GROWTH, DEVELOPMENT AND QUALITY OF VANILLA (*Vanilla planifolia* Andrews) AS INFLUENCED BY ORGANICS AND GROWTH REGULATORS

By

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THESIS

submitted in partial fulfilment of the requirements for the degree of

Master of Science in Horticulture

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DECLARATION

I hereby declare that the thesis entitled **"Growth, development and quality of vanilla (*Vanilla planifolia* Andrews) as influenced by organics and growth regulators"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

Vellanikkara

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CERTIFICATE

Certified that the thesis entitled **"Growth, development and quality of vanilla (*Vanilla planifolia* Andrews) as influenced by organics and growth regulators"** is a record of research work done independently by **Miss Anuja Gopal** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, associateship or fellowship to her.

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We, the undersigned members of the Advisory Committee of **Miss Anuja Gopal,** a candidate for the degree of **Master of Science in Horticulture**, with *major field in* Plantation Crops and Spices, agree that the thesis entitled **"Growth, development and quality of vanilla (*Vanilla planifolia* Andrews) as influenced by organics and growth regulators"** may be submitted by Miss *Anuja Gopal, in partial fulfilment of the requirements for the degree.*

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Anuja Gopal

TABLE OF CONTENTS

Dedicated

To My Loving

Parents

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

INTRODUCTION

INTRODUCTION

Spices, though added in small quantities, find an important place in almost all food preparations to impart aroma, flavour, pungency and colour. Food flavours play a major role in human food habits and among the flavors, vanilla has a prime position, its essence being largely used in the preparation of ice creams, chocolates, bakery products, liquors and also in perfumery and pharmaceuticals.

Now, in a more health conscious world, the consumer preference is for natural foods. The use of natural flavours, colours and foods are reported to be growing at an annual rate of two to four per cent, which elucidates the increased demand for natural vanillin. Moreover, most of the European countries have banned the use of synthetic vanillin.

Vanilla (*Vanilla planifolia* Andrews) is a tropical orchid which is indigenous to wet low land forests in South Eastern Mexico, Guatemala and other parts of Central America. The total area under vanilla cultivation in the world is 40,486 ha with a production of 5,583 t (Sudharshan, 2002). Vanilla was introduced to India in the eighteenth century, but the commercial cultivation started from 1990 onwards. Now the crop occupies an area of about 3,400 hectares with a production of about 131 tonnes (Anon., 2004).

Vanilla is completely an export oriented crop, the global demand of which is on the increase. Presently, the global demand is estimated as 71400 tonnes of cured beans. The very high price in the international market motivated the farmers to cultivate the crop on a large scale. Moreover, the prevailing agroclimatic conditions in India is congenial for its cultivation. Hence there is immense potential to extend the cultivation of vanilla. The cost of one kg of synthetic vanillin is only US $ 20 whereas the same quantity of natural vanillin costs US $ 2000 in the international market.

There is an increasing demand for organic spices in the international market. Vanilla is a crop, which is highly responsive to organic cultivation. Treatments to enhance growth assume prime importance in commercial cultivation of vanilla, as flowering occurs in one year old shoots. However, no scientific investigations on the effect of organic inputs on yield and quality of vanilla have so far been carried out.

Pollination accounts for the major share of expenditure in vanilla cultivation. Therefore, development of parthenocarpic beans would be of great economic importance. Vanillin content determines the quality and price of vanilla in the international market. Research data on scientific cultivation of vanilla so as to enhance yield and quality of beans are meagre. In the above context, investigations were carried out with the following major objectives:

- To evaluate the influence of organic inputs on the growth of vine
- To induce parthenocarpic beans through the application of growth regulators
- To improve the vanillin content of beans by the use of growth regulators

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Vanilla (*Vanilla planifolia* Andrews) is a tropical orchid belonging to the family Orchidaceae. It has a prime position among food flavours. It is indigenous to wet low land forests in South Eastern Mexico, Guatemala and other parts of Central America. Vanilla is predominantly an export oriented crop and its very high price in the international market motivated the farmers to cultivate the crop on a large scale. In vanilla, earliness in flowering depends on the initial growth of the vine. Growth regulators could be used for the induction of parthenocarpic fruits and to improve the vanillin content of beans. Research works done on this aspect in vanilla and other horticultural crops are reviewed hereunder:

2.1 MORPHOLOGY

Vanilla planifolia is a herbaceous perennial vine climbing on trees or other supports to a height of 10 to 15 m by means of adventitious roots. In cultivation, the vine is trained to a height, which facilitates hand pollination and harvesting. The aerial adventitious roots are long whitish, proceed singly opposite the leaves and adhere firmly to the support plant. The roots at the base ramify in the humus or mulch layer. The stem is long, cylindrical, succulent and branched. It is dark green and photosynthetic with stomata. The internodes are 5 - 15 cm in length. Leaves are large, fleshy, flat and alternate with parallel venation and distinct veins. The petiole is thick, short and canalised above.

The stout racemose inflorescence is axillary and single or rarely branched. They bear 10 - 26 flowers opening from the base. Flowering is usually from February to March and it takes 30 - 45 days from the initiation of inflorescence to flowering.

2.2 FLORAL BIOLOGY

Flowers are large, waxy, pale greenish yellow, bisexual and zygomorphic. The sepals and petals are commonly called perianth. The lower petal is short broad and it is modified into a labellum. The lower part of the labellum envelops a central structure called the column or gynostemium. The column or gynostemium is 3-4 cm long and is attached to the labellum for most of its length. Bearing at its tip, the single stamen containing the two pollen masses or pollinia covered by a cap and below is concave sticky stigma, which is separated from the stamen by the thin flap like rostellum.

Preliminary research on vanilla was undertaken at the Horticulture Research Station (present Regional Agricultural Research Station), Ambalavayal, Kerala Agricultural University in 1960. A descriptor for vanilla, using minimum characters was developed by Kuruvilla *et al.* (2000). Sankaran *et al.* (1995) developed a multiple regression equation based on biometrical observations with 82.5 per cent precision for easy determination of vine length in vanilla. Estimation of leaf area in vanilla using the formula A = 62.246 +3.376L +13.294W was reported by Krishnakumar *et al.* (1997).

2.3 GROWTH ANALYSIS

To enhance the growth of vine, various practices are being adopted by farmers such as application of dilute biogas slurry, biogas slurry along with fermented groundnut cake etc.

2.3.1 Organic Manure

Vanilla is highly amenable to organic cultivation. Decomposed organic matter, bone meal, rotten cow dung, compost, fermented cakes etc. can be used as manure for vanilla (Spices Board, 2003).

Application of 120 g N in the form of leaf mould or farmyard manure in two split doses in June–July and September is recommended for vanilla by Kerala Agricultural University (KAU, 2004).

Vanilla cuttings planted in soil, farmyard manure mixture in the ratio 1:1 was found best in terms of number of leaves produced and bud length at three or four months after planting (Rosman and Tasma, 1988).

Application of farmyard manure resulted in higher vegetative mass, dry weight, plant height and rate of dry matter increment per unit leaf area of capsicum (Cerna, 1980; Freitas *et al.*, 1982 and Valsikova and Ivanic, 1982).

Farmyard manure at the rate of 48 t ha^{-1} resulted in higher yield in ginger (Nybe, 2001). In turmeric, Saha (1988) recorded the highest yield (11820 kg) of fresh rhizomes from plots supplied with 50 t ha^{-1} farmyard manure. Experiments conducted by Gill *et al.* (1999) also confirmed the rhizome yield increase in turmeric by farmyard manure application.

In an experiment on the effect of different media on germination and seedling growth of clove, sand and farmyard manure (1:1) gave the highest germination percentage whereas soil and farmyard manure (2:1) recorded the best seedling growth (Sabale *et al.*, 1995).

Khandkar and Nigam (1996) reported that farmyard manure application in ginger increased the number of leaves and tillers per plant and improved the water holding capacity of soil. In a field experiment conducted in ginger, it was revealed that with respect to height of the plant, the response of all organic manures was better and with respect to total leaf area per plant, farmyard manure and poultry manure were found significantly superior (Chengat, 1997).

Plant height, leaf area index, crop growth rate and dry matter accumulation

increased with the increase in farmyard manure up to 15 t ha^{-1} at all stages of crop growth in fenugreek. Seed yield was also enhanced significantly with farmyard manure up to 15 t ha^{-1} (Khiriya *et al.*, 2001).

Experiments conducted in mulberry by Shankar *et al.* (1992) have revealed that there was a marked improvement in silk quality such as elongation, tenacity, evenness, neatness and cleanliness after application of 20 t ha^{-1} of farmyard manure without supplementation of inorganic fertilizer.

According to Maheswarappa *et al.* (1999), organic manures like farmyard manure and vermicompost were able to improve pH, organic carbon and soil microbial population when arrowroot was grown as an intercrop in coconut garden, while significantly higher yield components and rhizome yield were obtained by farmyard manure + NPK treatment in the crop.

2.3.2 Organic Slurry

In a field experiment conducted to study the effect of organic manures in tomato, it was found that vigorous growth of tomato with early flowering and high yield was obtained with the application of FYM and biogas slurry giving an increased yield (Renuka and Sankar, 2001).

Rajwade *et al.* (2000) reported that 10-20 t biogas slurry per ha + 75 per cent of the NPK dose (150 kg N, 120 kg P_2O_5 and 80 kg K_2O ha^{-1}) gave better dry matter accumulation, leaf area index, crop growth rate and relative growth rate in potato.

In tomato, the application of biogas slurry gave more vegetative growth and tends to flower and fruit much earlier. The number of fruits per plant and the total yield increased significantly due to the application (Jothi *et al.*, 2003).

2.3.3 Arbuscular Mycorrhizal Fungi

The arbuscular mycorrhizal fungi are obligate symbionts that possess special structure known as vesicles and arbuscles, the latter helping in the transfer of nutrients from soil into the root system. AM association enables greater uptake of P from soil and increased absorption of some of the minor elements such as Zn, Cu, S, Al, Mg and Fe (Gilmore, 1971).

Association of mycorrhizae is essential for germination of orchid seeds in most species for access to carbohydrate sources, as the orchid roots are capable of absorbing only fungal sugars and not cellulose directly (Peterson, 1990).

Increased shoot dry weight and lowered mortality were observed in orchid plants inoculated with VAM (Wang and Gregg, 1994). Addition of orchid mycorrhizal fungi to enhance growth of vanilla vine was reported by Madhaiyan *et al.* (2001).

AMF inoculation increased seedling growth, phosphorous uptake and seedling survival after transplanting to the field and ultimately the yield in coffee (Siqueria *et al.*, 1995).

Effect of VAM on growth of ginger (*Zingiber officinale*) was studied by Sharma *et al.* (1997) who observed that inoculation with *Glomus mosseae* at 21-spores g^{-1} soil gave the tallest plants, with the highest yield (46.5 g pot^{-1}) and the greatest number of tillers per plant. Inoculation with *Gigaspora margarita* (2.5 g per rhizome) at the time of planting increased plant height, number of leaves, tillers, root weight and yield of ginger.

Deokar and Sawant (2001) evaluated response of chilli (*Capsicum annuum*) to various biofertilizers and observed that, combined application of VAM at the rate of 50 g pot^{-1} and with *Azotobacter* at the rate of 250 g pot^{-1}

resulted in maximum growth and nutrient uptake compared to other biofertilizer treatments.

Suppressive effects of AMF on root damage caused by *Phytophthora capsicii*, *Radopholus similis* and *Meloidogyne incognita* in black pepper were studied by Anandaraj *et al.* (1996). AMF gave better protection of root system against pathogens and inoculated plants show enhanced growth and dry matter production.

Experiments conducted by Bopaiah and Khader (1989) on the effect of biofertilizers on growth of black pepper revealed that plant height and shoot and root weight were highest in VAM treated plants.

The effect of inoculation of biofertilizers (*Azospirillum*, phosphobacteria and VAM) on growth and nutrient content of black pepper was studied by Kandiannan *et al.* (2000). Plant height, leaf area and biomass, dry matter and nutrient contents were higher in inoculated plants than in the uninoculated plants. Growth was significantly higher in combined inoculation of biofertilizers as compared to individual inoculations and control. Among the individual inoculations maximum growth was observed in VAM.

2.3.4 Vermicompost and Vermiwash

Rajalekshmi (1996) reported that application of organic manure in the form of vermicompost in soil recorded the highest value for all the available nutrients in the soil. A well decomposed farmyard manure or vermicompost application as well as spraying of vermiwash encourage good growth in vanilla (Thomas *et al.*, 2004).

Among the different media studied for rooting vanilla cutting, best results were obtained with vermicompost and decomposed coir pith, when number of

sprouts, sprout length, number of leaves per vine, leaf area per vine, number of roots and root length were assessed (Gangaih *et al.*, 1996).

Yadav and Vijayakumari (2003) reported that shoot length, fresh weight and dry weight of chilli plants were higher in vermicompost treatments along with NPK. Vermicomposting in turmeric recorded 30 per cent more plant height and over 70 per cent more leaf area. The fresh rhizome yield was also high (Vadiraj *et al.*, 1999).

Hangarge *et al.* (2001) reported that in chilli the application of vermicompost or soil conditioner in combination with chemical and organic fertilizers significantly increased growth and yield attributes compared to organic and chemical fertilizers alone. In coriander, application of vermicompost significantly increased herbage and seed yield, which was comparable to applying chemical fertilizers (Vadiraj *et al.*, 1998).

Thankamani *et al.* (1996) studied the influence of potting media on growth of clove seedlings and black pepper cuttings. Plant height, number of branches, taproot length and root dry weight were more in the media containing vermicompost and soil (1: 1). Black pepper cuttings raised in vermicompost were significantly taller and had more leaves.

