPK 30:10:10 at 0.2 per cent. The least number of shoots was recorded in the case of NPK 10:10:10 at 0.1 per cent. Similar results were observed in *Cymbidium* 'Pharoah Pathfinder' by Nichols (1982), where he obtained increased number of shoots with increase in nitrogen supply. The behaviour of *Cymbidium* 'Pendragon Sikkim' also showed similar trend (Bik and Van den Berg, 1983).

During the initial stages of the study, the influence of growth regulators on shoot production was not evident. At four MAP, GA_3 was superior in terms of shoot production. This was followed by BA. Very few number of shoots was produced by IAA. But as the growth progressed, BA significantly promoted the production of shoots. Effect of BA in increasing number of shoots can be attributed to the cell dividing or multiplying properties of cytokinins. Beneficial effects of BAP in

Ascocenda and *Paphiopedilum*, where a higher dose of BAP i.e., 1000 mg l^{-1} was used as reported by Kunisaki (1975), was in tune with the results in the present study.

Among the three growth regulators tried, GA_3 at both the levels gave the least shoot number as the growth advanced. Continuous treatment with GA_3 was found to reduce the shoot number gradually and gave a negative effect on shoot production. This was evident from the lesser number of shoots produced in GA_3 treatments, compared to the control. Higher nutrient concentrations applied more frequently combined with the higher dose of BA, i.e., 200 ppm further increased the number of shoots.

Number of leaves in a plant is an indication of better photosynthetic efficiency and thereby better growth of the plant, as this influences the total leaf area of the plant. Nutrients had a positive effect on the leaf production in dendrobium. More leaves were produced as the nutrient concentration increased. Maximum leaf production (10.3) was observed in plants which received the highest nutrient concentration. Higher nitrogen received can be the reason for the proportional increase in the leaf number with nutrient concentration. Application frequency also was directly proportional to leaf number. Similar observations were made by Banfield (1981) and Stewart (1988) in *Paphiopedilum* and Umamaheswari (1999) in *Dendrobium* Sonia 17. Effect of growth regulators on increasing leaf number was very much distinct. At a higher dose, BA was beneficial in producing distinctly more number of leaves, without affecting size or shape of the leaf. The increased shoot size and number due to the effect of BA could be the explanation for more leaf number. A negative impact on leaf number was produced by GA_3, as evident from the lesser number of leaves, compared to the control.

Total leaf area is a more direct indication of photosynthetic efficiency of a plant. In the case of dendrobium it is more so, because, being an epiphytic plant, nutrition is little through the growing media. Instead, foliar spray is the common practice for supplying nutrients where increased leaf area favours increased absorption. In the present study, total leaf area showed an increase with the increase in the nutrient concentration. Similar was the response to increased frequency of application of nutrients also. These findings conformed to those by Schenk and Brundert (1983) in *Phalaenopsis*, Sakai *et al.* (1985) and Stewart (1988) in *Dendrobium*, Banfield (1981) in *Paphiopedilum* and Sobhana and Rajeevan (1995) in *Cymbidium traceanum*. In all these reports, higher nitrogen was reported to increase leaf number and area. Growth regulators also influenced the total leaf area. Initially, IAA 500 ppm and later on BA 200 ppm significantly enhanced total leaf area. Benzyl adenine is also reported to have an influence on reduction in leaf senescence and shedding (Pileuk *et al.*, 1992) which could be one of the reasons for enhanced total leaf area, compared to other growth regulators.

Shoots or pseudobulbs in the case of a sympodial orchid like *Dendrobium* is an important sink for assimilates. Hence increased thickness of pseudobulbs can be indicative of storage of more assimilates and thereby better growth and development. Shoot girth hence becomes a significant growth parameter.

Nutrients when applied at higher concentration and greater frequency produced thicker shoots in the present study. During earlier stages of growth, IAA 500 ppm recorded maximum girth of shoot. Both the concentrations of BA were on par with this. Later, at ten and twelve MAP, BA 200 ppm recorded higher shoot girth and IAA 500 ppm was on par with it. Least thickness of shoots was observed in plants treated with GA_3. As the concentration of GA_3 was increased from 10 ppm to 20 ppm, shoots became thinner.

The result of the present experiment is in agreement with that by Yadav and Bose (1986) in *Aerides multiflorum*, but contradictory to that obtained by Higaki and Imamura (1987) in *Vanda* Miss Joaquim, where the nutrient ratio containing lesser nitrogen was found to enhance stem girth. Taejung (1998) also obtained healthy, compact stout plants in *Cymbidium* when nutrient ratio containing higher K concentration was applied. On the other hand, the diameter of pseudobulbs was reported to increase with increase in nitrogen supplied in *Phalaenopsis* 'Sylba Nopsya' and 'Abylos' (Ochsenbeuer, 1996).

All the growth parameters studied cumulatively decide the growth in *Dendrobium*. From the present study, the positive effect of higher fertilizer dose on vegetative parameters is clearly evident. Similarly, the frequency of application and growth regulators also had independent contribution in enhancing vegetative growth. The positive effect of more frequent application of nutrients and the growth regulator BA was also observed. From the study, it is clear that the combined effect of these three factors is far superior to the individual effect of a factor and hence a combination could be more beneficial.

Root production was influenced by treatments involding higher levels of nutrients and IAA. Higher dose of IAA produced more number of roots. The role of auxins in root production is established.

Flowering was earliest in plants which obtained the highest nutrient dose of NPK 30:10:10 at 0.2 per cent, weekly twice, combined with application of BA at 200 ppm. The effect of highest nutrient level is contradictory to that obtained by Uesato *et al.* (1987) in *Dendrobium* 'Lim Hepa' where higher N dose was found to delay flowering.

Supportive results for induction of flowering by BA have been recorded earlier in many orchid species. Generally, flowering is found to be initiated by cytokinins in both monopodial and sympodial orchids (Goh and Arditti, 1985). In the present study, GA_3 did not have a positive effect on flowering, which conform the observation of Goh and Yang (1978) in *Dendrobium*. However, GA_3 was, found to have positive effect when used in combination with BA. But Lee and Koay (1986) have reported that a combination does not work in *Dendrobium* Louisae.

Normally, the time taken for the *Dendrobium* mericlones from hardening to flowering is about 15 months. In the present study, with appropriate combinations of nutrients and growth regulators, the duration could be reduced to 10 months.

5.1.2 Nutrient status

Conclusions cannot be drawn based on the vegetative parameters alone. Nutrient concentration in a plant is an indication of the overall growth of the plant, the assimilates accumulated in the sink of the plant body and the potential of that plant to effectively utilize the nutrient sources provided. The nutrients supplied, if properly absorbed and assimilated, only can contribute to the development in any plant. Hence it is essential to study whether the supplied nutrients are absorbed and also whether the growth regulators have any role in enhancing the absorption of nutrients by plants. Nutrient content in the plant parts as well as the uptake are hence of great importance.

The study revealed that nitrogen content in the plant was directly proportional to the nitrogen level applied. Highest nitrogen content was recorded corresponding to NPK 30:10:10 at 0.2 per cent, applied weekly twice. Phosphorus content was maximum in plants which received NPK 10:10:10 at 0.1 per cent and potassium content in those which received NPK 10:10:10 at 0.2 per cent. All the three nutrients were found to increase considerably in plant parts when the plants were fertilized more frequently. Nitrogen content was highest corresponding to BA 200 ppm, whereas P was highest for BA 100 ppm and K for IAA 250 ppm.

Calcium content was found to increase when the plants were fertilized using NPK 30:10:10 at 0.2 per cent, weekly twice and IAA 500 ppm at monthly interval. Magnesium also showed the same trend and BA 200 ppm in the above combination gave similar results. Micronutrients like Cu, Fe, Zn also showed a similar trend.

Increased nitrogen content with increased application is attributed as an indication of the luxury consumption of nitrogen in orchid. Conclusions were drawn in this line in *Cattleya* and *Phalaenopsis* (Tanaka *et al.*, 1988a and 1989). In the present study, higher content of nitrogen was found to improve the vegetative characters and hence cannot be considered as luxury consumption, at least at the higher levels tried in the present study. However, it is generally held that while the nutrient levels should be higher for *Dendrobium* than for many orchids, excessive nitrogen level should be avoided. Alternate applications of high nitrogen fertilizer with low nitrogen fertilizer would be a solution for this (Baker and Baker, 1996). In the high rainfall, high humidity climate prevailing in Kerala, excess nitrogen may also induce rapid vegetative growth resulting in softened tissues rendering the plants more susceptible to diseases.

Total biomass production as well as nutrient uptake were enhanced by higher concentration of nutrients, higher frequency of application and application of BA 200 ppm. Similar results were obtained in *Dendrobium* by Seeni and Latha (1990), Thekkayam (1996) and Umamaheshwari (1999). But contradictory observations were made by Schum and Fischer (1985) in *Phalaenopsis*, where they got maximum biomass accumulation when an NPK ratio of 1:1:1 was applied.

Considering the effect on various growth parameters, nutrient uptake and the time taken to first flowering, conclusions can be drawn favouring a treatment combination of NPK 30:10:10 at 0.2 per cent applied weekly twice + BA 200 ppm, for best results. Though some other treatment combinations were found to favour certain parameters, the above combination was significantly superior when the economically important characters were considered. The best nutrient dose can be met at an expense of 0.30 ps. per plant per year. An additional expense of Rs.3.74 per plant per year is required for BA application. But considering the reduction in the pre-blooming period by about five months the viability of this additional cost incurred cannot be ruled out.

5.2 Improvement of flower yield and quality

Flower characters in orchid genus *Dendrobium* are found to be influenced by nutrients and growth regulators. *Dendrobium* being epiphytic can be easily tuned to vegetative or flowering phase by changing the concentration of nutrients as well as growth regulators.

Floral characters were improved by increasing the level and frequency of nutrient application. The relative proportion of nutrients, especially that of N, is considered to be more important. Number of florets, number of spikes, spike length, rachis length and internodal length were maximum with NPK 10:20:10 at 0.2 per cent. Stalk length and spike girth were highest when NPK 10:20:20 at 0.2 per cent was supplied. The least interval between consecutive spike production was recorded in plants treated with NPK 10:20:10 at 0.2 per cent.