2.3.5 Integrated Nutrient Management

Chemical analysis revealed that considerable amount of inorganic nutrients are absorbed by different organs of vanilla (Guzeman, 2001). The growth of orchids is markedly improved by regular schedule of fertilizing the plants in liquid form (Bose and Bhattacharjee, 1980).

It has been observed that a combined application of NPK @ 20: 10: 30 g per vine per year through soil and 1 per cent urea, 0.5 per cent super phosphate

and 1.5 per cent muriate of potash as foliar during January, May and September months enhanced yield in vanilla (Spices Board, 1999).

Guzeman (2001) reported that spraying of 1 per cent solution of fertilizer complex (17:17:17) once a month enhances growth and flowering in vanilla. A fertilizer complex of (30:30:10) NPK rich in nitrogen was found good for vegetative growth and this mixture was recommended for orchids by Boodley (1981); Linda (1987); Peter (1990). Sobhana and Rajeevan (1995) reported that plants sprayed with NPK 17:17:17 complex at weekly intervals @ 10 g l^{-1} could increase the number of shoots and leaves in the orchid, *Cymbidium traceanum.*

Studies in turmeric showed that 30 kg N, 30 kg P and 60 kg K per ha gave maximum plant height, leaf area index, dry matter production, crop growth rate, fresh rhizome yield, recovery of dry rhizome and volatile oil. Effect of graded doses of N, P, and K on growth was studied in ginger and it was found that the height of tiller and total dry matter content were markedly increased by the application of fertilizers (Nybe, 2001).

In a field experiment, Gopalakrishna *et al.* (1997) could get highest yield (33.8 t ha^{-1}) and highest net returns by the application of 250 kg N + 5 t farmyard manure per hectare in turmeric.

Maheswarappa *et al.* (2000) reported that growth, yield characters, yield, essential oil and oleoresin contents of *Kaempferia* were better in the farmyard manure + NPK combinations followed by farmyard manure and vermicompost treatments compared to other fertilizer treatments.

Long term studies in cardamom on integrated nutrient management revealed that inorganic manure application alone gave highest yield over the control and 100 per cent organic manure application (AICRPS, 2000).

Application of 1.0 g N+ 0.5 g P + 2.0 g K per plot at bimonthly intervals or neem cake (30 g / plot) at bimonthly intervals resulted in the higher yields in bush pepper under green house conditions (Sadanandan and Hamza, 1998).

Krishnakumar *et al.* (1999) conducted trials with organic and biofertilizers in black pepper and found that *Piper nigrum* could be grown quite successfully using organic methods.

Stephen (2002) reported that in black pepper the application of organics and biofertilizers did not show any significant effects with respect to the vegetative characters like height of bearing column, canopy spread, number of laterals and spikes, internodal length, leaf area as well as spike and berry characters.

From a field trial to study the effect of organic and inorganic fertilizers on growth and yield of chilli, Shasidhara *et al.* (1998) found that application of organic inputs like farmyard manure (5 t ha^{-1}), vermicompost (2.5 t ha^{-1}), red gram stalks and biogas slurry (5 t ha^{-1}) had no significant influence on dry pod yield.

2.4 INDUCTION OF PARTHENOCARPY

The structure of vanilla flower is such that self pollination of the individual flower is impossible, unless hand pollinated, due to the separation of stamen from the stigma by the rostellum. The method of hand pollination was first suggested by Morren in Leige in1836 (Purseglove *et al.*, 1981).

Studies on floral biology and fruit set were carried out at RARS, Ambalavayal as early as 1969 (Nair and Mathew, 1969). It was reported that hand pollination could be done with 97.5 to 100 per cent success between 6 am and 6 pm on the day of flower opening.

Artificial hand pollination is to be carried out for good fruit set and crop production. Pollination is performed with the help of a pointed bamboo splinter, stem of a stiff grass or sharpened tooth prick. Using this, the rostellum is pushed back and the overhanging anther is pressed against the stigma with the thumb and thus smearing pollen over it (Madhusoodanan *et al.*, 2003). A new method of hand pollination in vanilla was reported from RRS, Mudigere giving 100 per cent set and taking nearly 5-6 seconds to complete pollination in a flower (Shadakshari *et al.*, 1995).

Studies on anthesis, stigma receptivity and hand pollination conducted at RRS Mudigere revealed the effectiveness of pollination between 6.00 to 11.00 hours. The growth and development of fruits were the highest when high pollen load was used for hand pollination (Bhat and Sudharshan, 2000).

Detailed studies on anthesis, anther dehiscence, pollen viability and stigma receptivity conducted by Bhat and Sudharshan (2004) revealed that stigma receptivity commenced 40 hours before anthesis and it lasted 16 hours after anthesis. Thus the total period of stigmatic receptivity in vanilla is 56 hours. Studies on time of pollination indicated that the fruit setting percentage was maximum at 8 am (100 per cent) and showed decreasing trend as pollination was delayed.

Hand pollination is a labour intensive operation in vanilla cultivation. Plant growth regulators may overcome this. Plant growth regulators are synthetic chemical substances other than nutrients, which can modify the growth when added in very small quantities, usually by stimulating or inhibiting the indigenous plant hormones. Many growth regulators were studied for the induction of parthenocarpy in various crops.

The application of growth regulators like 2,4-D, dicamba (2-methoxy-3, 6-dichloro benzoic acid), and IAA induce development of parthenocarpic fruits

and give high percentage of fruit set in vanilla (Gregory *et al.*, 1967). The application of 0.1 mg of 2,4-D in lanolin paste around the base of calyx resulted in fruit set which although weighing less, were similar in size to those from hand pollinated flowers.

Spraying 2,4,5-T at a concentration of 100 to 500 ppm and GA at 20-100 ppm on the previous day or the day of flower opening to induce fruit set in vanilla was reported by Nair and Mathew (1969). Most of the beans dropped before maturity and the size of the surviving beans were only one fourth to one third of the beans obtained by hand pollination. IAA, IBA and NAA had no effect on fruit set.

Unpollinated ovaries of *Lagenaria siceraria* were treated with the growth regulators CPPU, NAA and GA. CPPU show high activity in parthenocarpy and NAA and GA induced parthenocarpic fruit set in 37.5 and 45.5 percent of treated ovaries respectively, but they could not induce parthenocarpic fruits of normal size (Yu, 1999)

Kadioglu and Atalay (1999) reported that GA_3 induced parthenocarpic fruits in *Rosa canina* and *Diospyros lotus*, but GA_3 caused a decrease in the fresh mass and size of both fruits.

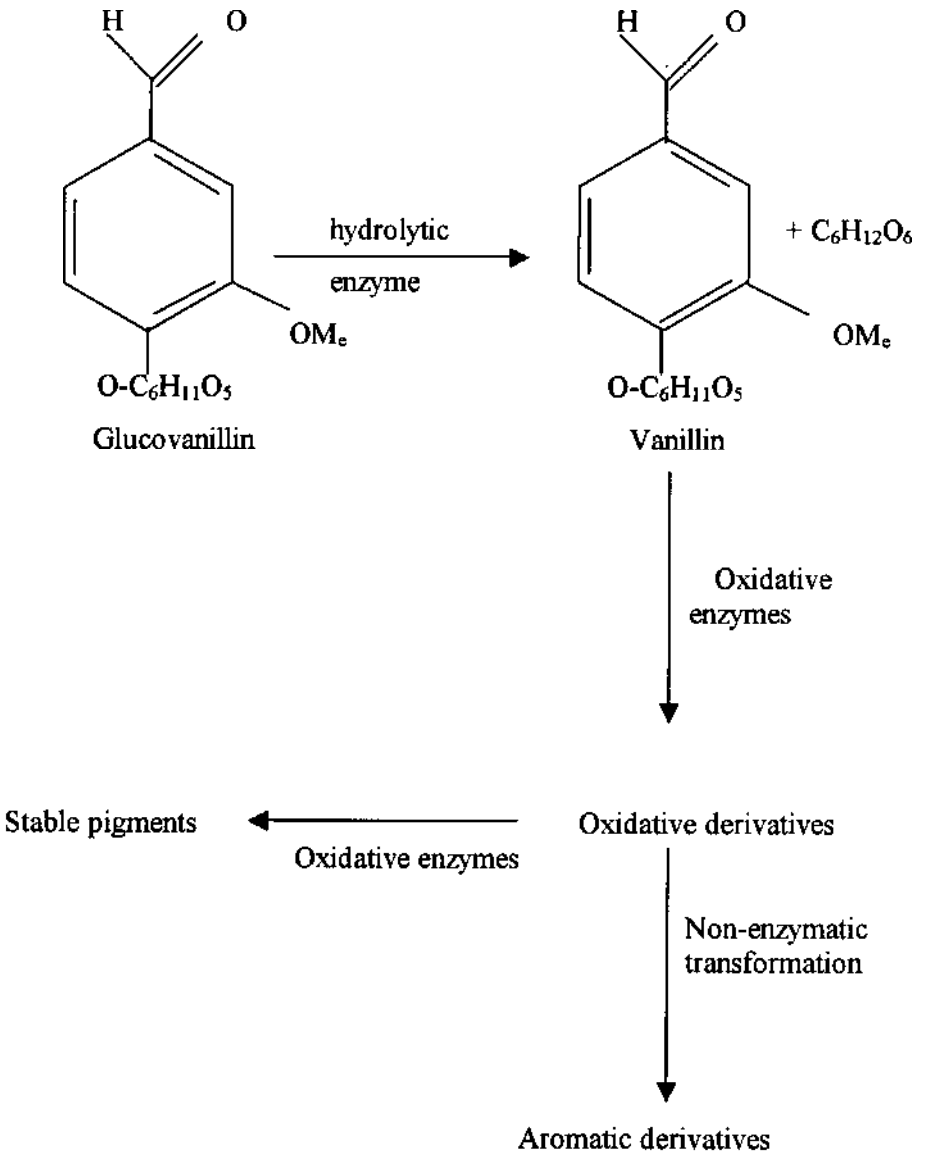
In kiwi fruits treatment with 0.2 per cent 2,4-D in lanolin paste, painted on to the pedicels reduced the average number of seeds per fruit significantly (Xiang and Chen, 1999). In *Capsicum baccatum* GA_3 increased the percentage of parthenocarpic fruits (94.6% with 2100 mg GA_3 per litre). The GA application decreased the fruit production and reduced the fruit quality (Tofanelli *et al.*, 2003).

2.5 GROWTH REGULATORS AND QUALITY IMPROVEMENT

The volatile constituents primarily determine the organoleptic properties of cured vanilla beans. Vanillin is the most abundant volatile aromatic constituent. It determines the quality of beans. Numerous other constituents, present in trace amount also contribute to the organoleptic character and they also determine the aroma and flavour of natural vanillin.

Vanillin is formed by the action of a hydrolytic enzyme on glucovanillin (Fig.1) and hydrolysis of other glucosides yield additional volatile compounds that contribute to the overall aroma and flavour. After hydrolysis of the glucosides, the vanillin and other liberated phenols undergo transformations by the action of oxidizing enzymes to yield other aromatic compounds, quinines and eventually stable pigments (Purseglove, 1981).

Fig.1 Transformations of glucovanillin and vanillin during the curing of vanilla beans.



The application of growth regulators was made to increase the quality aspects in many of the crops. NAA at 0.5 or 1.0 mg per litre enhanced the formation of extractable phenolics in cell suspension cultures of *Vanilla planifolia*. Kinetin at 0.5 mg per litre and BA at 0.2, 0.5 or 1.0 mg per litre favoured lignin biosynthesis in vanilla (Funk and Brodelius, 1990).

Kinetin was also used as an elicitor to induce vanillic acid formation in cell suspension cultures of *Vanilla planifolia*. Maximum induction was observed in kinetin concentration of 20 µg per g of cells. Kinetin has action on activity of some enzymes of phenyl propanoid pathway with maximum activity 50 hours after induction (Funk and Brodelius, 1992).

Dipping in gibberellic acid at 25 and 50 ppm at full bloom and fruit set stage in grapes decreased total phenol content and increased the reducing sugar content (Godara *et al.*, 2002). Padmapriya and Chezhiyan (2003) reported that the application of GA_3 at 100 and 150 ppm increased the total phenol content in the leaves of chrysanthemum.

Kinetin at 50 ppm increased contents of volatile oil, non volatile oil, ether extract and starch in ginger (Jayachandran and Sethumadhavan, 1988). Spraying of GA at 500 ppm + kinetin at 50 ppm gave the highest foliar contents of N, caffeine and protein and the lowest polyphenol percentage in tea (Sarkar *et al.*, 1990).

Soil drenching in mango with paclobutrazol in the previous season in mango, increased the phenol content in the dormant apical buds with increasing concentration (Kurian *et al.*, 1994). Application of 50 ppm 2,4,5-T or 50 ppm NAA increased total soluble sugars, ascorbic acid content and sugar content in guava (Brahmachari *et al.*, 1995).

GA at 25ppm showed higher phenol content (2.39 %) in aonla (Singh and

Kumar, 2000). Geetha (1981) observed that by the application of 150 ppm of NAA, the oleoresin content of the berries was increased in pepper. Ethrel application at 100 ppm increased the oleoresin content in ginger (Kosla and Kumar, 1998).

Belakbir *et al.* (1998) studied the effectiveness of different bioregulators in enhancing yield and fruit quality in *Capsicum annuum*. The commercial bioregulators CCC, NAA, GA_3 and BiozymeR (GA_3 + IAA + zeatin + micronutrients) were applied. GA_3 increased fruit ascorbic acid and citric acid concentrations and Biozyme increased fruit fructose, sucrose, carotenoid and lycopene concentrations.