Spike production, length of spike, rachis length, internodal length and least interval between spike production are the commercially important characters of spikes in orchids. Considering these factors, NPK 10:20:10 at 0.2 per cent can be suggested as an ideal nutrient combination for dendrobium. The results of the present study are contradictory to those observed by Vacharotayan and Keethapirom (1975), where NPK ratio with higher N and P content was found to enhance floral characters. Bhattacharjee (1982) in *Rhynostylis gigantea* and Schenk and Brundert (1983) in *Phalaenopsis* also have made observations. But Abraham and Vatsala (1981) and Merimman (1987) recorded results similar to those obtained in the present study, i.e., higher P content in the nutrient combination had a positive effect on flowering and floral characters. Baker and Baker (1996) also suggested that changing to high phosphatic fertilizer, such as 10-20-10 promotes blooming in dendrobium. The balance between N and K is important and for best results it should be 1:1, unless media requiring high nitrogen are used for growing the plants.

Number of spikes was found to be the highest in plants treated with BA 100 ppm. Spike length and stalk length also showed similar trend. But significant reduction in internodal length was obtained when BA 100 ppm was applied. Internodal length was highest in plants which received GA_3 20 ppm. Similarly, floral size also reduced drastically with BA treatment. This was found to adversely affect the appearance of the spike. However, this detrimental effect of BA was reduced when GA_3 was applied together with BA. A combination of BA 50 ppm and GA_3 10 ppm produced normal sized florets with sufficient internodal length. Productivity, though not as high as in the case of BA 100 ppm, was also substantially higher compared to control treatment. Hence a combination of both the growth regulators can be recommended to enhance productivity, without adversely affecting the quality of the spikes.

The results obtained by Higuchi and Sakai (1977) were partly in agreement with the results in the present study. They observed reduced number of florets in *Dendrobium* with the application of BAP at 4000 ppm but productivity was found to increase. GA_3 was reported to have no effect on floral characters, according to Goh and Yang, 1978. They also found that when combined with BA, GA_3 gave good results, which is supportive to the present study.

Branched inflorescence occurred more frequently when plants were treated with BA, both at 50 and 100 ppm. This is in agreement with the results obtained by Goh (1977).

From the data obtained during the experimental period of seven months, annual yield of spikes and the economics was computed. It was found that NPK 10:20:10 at 0.2 per cent applied twice a week and monthly application of BA 50 ppm + GA_3 10 ppm produced the highest number of spikes, without affecting the quality of spikes. The above combination of nutrients and growth regulators produced 35.27 per cent increment in flower yield compared to the plants receiving lowest nutrient dose and no growth regulator. There was also an increment of 6.21 per cent in yield over plants receiving the same nutrient dose, without the growth regulator treatment.

The cost incurred per plant per year for the best treatment was Rs.2.55 and the nutrient treatment alone was Rs.0.69. The additional expense of Rs.1.86 per plant for growth regulator application is negligible when the productivity for a larger area is considered.

5.3 Post harvest studies

The condition of the spike at the time of sale is one of the deciding factors in the marketing of orchids. Eventhough orchid blooms stay fresh for a comparatively longer period, a little care taken at the post-harvest level can reduce losses due to cultural, mechanical, physiological and pathological reasons (Salunkhe *et al.*, 1990). In orchids, fading of flowers also occurs due to disturbed pollinia and exposure to ethylene.

Loss reduction biotechnologies in orchids involve the use of improved methods of harvesting, packing, transporting, use of low temperature, low pressure and controlled atmospheric storage, use of chemicals which inactivate the liberated ethylene and controls microbial contamination and resulting reduction of life of cut spikes. Such techniques are rarely advocated by growers in Kerala, probably due to the fact that orchids naturally have a longer vase life. However, it is felt that standardization of pulsing and holding treatments in the popular dendrobium variety Sonia 17 would be necessary which may also help to draw some conclusions on the behaviour of dendrobium spikes in general. The spikes which have 5-7 florets (4-5 open flowers and 1-2 buds) were used for the study.

5.3.1 Pulsing treatments

Pulsing is the treatment given to the flower stems using a solution containing floral preservatives or using environment modifications for a period ranging from few hours to as long as two days immediately after harvest so as to effectively modify the vase life and quality of cut flowers. This is a treatment usually given before they are stored or marketed. One special attraction of pulsing treatments is that they are effective in extending vase life even if preservatives are not used subsequently, at the wholesaler or consumer level.

In the present study, pulsing with a solution containing HQ 500 ppm and sucrose 5 per cent for 12 hours could extend the vase life up to 19.92 days which was 5.37 days more compared to the control. Physiological loss in weight was minimum for spikes which received a pulsing treatment of HQ 500 ppm + sucrose 5 per cent for 6 hours and maximum for spikes which did not receive any pulsing treatment. Minimum value for EC and maximum longevity of individual floret were observed for pulsing treatment with HQ 500 ppm + sucrose 5 per cent for 12 hours. Water uptake was maximum for hot water treatment of spikes at 50-60°C for 10 seconds. Minimum recorded values for all these characters were for the control, which had a longevity of 15.60 days and vase life of only 6.50 days. Beneficial effects of 8-HQ and sucrose for pulsing was observed in gladiolus too (Kofranek and Halevy, 1976).

5.3.2 Holding solutions

Use of floral preservatives can often at least double the longevity of cut flowers (Staby and Robertson, 1982).

Distinct influence of different holding solutions on the post harvest characters was observed in the present study. Maximum vase life of 24.73 days and maximum longevity of individual florets of 27.50 days were observed for holding solutions of $AgNO_3$ 50 ppm + HQ 400 ppm + sucrose 5 per cent. Minimum physiological loss in weight (0.13 g) and EC (0.11 mS g^{-1}) were also observed in the same treatment. Similar observations were reported in carnations by Chung *et al.* (1986) and Ketsa (1989) in *Dendrobium* 'Pompadour' using 200 mg 8-HQ + 50 mg $AgNO_3$ l^{-1} + sucrose 8 per cent and Ong and Lee (1983) in *Oncidium* 'Golden Shower' using $AgNO_3$ 25-40 ppm + 8-HQ 200 mg l^{-1}. Vase life and longevity of individual floret was minimum in the control, i.e., distilled water.

5.3.3 Effect of combination of pulsing and holding treatments

Vase life, final EC and difference in EC were highest when pulsing treatment of HQ 500 ppm + sucrose 5 per cent for 6 hours was combined with holding treatment containing $AgNO_3$ 50 ppm + HQ 400 ppm + sucrose 5 per cent. Water uptake and longevity of individual floret were highest for combination of pulsing with HQ 500 ppm + sucrose 5 per cent and holding containing $AgNO_3$ 50 ppm + HQ 400 ppm and sucrose 5 per cent. Physiological loss in weight of spikes is an indication of the post-harvest life. Minimum physiological loss in weight was recorded when spikes were pulsed with HQ 500 ppm and sucrose 5 per cent and subsequently kept in vase solution containing $AgNO_3$ 50 ppm + HQ 400 ppm + sucrose 5 per cent.

Autocatalytic ethylene production by flowers is found to be the main reason for senescence in orchids (Arditti, 1979). Appropriate holding solution which would allow the flowers to open normally and stay fresh for a greater period would be beneficial. A common ingredient of holding solutions for cut flowers 8-HQ is a bactericide (Rogers, 1973; Halevy and Mayak, 1981), having beneficial effect on water uptake by reducing physiological plugging (Coorts *et al.*, 1965) and helps in stomatal closure, thereby reducing transpiration and physiological loss in weight (Aarts, 1957). Alone as well as with sucrose, 8-HQ maintains potential xylem conductivity and sucrose favourably acts on the appearance of cut flowers (Gilman and Steponkus, 1972). The results in the foregoing discussion point to the significance of the above said characters of 8-HQ alone and in combination with other chemicals like silver nitrate and sucrose in extending the vase life of orchids.

The effects of HQs plus sucrose and other chemicals on the extension of vase-life of certain tropical orchids have been studied and some species were positively affected but others were not (Novak and Vacharotayan, 1980). In the present study, combination of 8-HQ and sucrose was found beneficial both in pulsing and holding treatments. This is in agreement with the report by Ong (1982) where an increase in vase life by 14 days was obtained and Hew (1987) where *Oncidium* flowers showed extended vase life of 20.2 days by combining 8-HQ 100 ppm and sucrose 4 per cent.

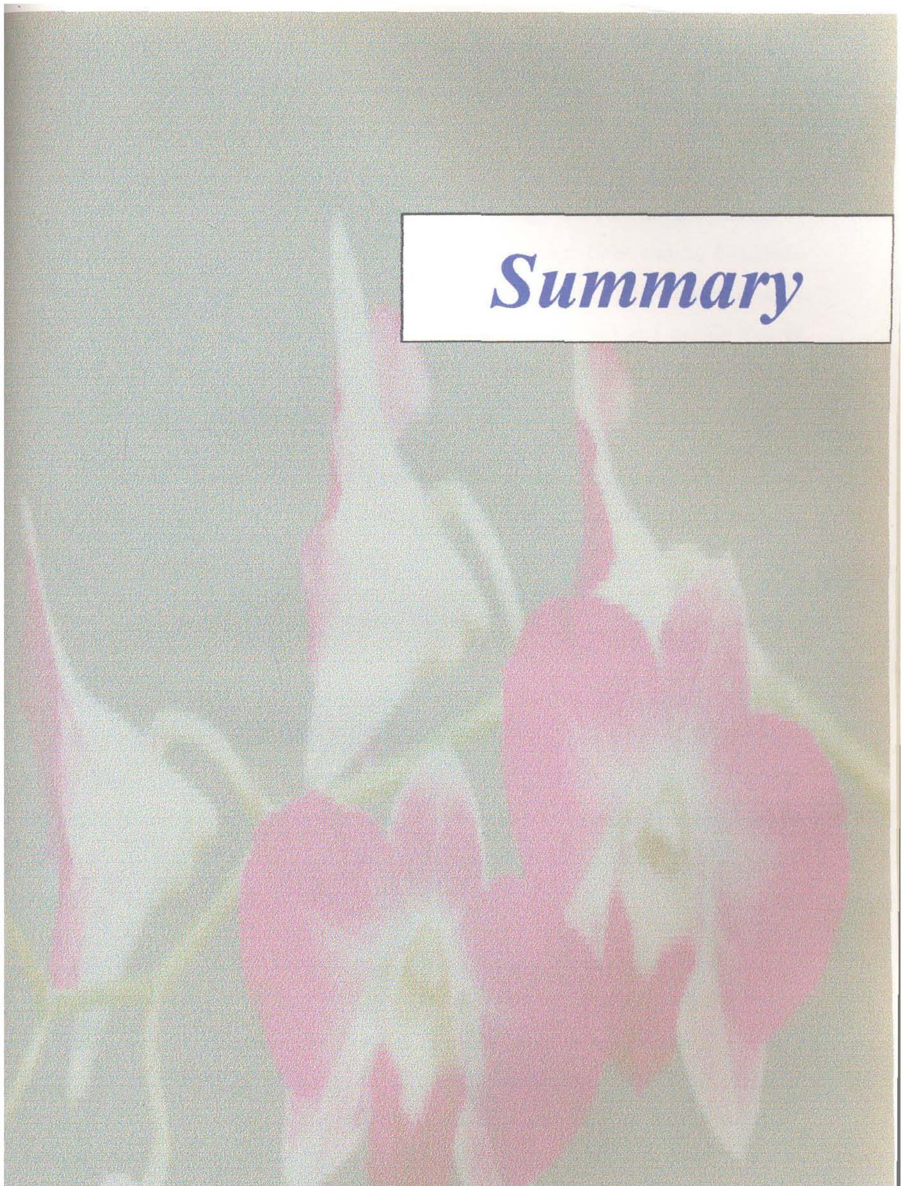
It was observed from the present study that hot water dip of spikes at 50-60°C for 5 seconds increases vase life by 12.50 days over control. Supportive results were obtained by Wangkean and Techanpiyawat (1992). Hot water treatment was found to enhance the postharvest life by helping the stem to recover turgidity.