Application of GA_3 (25 or 50 mg/ l) significantly increased the artimisin content and essential oil content and kinetin (10 or 20 mg/ l) increased the essential oil content in *Artemisia annua* (Farooqi *et al.*, 1996).

Kinetin sprayed at 25 ppm or drenched at 50 ppm significantly increased fruit Ca and titratable acidity contents in *Capsicum annuum* (El Asdoudi, 1993). In sweet pepper GA_3 promoted alpha amylase activity which was further enhanced by the combination of GA_3 with ethrel or kinetin. Reducing sugar content increased as alpha amylase activity increased (Khider, 1999).

Lynrah *et al.* (2002) studied the effect of CCC, Kinetin, NAA and KNO_3 on the curcumin content of turmeric. Application of all the chemicals influenced the curcumin content significantly. NAA and KNO_3 treated plants showed higher curcumin content.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The study on "Growth, development and quality of vanilla (*Vanilla planifolia* Andrews) as influenced by organics and growth regulators" was conducted during November 2002 to October 2004 at the College of Horticulture, Vellanikkara. The whole study was undertaken as three different experiments as detailed hereunder:

3.1 GROWTH ANALYSIS

The plant growth as influenced by organic and inorganic inputs were studied under this experiment. For this, 48 vines of one-year old plants were randomly selected from the existing vanilla garden of the Department of Plantation Crops and Spices and were given the following six treatments in Randomized Block Design. Each treatment consisted of single plant and was replicated eight times. The vines were grown in the interspaces of coconut plantation (twenty two years old) and were of uniform growth. The following are the treatments induced.

T_1 – Package of practices + biogas slurry

T_2 - T_1 + groundnut cake slurry

T_3 - Package of practices + AMF

T_4 - Package of practices + vermicompost + vermiwash

T_5 - Package of practices + 17:17:17 fertilizer complex

T_6 – Control

Biogas slurry and groundnut cake slurry were applied around the base of the plant at the rate of two litres per plant as soil application at bimonthly intervals starting from August 2003 till the end of the experiment. Biogas slurry and groundnut cake slurry were also given as foliar spray at 10 times dilution at monthly intervals. Groundnut cake slurry was prepared by fermenting the

groundnut cake two weeks before application. AMF was applied at the rate of 50 g per plant as soil application around the plant. Vermicompost was given at the rate of one kg per plant as soil application at monthly intervals. Vermiwash was applied as spray for the whole plant at five times dilution at monthly intervals. For comparison, one inorganic treatment was also included as one per cent spray of 17: 17: 17 fertilizer complex at bimonthly interval. As control, POP recommendation of Kerala Agricultural University, ie. 120 g N per plant in the form of farmyard manure was given as two split doses in June - July and September - October.

The following biometric observations were recorded with regard to the experiment on growth analysis from August till the end of the experiment.

3.1.1 Length of Vine

The total length of the vine from the collar region to the tip and the length of the branches were recorded monthly. The monthly growth rate was computed and expressed in centimetres.

3.1.2 Number of Leaves

Count on total number of leaves in the vine was recorded monthly.

3.1.3 Length of Leaf

Three randomly tagged leaves from bottom, middle and top of each vine were used for recording length of the leaf and the value was expressed in centimeters.

3.1.4 Breadth of Leaf

The leaves tagged for taking length were used for observing breadth also. The breadth of the leaf at the centre was observed and expressed in centimeters.

3.1.5 Leaf Area

The area of leaf was computed using the formula:

Leaf area (A) = 62.246 + 3.376 l + 13.294 w, where l and w were length and breadth of leaf respectively (Krishnakumar *et al.*, 1997).

3.1.6 Number of Nodes

The number of nodes in each vine was observed at monthly intervals.

3.1.7 Internodal Length

Three internodes were marked randomly at bottom, middle and top portions of the vine and the length was noted at monthly intervals.

3.1.8 Girth of Vine

Girth of vine at the middle portion of vine was observed and expressed in centimeters.

3.1.9 Duration of Leaf Emergence to Maturity

One emerging leaf from each vine was tagged and time taken to maturity (full development of leaf with dark green colour) was noted.

3.1.10 Number of Aerial Roots

Total number of aerial roots in each vine was recorded at monthly intervals.

3.1.11 Chemical Analyses

3.1.11.1 Foliar Nutrients

Foliar nutrient analysis was conducted to determine the N, P, and K contents in the leaves immediately after the treatment (in August 2004). For analysis first matured leaf (usually fourth or fifth leaf from the tip of the vine) was taken. The leaf samples were dried in an oven at a temperature of 60^0 C. After drying the samples were powdered and the fine powder was used for estimation of nutrient elements.

Table 1. Methods of estimation followed for foliar analysis

Nutrient	Digestion Procedure	Method of estimation	Reference
N	H_2SO_4 digestion	Colorimetric method using Nessler's reagent in spectrophotometer.	Snell and Snell (1967)
P	9:4 HNO_3: $HClO_4$ diacid digestion	Vanadomolybdate yellow colour method using spectrophotometer.	Jackson (1973)
K	9:4 HNO_3: $HClO_4$ diacid digestion	Direct reading using Flame Photometer	Jackson (1973)

3.1.11.2 Total Carbohydrate

The total carbohydrate in the leaf sample was determined using the Phenol-Sulphuric Acid Method suggested by Sadasivam and Manickam (1996). Leaf sample of 0.1 g was hydrolysed with 5 ml of 2.5 N hydrochloric acid in a boiling water bath for 2 h. The residue was then cooled to room temperature and neutralized with solid sodium carbonate until effervescence ceased. Then it was made up to 100 ml and 0.2 ml of the aliquot was pipetted out into a test tube. Made up the volume to one ml with water. Added one ml of 5 per cent phenol and 5 ml of 96 per cent sulphuric acid. After 10 minutes the contents were shaken well and kept as such in room temperature for thirty minutes. Read the absorbance at 490 nm against a reagent blank. The total carbohydrate content was determined with reference to a standard prepared from different concentrations of glucose and expressed as percentage.

3.1.11.3 Starch

The foliar starch content was analysed immediately after the treatments using the Anthrone Reagent Method suggested by Sadasivam and Manickam (1996). Sample of 0.5 g was homogenized with 80 per cent ethanol and centrifuged and retained the residue. To the residue, 3.0 ml of distilled water and 6.5 ml of 52 per cent perchloric acid was added, centrifuged at 0^0C for 20 minutes and the supernatant saved. Repeated the extraction using fresh perchloric acid, centrifuged and pooled the supernatants. Pipetted out 0.2 ml of the aliquot and made up the volume to 1 ml with distilled water. Added 4 ml of anthrone reagent and heated for 8 minutes. Cooled the solution rapidly and read the intensity of the colour at 630 nm. The starch content was determined with reference to standard prepared from different concentrations of glucose and expressed in percentage.

3.1.11.4 Acid Phosphatase

The acid phosphatase activity in the leaves was estimated immediately after the experiment using the method suggested by Malik and Singh (1980). Sample (0.2 g) was taken and was macerated with 5 ml acetate buffer and made up to 25 ml and the enzyme extract was prepared. 0.5 ml of the substrate solution (50 mg p- nitrophenyl phosphate in 10 ml water + 25 ml acetate buffer, 0.1 M, pH 4.8) was added to 0.5 ml of the enzyme extract solution. Incubated this for about 30 minutes at 35^0C. Terminated the reaction by adding 3.5 ml 0.1 N NaOH and made up the volume to 4 ml. Read the absorbance at 410 nm. The phosphatase activity was expressed as micromoles of p- nitrophenol released per unit time.

3.2 INDUCTION OF PARTHENOCARPY

For the induction of parthenocarpic fruits, flowers were treated with growth regulators 2,4-D and GA at two different concentrations by swabbing and spraying (Plate. 1). The treatments given were as follows:

PT_1 – 2,4-D 0.10 mg / flower bud, swabbing
PT_2 – 2,4-D 0.20 mg / flower bud, swabbing
PT_3 - 2,4-D 150 ppm floral spray
PT_4 – 2,4-D 300 ppm floral spray
PT_5 – GA 0.10 mg / flower bud, swabbing
PT_6 – GA 0.20 mg / flower bud, swabbing
PT_7 – GA 25 ppm floral spray
PT_8 – GA 50 ppm floral spray
PT_9 – Control (hand pollination)

Suitable quantity of growth regulators were mixed with petroleum jelly so as to get the desired quantity in each flower bud.

Design: Completely Randomised Design with three inflorescences / treatment

The treatments were given on the day before flower opening. In each treatment three inflorescences were selected per vine and fifteen buds per inflorescence were given the treatments. For swabbing, the growth regulators were mixed with petroleum jelly and the paste was swabbed on the base of calyx of the flower with a hairbrush (Plate. 2). For floral spray, the growth regulator at the required concentration was sprayed on the flower bud with a hand sprayer one day before opening (Plate. 3). The other buds in the inflorescence were covered with aluminium foil during the time of spraying to avoid the same bud getting more number of sprays. The control for the experiment was hand pollination. Hand pollination was done on the day of flower opening between 6 am and 11 am.

The observations recorded were as follows:

3.2.1 Percentage Fruit Set

The number of beans set in an inflorescence was counted three days after hormone application/hand pollination and the percentage was worked out.

3.2.2 Colour of Beans

Colour of beans from fruit set to harvest was noted.

Plate 1. General view of the experimental plot

Plate 2. Swabbing of flower buds with growth regulators (around calyx)

Plate 3. Spraying of flower buds with growth regulators (unopened buds covered with aluminium foil)

3.2.3 Length of Beans

The length of three randomly selected beans per inflorescence was measured at weekly intervals till growth ceases using a flexible tape and expressed in centimetres.

3.2.4 Width of Beans

The beans selected for taking length were observed for recording the width as well. The width of beans at the centre was measured at weekly intervals and expressed in centimeters.

3.2.5 Volume of Beans

Volume of fresh beans was recorded immediately after harvest by water displacement method using glass volumetric jar and expressed in cubic centimeters.

3.2.6 Weight of Beans

Mean fresh weight of three beans was noted at the time of harvest and expressed in grams.

3.2.7 Shape of Beans

Shape of harvested beans was noted and was observed for cracks and blemishes.

3.2.8 Precursor of Vanillin in Beans (Glucovanillin)

The precursor of vanillin in the sample was determined by the method suggested by Sadasivam and Manickam (1996) immediately after harvest. Sample (0.1 g) was hydrolysed with five ml of 2.5N hydrochloric acid in a boiling water bath for two hours. The residue was then cooled to room temperature and neutralized with solid sodium carbonate until effervescence ceases. Then it was made up to 100 ml and 0.2 ml of the aliquot was pipetted out into a test tube. Made up the volume to 1 ml with water. Added 1 ml of 5 per cent phenol and 5 ml of 96 per cent sulphuric acid and after 10 minutes the contents were shaken well and kept as such in room temperature for thirty minutes. Read the absorbance at 490 nm against a reagent blank. The content in the test solution was determined with reference to a standard curve prepared from different concentrations of glucose and expressed as mg g^{-1}.

3.3 IMPROVING VANILLIN CONTENT OF BEANS

To improve the vanillin content of beans, NAA, IBA, and Kinetin were applied at two concentrations each, on the beans. The following treatments were given:

VT_1 – NAA – 100 ppm
VT_2 – NAA – 200 ppm
VT_3 – IBA – 100 ppm
VT_4 – IBA – 200 ppm
VT_5 – Kinetin – 100 ppm
VT_6 – Kinetin – 200 ppm
VT_7 – Control (Water spray)

Design: Completely Randomized Design

The mature beans were harvested, graded according to the size, wiped clean with wet cotton cloth and were allowed to dry. Then beans were made in to groups of fifteen, consisting of different size for giving each treatment (Plate. 4). The beans in each treatment were placed on a polythene sheet and the growth regulator as per treatment was applied as a drenching spray on all sides of beans. The control was sprayed with water. They were allowed to air dry and tied in cloth bags.

The curing process started after 50 h of the growth regulator treatment. The curing process followed was the Bourbon method, which consists of four distinct stages namely killing, sweating, slow drying and conditioning.

3.3.1 Killing

The beans were killed with hot water. They were tied in cloth bags and were dipped in hot water at 65^0 C for three minutes. The beans of each treatment were killed separately. The killed beans were air-dried and were spread on woolen blanket, folded and kept in wooden box.

3.3.2 Sun Drying and Sweating

On the following day of killing, sun drying of beans was started. The beans were taken out from the sweating boxes and were spread on woolen blanket placed over cement platforms. Sun drying was carried out at the hottest part of the day ie. from 11.30 am to 2.00 pm. After 2.00 pm, the beans were folded in woolen blankets and were kept under sun for further half an hour in the folded condition to retain the heat inside the woolen blanket. After that, beans folded in woolen blanket were placed inside wooden boxes lined with woolen cloth. The temperature of the beans was noted at regular intervals.

Plate 4. Fresh beans (graded) used for spraying with growth regulators for improving vanillin content

Plate 5. Slow drying of beans in the drying chamber

Sun drying and sweating process were continued till the beans become dark brown and weight of the beans was reduced to 50 per cent of the initial weight. This was attained on the twelfth day of drying.

3.3.3 Slow Drying

Slow drying of the beans was done in a wooden chamber with racks (Plate. 5). The beans were taken out from the wooden blankets and were placed over the wooden racks. The relative humidity of the wooden chamber was maintained between 60 and 70 per cent using wet sponge pieces and cold water placed in vessels inside the chamber. The relative humidity of the chamber was monitored at regular intervals using hygrometer placed inside the chamber. The turning and straightening of beans were done daily. The beans were regularly checked for mould and fungal attack.

The beans after slow drying turned to dark brown in colour and became supple. At that stage the beans were transferred to the conditioning boxes. It took 8 to 31 days for the complete slow drying of all the beans.