From the present study, it is clear that *Dendrobium* var. Sonia 17 flowers harvested at 1 or 2 bud stage can be kept fresh in vase upto 3 weeks by giving a pulsing treatment with a combination of HQ 500 ppm and sucrose 5 per cent for 12 hours and adding HQ 400 ppm, $AgNO_3$ 50 ppm and sucrose 5 per cent to the holding solution. It was observed in the present study that even without using any special holding solutions, the vase life could be extended to 19.92 days by pulsing which was 13.42 days more than the control. The advantage is that while it is still possible for the grower to despatch the consignment within a day, he can play a significant role in extending the vase life. Pulsing with warm water at 50-60°C for 5 seconds, on the other hand, can be employed as a practically easier and economic way of enhancing vase life.

An observation on the refrigeration of flowers at a temperature ranging from 10°C to 20°C as pulsing treatment was not much effective as tropical orchids might be sensitive to low temperatures. Treatment at temperature of 16°C to 20°C for 24 hours was found to spoil the spikes as the petals were completely water soaked.

Future line of work

The present studies on dendrobium var. Sonia 17 can not be considered conclusive. Hence investigations have to be undertaken to refine the results of the present study. Since the higher nitrogen ratio was found to enhance vegetative growth, ratios having even higher nitrogen can be tried. For improvement of flower yield and quality more treatments with combinations of GA_3 and BA can be studied. The results of the experiment can also be extended to find effects on other important varieties of dendrobium as well as other genera. The results of experiment I and experiment II have to be tried to the same lot of plants to find the combined effect.



Summary

6. SUMMARY

Studies on 'Regulation of growth and flowering in dendrobium var. Sonia 17' were conducted in the Department of Pomology and Floriculture, College of Horticulture, Vellanikkara from June 1998 to November 1999 and at Padikkala Orchids, Thrissur from February to September 1999. The main objectives of the trial were to reduce the pre-blooming period, to improve the yield and quality and to enhance the post harvest life of spikes using various chemicals and growth substances. The results of the study are summarised below.

The influence of nutrient concentrations, frequency of nutrient application and growth regulators was clearly evident at the various stages of the growth in dendrobium var. Sonia 17.

Plant height was significantly superior from six to twelve months after planting when nutrient concentration used was NPK 30:10:10 at 0.2 per cent (11.04 cm, at 12 MAP). Nutrient application weekly twice was markedly superior to that at weekly once, producing taller plants with the height of 8.98 cm at 12 MAP. Among the growth regulators studied, GA_3 20 ppm was found to produce taller plants during the entire period of the study and produced plants with a height of 11.81 cm at 12 MAP. At 10 MAP, GA_3 10 ppm was on par with GA_3 20 ppm with respect to plant height.

NPK 30:10:10 at 0.2 per cent along with weekly twice application frequency recorded plant heights 2.41 cm, 3.94 cm, 6.05 cm, 8.76 cm, 11.66 cm and 14.27 cm from two to 12 MAP, respectively, which excelled all other combinations. Nutrient concentration of NPK 30:10:10 at 0.2 per cent in combination with GA_3 20 ppm significantly improved height of plants throughout the period of investigation (14.47 cm and 17.88 cm, respectively, at 10 and 12 MAP). NPK 20:10:10 at 0.2 per cent + GA_3 20 ppm was on par with the above at eight, 10 and 12 MAP (11.24 cm and

12.81 cm, respectively). Combination of NPK 30:10:10 at 0.2 per cent applied weekly twice + GA_3 20 ppm produced tallest plants and was significantly superior to all other treatments (plant height of 19.50 cm, at 10 MAP).

Shoot production differed markedly with the treatments. During early months of observation nutrient concentration did not significantly influence shoot production. At 10 and 12 MAP the highest value for number of shoots (4.80 and 5.30 shoots, respectively) was recorded in plants, which received NPK 30:10:10 at 0.2 per cent. Superiority of application of nutrients weekly twice with respect to number of shoots was clearly evident from initial stages to final month of observation producing 2.23, 2.65, 3.41, 4.20, 5.24 and 5.92 shoots, respectively, from two to 12 MAP. Among the growth regulators BA 200 ppm was significantly superior to all other growth regulators in increasing shoot production from four to 12 MAP (2.40, 3.26, 4.58, 6.06 and 7.39 shoots, respectively). At two and four months after planting BA 100 ppm was on par with the above.

Significantly higher shoot production (6.34 shoots, at 12 MAP) was noticed when NPK 30:10:10 at 0.2 per cent was combined with weekly twice application frequency. Treatment combination of NPK 30:10:10 at 0.2 per cent and BA 200 ppm was found to enhance number of shoots significantly, producing 8.25 shoots at 12 MAP. Combination of BA 200 ppm and weekly twice application of nutrients markedly enhanced shoot production (9.03 shoots at 12 MAP). Among the combination of all the three factors, NPK 30:10:10 at 0.1 per cent as well as 0.2 per cent, applied weekly twice + BA 200 ppm were significantly superior to all other treatment combinations with respect to number of shoots (7.67).

In the case of shoot girth, maximum value was recorded when NPK 30:10:10 at 0.2 per cent was applied (4.85 cm at 12 MAP). Significant increase in girth of pseudostem was evident for weekly twice application of nutrients throughout the study (1.91 cm, 2.53 cm, 3.08 cm, 3.49 cm, 4.32 cm and 4.74 cm, respectively from two to 12 MAP). Among the growth regulators IAA, 500 ppm recorded maximum values for shoot girth at two (2.04 cm), four (2.69 cm), six (3.21 cm) and eight (3.39 cm) MAP. At 10 and 12 MAP, BA 200 ppm produced maximum girth of 4.39 cm and 4.68 cm, respectively. IAA 500 ppm recorded values on par with the above (4.32 cm and 4.65 cm, respectively).

Maximum shoot girth was observed when NPK 30:10:10 at 0.2 per cent was applied weekly twice (5.39 cm, at 12 MAP). Combination of IAA 250 ppm and NPK 30:10:10 at 0.2 per cent recorded the highest value for shoot girth (5.28 cm) at 12 MAP. BA 200 ppm substituted in the above gave values on par (5.25 cm, at 12 MAP). When IAA 500 ppm was applied in plants receiving nutrients weekly twice, maximum shoot girth was obtained (5.36 cm, at 12 MAP). At 10 MAP, treatment combination of NPK 30:10:10 at 0.2 per cent applied weekly twice + IAA 500 ppm gave the highest value of 5.80 cm for shoot girth.

Leaf production was significantly superior in plants which received NPK 30:10:10 at 0.2 per cent throughout the period of observation (10.3 leaves, at 10 MAP). Significant increase in the number of leaves was observed when application of nutrients was weekly twice (4.27, 5.03, 5.92, 6.99, 8.83 and 11.27 leaves from two to 12 MAP). BA 200 ppm produced maximum number of leaves from four to 12 MAP (4.94, 6.25, 7.81, 10.57 and 15.40 leaves, respectively). At four MAP, BA 100 ppm recorded leaf number on par with the above (4.88).

Interaction effect of NPK 30:10:10 at 0.2 per cent and weekly twice application frequency recorded significantly more number of leaves (4.91, 5.83, 7.38, 9.10, 10.83 and 13.07, respectively, from two to 12 MAP) compared to other combinations. NPK 30:10:10 at 0.2 per cent + BA 200 ppm recorded maximum number of leaves (17.33, at 12 MAP). For weekly twice application of nutrients BA 200 ppm was found to produce significantly greater number of leaves (9.67, 14.89 and 21.31 leaves, respectively, from eight to 12 MAP). A combination of NPK 30:10:10 at

0.2 per cent applied weekly twice with BA 200 ppm was superior compared to other combinations in producing more number of leaves (19.83 at 10 MAP).

Total leaf area showed maximum values of 29.74 cm^2, 41.00 cm^2, 58.80 cm^2, 99.10 cm^2, 139.92 cm^2 and 198.65 cm^2, respectively, from two to 12 MAP when nutrient concentration of NPK 30:10:10 at 0.2 per cent was applied. Application of nutrients weekly twice could significantly enhance the leaf area (158.25 cm^2, compared to 99.33 cm^2 for weekly once). Highest leaf area was produced in plants when BA 200 ppm was applied from fourth month after planting. Initially, IAA 500 ppm recorded the highest values of 26.00 cm^2, 39.08 cm^2, 59.68 cm^2, 123.17 cm^2, 174.60 cm^2 and 223.00 cm^2, respectively, for total leaf area and at four MAP, IAA 500 ppm recorded values on par with BA 200 ppm, recording a leaf area of 38.62 cm^2.

Total leaf area was significantly higher throughout the experiment when NPK 30:10:10 at 0.1 per cent was applied weekly twice (19.36 cm^2, 41.20 cm^2, 58.98 cm^2, 100.84 cm^2, 148.30 cm^2, 203.35 cm^2, respectively from two to 12 MAP). Combination of NPK 30:10:10 at 0.2 per cent and BA 200 ppm produced the highest values for total leaf area from four to 12 MAP (48.98 cm^2, 55.75 cm^2, 89,36 cm^2, 175.23 cm^2 and 203.41 cm^2, respectively). BA 100 ppm substituted in the above combination recorded values on par with the above. BA 200 ppm was found to produce highest values for total leaf area when applied in plants which received NPK 30:10:10 at 0.2 per cent weekly twice.

Number of roots was markedly higher for NPK 30:10:10 at 0.2 per cent(33.14), weekly twice application (29.19) and IAA 500 ppm (32.00). Among the growth regulators, IAA 250 ppm, BA 200 ppm and 100 ppm were on par with the above (29.6, 26.6 and 26.0 roots, respectively). Combinations which significantly increased root number were NPK 30:10:10 at 0.2 per cent weekly twice, NPK

30:10:10 + BA 200 ppm and weekly twice application of nutrients + BA 100 ppm, which produced 38.9, 42.0 and 33.2 roots, respectively.

Biomass production was the highest for NPK 30:10:10 at 0.2 per cent (6.09 g), weekly twice nutrient application (3.20 g) and BA 200 ppm (4.46 g), which showed individual direct effect. Combinations which were found superior with respect to biomass production were NPK 30:10:10 at 0.2 per cent applied weekly twice, NPK 30:10:10 at 0.2 per cent + BA 200 ppm and nutrient application weekly twice + BA 200 ppm (7.40 g, 6.94 g and 5.66 g, respectively).

Nitrogen content in dendrobium var. Sonia 17 was significantly higher when nutrient applied was NPK 30:10:10 at 0.2 per cent (1.58%) and frequency was weekly twice (1.91%). Among the growth regulators tried, BA 200 ppm recorded the highest nitrogen content (1.39%) followed by BA 100 ppm (1.37%) and IAA 500 ppm (1.37%) which were on par with the above.

NPK 30:10:10 at 0.2 per cent applied weekly twice recorded maximum N content of 2.23 per cent. When nutrients and growth regulators were applied in combination, NPK 30:10:10 at 0.2 per cent + IAA 250 ppm recorded the maximum N content (1.72%). BA 200 ppm, IAA 500 ppm and BA 100 ppm substituted in the above combination produced values on par with the above (1.69%, 1.69% and 1.66%, respectively). BA 200 ppm when applied to plants, which received nutrients twice weekly gave the highest value for N content (2.04%). Combination of NPK 30:10:10 at 0.2 per cent applied weekly twice + IAA 250 ppm was significantly superior to all other combinations with respect to N content (2.47%).

Phosphorus content in plant parts was maximum (0.38%) when NPK 10:10:10 at 0.1 per cent was applied. Frequency of application weekly twice was superior (0.46%) compared to weekly once (0.14%). BA 100 ppm recorded highest value for P content (0.39%). NPK 10:10:10 at 0.2 per cent when combined with weekly twice application frequency recorded the highest P content of 0.60 per cent.

Combination of 10:10:10 NPK 0.1 per cent with IAA 500 ppm gave the highest value for P content (0.47 per cent). For plants receiving nutrients weekly twice, IAA 500 ppm produced the highest P content in plant parts (0.54%). Maximum value for P content (0.66%) was observed in plants which received a combination of NPK 30:10:10 at 0.2 per cent sprayed weekly twice + IAA 250 ppm.

Potassium content in plant parts was significantly higher due to the single direct effect of NPK 10:10:10 at 0.2 per cent (2.71%), weekly twice application frequency of nutrients (2.51%) and IAA 250 ppm (2.62%). The combinations which yielded highest values for K content were NPK 20:10:10 at 0.2 per cent + weekly twice application frequency, NPK 30:10:10 at 0.2 per cent + IAA 500 ppm, nutrients applied weekly twice + IAA 500 ppm and NPK 30:10:10 at 0.2 per cent applied weekly twice + IAA 250 ppm (2.81%, 2.96%, 2.99% and 4.00%, respectively).

Calcium content recorded was the highest for NPK 30:10:10 at 0.2 per cent (2.83%), weekly twice frequency of nutrient application (3.66%) and BA 200 ppm (2.86%). Combinations of different treatments which gave the highest Ca content were NPK 30:10:10 applied twice a week (4.74%), NPK 30:10:10 at 0.2 per cent + IAA 500 ppm (3.63%) and IAA 500 ppm + weekly twice application of nutrients (4.42%).

Nutrient concentration which gave the highest Mg content of 0.85 per cent was NPK 30:10:10 at 0.2 per cent. Weekly twice application of nutrients (1.10%) and IAA 250 ppm (0.96%) had maximum single direct effect on Mg content. Interaction was significantly superior for NPK 30:10:10 at 0.2 per cent + weekly twice application frequency (1.42%), NPK 30:10:10 at 0.2 per cent + BA 200 ppm (1.06%) and weekly twice application of nutrients + BA 200 ppm (1.37%).

Copper content was the highest due to single direct effect of NPK 20:10:10 at 0.2 per cent (16.68 ppm), weekly twice application of nutrients (15.17 ppm) and IAA 500 ppm (16.42 ppm). Combination of treatments which gave significantly higher copper content were NPK 30:10:10 at 0.2 per cent applied weekly twice (20.57 ppm) and NPK 30:10:10 at 0.2 per cent + BA 200 ppm (25.50 ppm) and weekly twice application of nutrients + IAA 500 ppm (23.17 ppm).

NPK 10:10:10 at 0.1 per cent recorded the highest Fe content of 882 ppm, which was significantly superior to all other nutrient concentrations. Weekly twice application of nutrients (520 ppm) and IAA 500 ppm (610 ppm) also had single direct effect. Among the combination of treatments NPK 30:10:10 at 0.2 per cent applied twice a week (574 ppm), NPK 30:10:10 at 0.2 per cent + IAA 500 ppm (872 ppm) and weekly twice nutrient application + IAA 500 ppm gave the highest iron content (659 ppm).

Treatments like NPK 10:10:10 at 0.1 per cent (482 ppm), nutrient application twice a week (281 ppm) and IAA 500 ppm (291 ppm) gave the highest Zn content in the plant parts. Treatment combinations, viz., weekly twice application of NPK 30:10:10 at 0.2 per cent (371 ppm), NPK 30:10:10 at 0.2 per cent + BA 200 ppm (416 ppm) and IAA 500 ppm + weekly twice application of nutrients (313 ppm) gave the highest Zn content in dendrobium var. Sonia 17.

For Mn content, individual direct effect of NPK 30:10:10 at 0.2 per cent (801 ppm), weekly twice application frequency (700 ppm) and IAA 500 ppm (479 ppm) were recorded highest values. A combination of NPK 30:10:10 at 0.2 per cent applied weekly twice (956 ppm), NPK 30:10:10 at 0.2 per cent IAA 500 ppm (983 ppm) were found to be significantly superior.

Uptake of N, P and K was significantly high when NPK 30:10:10 at 0.2 per cent was applied (9.62 g, 2.31 g and 15.98 g, respectively). Uptake of all the three major nutrients was the highest (9.93 g, 2.39 g and 13.05 g, respectively) when nutrients were applied weekly twice. Uptake of N was significantly high (6.20 g) when BA 200 ppm was sprayed, whereas IAA 500 ppm recorded the highest values in the case of P and K uptake (1.46 g and 9.98 g, respectively). Combination of NPK 20:10:10 at 0.2 per cent with weekly twice application recorded highest N content of

16.79 g, whereas NPK 30:10:10 at 0.2 per cent applied weekly twice was significantly superior in the case of P (4.22 g) and K (25.53 g) uptake. N, P and K uptake was significantly increased by combination of NPK 30:10:10 at 0.2 per cent + BA 200 ppm (11.73 g, 2.71 g and 19.50 g, respectively). N uptake recorded highest value when BA 200 ppm was applied to plants receiving nutrients weekly twice (11.55 g), whereas P and K uptake (2.88 g and 15.97 g, repectively) were higher in plants which received nutrients twice weekly + IAA 500 ppm.

Earliest flowering (300 DAP) was recorded in plants which received a treatment combination of NPK 30:10:10 at 0.2 per cent applied weekly twice + BA 200 ppm, followed by NPK 20:10:10 at 0.2 per cent in the above combination (308 DAP). Since plants of most of the other treatments were not expected to flower in the near future the data were not recorded here.

Nutrients, frequency of nutrient application and growth regulators markedly influenced flower yield and quality in dendrobium var. Sonia 17. Individual effect of NPK 10:20:20 at 0.2 per cent (5.62 spikes), weekly twice nutrient application (5.21 spikes) and BA 100 ppm (5.26 spikes) recorded the maximum number. NPK 10:20:10 at 0.2 per cent applied weekly twice gave 5.61 spikes. Combinations of BA 100 ppm spray + weekly twice application of nutrients and NPK 10:20:10 at 0.2 per cent weekly twice + BA 100 ppm gave maximum spike production per plant (5.59 and 6.49 spikes, respectively).

Maximum number of florets per spike was produced by single direct effect of NPK 10:20:20 at 0.2 per cent (7.63), twice weekly application of nutrients (7.53) and BA 100 ppm (8.46). BA 50 ppm + GA_3 10 ppm recorded values on par with the above. Combination of NPK 10:20:20 at 0.2 per cent applied twice and NPK 10:20:10 at 0.2 per cent in combination with BA 100 ppm gave maximum number of florets per spike (8.29 and 9.75 spikes, respectively). BA 100 ppm combined with weekly twice application of nutrients was superior with respect to number of florets per spike (9.25).

Spike length was significantly superior when nutrient applied was NPK 10:20:20 at 0.2 per cent (44.49 cm) and NPK 10:20:10 at 0.2 per cent. Weekly twice application of nutrients (46.32 cm) and GA_3 20 ppm (48.89 cm) had positive single direct effect on spike length. Positive effect of treatment combination was recorded for NPK 10:20:10 at 0.2 per cent applied weekly twice (47.33 cm), NPK 10:20:10 at 0.2 per cent + GA_3 20 ppm (50.30) and NPK 10:20:20 at 0.2 per cent applied weekly twice + GA_3 20 ppm (52.37 cm).