3.3.4 Conditioning

After slow drying, the beans were kept for conditioning. For this, the beans were straightened by hand after slow drying. Each lot of twenty beans was tied together at both ends and then wrapped in wax paper and placed in wooden boxes lined with woolen cloth for conditioning.

3.3.5 Appearance of Beans

Characters that influence the physical appearance of beans such as colour, texture/ flexibility, luster and blemishes were observed visually and recorded before curing and during curing.

3.3.6 Weight of Beans

Mean weight of ten beans was noted before curing, during different stages of curing and after curing. The rate of loss in weight was calculated and expressed in percentage.

3.3.7 Moisture Content

Moisture content of the beans at the biochemical level ie. at 60^0 C was analysed. The fresh weight of beans before killing was noted. The weight of beans after conditioning was also recorded when they attained constant weight at 60^0 C in hot air oven. The difference in weights was found out and the moisture content worked out.

3.3.8 Curing percentage

Fresh weight of beans before killing was recorded. The weight of beans after conditioning was also recorded. Percentage weight loss of the beans was worked out and expressed as curing percentage.

3.3.9 Vanillin Content in Beans

The vanillin content of the beans was estimated at different stages of curing. Vanillin content of fresh beans was estimated and after that analysis was conducted at fortnightly intervals.

Method

Working standard

One hundred mg vanillin was dissolved in 5 ml alcohol and diluted to100 ml with distilled water. Transferred, 2, 4, 6, 8, and 10 ml each to 100 ml volumetric flasks. Made up the volume to 100 ml with distilled water. Pipetted out 10 ml each of working standard to 100 ml volumetric flask, made up the volume and mixed thoroughly. Read the absorbance at 348 nm.

Another set of pure vanillin solution of 2, 4, 6, 8, and 10 ml was taken in separate volumetric flasks of 100 ml. Made up the volume with distilled water and 10 ml each of the solution was pipetted out to 100 ml volumetric flask and to it 2 ml 0.1N NaOH was added. The volume was made up to 100 ml and the absorbance read at 348 nm. The standard graph was plotted using difference in the values obtained with and without NaOH.

Sample

From each treatment, 0.5g of cured beans was taken from the composite sample consisting of fifteen beans. It was then macerated in mortar and pestle with 5 ml ethanol. It was transferred to 100 ml volumetric flask and made up the volume. Then 10 ml of the solution was transferred to 100 ml flask and 2 ml 0.1 N NaOH was added and the volume made up with distilled water. Read the absorbance at 348 nm. The vanillin content was expressed as percentage on dry weight basis.

3.3.10 Total Phenol

The total phenol content was estimated during different stages of curing using the Folin Ciocalteau Method suggested by Sadasivam and Manickam (1996). 0.1 g of the sample was ground with a mortar and pestle with ten times volume of ethanol. The homogenated material was centrifuged at 10000 rpm and the supernatant was separated. The residue was re-extracetd by centrifuging again with alcohol. The supernatants were pooled and evaporated to dryness. The residue after evaporation was dissolved in 5 ml water. From this 0.2 ml was

pipetted out to a test tube and made up the volume to 3 ml with distilled water. To this 0.5 ml of Folin Ciocalteau reagent was added. After three minutes, 2 ml of 20 per cent sodium carbonate solution was added and mixed thoroughly. The tubes were then placed in a boiling water bath for exactly one minute. After cooling, read the absorbance at 650 nm against a reagent blank. The total phenol content of the test solution was determined with reference to a standard curve prepared from different concentrations of catechol and expressed as mg g^{-1} of weight of sample.

3.3.11 Sugar

The sugar in the sample was determined by the method suggested by Sadasivam and Manickam (1996). 0.1 g of the sample was hydrolysed with five ml of 2.5N hydrochloric acid in a boiling water bath for 2 h. The residue was then cooled to room temperature and neutralized with solid sodium carbonate until effervescence ceases. Then it was made up to 100 ml and 0.2 ml of the aliquot was pipetted out into a test tube. Made up the volume to 1 ml with water. Added 1 ml of 5 per cent phenol and 5 ml of 96 per cent sulphuric acid and after 10 minutes the contents were shaken well and kept as such in room temperature for 20 minutes. Read the absorbance at 490 nm against a reagent blank. The sugar content in the test solution was determined with reference to a standard curve prepared from different concentrations of glucose and expressed as percentage.

3.3.12 Statistical Analysis

MSTAT C package was followed for the statistical analysis. Data relating to different characters were analysed by applying the technique of Analysis of Variance and significance was tested by Duncan's Multiple Range Test.

RESULTS

4. RESULTS

The field experiment on "Growth, development and quality of vanilla (*Vanilla planifolia* Andrews) as influenced by organics and growth regulators" was carried out at the Department of Plantation Crops and Spices, College of Horticulture, Kerala Agricultural University, Vellanikkara during 2002- 2004. Biometric observations on the extension growth were recorded. Foliar nutrient contents and biochemical parameters were analysed immediately after the experiment. Biometrical observations on bean characters and biochemical analysis of beans were also conducted. The results obtained are described hereunder:

4.1 GROWTH ANALYSIS

Data on various growth characters were subjected to statistical analysis and the results revealed that, most of the characters under study were not significantly influenced by the treatments. Even though the morphological characters were not statistically significant, they showed an increasing trend during the course of experiment.

4.1.1 Rate of Growth of Vine

The rate of growth of vine showed significant differences among treatments during the months of December and February of the experimental year (Table 2). During all other months, the rate of growth of vine remained non significant.

T_1 (POP + Biogas slurry) gave the maximum growth rate of 58.62 cm in December, which was on par with T_2, T_5 and T_6. The lowest growth rate of 29.00 cm

Table 2. Effects of organics and inorganics on length of vine (cm)

Treatment	Mean length before treatment application	Rate of growth												
		Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug	Mean monthly growth rate
T_1	167.12	25.75	48.75	50.87	58.62[a]	49.37	46.25[a]	43.47	35.62	32.25	32.37	44.25	40.37	42.32
T_2	277.62	30.87	42.38	42.37	52.37[ab]	46.62	46.36[a]	40.12	36.25	33.87	34.00	39.87	42.75	40.65
T_3	227.87	38.75	28.00	32.00	30.87[b]	31.12	30.75[ab]	27.50	25.50	26.25	25.50	35.25	36.75	30.68
T_4	162.62	27.37	22.75	24.00	29.00[b]	29.87	27.25[b]	28.25	26.50	25.12	23.50	31.75	34.87	27.52
T_5	194.87	26.37	36.25	46.75	50.62[ab]	47.75	45.75[a]	44.00	39.87	38.12	40.37	45.87	43.50	42.10
T_6	180.50	25.50	43.25	47.25	42.87[ab]	41.87	37.00[ab]	35.12	32.75	31.25	38.75	42.25	46.25	38.67
Mean	201.77	29.10	39.89	40.54	44.06	41.10	38.89	36.39	32.75	31.14	32.41	39.87	40.75	36.99
	NS	NS	NS	NS	-	NS	-	NS	NS	NS	NS	NS	NS	-

T_1 - Package of practices + Biogas slurry
T_2 - T_1 + Groundnut cake slurry
T_3 - Package of practices + AMF
T_4 - Package of practices + Vermicompost + vermiwash
T_5 - Package of practices + 17:17:17 complex
T_6 - Control

was recorded by T_4 (POP + vermicompost + vermiwash spray), which was on par with T_3.

In February, T_2 (POP + biogas slurry + groundnut cake slurry) gave the maximum growth rate of 46.36 cm, which was on par with T_1 (46.25 cm) and T_5 (45.75 cm). The minimum growth rate was shown by T_4 (27.25 cm), which was on par with T_3 and T_6.

The average growth rate for the month of December was 44.06 cm and for February it was 38.89 cm. The average monthly growth rate for the experimental year was the maximum in T_1, which was 42.32 cm, and it was minimum in T_4 (27.52 cm). The average growth rate per month, when all the treatments were considered together was maximum in December (44.06 cm) and minimum in September (29.10 cm).

4.1.2 Number of Leaves

The effect of treatments showed no significant difference among treatments with respect to number of leaves per vine (Table 3). The number of leaves produced per month was the maximum in T_1 (9.62) in the month of January. The minimum number of leaves of 4.12 per month was observed in T_3 (POP + AMF) in the month of April. The average number of leaves per month was maximum in T_1 with 7.10 and minimum in T_4 (5.49). When all the treatments were considered together, maximum and minimum numbers of leaves per month were recorded during August (7.53) and May (5.24) respectively.

4.1.3 Length of Leaf

The length of leaf showed no significant difference among various treatments tried (Table 4). The leaf length was maximum (15.25 cm) in T_2 (POP + Biogas slurry + groundnut cake slurry). The length of leaf was minimum (12.02

Table 3. Effects of organics and inorganics on number of leaves per vine

Treatment	Before treatment application (Mean no: of leaves)	Rate of growth (No)												
		Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug	Mean monthly growth rate
T_1	(25.87)	4.50 (30.37)	7.87 (38.25)	8.00 (46.25)	9.37 (55.67)	9.62 (65.25)	7.75 (73.00)	6.62 (79.62)	6.25 (85.87)	5.37 (91.25)	5.50 (96.75)	7.25 (104.00)	7.12 (111.12)	7.10
T_2	(41.00)	5.87 (46.87)	6.87 (53.75)	6.75 (60.50)	6.25 (66.75)	6.75 (73.50)	6.37 (79.87)	6.00 (85.87)	5.50 (91.37)	5.62 (97.00)	7.37 (104.37)	7.50 (111.87)	7.37 (119.25)	6.51
T_3	(35.12)	6.00 (41.12)	5.25 (46.37)	5.37 (51.75)	6.75 (58.50)	5.00 (63.50)	5.25 (68.75)	4.62 (73.37)	4.12 (77.50)	4.50 (82.00)	6.12 (88.12)	6.62 (94.75)	7.75 (102.50)	5.61
T_4	(25.25)	5.25 (30.50)	4.87 (35.37)	5.12 (40.50)	5.87 (46.37)	5.37 (51.75)	4.87 (56.62)	5.12 (61.75)	4.50 (66.25)	4.50 (70.75)	6.37 (77.12)	6.87 (84.00)	7.25 (91.25)	5.49
T_5	(30.37)	6.25 (36.62)	6.37 (43.00)	7.37 (50.375)	9.37 (59.75)	7.12 (66.87)	6.25 (73.12)	6.62 (79.75)	6.12 (85.87)	6.25 (92.12)	7.25 (99.37)	7.50 (106.87)	7.37 (114.25)	6.98
T_6	(28.37)	4.75 (33.12)	6.75 (39.87)	8.12 (48.00)	7.37 (55.37)	6.75 (62.12)	6.25 (68.37)	5.62 (74.00)	5.62 (79.62)	5.25 (84.87)	6.25 (91.12)	6.87 (98.00)	8.37 (106.37)	7.01
Mean	(31.00)	5.44	6.33	6.79	7.49	6.76	6.12	5.76	5.35	5.24	6.47	7.10	7.53	6.45
	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	-

Figures in parenthesis show the actual values for number of leaves

T_1 - Package of practices + Biogas slurry
T_2 - T_1 + Groundnut cake slurry
T_3 - Package of practices + AMF
T_4 - Package of practices + Vermicompost + vermiwash
T_5 - Package of practices + 17:17:17 complex
T_6 - Control

cm) in T_3 (POP + AMF). The treatments T_5, and T_6 were on par. The rate of growth observed was maximum (0.14 cm) in T_6 (control – POP alone) during the months of December and January. The minimum rate of growth of 0.01 cm was observed in T_3 during August. The average growth rate per month, when all the treatments were considered together was maximum in the month of January (0.10 cm) and the minimum value of 0.05 cm was observed in the months of April and August.

4.1.4 Breadth of Leaf

From the data furnished in Table 5, it could be seen that there exist no significant difference among treatments in respect to breadth of leaf. However, the breadth was more in T_2 (POP + Biogas slurry + groundnut cake slurry), with 5.14cm. T_1 (POP + Bio gas slurry) and T_3 (POP + AMF) showed minimum values of 4.23 cm. The rate of growth was maximum in T_2 (0.11 cm). The least growth rate 0.02 cm was observed in T_3 and T_5 during the months of May and August respectively. The breadth of leaf varied from 5.14 cm to 4.23 cm. The average growth rate per month was maximum in November with a growth rate of 0.08 cm.

4.1.5 Area of Leaf

The leaf area recorded did not exhibit any significant difference among treatments (Table 6). However, variations were noticed with T_2 (POP + Biogas slurry + groundnut cake slurry) showing the highest value of 182.06 cm^2 and T_3 (POP + AMF) with the least value of 159.05 cm^2. The treatments T_4 and T_6 were on par and the treatments T_1 and T_3 were on par. The average value among the treatments was 160.08 cm^2.

Table 4. Effects of organics and inorganics on the length of leaf (cm)

Treatment	Mean length before treatment application	Rate of growth												
		Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug	Mean monthly growth rate
T_1	(11.54)	0.06 (11.60)	0.04 (11.64)	0.06 (11.70)	0.06 (11.76)	0.06 (11.83)	0.06 (11.89)	0.03 (11.91)	0.06 (11.97)	0.06 (12.05)	0.06 (12.10)	0.06 (12.16)	0.06 (12.22)	0.06
T_2	(14.43)	0.08 (14.51)	0.08 (14.58)	0.11 (14.70)	0.05 (14.75)	0.06 (14.81)	0.10 (14.91)	0.05 (14.96)	0.04 (15.00)	0.05 (15.05)	0.07 (15.12)	0.07 (15.20)	0.05 (15.25)	0.07
T_3	(11.30)	0.07 (11.28)	0.07 (11.45)	0.07 (11.53)	0.08 (11.61)	0.11 (11.72)	0.04 (11.76)	0.07 (11.84)	0.02 (11.86)	0.06 (11.92)	0.03 (11.95)	0.06 (12.01)	0.01 (12.02)	0.06
T_4	(11.53)	0.09 (11.63)	0.06 (11.68)	0.12 (11.81)	0.09 (11.90)	0.10 (12.00)	0.06 (12.06)	0.06 (12.12)	0.05 (12.17)	0.04 (12.21)	0.06 (12.27)	0.06 (12.34)	0.05 (12.38)	0.07
T_5	(11.76)	0.08 (11.85)	0.12 (11.98)	0.08 (12.05)	0.06 (12.11)	0.11 (12.23)	0.10 (12.33)	0.10 (12.42)	0.07 (12.50)	0.06 (12.56)	0.08 (12.65)	0.10 (12.75)	0.05 (12.80)	0.08
T_6	(11.64)	0.07 (11.71)	0.07 (11.79)	0.10 (11.88)	0.14 (12.02)	0.14 (12.16)	0.13 (12.29)	0.10 (12.39)	0.05 (12.43)	0.09 (12.52)	0.10 (12.62)	0.10 (12.72)	0.09 (12.81)	0.09
Mean	(12.03)	0.07	0.07	0.09	0.08	0.10	0.08	0.07	0.05	0.06	0.07	0.08	0.05	0.07
	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	-

Figures in parenthesis shows actual values for length of leaf

T_1 - Package of practices + Biogas slurry
T_2 - T_1 + Groundnut cake slurry
T_3 - Package of practices + AMF
T_4 - Package of practices + Vermicompost + vermiwash
T_5 - Package of practices + 17:17:17 complex
T_6 - Control

Table 5. Effects of organics and inorganics on breadth of leaf (cm)

Treatment	Mean breadth before treatment application	Rate of growth												
		Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug	Mean monthly growth rate
T_1	(3.61)	0.04 (3.65)	0.05 (3.70)	0.05 (3.75)	0.06 (3.81)	0.05 (3.86)	0.03 (3.89)	0.07 (3.96)	0.03 (3.99)	0.06 (4.05)	0.05 (4.10)	0.07 (4.16)	0.07 (4.23)	0.05
T_2	(4.29)	0.09 (4.38)	0.05 (4.43)	0.08 (4.51)	0.05 (4.56)	0.10 (4.66)	0.05 (4.71)	0.11 (4.82)	0.09 (4.91)	0.07 (4.98)	0.06 (5.04)	0.05 (5.09)	0.05 (5.14)	0.07
T_3	(3.51)	0.09 (3.60)	0.05 (3.65)	0.08 (3.73)	0.07 (3.80)	0.05 (3.85)	0.08 (3.92)	0.03 (3.96)	0.08 (4.04)	0.02 (4.06)	0.05 (4.11)	0.09 (4.20)	0.03 (4.23)	0.06
T_4	(3.84)	0.07 (3.91)	0.07 (3.98)	0.10 (4.08)	0.07 (4.15)	0.04 (4.19)	0.07 (4.26)	0.07 (4.33)	0.07 (4.40)	0.04 (4.44)	0.09 (4.53)	0.07 (4.60)	0.06 (4.66)	0.07
T_5	(3.71)	0.05 (3.76)	0.08 (3.84)	0.06 (3.90)	0.06 (3.96)	0.05 (4.01)	0.04 (4.05)	0.08 (4.13)	0.05 (4.18)	0.07 (4.25)	0.05 (4.30)	0.06 (4.36)	0.02 (4.38)	0.06
T_6	(3.83)	0.07 (3.88)	0.07 (3.96)	0.08 (4.08)	0.05 (4.14)	0.06 (4.21)	0.06 (4.29)	0.08 (4.34)	0.05 (4.40)	0.05 (4.45)	0.06 (4.53)	0.07 (4.58)	0.04 (4.60)	0.06
Mean	(3.80)	0.07	0.06	0.08	0.06	0.06	0.06	0.07	0.06	0.05	0.06	0.07	0.05	0.06
	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	-

Figures in parenthesis shows actual values for breadth of leaf

T_1 - Package of practices + Biogas slurry
T_2 - T_1 + Groundnut cake slurry
T_3 - Package of practices + AMF
T_4 - Package of practices + Vermicompost + vermiwash
T_5 - Package of practices + 17:17:17 complex
T_6 - Control

Table 6. Effects of organics and inorganics on the area of leaf (cm^2)

Treatment	Mean leaf area before treatment application	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug	Mean
T_1	149.20	149.93	150.73	151.60	152.60	153.50	154.10	155.10	155.70	156.77	157.60	158.60	159.73	154.24
T_2	168.00	169.45	170.36	171.83	172.66	174.20	175.20	176.83	178.16	179.25	180.30	181.23	182.06	175.35
T_3	147.05	148.19	149.42	150.76	151.96	153.00	154.06	154.86	156.00	156.46	157.23	158.63	159.05	153.59
T_4	152.22	153.49	154.59	156.36	157.59	158.46	159.59	160.72	161.83	162.49	163.90	165.05	165.99	159.41
T_5	151.27	152.24	153.74	154.77	155.77	156.84	157.71	159.08	160.01	161.15	162.12	163.25	163.69	157.81
T_6	152.38	153.36	154.69	156.59	157.86	159.26	160.77	161.77	162.70	163.67	165.07	166.07	166.65	160.06
Mean	153.35	154.44	155.59	156.99	158.07	159.21	160.24	161.39	162.40	163.30	164.37	165.47	166.20	160.08
	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	-

T_1 - Package of practices + Biogas slurry
T_2 - T_1 + Groundnut cake slurry
T_3 - Package of practices + AMF
T_4 - Package of practices + Vermicompost + vermiwash
T_5 - Package of practices + 17:17:17 complex
T_6 - Control

4.1.6 Number of Nodes

As presented in Table 7, the number of nodes was not significantly influenced by the treatments tried. Maximum number of nodes per month of 9.62 was produced by T_1 (POP + biogas slurry) in January and minimum number of nodes per month was observed in T_3 (4.12) in April. The monthly average number of nodes was the maximum in T_1 (7.07) and minimum in T_4 (5.50). The average number of nodes per month when all the treatments were considered together was more in August (7.53) and minimum in May (5.22). The number nodes showed an increasing trend during the course of experiment.

4.1.7 Internodal Length

The effect of treatments showed no significant difference in respect of internodal length of the vine (Table 8). The rate of growth of internodes varied among the treatments with a maximum rate of 0.21 cm in T_1 (POP + Biogas slurry) in the month of June and a least growth rate of 0.03 cm in all the treatments during different months of the experiment, except in T_6. The average growth rate of 0.11 cm was showed by T_6, which was the highest among the treatments and the minimum was observed in T_2 and T_4 (0.08 cm). The average growth rate was the maximum in July (0.16 cm) when all the treatments were considered together.

4.1.8 Girth of Vine

The girth of vine showed no significant difference among treatments (Table 9). The maximum growth rate of 0.18 cm was recorded by T_1 (POP + Biogas slurry) in the month of June and 0.01 cm was the minimum growth rate obtained in T_6 during the month of April. The average growth rate of the whole experimental year was maximum in T_1 (POP + biogas slurry), which was 0.10 cm. The average growth rate

Table 7. Effects of organics and inorganics on number of nodes

Treatment	Mean no: of nodes before treatment application	No: of nodes												
		Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug	Mean monthly growth rate
T_1	(27.13)	4.47 (31.63)	7.90 (39.50)	8.00 (47.50)	9.08 (56.88)	9.62 (66.50)	6.75 (73.25)	7.63 (80.88)	6.25 (87.13)	5.37 (92.50)	5.50 (98.00)	7.25 (105.25)	7.13 (112.38)	7.07
T_2	(42.13)	5.87 (48.00)	7.00 (55.00)	6.63 (61.63)	6.25 (67.88)	6.75 (74.63)	6.37 (81.00)	6.00 (87.00)	5.50 (92.50)	5.63 (98.13)	7.37 (105.50)	7.50 (113.00)	7.38 (120.38)	6.52
T_3	(37.38)	6.00 (43.38)	5.25 (48.63)	5.37 (54.00)	6.75 (60.75)	5.00 (65.75)	5.25 (71.00)	4.60 (75.63)	4.12 (79.75)	4.50 (84.25)	6.13 (90.38)	6.62 (97.00)	7.70 (104.75)	5.60
T_4	(26.25)	5.25 (31.50)	4.88 (36.38)	5.12 (41.50)	5.88 (47.38)	5.37 (52.75)	4.88 (57.63)	5.12 (62.75)	4.63 (67.38)	4.37 (71.75)	6.38 (71.75)	6.87 (85.00)	7.25 (92.25)	5.50
T_5	(31.75)	5.25 (37.00)	6.38 (43.38)	7.37 (50.75)	9.38 (60.13)	7.12 (67.25)	6.25 (73.50)	6.63 (80.13)	6.12 (86.25)	6.25 (92.50)	7.25 (9.75)	7.50 (107.25)	7.38 (114.63)	6.90
T_6	(29.13)	4.75 (33.88)	6.87 (40.75)	8.00 (48.75)	7.38 (56.13)	6.75 (62.88)	6.25 (69.13)	5.62 (74.75)	5.63 (80.38)	5.25 (85.63)	6.25 (91.88)	6.87 (98.75)	8.38 (107.13)	6.50
Mean	(32.29)	5.26	6.38	6.74	7.45	6.76	5.95	5.93	5.37	5.22	6.48	7.10	7.53	6.35
	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	-

Figures in parenthesis show the actual values for number of nodes

T_1 - Package of practices + Biogas slurry
T_2 - T_1 + Groundnut cake slurry
T_3 - Package of practices + AMF
T_4 - Package of practices + Vermicompost + vermiwash
T_5 - Package of practices + 17:17:17 complex
T_6 - Control

Table 8. Effects of organics and inorganics on internodal length (cm)

Treatment	Mean length before treatment application	Rate of growth											
		Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug	Mean monthly growth rate
T_1	(6.25)	0.08 (6.33)	0.11 (6.45)	0.11 (6.56)	0.12 (6.68)	0.12 (6.81)	0.08 (6.90)	0.03 (6.93)	0.05 (6.98)	0.05 (7.03)	0.21 (7.25)	0.18 (7.43)	0.13 (7.57)	0.10
T_2	(5.73)	0.05 (5.78)	0.10 (5.88)	0.07 (5.96)	0.08 (6.05)	0.07 (6.12)	0.07 (6.20)	0.03 (6.23)	0.03 (6.27)	0.07 (6.35)	0.13 (6.48)	0.18 (6.66)	0.10 (6.76)	0.08
T_3	(6.39)	0.10 (6.49)	0.17 (6.66)	0.05 (6.71)	0.15 (6.86)	0.07 (6.93)	0.07 (7.01)	0.03 (7.05)	0.10 (7.15)	0.06 (7.21)	0.15 (7.36)	0.15 (7.51)	0.15 (7.66)	0.10
T_4	(6.23)	0.08 (6.32)	0.08 (6.41)	0.06 (6.47)	0.10 (6.57)	0.12 (6.70)	0.06 (6.76)	0.08 (6.85)	0.03 (6.88)	0.06 (6.95)	0.13 (7.08)	0.11 (7.20)	0.13 (7.33)	0.08
T_5	(7.36)	0.06 (7.42)	0.10 (7.52)	0.10 (7.62)	0.10 (7.72)	0.07 (7.80)	0.10 (7.90)	0.03 (7.93)	0.07 (8.01)	0.07 (8.08)	0.12 (8.21)	0.15 (8.36)	0.12 (8.48)	0.09
T_6	(5.80)	0.07 (5.87)	0.10 (5.97)	0.08 (6.06)	0.13 (6.20)	0.11 (6.31)	0.09 (6.41)	0.10 (6.51)	0.08 (6.60)	0.08 (6.68)	0.14 (6.82)	0.18 (7.01)	0.15 (7.16)	0.11
Mean	(6.27)	0.07	0.12	0.07	0.11	0.09	0.07	0.05	0.06	0.06	0.14	0.16	0.13	0.09
	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	-

Figures in parenthesis show the actual values for internodal length

T_1 - Package of practices + Biogas slurry
T_2 - T_1 + Groundnut cake slurry
T_3 - Package of practices + AMF
T_4 - Package of practices + Vermicompost + vermiwash
T_5 - Package of practices + 17:17:17 complex
T_6 - Control

Table 9. Effects of organics and inorganics on girth of vine (cm)

Treatment	Mean girth before treatment application	Rate of growth												
		Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug	Mean monthly growth rate
T_1	(2.15)	0.10 (2.25)	0.10 (2.35)	0.11 (2.46)	0.10 (2.56)	0.08 (2.65)	0.10 (2.75)	0.03 (2.78)	0.10 (2.85)	0.10 (2.95)	0.18 (3.08)	0.13 (3.22)	0.00 (3.31)	0.10
T_2	(2.55)	0.13 (2.68)	0.08 (2.77)	0.10 (2.87)	0.03 (2.91)	0.07 (2.98)	0.02 (3.01)	0.08 (3.10)	0.02 (3.12)	0.10 (3.22)	0.13 (3.36)	0.10 (3.46)	0.06 (3.52)	0.07
T_3	(2.11)	0.11 (2.22)	0.10 (2.32)	0.08 (2.41)	0.08 (2.50)	0.03 (2.53)	0.04 (2.58)	0.08 (2.68)	0.03 (2.72)	0.10 (2.82)	0.12 (2.95)	0.11 (3.06)	0.15 (3.21)	0.08
T_4	(2.12)	0.11 (2.23)	0.10 (2.33)	0.11 (2.45)	0.06 (2.51)	0.08 92.60)	0.03 (2.63)	0.06 (2.70)	0.06 (2.76)	0.08 (2.85)	0.13 (2.98)	0.10 (3.08)	0.14 (3.23)	0.08
T_5	(2.36)	0.12 (2.48)	0.10 (2.58)	0.11 (2.70)	0.11 (2.81)	0.06 (2.87)	0.05 (2.92)	0.08 (3.01)	0.03 (3.05)	0.08 (3.13)	0.12 (3.26)	0.13 (3.40)	0.12 (3.52)	0.09
T_6	(2.35)	0.12 (2.47)	0.08 (2.56)	0.11 (2.67)	0.10 (2.77)	0.05 (2.82)	0.07 (2.89)	0.09 (2.98)	0.01 (2.99)	0.09 (3.08)	0.12 (3.21)	0.09 (3.31)	0.09 (3.40)	0.08
Mean	(2.27)	0.11	0.09	0.10	0.08	0.07	0.05	0.07	0.04	0.09	0.13	0.11	0.11	0.08
	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	-

Figures in parenthesis show the actual values for girth of vine

T_1 - Package of practices + Biogas slurry
T_2 - T_1 + Groundnut cake slurry
T_3 - Package of practices + AMF
T_4 - Package of practices + Vermicompost + vermiwash
T_5 - Package of practices + 17:17:17 complex
T_6 - Control

among the months was maximum in September (0.11 cm), which was on par with July and August. The minimum growth rate was observed in April (0.04 cm)

4.1.9 Duration of Leaf Emergence to Maturity

The duration of leaf emergence to maturity varied among the treatments (Table 10). The duration was less in T_2 (POP + biogas slurry + groundnut cake slurry), which was 169 days followed by T_3 (170 days). The duration was more in T_4 (POP + vermicompost + vermiwash) with 189 days. The mean number of days for leaf emergence among the treatments was 178.5.