Marked differences in stalk length were not observed due to influence of nutrient concentrations. Application of nutrients weekly twice was found to produce more stalk length than weekly once (24.02 cm). BA 100 ppm recorded significantly higher values for stalk length throughout the experimental period (26.02 cm). Among treatment combinations, NPK 10:10:10 at 0.2 per cent gave the highest value when applied weekly twice (25.14 cm). At seven months after treatment, NPK 10:20:20 at 0.2 per cent + BA 100 ppm (26.45 cm) and weekly twice nutrient application + BA 100 ppm recorded the highest value (29.52 cm) for stalk length of spikes. Combination of NPK 10:20:20 at 0.2 per cent applied weekly twice + BA 100 ppm gave maximum stalk length (29.90 cm).

Rachis length was due to positive single direct effect of NPK 10:20:10 at 0.2 per cent (23.91 cm), weekly twice nutrient application (23.05 cm) and BA 50 ppm + GA_3 10 ppm (25.17 cm). GA_3 20 ppm and 10 ppm were on par with the above growth regulator treatment. Among the treatment combinations, NPK 10:20:10 at 0.2 per cent applied weekly twice (23.91 cm), NPK 10:20:10 at 0.2 per cent + GA_3 20 ppm (27.51 cm), weekly twice application of nutrients along with BA 50 ppm + GA_3 10 ppm gave the highest rachis length (27.20 cm). Among the combination of all the three factors, highest rachis length was recorded for NPK 10:20:10 at 0.2 per cent applied weekly twice in combination with BA 50 ppm + GA_3 10 ppm (30.15 cm).

Internodal length was highest due to the direct single effect of NPK 10:20:10 at 0.2 per cent (3.44 cm), weekly twice application of nutrients (3.40 cm) and GA_3 20 ppm (4.10 cm). GA_3 10 ppm was on par with the above. Combination of nutrient concentration NPK 10:20:10 at 0.2 per cent applied weekly once (3.58 cm) and NPK 10:20:10 at 0.2 per cent + GA_3 20 ppm (4.62 cm) significantly enhanced internodal length. In the case of combination of all the three factors, NPK 10:20:10 at 0.2 per cent applied weekly once + GA_3 20 ppm produced the longest internodes (5.14 cm).

Girth of spike was increased with NPK 10:20:20 at 0.2 per cent (1.74 cm), application of nutrients weekly twice (1.61 cm) and BA 100 ppm (1.97 cm). Combinations of treatments which gave maximum girth of spike were NPK 10:20:20 at 0.2 per cent (1.80 cm) applied weekly once, NPK 10:20:20 at 0.2 per cent + BA 100 ppm (2.41 cm), weekly twice application of nutrients + BA 100 ppm (2.20 cm) and NPK 10:20:20 at 0.2 per cent applied weekly twice + BA 100 ppm (2.95 cm).

Annual spike production was the highest for individual effect of NPK 10:20:20 at 0.2 per cent (11.14), weekly twice application of nutrient (10.42) and BA 100 ppm (10.52). In the combination of treatments, NPK 10:20:10 at 0.2 per cent applied weekly twice (11.22), NPK 10:20:10 at 0.2% + BA 100 ppm (12.98) and weekly twice application of nutrients + BA 100 ppm (11.10) were superior.

Interval of spike production was the lowest for NPK 10:20:10 at 0.2 per cent (32.62 days), weekly twice application of nutrients (35.03 days) and BA 100 ppm (34.70 days). Among combination of treatments, NPK 10:20:10 at 0.2 per cent applied weekly twice (32.53 days), NPK 10:20:10 at 0.2 per cent + BA 100 ppm and weekly twice application of nutrients + BA 100 ppm produced consecutive spikes with minimum interval (28.12 days and 32.65 days, respectively).

Floret size was found to be significantly influenced by treatment combinations. NPK 10:10:10 at 0.1 and 0.2 per cent applied weekly once + BA 100 ppm and NPK 10:20:20 at 0.1 per cent weekly once + BA 100 ppm reduced the size of floret to 6.0 cm x 6.0 cm. Largest floret (8.0 cm x 8.5 cm) was observed in plants receiving NPK 10:20:10 at 0.1 per cent applied weekly once and twice + GA_3 20 ppm.

Various pulsing and holding treatments and their combinations significantly influenced post harvest behaviour of spikes. Among the pulsing treatments, the minimum loss of weight (0.93 g) of spikes was recorded for HQ 500 ppm + sucrose 5 per cent for 6 hours. Spikes took longest time for wilt of one floret (19.92 days) when pulsed with HQ 500 ppm + sucrose 5 per cent. Final EC (2.13 mS g^{-1}) and water uptake (19.99 ml) were maximum in hot water dip treatment at 50°-60°C for 10 seconds. Days taken to wilt of last floret was the highest for HQ 500 ppm + sucrose 5 per cent for 12 hours (25.00 days).

Loss of weight of spikes was minimum (0.13 g) and vase life of spike was maximum (24.73 days) for holding treatment containing $AgNO_3$ 50 ppm + HQ 400 ppm + sucrose 5 per cent. Maximum EC was recorded in holding solution containing Triadimefon 20 ppm (3.75 mS g^{-1}). Difference between initial and final EC was maximum for $AgNO_3$ 50 ppm + HQ 400 ppm + sucrose 5 per cent (0.11 mS g^{-1}). Water uptake was the highest in $AgNO_3$ 25 ppm + sucrose 5 per cent (19.50 ml). Days taken to wilt of last floret was maximum (30.50 days) in $AgNO_3$ 50 ppm + HQ 400 ppm + sucrose 5 per cent.

Pulsing and holding in combination gave significant differences in post harvest characters. Minimum weight loss (0.10 g) was observed for pulsing with HQ 500 ppm + sucrose 5 per cent and holding solution containing $AgNO_3$ 50 ppm + HQ 400 ppm + sucrose 5 per cent. Time taken for wilting of one floret was maximum (28.50 days) for a combination of pulsing solution containing HQ 500 ppm + sucrose 5 per cent for 6 hrs and holding solution containing $AgNO_3$ 50 ppm + HQ 400 ppm + sucrose 5 per cent. Final EC (0.28 mS g^{-1}) of holding solution and difference in EC (0.06 mS g^{-1}) were the highest for the combination of pulsing in HQ 500 ppm +

sucrose 5 per cent for 6 hours and holding in $AgNO_3$ 50 ppm + HQ 200 ppm + sucrose 5 per cent. Water uptake by spikes (28.20 ml) and days taken to wilt of the last floret (32.00 days) were maximum when the spikes were pulsed with HQ 500 ppm + sucrose 5 per cent for 12 hours and kept in holding solution containing $AgNO_3$ 50 ppm + HQ 400 ppm + sucrose 5 per cent.

References

REFERENCES

Aarts, J.F.T. 1957. On the keepability of cut flowers. *Mededelingen landbouwhogeschool Wageningen* **57**(9):1-62

Abraham, A. and Vatsala, P. 1981. *Introduction to orchids.* Tropical Botanical Garden and Research Institute, Trivandrum, p.533

Akamine, E.K. 1963. Ethylene production in fading *Vanda* orchid blossoms. *Science* **140**:1217-1218

Arditti, J. 1979. Aspect of physiology of orchids. *Adv. Bot. Res,* Academic Press, London, p.421-655

Arditti, J. 1990. Lewis Knudson (1884-1958) his science, times and legacy. Lindleyana **5**:1-79

Baker, M.L. and Baker, C.O. 1996. *Orchid species Culture - Dendrobium.* Timbei Press, Singapore, p.852

Banfield, P.G. 1981. Growing mottled-leaved *Paphiopedilum* species. *Orchid Rev.* **89**(1048):62-63

Beyer, J.E. 1976. Silver ion- A potent antiethylene agent. *HortScience* **11**:195-196

Bhattacharjee, S.K. 1977. Cultivation notes on monotypic orchid genera of India. *Orchid Digest* **40**(6):223-226

Bhattacharjee, S.K. 1981. The effects of nitrogen, phosphorus and potassium on growth and flowering of *Dendrobium moschatum* (Willd). Sw. *Cymbidium moschatum* Wild, *Thicuania moschata* Rafin. *Gartenbauwissenschaft* **46**(4):178-181

Bhattacharjee, S.K. 1982. Effect of nutrition on growth and flowering of *Aerides multiflorum* Rchb. *Lalbaugh J.* **27**(3):13-18

Bhattacharjee, S.K. 1994. Senescence of cut flowers. *Indian Horticulture* **39**(2):4-6

Bhattacharjee, S.K. 1995. Cultural requirements of orchids. *Advances in Horticulture Vol.12. Ornamental Plants.* (ed. Chadha, K.L. and Bhattacharjee, S.K.). Malhotra Publishing House, New Delhi, p.678-701

Bhattacharjee, S.K. 1997. Packaging fresh cut flowers. *Indian Horticulture* **41**(4):23-27

Bik, R.A. and van den Berg, T.J.M. 1982. Stikstof-en kalkbenesting by Mini-Cymbidium. *Bedrijsontwikkeling* **13**(6):562-563

Bik, R.A. and van den Berg, T.J.M. 1983. Effect of substrate and nitrogen supply on yield and quality of mini *Cymbidium. Acta Hort.* **150**:289-295

Bivins, J.L. 1968. Effect on growth regulating substances on the size of flower and bloom date of *Cymbidium* Sicily Grandee. *Amer. Orchic Soc. Bull.* **37**:385-387

Bivins, J.L. 1970. Effect of gibberellic acid on flower size and bloom date of *Cymbidium* Guelda. *Amer. Orchid Soc. Bull.* **39**:1005-1006

Bose, T.K. 1978. *Commercial Flowers*. Naya Prakash, Calcutta, p.635

Boon, T.E.A. 1982. Growing variegated Oncidiums. *Australian Orchid Rev.* **47**(4):34-36

Bose, T.K. and Bhattacharji, S.K. 1972. Orchid growing in warm climate. *Indian Hort.* **17**(2):25-27

Boyd, H. 1985. Bud drop of orchids. *Gardners chronicle* **27**:510-511

Brewer, K., Gradowski, C. and Meyer, M. 1989. Effect of gibberllic acid on *Cymbidium* orchid plants. *Amer. Orchid Soc. Bull.* **38**:591-592

Brundert, W. 1983. Flowering studies in Phalaenopsis. *Deutsher Gartenbau.* **37**(39):1781-1783

Burg, S.P. 1973. Hypobaric storage of cut flowers. *HortScience* **8**:202-205

Burg, S.P. and Dijkman, M.J. 1967. Ethylene induced senescence in orchids. *Planta* **150**:439-442