4.1.10 Number of Aerial Roots

The treatments did not show any statistical significance with respect to the number of aerial roots (Table 11). It showed an increasing trend during the whole experimental year with a minimum increase during the month of May (4.62) and a maximum of 7.64 in August. The rate of growth in number of aerial roots was maximum in T_5 (POP + 17: 17: 17 mixture) with 9.87 aerial roots in August and the minimum number of 3.62 was observed in T_3 (POP + AMF) during the month of May. The average monthly growth rate among the treatments during the experimental year was maximum in T_5 (6.89) and minimum in T_3 (5.31).

4.1.11 Foliar Nutrient Analysis

4.1.11.1 Nitrogen

The treatments did not show any statistical significance with respect to foliar nitrogen (Table 12). However T_3 (POP + AMF) registered the highest value for foliar

Table 10. Effect of organics and inorganics on duration of leaf emergence to maturity

Treatment	Leaf emergence to maturity (Mean number of days)
T_1	178
T_2	169
T_3	170
T_4	189
T_5	185
T_6	180
Mean	178.5

T_1 - Package of practices + Biogas slurry
T_2 - T_1 + Groundnut cake slurry
T_3 - Package of practices + AMF
T_4 - Package of practices + Vermicompost + vermiwash
T_5 - Package of practices + 17:17:17 complex
T_6 - Control

Table 11. Effects of organics and inorganics on number of aerial roots

Treatment	Mean no: of aerial roots before treatment application	No: of aerial roots												
		Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug	Mean monthly growth rate
T_1	(19.62)	3.87 (23.50)	6.75 (30.25)	7.12 (37.37)	8.25 (45.62)	7.87 (53.50)	6.75 (60.25)	5.75 (66.00)	5.62 (71.62)	4.87 (76.50)	4.75 (81.25)	6.37 (87.62)	6.25 (93.87)	6.19
T_2	(35.87)	5.75 (41.62)	6.62 (48.25)	6.00 (54.25)	5.62 (59.87)	6.12 (66.00)	5.75 (71.75)	5.37 (77.12)	5.00 (82.12)	5.12 (87.25)	6.75 (94.00)	6.87 (100.87)	6.87 (107.75)	5.99
T_3	(30.25)	4.87 (35.12)	5.25 (40.37)	4.87 (45.25)	5.50 (50.75)	4.87 (55.62)	5.50 (61.12)	4.50 65.62)	4.25 (69.87)	3.62 (73.50)	6.50 (84.00)	6.50 (86.50)	7.50 (94.00)	5.31
T_4	(20.37)	4.25 (24.62)	6.00 (30.62)	5.37 (36.00)	4.37 (40.37)	5.37 (45.75)	5.12 (50.87)	4.87 (55.75)	4.87 (60.62)	4.12 (64.75)	6.37 (71.12)	6.87 (78.00)	7.00 (85.00)	5.38
T_5	(25.25)	5.02 (30.37)	6.37 (36.75)	7.37 (44.12)	8.25 (52.37)	8.37 (60.75)	6.25 (67.00)	6.62 (73.62)	6.12 (79.75)	6.00 (85.75)	6.50 (92.25)	6.00 (98.25)	9.87 (108.12)	6.89
T_6	(25.00)	4.62 (29.62)	7.07 (36.37)	7.75 (44.12)	7.62 (51.75)	6.75 (58.50)	6.25 (64.75)	6.62 (71.37)	5.87 (77.25)	4.00 (81.25)	6.25 (87.50)	6.87 (4.37)	8.37 (102.75)	6.50
Mean	(26.06)	4.73	6.34	6.41	6.60	6.56	5.94	5.62	5.28	4.62	6.19	6.58	7.64	6.04
	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	-

Figures in parenthesis show the actual values for number of aerial roots

T_1 - Package of practices + Biogas slurry
T_2 - T_1 + Groundnut cake slurry
T_3 - Package of practices + AMF
T_4 - Package of practices + Vermicompost + vermiwash
T_5 - Package of practices + 17:17:17 complex
T_6 - Control

nitrogen with 2.98 per cent followed by T_2 (2.96 per cent) and the least content in T_5 with 2.66 per cent. The average value for foliar N was 2.86 per cent.

4.1.11.2 Phosphorous

Data furnished in Table 12 show that the effect of treatments was not significant on foliar phosphorous content. T_3 (POP + AMF) recorded the highest foliar phosphorous content of 0.38 per cent. The minimum content of 0.24 per cent was observed in T_6 (control – POP alone). The average value for foliar phosphorous was 0.31 per cent.

4.1.11.3 Potassium

The foliar potassium content showed significant differences among treatments (Table 12). The treatment T_5 (POP + 17: 17: 17 mixture 1 per cent spray) showed the maximum potassium content of 3.80 per cent, which was on par with T_1, T_4 and T_6. The minimum potassium content was observed in T_2 (2.96 per cent). The average potassium content among the treatments was 3.39 per cent.

4.1.12 Total Carbohydrate

Data furnished in Table 13 show that the total carbohydrate content in leaves vary among the treatments. The total carbohydrate content was more in T_2 (POP + Biogas slurry + groundnut cake slurry) with 1.44 per cent followed by T6 with a carbohydrate content of 1.40 per cent. The minimum content of carbohydrate observed was 0.96 per cent in T_3 (POP + AMF). The average content of carbohydrate among the treatments was 1.27 per cent.

Table 12. Effect of organics and inorganics on foliar nutrient content (%)

Treatment	Nitrogen	Phosphorous	Potassium
T_1	2.83	0.34	3.64^{ab}
T_2	2.96	0.32	2.96^{c}
T_3	2.98	0.38	3.16^{bc}
T_4	2.92	0.31	3.28^{abc}
T_5	2.66	0.28	3.80^{a}
T_6	2.83	0.24	3.52^{ab}
Mean	2.86	0.31	3.39
	NS	NS	-

T_1 - Package of practices + Biogas slurry
T_2 - T_1 + Groundnut cake slurry
T_3 - Package of practices + AMF
T_4 - Package of practices + Vermicompost + vermiwash
T_5 - Package of practices + 17:17:17 complex
T_6 - Control

4.1.13 Starch

The starch content varied among the treatments (Table 13). The maximum starch content observed was 0.81 per cent in T_6 (Control – POP alone) and minimum of 0.31 per cent in T_3 (POP + AMF). The average starch content among the treatments was 0.53 per cent.

4.1.14 Phosphatase Activity

The phosphatase activity varied among the treatments (Table 14). The activity was more (55.82 micro moles per 30 minutes at 30^0C) in vines, which received inputs as per POP recommendation and biogas slurry. T_4 also show more phosphatase activity with a value of 52.85 micromoles per 30 minutes. The phosphatase activity was minimum in T_3 (40.97 micro moles per 30 minutes). The average value among the treatments was 46.69 micro moles per 30 minutes.

4.2 INDUCTION OF PARTHENOCARPY

Analysis of variance has been performed for comparing the treatments and the results revealed that the treatments significantly influenced the parthenocarpic development of beans.

4.2.1 Percentage Fruit Set

The application of growth regulators both 2,4-D and GA showed 100 per cent fruit set (Table 15) in both flower bud swabbing treatment and the floral spray treatment. In the inflorescences treated with GA (flower bud swabbing), some beans dropped from the vine one or two weeks after set. The beans dried off before reaching maturity (Plate. 11). The percentage set was 100 in hand pollinated flowers also.

Table 13. Effect of organics and inorganics on foliar total carbohydrate and starch content

Treatment	Total carbohydrate (%)	Starch (%)
T_1	1.26	0.38
T_2	1.44	0.67
T_3	0.96	0.31
T_4	1.34	0.66
T_5	1.24	0.36
T_6	1.40	0.81
Mean	1.27	0.53

T_1 - Package of practices + Biogas slurry
T_2 - T_1 + Groundnut cake slurry
T_3 - Package of practices + AMF
T_4 - Package of practices + Vermicompost + vermiwash
T_5 - Package of practices + 17:17:17 complex
T_6 - Control

Table 14. Effect of organics and inorganics on acid phosphatase activity

Treatment	Acid phosphatase activity (µmoles/30 min)
T_1	55.82
T_2	43.37
T_3	40.97
T_4	52.86
T_5	43.37
T_6	43.79
Mean	46.69

T_1 - Package of practices + Biogas slurry
T_2 - T_1 + Groundnut cake slurry
T_3 - Package of practices + AMF
T_4 - Package of practices + Vermicompost + vermiwash
T_5 - Package of practices + 17:17:17 complex
T_6 - Control

Table. 15 Effect of growth regulators on percentage fruit set

Treatment	No of flowers treated per inflorescence	No of fruits set	Percentage fruit set
PT_1	15	15	100
PT_2	15	15	100
PT_3	15	15	100
PT_4	15	15	100
PT_5	15	15	100
PT_6	15	15	100
PT_7	15	15	100
PT_8	15	15	100
PT_9	15	15	100

PT_1 – 2,4-D – 0.10 mg flower bud swabbing
PT_2 – 2,4-D – 0.20 mg flower bud swabbing
PT_3 – 2,4-D – 150 ppm floral spray
PT_4 – 2,4-D – 200 ppm floral spray
PT_5 – GA – 0.10 mg flower bud swabbing
PT_6 – GA – 0.20 mg flower bud swabbing
PT7 –GA– 150 ppm floral spray
PT8 –GA– 200 ppm floral spray
PT9 – Control (hand pollination)

4.2.2 Colour of Beans

In general, the colour of beans varied from light green to dark green in all the treatments. The beans turned yellow before reaching maturity. No distinct colour variation among the treatments could be observed.

4.2.3 Length of Beans

Length of beans showed significant difference among treatments (Table 16). The length of beans was more (15.88 cm) in PT_2 (2,4-D – 0.20 mg flower bud swabbing), which was on par with PT_3, PT_4, PT_7, PT_8 and PT_9. The treatment PT_6 (GA – 0.20 mg flower bud swabbing) recorded the minimum length of 10.06 cm, which was on par with PT_5 (10.61 cm). The rate of growth of beans was maximum in PT_2 during the third week, which was 0.81 cm. The length of beans showed an increasing trend till the seventh week and almost stopped after the eighth week. The average length of beans among the treatments after eight weeks was 13.35 cm

4.2.4 Girth of Beans

The data presented in Table 17 revealed that the growth regulators showed significant reduction in the girth of beans. The girth of beans showed an increasing trend till the seventh week and almost stopped after the eighth week. The maximum girth of 4.12 cm was observed in beans that received hand pollination during eighth week, which was significantly superior to all other treatments. The treatments PT_1, PT_2, PT_3, PT_4 and PT_6 were on par. The minimum girth of 2.76 cm was observed in PT_5 (GA – 0.10 mg flower bud swabbing), which was on par with PT_1, PT_6, PT_7 and PT_8. The maximum rate of growth of beans with respect to girth was observed in hand pollinated beans (0.43 cm) (PT_9) after two weeks, and minimum (0.20 cm)

Table 16. Effect of growth regulators on length of beans

Treatment	Rate of growth (cm)							
	1 week after treatment	2 weeks after treatment	3 weeks after treatment	4 weeks after treatment	5 weeks after treatment	6 weeks after treatment	7 weeks after treatment	8 weeks after treatment
PT_1	(10.04^{b})	0.41^{b} (10.45)	0.51^{b} (10.96)	0.44^{b} (11.41)	0.43^{bc} (11.84)	0.41^{bc} (12.25)	0.38^{b} (12.64)	0.23^{b} (12.87)
PT_2	(11.56^{a})	0.76^{a} (12.33)	0.81^{a} (13.14)	0.66^{a} (13.81)	0.84^{a} (14.65)	0.53^{a} (15.18)	0.43^{a} (15.2)	0.26^{a} (15.88)
PT_3	(11.17^{ab})	0.58^{ab} (11.76)	0.51^{ab} (12.27)	0.65^{ab} (12.93)	0.60^{ab} (13.53)	0.40^{ab} (13.93)	0.51^{ab} (14.44)	0.28^{ab} (14.73)
PT_4	(10.88^{ab})	0.51^{ab} (11.40)	0.48^{ab} (11.88)	0.55^{ab} (12.44)	0.41^{ab} (12.85)	0.52^{ab} (13.37)	0.37^{ab} (13.75)	0.33^{ab} (14.08)
PT_5	(8.64^{c})	0.27^{c} (8.92)	0.40^{c} (9.32)	0.43^{c} (9.57)	0.43^{cd} (10.18)	0.28^{cd} (10.47)	0.13^{c} (10.61)	0.00^{c} (10.61)
PT_6	(8.54^{c})	0.28^{c} (8.83)	0.35^{c} (9.18)	0.38^{c} (9.57)	0.24^{d} (9.82)	0.16^{d} (9.98)	0.07^{c} (10.06)	0.00^{c} (10.06)
PT_7	(10.94^{ab})	0.68^{ab} (11.63)	0.60^{ab} (12.23)	0.55^{ab} (12.78)	0.62^{ab} (13.41)	0.47^{ab} (13.88)	0.77^{ab} (14.16)	0.07^{ab} (14.24)
PT_8	(10.73^{ab})	0.55^{ab} (11.28)	0.57^{ab} (11.86)	0.58^{ab} (12.45)	0.57^{ab} (13.03)	0.55^{ab} (13.58)	0.33^{ab} (13.92)	0.12^{ab} (14.04)
PT_9	(10.38^{ab})	0.54^{ab} (10.93)	0.43^{b} (11.36)	0.56 (11.93)	0.60^{b} (12.53)	0.51^{b} (13.04)	0.42^{ab} (13.46)	0.15^{ab} (13.62)
Mean	(10.32)	0.51	0.52	0.53	0.53	0.42	0.38	0.16

Figures in parenthesis show the actual length of beans

PT_1 - 2,4-D - 0.10 mg swabbing

PT_2 - 2,4-D - 0.20 mg swabbing

PT_3 - 2,4-D - 150 ppm floral spray

PT_4 - 2,4-D - 300 ppm floral spray

PT_5 - GA - 0.10 mg/floral bud swabbing

PT_6 - GA - 0.20 mg/floral bud swabbing

PT_7 - GA - 25 ppm floral spray

PT_8 - GA - 50 ppm floral spray

PT_9 - Control (pollination)

Table 17. Effect of growth regulators on girth of beans

Treatment	Rate of growth (cm)							
	1 week after treatment	2 weeks after treatment	3 weeks after treatment	4 weeks after treatment	5 weeks after treatment	6 weeks after treatment	7 weeks after treatment	8 weeks after treatment
PT_1	(2.28^{ab})	0.20^{bc} (2.48)	0.22^{bc} (2.71)	0.14^{bc} (2.85)	0.10^{bc} (2.95)	0.13^{bc} (3.08)	0.01^{bc} (3.10)	0.00^{bc} (3.10)
PT_2	(2.02^{bc})	0.42^{bc} (2.44)	0.24^{bc} (2.68)	0.33^{b} (3.02)	0.14^{b} (3.16)	0.11^{b} (3.27)	0.01^{b} (3.28)	0.00^{b} (3.28)
PT_3	(2.26^{ab})	0.34^{ab} (2.61)	0.18^{b} (2.80)	0.22^{b} (3.02)	0.10^{b} (3.12)	0.16^{b} (3.28)	0.05^{b} (3.34)	0.00^{b} (3.34)
PT_4	(2.20^{ab})	0.30^{bc} (2.50)	0.33^{b} (2.83)	0.25^{b} (3.08)	0.13^{b} (3.22)	0.08^{b} (3.31)	0.04^{b} (3.35)	0.00^{b} (3.35)
PT_5	(1.83^{cd})	0.26^{d} (2.10)	0.17^{d} (2.27)	0.24^{c} (2.52)	0.10^{d} (2.62)	0.07^{d} (2.69)	0.03^{d} (2.73)	0.03^{c} (2.76)
PT_6	(1.92^{d})	0.34^{cd} (2.26)	0.28^{bcd} (2.55)	0.27^{bc} (2.83)	0.17^{bc} (3.01)	0.02^{bcd} (3.03)	0.00^{bcd} (3.03)	0.00^{bc} (3.03)
PT_7	(2.03^{bc})	0.23^{cd} (2.26)	0.17^{cd} (2.44)	0.11^{c} (2.55)	0.20^{cd} (2.75)	0.10^{cd} (2.85)	0.00^{cd} (2.85)	0.00^{c} (2.85)
PT_8	(1.97^{bc})	0.22^{cd} (2.20)	0.21^{cd} (2.41)	0.21^{c} (2.62)	0.12^{cd} (2.74)	0.08^{cd} (2.83)	0.02^{cd} (2.85)	0.00^{c} (2.85)
PT_9	(2.42^{a})	0.43^{a} (2.85)	0.28^{a} (3.14)	0.27^{a} (3.42)	0.25^{a} (3.67)	0.30^{a} (3.97)	0.14^{a} (4.12)	0.00^{a} (4.12)
Mean	2.10	0.30	0.23	0.23	0.15	0.12	0.03	0.00

Figures in parenthesis show the actual girth of beans

PT_1 - 2,4-D - 0.10 mg swabbing
PT_2 - 2,4-D - 0.20 mg swabbing
PT_3 - 2,4-D - 150 ppm floral spray
PT_4 - 2,4-D - 300 ppm floral spray
PT_5 - GA - 0.10 mg/floral bud swabbing
PT_6 - GA - 0.20 mg/floral bud swabbing
PT_7 - GA - 25 ppm floral spray
PT_8 - GA - 50 ppm floral spray
PT_9 - Control (pollination)

during the same period in PT_1 (2,4-D, 0.10 mg swabbing). The average girth of beans among the treatments was 3.19 cm.

4.2.5 Volume of Beans

The final volume of beans showed significant differences among the treatments as shown in Table 18. The treatment PT_2 (2,4-D – 0.20 mg flower bud swabbing) recorded the highest value of 6.99 cc. The beans of PT_9 (Hand pollination) were on par with PT_2 (2,4-D, 0.20 mg swabbing) with a volume of 6.67 cc. The minimum volume of 3.28 cc was observed in beans from the inflorescences to which PT_6 (GA 0.20 mg flower bud swabbing) treatment was given, which was on par with PT_5 (3.33 cc) (GA 0.10 mg flower bud swabbing). The average volume of beans among the treatments was 5.17 cc.

4.2.6 Weight of Beans

With respect to weight of beans, the treatments showed significant differences among themselves (Table 18). The hand pollinated beans recorded maximum weight of 7.48 g, which was significantly superior to all other treatments. The treatments PT_1, PT_2, PT_3, PT_4, PT_7 and PT_8 were on par. The minimum weight was recorded by beans treated with PT_5 (GA 0.10 mg flower bud swabbing) with 3.19 g, which was on par with PT_6 (3.26 g). The average weight of beans among treatments was 5.12 cc.

4.2.7 Shape of Beans

Only visual assessment was made with respect to shape of beans at the time of harvest. In both 2,4-D and GA treatments, straight and curved beans were observed. The curved beans were more in flower bud swabbing treatments. In floral spray

Table 18. Effect of growth regulators on final volume and weight of beans

Treatment	Volume (cc)	Weight (g)
PT_1	4.78^{b}	4.98^{b}
PT_2	6.99^{a}	6.06^{b}
PT_3	5.89^{ab}	5.91^{b}
PT_4	4.83^{b}	5.30^{b}
PT_5	3.33^{c}	3.19^{c}
PT_6	3.28^{c}	3.26^{c}
PT_7	5.56^{ab}	5.11^{b}
PT_8	5.00^{b}	4.86^{b}
PT_9	6.67^{a}	7.48^{a}
Mean	5.17	5.12

PT_1 – 2,4-D – 0.10 mg flower bud swabbing
PT_2 – 2,4-D – 0.20 mg flower bud swabbing
P T_3 – 2,4-D – 150 ppm floral spray
PT_4 – 2,4-D – 200 ppm floral spray
PT_5 – GA – 0.10 mg flower bud swabbing
PT_6 – GA – 0.20 mg flower bud swabbing
PT7 –GA– 150 ppm floral spray
PT8 –GA– 200 ppm floral spray
PT9 – Control (hand pollination)

treatments (PT_3, PT_4, PT_7 and PT_8), the beans were almost straight and cylindrical. The beans through hand pollination also showed both curved and straight beans.

4.2.8 Precursor of Vanillin (Glucoside)

Table 19 show that the content of precursor of vanillin varied among different treatments tried. The highest content was observed in PT_1 (31.1 mg g^{-1}). The treatments PT_7, PT_8 and PT_9 were on par. The minimum value was observed in PT_5 (21.7 mg g^{-1}). The average value was 27.00 mg g^{-1} among the treatments.

4.3 IMPROVING VANILLIN CONTENT OF BEANS

4.3.1 Curing and Quality of Beans

Analysis of variance was performed for comparing the treatments for assessing the quality and the results revealed that the treatments significantly influenced the quality of beans in terms of physical and biochemical parameters.

4.3.1.1 Weight of Beans

The weight of beans was reduced during the curing process (Table 20). The weight of beans was reduced to half of the fresh weight after sun drying. After sun drying VT_1 (NAA – 100 ppm) with 9.765 g showed the highest value. VT_3 and VT_5 were on par with VT_1. The weight after slow drying was reduced to about one third of the weight after sun drying. VT_1 showed the maximum weight of 3.787 g, which was on par with. VT_3, VT_5 and VT_6. The treatment VT_2 (NAA – 200 ppm) recorded the minimum weight of 2.661 g and was on par with all other treatments except VT_1. The weight continued to reduce during conditioning period also. After three months of conditioning there was no significant difference among treatments in respect of bean

Table 19. Effect of growth regulators on precursor of vanillin content

Treatment	Precursor of vanillin (mg g^{-1})
PT_1	31.1
PT_2	25.4
PT_3	24.1
PT_4	27.7
PT_5	21.7
PT_6	24.9
PT_7	30.1
PT_8	28.8
PT_9	29.7
Mean	27.0

PT_1 – 2,4-D – 0.10 mg flower bud swabbing
PT_2 – 2,4-D – 0.20 mg flower bud swabbing
PT_3 – 2,4-D – 150 ppm floral spray
PT_4 – 2,4-D – 200 ppm floral spray
PT_5 – GA – 0.10 mg flower bud swabbing
PT_6 – GA – 0.20 mg flower bud swabbing
PT7 –GA– 150 ppm floral spray
PT8 –GA– 200 ppm floral spray
PT9 – Control (hand pollination)

weight. The average weight of beans after conditioning was 2.289 g among the treatments.

The percentage reduction in weight varied among the treatments during the curing period. After sun drying, the highest reduction percentage of 50.51 was recorded by VT_2 and lowest value was recorded by VT_1. After slow drying the reduction percentage was high in VT_3 (64.86) and low in VT_6 (60.18). After conditioning the rate of reduction percentage was low in all treatments except in VT_1 which was 46.15. The lowest value was recorded by VT_3 (6.92)

4.3.1.2 Moisture Content

Moisture content of beans after curing varied among the treatments (Table 21). The moisture content was the highest in VT_3 (IBA – 100 ppm) with a value of 89.40 per cent and minimum (83.45 per cent) in VT_7 (Control- water spray) with a mean value of 87.38 per cent.

4.3.1.3 Curing Percentage

Curing percent varied among the treatments (Table 22). The highest curing percent was recorded by VT_6 (Kinetin – 200 ppm), with 15.50 per cent. The lowest value of 13.72 was recorded by VT_3. The average value among the treatments was 14.64 per cent.

4.3.1.4 Texture/ Flexibility

Visual observations were made to judge the texture of beans at various stages. In general, the texture of the beans varied during the curing process. The beans were non flexible after sun drying (Plate. 12). However, they became flexible and supple

Table 20. Effect of growth regulators on weight of beans during curing (g)

Treatment	Fresh weight	Weight after sun drying	Weight after slow drying	Weight 1 month after conditioning	Weight 2 months after conditioning	Weight 3 months after conditioning
VT_1	18.76^{a}	9.77^{a} (47.95)	3.79^{a} (61.22)	3.75^{a} (0.98)	3.32^{a} (11.55)	2.17^{a} (46.15)
VT_2	14.06^{b}	6.96^{b} (50.51)	2.66^{b} (61.75)	2.52^{b} (5.30)	2.39^{b} (5.36)	2.13^{a} (10.69)
VT_3	16.47^{ab}	8.23^{ab} (50.00)	2.89^{ab} (64.86)	2.74^{b} (5.15)	2.43^{b} (11.55)	2.26^{a} (6.92)
VT_4	14.48^{b}	7.24^{b} (49.10)	2.86^{b} (60.44)	2.70^{b} (5.80)	2.47^{b} (8.38)	2.18^{a} (11.81)
VT_5	16.68^{ab}	8.33^{ab} (50.05)	3.17^{ab} (61.98)	2.96^{ab} (6.41)	2.74^{ab} (7.73)	2.413 (11.77)
VT_6	14.78^{b}	7.39^{b} (49.10)	2.94^{ab} (60.18)	2.81^{b} (4.55)	2.57^{b} (8.44)	2.29^{a} (10.93)
VT_7	14.61^{b}	7.30^{b} (50.01)	2.85^{b} (61.01)	2.69^{b} (5.72)	2.47^{b} (7.93)	2.14^{a} (13.47)
Mean	15.69	7.89	3.02	2.88	2.63	2.23

Figures in parenthesis show the percentage reduction in weight

VT_1 - NAA – 100 ppm
VT_2 - NAA – 200 ppm
VT_3 - IBA – 100 ppm
VT_4 - IBA – 200 ppm
VT_5 - Kinetin - 100 ppm
VT_6 - Kinetin – 200 ppm
VT_7 - Control (water spray)

Table 21. Effect of growth regulators on moisture content of cured beans

Treatment	Moisture content (%)
VT_1	89.33
VT_2	88.56
VT_3	89.40
VT_4	86.41
VT_5	86.54
VT_6	87.94
VT_7	83.45
Mean	87.38

Table 22. Effect of growth regulators on curing percent of beans

Treatment	Curing percent
VT_1	13.95
VT_2	15.15
VT_3	13.72
VT_4	15.06
VT_5	14.47
VT_6	15.50
VT_7	14.64
Mean	14.64

VT_1 - NAA – 100 ppm
VT_2 - NAA – 200 ppm
VT_3 - IBA – 100 ppm
VT_4 - IBA – 200 ppm
VT_5 - Kinetin - 100 ppm
VT_6 - Kinetin – 200 ppm
VT_7 - Control (water spray)

after the slow drying process. But most of the beans remained non flexible after the conditioning period (Plate. 13).