Burovac, M.J. and Wittwer, S.H. 1956. Gibberellin and higher plants. I. General growth responses. *Bull. Michigan Agric. Exp. Stn.* **39**(2):307-320

Chadha, K.L. 1992. The Indian Orchid Scenario. *J. Orchid Soc. India* **5**(1-2):1-4

Chadwick, A.V., Hogan, N.M. and Arditti, J. 1980. Post pollination phenomena in orchid flowers. IX. Induction and inhibition of ethylene evolution, anthocyanin synthesis and perianth senescence. *Bot. Gazette* **141**:422-427

Chen, W.S., Chang, H.W., Chen, W.H. and Lin, Y.S. 1997. Gibberellic acid and cytokinin affect *Phalaenopsis* flower morphology at high temperature. *HortScience* **32**(6):1069-1073

Chung, G.Y., Lee, J.S. and Kim, Y.R. 1986. Effects of silver nitrate and silver thiosulphate on the vaselife and senescence of cut carnation flowers. *J. Korean Soc. Hort. Sci.* **27**(3):275-282

Clifford, P.E., Neo, H.H. and Hew, C.S. 1992. Partitioning of C^{14}-assimilate between sources and sinks in the monopodial orchid *Aranda* Tay Swee Eng. *Annals of Botany.* **69**:209-212

Coorts, G.P., Gartner, J.B. and Mc Collum, J.P. 1965. Effect of senescence and preservatives on respiration in cut flowers of *Rosa hybrida* 'Velvet Times'. *Proc. Amer. Soc. Hort. Sci.* **86**:779-790

Davidson, O.W. 1949. Effects of ethylene on orchid flowers. *Proc. Amer. Soc. Hort. Sci.* **53**:440-446

Downs, C.G., Reihana, M. and Dick, H. 1988. Bud opening treatments to improve *Gypsophila* quality after transport. *Scientia Hort.* **34**:301-310

Durkin, D. and Kue, R. 1966. Vascular blockage and senescence of the cut rose flower. *Proc. Amer. Soc. Hort. Sci.* **88**:540-543

FIFA (Federation of Indian Floriculturists Association). 1997. *Model scheme for orchids and anthuriums - Report of Task Force on Innovative Agriculture,* Ninth Five Year Plan, Thiruvananthapuram, Kerala. P.39-41

Gething, P.A. 1974. Using fertilizers on Odontoglossum. *Orchid Rev.* **82**(971):133-135

Gilman, K.T. and Steponkus, P.L. 1972. Vascular blockage in cut flowers. *J. Amer. Soc. Hort. Sci.* **97**(5):662-667

Goh, C.J. 1976. Growth regulators in selected orchids. *Annals of Bot.* **40**:645-646

Goh, C.J. 1977. Growth retardants on *Aranda* Deborah. *Annals of Bot.* **41**:1061-1063

Goh, C.J. and Arditti, J. 1985. Orchidaceae. *Handbook of flowering Vol.1* (ed. Halevy, A.H.). CRC Press, Florida, p.336

Goh, C.J. and Seetoh, H.C. 1973. Orchid physiology. *Annals of Bot.* **37**:113-119

Goh, C.J. and Wan, H.Y. 1974. *Plant Growth Substances* Hirokawa Pub. Co., Tokyo, p.135

Goh, C.J. and Yang, A.L. 1978. Effects of growth regulators and decapitation on flowering of *Dendrobium* orchid hybrids. *Plant Sci. Letter* **12**:287-292

Goh, C.J., Halevy, A.H., Engel, R. and Kofranek, A.M. 1985. Ethylene evolution and sensitivity in cut orchid flowers. *Scientia Hort.* **26**:57-67

Gomi, K., Ogina, Y. and Tanaka, T. 1980. Fertilization and potting media for *Phalaenopsis* hybrid. *Bull. Faculty Agric. Miyazaki Univ.* **27**(2):267-276

Halevy, A.H. and Kofranek, A.M. 1977. Silver treatment of carnation flowers for reducing ethylene damage and extending longevity. *J. Amer. Soc. Hort. Sci.* **102**(1):76-77

Halevy, A.H. and Mayak, S. 1979. Senescence and postharvest physiology of cut flowers. Part I. *Hort. Rev.* (ed. Janick, J.) AVI, Westpost, p.59-143

Halevy, A.H. and Mayak, S. 1981. Senescence and post harvest physiology of cut flowers. Part 2. *Hort. Rev.* (ed. Janick, J.). AVI, West port, p.59-148

Hew, C.S. 1987. The effect of 8-hydroxyquinoline sulphate, acetylsalicylic acid and sucrose on bud opening of *Oncidium* flowers. *J. Hort. Sci.* **62**(1):75-78

Hew, C.S. 1989. Orchid cut flower production in Singapore and neighbouring Asian countries. *Amer. Orchid Soc. Bull.* **58**:887-897

Hew, C.S. 1993. Orchid cut flower production in Asean countries. *Orchid Biology-Review and Perspective-VI.* (ed. Arditti, J.). John Wiley, New York, p.238

Hew, C.S., Wee, K.H. and Lee, F.Y. 1987. Factors affecting the longevity of cut *Aranda* flowers. *Acta Hort.* **205**:195-202

Hew, C.S. and Clifford, P.E. 1993. Plant growth regulators and the orchid cut-flower industry. *Plant Growth Regulation.* **13**:231-239

Higaki, T. 1989. Effects of culture medium and fertilizer on *Dendrobium* Jaquelyn Thomas. *HITARI - Univ. of Hawaii Res. Series.* **5**:11-13

Higaki, T. and Imamura, J.S. 1987. NPK requirements of *Vanda* Miss Joaquim orchid plants. *Research Extension Series*: *Hawaii Institute of Tropical Agriculture and Human Resources* **5**(87):5

Higuchi, H. and Sakai, K. 1977. The effect of N^6-Benzyladenine on the flowering of *Dendrobium* nodoka. *Res. Bull. Aichi-ken Agric. Res. Centre Series B* **9**:79-81

Huang, C.C., Pan, M.H. and Wang, T.T. 1997. Senescence, ethylene production and electrolyte leakage of different parts of chilled *Phalaenopsis* flower. *J. Agric. Res. China* **46**(2):167-180

Jackson, M.L. 1958. *Soil Chemical Analysis*. Prentice Hall Inc., USA, p.363

Johnson, W.R.B. 1984a. Fertilizer deficiencies and orchid nutrition. *Australian orchid* Rev. **49**(2):97-100

Johnson, W.R.B. 1984b. A simple liquid nutritional programme for orchids. *Australian orchid Rev.* **49**(3):197-204

Johnson, C.M. and Ulrich, A. 1959. Analytical methods for use in plant analysis. *Calif. Agric. Expt. Station Bull.* **766**:26-76

Jomy, T.G. 1998. Enhancement of post-harvest life of *Dendrobium* flower. M.Sc. Thesis, Kerala Agricultural University, Thrissur, Kerala

Jung Nam., Ohkawa, K. and Kwack, B.H. 1998. Senescence symptoms after emasculation vary among *Cymbidium* cultivars. *HortScience* **33**(4):734-735

Keithly, J.W., Jones, D.P. and Yokoyama, H. 1991. Survival and growth of transplanted orchid seedings enhanced by DCPTA. *HortScience* **26**(10):1284-1286

Ketsa, S. 1986. Comparitive studies on holding solutions for *Dendrobium* 'Pompadour' flowers. *Proc. Sixth ASEAN Orchid* Congress. Bangkok, Thailand, p.130-134

Ketsa, S. 1989. Vase life characteristics of inflorescence of *Dendrobium* 'Pompadour'. *J. Hort. Sci.* **64**(5):611-615

Ketsa, S. and Amutiratana, D. 1986. Effect of sucrose, silver nitrate and 8-hydroxyquinoline sulfate on postharvest behaviour of *Dendrobium* 'Pompadour' flowers. *Proc. Sixth ASEAN Orchid Congress.* Bangkok, Thailand, p.124-129

Ketsa, S. and Boonrote, A. 1990. Holding solution for maximising bud opening and vase life of *Dendrobium* 'Youppadeewan' flowers. *J. Hort. Sci.* **65**(1):41-47

Ketsa, S., Piyasaenthong, Y. and Prathwangwong, S. 1995. Mode of action of $AgNO_3$ in maximising vase life of *Dendrobium* 'Pompadour' flower. *Post-harvest Biol. Technol.* **5**(1-2):109-117

Khaw, C.H. and Chew, P.S. 1980. Preliminary studies on the growth and nutrient requirements of orchids (*Aranda Noorah Alsa goff*). *Proc. Third Asean Orchid Congress* (ed. Singh, K.G.), Ministry of Agriculture, Malaysia, p.49-64

Koay, S.H. and Chua, S.E. 1981. Export oriented orchid production by chemical regulation of flowering. *Singapore Agric. J.* **9**:93-100

Kofranek, A.M. and Halevy, A.H. 1976. Effect of pulsing chemicals in gladiolus. *J. Amer. Soc. Hort. Sci.* **102**(2):92-94

Koval'skaya, L.A. and Zeimenko, N.V. 1991. Choice of subslide and mineral fertilizers for *Dendrobium phalaenopsis* Fitigg. Seedlings of different ages (Introdulctsiya Akklimalimatlzatsiya Rastenii) *Tsentral nyi. Respublikanskii Botaniches Kii Sad, Kiev, Ukraine* **13**:75-79

Kunisaki, J.T. 1975. Induction of keikis on ascocendas by cytokinin. *Amer. Orchid Soc. Bull.* **44**:1066-1067

Lee, S.K. and Koay, S.H. 1986. Effects of benzyladenine and gibberellic acid on flowering of *Dendrobium* Louisae. *Proc. 5th Asean Orchid Congress,* Singapore, p.88

Linberger, R.D. and Steponkus, P.L. 1976. Identification and localization of vascular occlusions in cut roses. *J. Amer. Soc. Hort. Sci.* **101**:246-250

Longman, H. 1989. *Orchid Growing.* Van Nosts and Runhold Co., New York, p.183

Ma, C.W. 1992. Photosynthate partitioning in sympodial orchids. *Bull. National Univ.* Singapore, p.56

Marousky, F.J. 1973. Recent advances in opening bud cut chrysanthemum flowers. *Hort. Sci.* **8**:199-202

Mayak, S., Garibaldi, E.A. and Kofranek, A.M. 1977. Carnation flower longevity:microbial populations as related to silver nitrate stem impregnation. *J. Amer. Soc. Hort. Sci.* **105**(5):637-639

Merriman, A.J. 1987. Factors that influence the growing and flowering of Cymbidiums to perfection. *Australian Orchid Rev.* **40**(1):45-49

Mukherjee, S.K. 1990. *Orchids*. Indian Council of Agricultural Research, New Delhi, p.9-16

Nair, H. 1984. Post harvest physiology and handling of orchids. *Proc. Eleventh World Orchid Congress* p.255-260

Nair, H. and Tong, H.F. 1987. Ethylene production and 1-amino cyclopropane-1-carboxylic acid levels in detatched orchid flowers of *Dendrobium* 'Pompadour'. *Scientia Hort.* **32**:145-151

Nair, H., Idris, Z.M. and Arditti, J. 1991. Effects of 1-amino cyclopropane-1-carboxylic acid on ethylene evolution and senescence of *Dendrobium* (Orchidaceae) flowers. *Lindleyana.* **6**:49-58

Nichols, D.G. 1982. Nutritional aspects in the culture of cymbidiums. *Australian orchid Rev.* **47**(2):106-108

Northen, R.T. 1970. *Home Orchid Growing*. Van Nostrand Reinhold, New York, p. 158-165

Novak, J. and Rudnicki, M.R. 1990. *Post harvest handling and storage of cut flowers, florist greens and potted plants.* Chapman and Hall India, p.45-163

Novak, J. and Vacharotayan, S. 1980. Evaluation of different chemical treatment for keeping quality and vase life prolongation of some orchid cultivars. *Proce Instytuty Sadownictwa w Kwiaciarstaw ser B.* **5**:83-92

Ochsenbauer, A.S. 1996. Nutrition and post-production performance of Phalaenopsis pot plants. *Proc. International Symposium on Growing Media and Plant Nutrition in Hort.* Freesing, Germany, 450:105-112

Ong, H.T. 1982. Uses of solutions with trace elements to influence the flowering and shelf life of flowers of *Oncidium* 'Goldiana'. *Orchid Rev.* **90**(1066):264-265

Ong, H.T. and Lee, L.L. 1983. Use of silver nitrate and citric acid to improve shelf life of Golden Shower flowers. *Orchid Rev.* **91**(1075):141-144

Panse, V.G. and Sukhatme, P.V. 1985. Statistical methods for agricultural workers. ICAR, New Delhi, p.97-123; 145-164

Pathak, P. and Kaur, S. 1996. Ethylene production and shelf life of flowers in orchids. *Orchid News.* **12**(1-2):12-13

Paull, R.E. and Goo, T.T.C. 1985. Ethylene and water stress in the senescence of cut anthurium flowers. *J. Amer. Soc. Hort. Sci.* **100**(1):84-88

Penningsfield, F. and Fast, G. 1962. Effect of deficiency and excess of nitrogen in *Paphiopedilum*, *soc. Bull.* **31**:301-304

Pileuk, C., Tong, Umpai, P. and Watthong, S. 1986. Effect of paclobutrazol on *Dendrobium* Hepa as a potted plant. *Proc. 6th Asean Orchid Conference,* Bangkok, p.157

Pileuk, C., Watthong, S. and Teweesomboom, W. 1992. Effect of cytokinin application in storage life of *Dendrobium* plants under low temperature. Fourth Asia Pacific Orchid Conference, Chiangmai, Thailand, *Abstracts*, p.78

Pirone, A.P. 1958. Gibberellin plant growth stimulator. J.N.Y., Botanic Garden News. **8**:42-46

Poole, H.A. and Seeley, T.J. 1978. Nitrogen, potassium and magnesium nutrition of three orchid genera. *J. Amer. Soc. Hort. Sci.* **103**(4):485-488

Poole, H.A. and Sheehan, T.J. 1970. Effects of media and supplementary microelement fertilization on growth and chemical composition of Cattleya. *Amer. Orchid Soc. Bull.* **46**:155-160

Porat, R., Borochov, A. and Halevy, A.H. 1994. Pollination induced changes in ethylene production and sensitivity to ethylene in cut dendrobium orchid flowers. *Scientia Hort.* **58**:215-221

Pradhan, U.C. 1976. *Indian Orchids : Guide to identification and culture. Vol.I.* Udai C. Pradhan, Kalimpong, India, p.12

Rajeevan, P.K. and Sobhana, A. 1993. Performance of certain epiphytic orchid species in Central Kerala. *J. Orchid Soc. India.* 7(1-2):31-35

Rajeevan, P.K., Sobhana, A. and Aravindakishan, M. 1993. Orchid industry in Kerala-Vying for a place in export market. Vasant-Rao Naik Memorial National Seminar on Export Oriented Horticultural Production - Research strategies, Abstracts, Punjabrao Krishi Vidhapeeth, Nagpur, p.77

Randhawa, G.S. 1981. *Plant Growth Regulators and Gibberellins. Indian Council of Agriculture Research.* New Delhi, p.138

Rogers, M.N. 1973. A historical and critical review of postharvest physiology research on cut flowers. *HortScience* **8**:189-194

Ruichi, P., Chen, J.Y. and Wen, Z.Q. 1994. Influence of different potassium levels on growth, development and physiology in *Cymbidium sinense* following potassium starvation. *J. Tropical and Subtropical Bot.* **2**(3):46-53

Sagarik, R. and Siripong, S. 1963. A study of some orchid fertilizers. *Amer. Orchid Soc. Bull.* **32**:174-176

Salunkhe, D.K., Bhatt, N.R. and Desai, B.B. 1990. Postharvest biotechnology of flowers and ornamental plants. Naya Prakash, Calcutta, p.390

Sanford, W.W. 1974. The ecology of orchids. *The orchids - Scientific studies* (ed. Withner, C.L.). John Wiley and Sons, New York, p.82

Sakai, K., Osuga, M. and Yonemura, K. 1985. Effect of fertilizer application on growth and flowering in *Dendrobium* spp. II : Ability of compost mixed with pumice and bark to substitute for sphagnum moss. *Res. Bull. Aichi. Agric. Res. Centre* **17**:239-247

Schenk, M. and Brundert, W. 1983. Early flowering of pot *Phalaenopsis* : Temperature reduction, light exclusion and manuring. *Deutscher Gartenbau* **37**(39):1781-1783

Schum, A. and Fischer, P. 1985. The N:K_2O ratio in *Phalaenopsis. Deutscher Gartenbau* **39**(36):1704-1706

Seeni, S. and Latha, P.G. 1990. Post transplantation growth of *Phalaenopsis* hybrid seedlings in community pots. *J. Orchid Soc. India.* **4**:127-135

Sharma, V. and Kaur, S. 1994. Regulation of flowering in orchids. *Orchid News.* **10**(1-2):15

Sheehan, T.J. 1960. Effects of nutrition and potting media on growth and flowering of certain epiphytic orchids. *Amer Orchid Soc. Bull.* **30**:289-292

Sheehan, T.J. 1966. The fertilization of orchids. *Proc. Fifth World Orchid Conference* (ed. De Garmo, L.R.). Fifth W.O.C. Inc., California, P.95-97

Singh, F. 1986. Orchids. *Ornamental Horticulture in India.* (ed. Chadha, K.L. and Chowdhary, B.). ICAR, New Delhi, p.130-136

Sobhana, A. and Rajeevan, P.K. 1995. Foliar application of nutrient formulations in *Cymbidium traceanum. J. Orchid Soc. India.* **9**(1-2):45-50

Staby, G.L. and Robertson, J.L. 1982. Enhancing vaselife using floral preservatives. *Tropical Agri. Res. Series* **8**:81-83

Stewart, J. 1988. *Orchids : The Royal Botanic garden, Kew.* The Hamlyn Pub. Group Ltd., England, p.45

Taejung, K. Hoon, S.J. and Yoeoup, P.K. 1998. Effect of NPK ratios on the growth and mineral content of temperate *Cymbidium J. Korean Soc. Hort Sci.* **39**(4):469-474

Tanaka, T., Matsuno, T., Masuda, M. and Gomi, K. 1988a. The effects of concentration of nutrient solution and potting media on the growth and chemical composition of a *Cattleya* hybrid. *J. Jap. Soc. Hort. Sci.* **57**(1):85-90

Tanaka, T., Matsuno, T., Masuda, M. and Gomi, K. 1988b. The effects of concentration of nutrient solutions and potting media on growth and chemical composition of *Phalaenopsis* hybrid. *J. Jap. Soc. Hort. Sci.* **57**(1):78-84

Tanaka, T., Kanya, Y., Masuda, M. and Gomi, K. 1989. Growth and nutrient uptake of a cattleya hybrid grown with different composts and fertilizers. *J. Jap. Soc. Hort. Sci.* **57**(4):674-684

Tanaka, T., Ogino, Y. and Gomi, K. 1981. Fertilizer application for *Cattleya* hybrid. *Bull. Faculty Agric. Miyazaki Univ.* **28**(1):129-135

Thekkayam, S.G. 1996. Performance of selected orchids under varying light regimes, culture methods and nutrition. Ph.D. thesis, Kerala Agricultural University, Thrissur, Kerala.

Tisdale, S.L., Nelson, W.L., Beaton, J.D. and Havlin, J.L. 1995. *Soil Fertility and Fertilizers*, vth Ed. Prentice Hall of India Pvt. Ltd., New Delhi, p.634

Uesato, K., Yagi, N. and Odo, S. 1987. Effects of nitrogen and phosphate on the growth of *Ceratobuim - Phalaenanthe* types *Dendrobium*. *Sci. Bull. College Agric. Rjukyus Univ.* **34**:11-19

Umamaheswari, R. 1999. Nutrition of tissue culture plants of *Dendrobium* Sonia 17. M.Sc. Thesis, Kerala Agricultural University, Thrissur, Kerala.

Vacharotayan, S. and Keethapirom, S. 1975. Effects of fertilizers upon growth and flowering of *Dendrobium* Pompadour. Report of the First ASEAN Orchid Conference, Bangkok, Thailand, p.138-156

Van, D.C. 1997. Developments in the use of growth regulators for the maintenance of post-harvest quality in cut flowers and potted plants. *Acta Hort.* **298**:195-209

Vries, T.J. 1953. Endogenous growth regulators in orchids. *Annales Bogoria* **1**:61-76

Wadasinghe, G. and Hew, C.S. 1995. The importance of back shoots as a source of photoassimilates for growth and flower production in *Dendrobium* cv. Jashika Pink (Orchidaceae). *J. Hort. Sci.* **70**(2):207-214

Wang, Y.T. 1996. Medium and fertilization affect performance of potted *Dendrobium* and *Phalaenopsis Hort. Technology.* **5**(3):234-237

Wang, Y.T. and Gregg, L.L. 1994. Medium and fertilizer affect the performance of *Phalaenopsis* orchids during two flowering cycles. *HortScience* **29**:269-271

Wangkean, W. and Techanpiyawat, S. 1992. Vaselife extension of orchid flowers by hot water treatment. *Proc. Fourth Asia Pacific Orchid Conference.* Chang Mai, Thailand, p.85

Widyastuti, D. and Soedjone, S. 1979. The effect of ethrel on the flowering of Golden shower oncidiums. *Bull. Penoli Hortikulturae* 7:3-6

Yadav, L.P. and Bose, T.K. 1986. Effects of nitrogen, phosphorus and potassium on growth and flowering of *Aerides multiflorum* Roxb. *Biology, conservation and culture of orchids.* (ed. Vij, S.P.). Affiliated East-West Press Pvt. Ltd., New Delhi, p.75-78

Yamane, K., Kuchi, E., Fujishige, N., Minegishi, N. and Ogata, R. 1997. Effects of BA pretreatment on vase life, ethylene production and soluble sugar contents in cut florets of four members of *Cattleya* alliance. *J. Jap. Soc. Hort. Sci.* 65(4):801-807

Yee, K.K. 1983. Triacantanol:Effect of flower application on *Dendrobium* hybrid orchid community pot seedlings. *Plant propagator*. 29:3-4

Yong, H.C. and Ong, H.T. 1979. Physiology of orchid flowers. *Orchid Rev.* 87:282-285

APPENDIX-I

Meteorological data during the cropping period from May 1998-October 1999

Month	Temperature °C		Rainfall (mm)	Rainy days	Relative humidity %		Mean sunshine (hrs)	Wind speed (km/h)
	Maximum	Minimum			Morning	Evening		
1998								
May	34.1	25.2	203.0	9	90	63	7.6	2.6
June	30.2	23.3	809.3	24	94	79	3.4	2.7
July	29.2	23.6	752.9	28	96	80	3.3	2.8
August	29.8	23.9	433.5	8	95	77	3.6	2.5
September	30.2	23.3	571.3	24	96	78	4.1	2.0
October	28.0	22.8	452.8	18	94	76	4.8	1.7
November	31.5	23.1	109.4	9	92	64	7.2	1.8
December	30.1	22.9	33.0	4	79	58	6.6	5.7
1999								
January	32.4	21.5	0.0	0	76	40	9.3	-
February	34.5	23.3	22.8	1	77	35	9.1	-
March	35.5	24.5	0.0	0	88	48	8.8	-
April	33.4	25.6	39.0	4	88	58	10.3	-
May	30.7	24.7	430.5	18	92	72	4.9	-
June	29.4	23.0	500.2	28	94	75	5.0	-
July	28.4	23.0	823.3	28	96	82	2.4	-
August	29.8	22.9	260.1	12	94	73	5.5	-
September	31.6	23.4	28.4	3	89	63	7.1	2.1
October	30.5	23.2	506.2	15	94	75	4.8	1.6

REGULATION OF GROWTH AND FLOWERING IN DENDROBIUM VAR. SONIA 17

By

SWAPNA, S.

ABSTRACT OF THE THESIS

Submitted in partial fulfillment of the requirement for the degree of

Doctor of Philosophy in Horticulture

Faculty of Agriculture
Kerala Agricultural University

DEPARTMENT OF POMOLOGY AND FLORICULTURE
COLLEGE OF HORTICULTURE
VELLANIKKARA, THRISSUR - 680 656
Kerala, India

2000

ABSTRACT

Studies on `Regulation of growth and flowering in dendrobium var. 'Sonia 17' were conducted in the Department of Pomology and Floriculture, College of Horticulture, Vellanikkara from June 1998 to November 1999 and at Padikkala Orchids, Thrissur from February to September 1999. The main objectives of the studies were to reduce the pre-blooming period, to improve the yield and quality and to enhance the post harvest life of spikes using various treatments.

Plant height was significantly superior (19.50 cm at 10 MAP) with the combination of NPK 30:10:10 at 0.2 per cent, applied weekly twice + GA_3 20 ppm. With respect to number of shoots, NPK 30:10:10 at 0.2 per cent, applied weekly twice + BA 200 ppm was most effective (with 7.67 shoots). Shoot girth recorded maximum value (5.80 cm) at 10 MAP in the treatment combination of NPK 30:10:10 at 0.2 per cent, applied weekly twice + IAA 500 ppm.

Plants which received NPK 30:10:10 at 0.2 per cent weekly twice along with BA 200 ppm recorded maximum leaf production (19.83 leaves at 10 MAP). In the case of total leaf area, BA 200 ppm produced maximum value (210.12 cm^2) in combination with NPK 30:10:10 at 0.2 per cent, applied weekly twice. Number of roots was markedly higher for NPK 30:10:10 at 0.2 per cent weekly twice with BA 200 ppm, which produced 42.0 roots.

Biomass production (dry weight) was the highest (6.94 g/plant) for NPK 30:10:10 at 0.2 per cent, applied weekly twice + BA 200 ppm. The combination of NPK 30:10:10 at 0.2 per cent, applied weekly twice + IAA 250 ppm recorded the highest nitrogen content of 2.47 per cent. This was on par with BA 200 ppm, IAA 50 ppm and BA 100 ppm in combination with the same level of nutrients. Maximum value for P content (0.69%) was observed in the combination of NPK 30:10:10 at 0.2 per cent, sprayed weekly twice + IAA 500 ppm. The growth regulator component was on par with IAA 250 ppm. The combination which yielded highest value for K content

(4.00%) was NPK 30:10:10 at 0.2 per cent, applied weekly twice + IAA 250 ppm. The same level of nutrients with IAA 500 ppm was on par with this.

The contents of Ca and Mg were higher with higher nitrogen levels and frequencies, coupled with BA 200 ppm (for Ca) or IAA 250 ppm (for Mg). In the case of micro-nutrients (Cu, Fe, Zn and Mn), lower levels of nitrogen at higher frequencies, in combination with IAA 500 ppm, recorded higher values.

Uptake of N, P and K was the highest with the combination of NPK 30:10:10 at 0.2 per cent, applied weekly twice + BA 200 ppm (11.73 g, 2.71 g and 19.50 g, respectively). Uptake of P was on par for IAA 500 ppm, with the above level of nutrients.

Earliest flowering (300 DAP) was recorded in plants which received a treatment combination of NPK 30:10:10 at 0.2 per cent, applied weekly twice + BA 200 ppm. Plants receiving the nutrient level of NPK 20:10:10 in the above combination flowered next (308 DAP).

Nutrients, their frequency of application and growth regulators markedly influenced flower yield and quality. A combination of NPK 10:20:10 at 0.2 per cent, applied weekly twice + BA 100 ppm recorded the maximum number of spikes per year (12.98) and number of florets per spike (10.50). Spike length was significantly superior (55.40 cm) for NPK 10:20:20 at 0.2 per cent, applied weekly twice + GA_3 20 ppm. Longest stalks (30.10 cm) were produced at the same level of nutrients, coupled with BA 100 ppm. A treatment combination of NPK 10:20:10 at 0.2 per cent applied weekly twice + (BA 50 ppm + GA_3 10 ppm) produced the longest rachis (30.25 cm), which was on par (30.16 cm) with the above nutrients applied weekly once + GA_3 20 ppm. Internodal length was the highest (5.14 cm) in the combination of NPK 10:20:10 at 0.2 per cent, applied weekly once + GA_3 20 ppm. Girth of spike was maximum (2.95 cm) with NPK 10:20:10 at 0.2 per cent, applied weekly twice + BA 100 ppm.

The interval of spike production was the least (28.12 days) for NPK 10:20:10 at 0.2 per cent, applied weekly twice + BA 100 ppm. Floret size was reduced to 6.0 cm x 6.0 cm by the treatment combinations NPK 10:10:10 at 0.1 per cent (weekly once or twice) or 0.2 per cent (weekly once) + BA 100 ppm. Largest floret size of 8.0 cm x 8.5 cm was observed in plants receiving NPK 10:20:10 at 0.1 or 0.2 per cent, applied weekly twice + GA_3 20 ppm.

Various pulsing and holding treatments and their combinations significantly influenced the post harvest behaviour of spikes. Among the pulsing treatments, minimum loss of weight (0.93 g) of spikes was recorded when kept in HQ 500 ppm + sucrose 5 per cent for 6 hours. Spikes took the longest time (19.92 days) for the wilting of one floret (vase life) when pulsed with HQ 500 ppm + sucrose 5 per cent for 12 hours. Final EC (2.13 mS g^{-1}) and water uptake (19.99 ml) were the highest in hot water dip treatment at 50°-60°C for 10 seconds. Days to wilt of the last floret was the highest (25.00 days) when treated with HQ 500 ppm + sucrose 5 per cent for 12 hours.

Minimum loss of weight of spike (0.13 g), maximum days to wilt of the last floret (30.50 days) and maximum vase life of spike (24.73 days) were recorded by the holding treatment containing $AgNO_3$ 50 ppm + HQ 400 ppm + sucrose 5 per cent. Maximum EC (3.75 mS g^{-1}) was recorded for Triadimefon 20 ppm. Difference between initial and final EC was maximum (0.11 mS g^{-1}) for $AgNO_3$ 50 ppm + HQ 400 ppm + sucrose 5 per cent. Water uptake was highest (19.50 ml) in $AgNO_3$ 25 ppm + sucrose 5 per cent.

Pulsing and holding treatments, in combination, gave significant differences in post harvest characters. Minimum weight loss (0.07 g) was observed when pulsed with HQ 500 ppm + sucrose 5 per cent for 12 hours and kept in the holding solution containing $AgNO_3$ 50 ppm + HQ 400 ppm + sucrose 5 per cent. Final EC (0.28 mS g^{-1}) of holding solution was the highest for the combination of pulsing treatment of HQ 500 ppm + sucrose 5 per cent for 12 hours and holding treatment of quality more treatments with combinations of GA_3 and BA can be studied. The results of the experiment can also be extended to find effects on other important varieties of dendrobium as well as other genera. The results of experiment I and experiment II have to be tried to the same lot of plants to find the combined effect.