4.3.1.5 Lustre

The beans were dark brown to black in colour with smooth skin and glossy appearance irrespective of the treatments given. The beans were glossy with oily appearance after conditioning.

4.3.1.6 Blemishes on Beans

The beans were visually observed for any blemishes on them. All the beans in all treatments were found free from any blemishes. The beans exhibited very smooth skin without scars and blemishes.

4.3.1.7 Vanillin Content of Cured Beans

The vanillin content was assessed during the curing period. Table 23 shows that there existed significant difference among treatments with respect to vanillin content.

VT_7 (Control- water spray) recorded the highest value for vanillin content (3.98 %) after sun drying, which was on par with VT_4 (IBA – 200 ppm). The lowest value (1.04 %) was registered by VT_1 (NAA – 100 ppm). The average vanillin content among the treatments after sun drying was 2.18 per cent.

The vanillin content varied significantly after slow drying. The treatment VT_4 (IBA 200 ppm) registered the highest value of 4.09 per cent followed by VT_7 (4.01 %). The minimum vanillin content was recorded by VT_1 (1.86 %), which was on par

Plate 10. Drying followed by shedding of beans before reaching maturity (GA swabbed treatment)

Plate 11. Beans ready for slow drying

Plate 12. Beans after conditioning

Table 23. Effect of growth regulators on vanillin content of beans (%)

Treatment	After sun drying	After slow drying	1 month after conditioning	2 months after conditioning	3 months after conditioning
VT_1	1.04^{d}	1.86^{c}	2.66^{b}	3.36^{b}	2.78^{b}
VT_2	1.90^{c}	2.00^{c}	2.90^{b}	2.99^{bc}	3.03^{b}
VT_3	3.07^{b}	3.32^{b}	2.83^{b}	2.51^{c}	2.73^{b}
VT_4	3.69^{a}	4.09^{a}	4.22^{a}	4.35^{a}	4.13^{a}
VT_5	2.96^{b}	2.92^{b}	2.79^{b}	3.45^{b}	3.80^{a}
VT_6	3.07^{b}	3.44^{b}	3.20^{b}	3.32^{b}	4.20^{a}
VT_7	3.98^{a}	4.01^{a}	4.21^{a}	4.08^{a}	4.13^{a}
Mean	2.18	3.09	3.26	3.44	3.54

VT_1 - NAA – 100 ppm
VT_2 - NAA – 200 ppm
VT_3 - IBA – 100 ppm
VT_4 - IBA – 200 ppm
VT_5 - Kinetin - 100 ppm
VT_6 - Kinetin – 200 ppm
VT_7 - Control (water spray)

with VT_2 (2.00 %). The average vanillin content after slow drying was 3.09 per cent when all the treatments were considered together.

During the conditioning period also the vanillin content varied significantly among treatments. After conditioning for three months, VT_6 (Kinetin – 200 ppm) recorded the highest content among the treatments with 4.20 per cent and VT_3 (IBA – 100 ppm) showed the lowest value with 2.73 per cent. VT_4, VT_5 and VT_7 were on par with VT_6. The average value after three months conditioning, among the treatments was 3.53 per cent.

4.3.1.8 Phenol Content

The content of phenol varied among treatments during the curing period. After sun drying the maximum content of 30.05mg g^{-1} was showed by control and the lowest content was recorded by VT_1 (17.19 mg g^{-1}) with an average value of 24.64 mg g^{-1} among the treatments. After slow drying, control recorded the highest phenol content of 30.25 mg g^{-1} and VT_1 recorded the lowest content of 21.59 mg g^{-1} with an average value of 26.31 mg g^{-1}. After conditioning, phenol was maximum in VT_6 which was 39.85 mg $g^{-1}$and the minimum phenol content of 27.33 mg g^{-1} was recorded by the beans which received IBA 100 ppm (VT_3) as presented in Table 24. The average phenol content among treatments after conditioning was 30.60 mg g^{-1}.

4.3.1.9 Sugar Content

The sugar content varied among treatments (Table 25). It showed a decreasing trend during the curing period. After sun drying the sugar content was maximum in VT_2 with 7.22 per cent and minimum sugar content was recorded by VT_5 (6.42) with an average value of 6.90 per cent among the treatments. The sugar content was maximum in VT_7 (6.79 per cent) and lowest content in VT_1 (5.95 per cent) after slow

Table 24. Effect of growth regulators on phenol content of beans (mg g^{-1})

Treatment	After sun drying	After slow drying	1 month after conditioning	2 months after conditioning	3 months after conditioning
VT_1	17.19	21.59	26.15	28.27	27.89
VT_2	21.23	22.68	25.19	27.64	28.27
VT_3	25.53	27.53	28.11	27.25	27.33
VT_4	26.25	28.08	30.11	31.95	31.85
VT_5	24.11	25.11	25.05	26.95	27.63
VT_6	28.12	28.91	27.16	28.16	39.85
VT_7	30.05	30.25	30.35	31.08	31.39
Mean	24.64	26.31	27.45	28.76	30.60

VT_1 - NAA – 100 ppm
VT_2 - NAA – 200 ppm
VT_3 - IBA – 100 ppm
VT_4 - IBA – 200 ppm
VT_5 - Kinetin - 100 ppm
VT_6 - Kinetin – 200 ppm
VT_7 - Control (water spray)

Table 25. Effect of growth regulators on sugar content of beans (%)

Treatment	After sun drying	After slow drying	1 month after conditioning	2 months after conditioning	3 months after conditioning
VT_1	7.20	5.95 (17.36)	3.16 (46.89)	2.72 (13.92)	2.34 (13.97)
VT_2	7.22	6.78 (6.09)	4.25 (37.32)	2.17 (48.94)	1.39 (35.94)
VT_3	7.00	6.34 (9.43)	4.78 (24.61)	1.98 (58.58)	1.50 (24.24)
VT_4	6.78	6.11 (9.88)	3.85 (36.99)	1.87 (51.43)	1.42 (24.06)
VT_5	6.42	5.96 (7.17)	3.54 (40.60)	2.66 (24.86)	2.06 (22.56)
VT_6	6.65	5.99 (9.92)	4.15 (30.72)	2.33 (43.86)	1.97 (15.45)
VT_7	7.03	6.79 (3.41)	4.31 (36.52)	2.78 (35.50)	1.98 (28.78)
Mean	6.90	6.27	4.01	2.36	1.81

Figures in parenthesis show the reduction percentage in sugar content during curing

VT_1 - NAA – 100 ppm
VT_2 - NAA – 200 ppm
VT_3 - IBA – 100 ppm
VT_4 - IBA – 200 ppm
VT_5 - Kinetin - 100 ppm
VT_6 - Kinetin – 200 ppm
VT_7 - Control (water spray)

drying. The average value among treatments after slow drying was 6.27 per cent. After conditioning sugar content reduced giving an average value of 1.81 per cent among the treatments. After curing maximum sugar content of 2.34 per cent was recorded by VT_1 (NAA 100 ppm) and minimum (1.39 per cent) in beans treated with NAA 100 ppm (VT_2).

The reduction percentage in sugar content varied among the treatments. The percentage was high (17.36) in VT_1 (NAA 100 ppm) and beans of control (3.41) recorded lowest percentage after sun drying. After conditioning the reduction percentage was high in VT_3 (35.94) and low in VT_1 (13.97).


DISCUSSION

5. DISCUSSION

Organic spices are gaining rapid momentum in the global market. The demand for organic spices in the world market is increasing. The use of natural flavours, colours and food is growing at a faster rate. The use of organic manure in soil improves the physical properties of the soil and balanced nutrient availability to plants and boost up production and quality. Biofertilizers are capable of supplementing the chemical fertilizers for meeting the nutritive needs of the crop.

The application of organic inputs and biofertilizers are found to increase the vegetative growth in many horticultural crops including spices. Vanilla is highly amenable to organic cultivation. Decomposed organic meal, rotten cow dung, compost, fermented organic cakes etc. can be used as manures for vanilla. Organic slurry was found to increase plant growth and quality of produce in many crops. Growth regulators are widely used to induce parthenocarpy in many fruit and vegetable crops. The application of growth regulators like 2,4-D, dicamba (2-methoxy-3, 6-dichloro benzoic acid), and IAA induce development of parthenocarpic fruits and give high percentage of fruit set. The growth regulators are also used to increase the quality of produce in a wide variety of crops. The investigations reported herein were undertaken to study the influence of organics and growth regulators on growth and quality of vanilla and the results obtained are discussed in this chapter.

5.1 GROWTH ANALYSIS

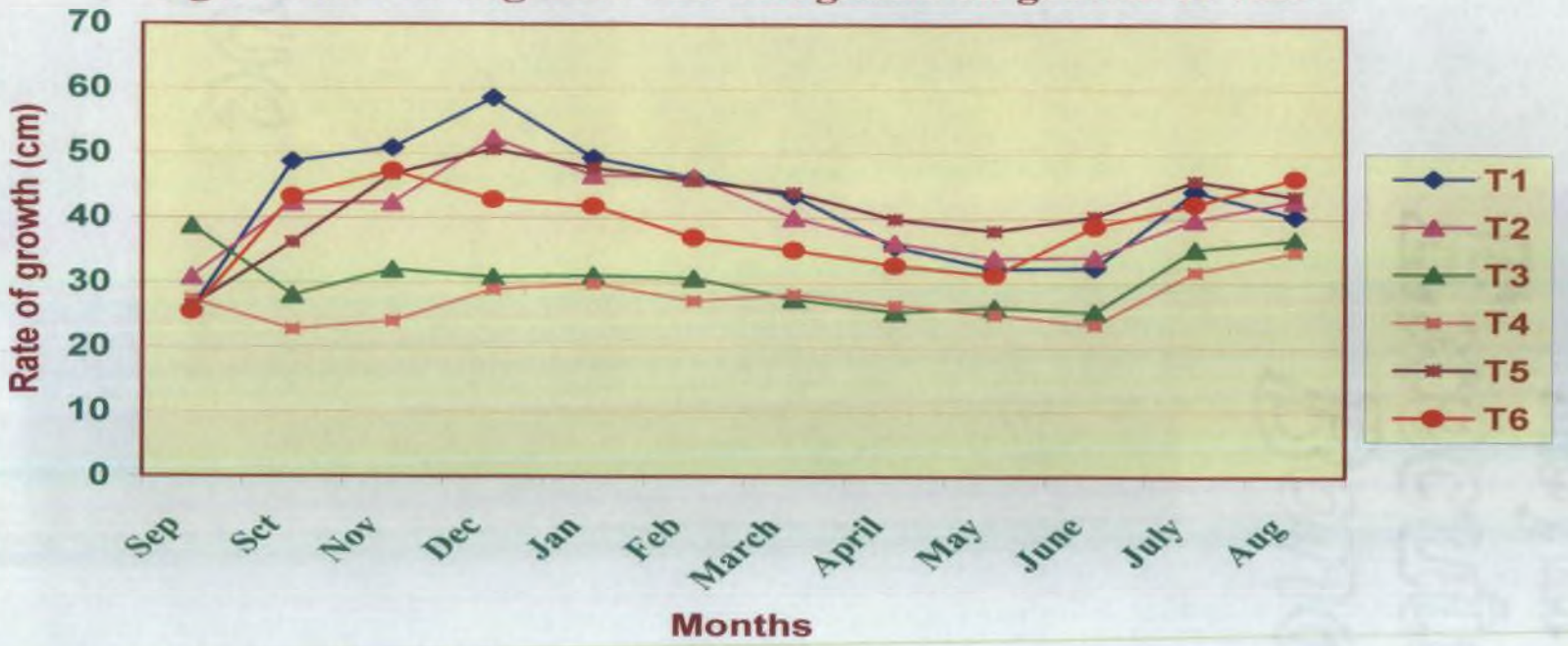
Most of the vegetative characters observed like the number of leaves, leaf length, leaf breadth, leaf area, number of nodes, internodal length, girth of vine, duration of leaf emergence to maturity and number of aerial roots failed to show any significant difference among treatments except for length of vine.

The rate of growth of vine showed significant differences during two stages ie. December and February of the experimental period (Fig.2). With respect to rate of growth of vine, T_1 (POP + biogas slurry) recorded the maximum growth rate of 58.62 cm in December and T_2 (POP + biogas slurry + groundnut cake slurry) produced the maximum growth rate of 46.36 cm in February. The least growth rate was recorded by T_4 (POP + vermicompost + vermiwash) in both December and February. The average growth rate for the month of December was 44.06 cm and for February it was 38.89 cm. The average monthly growth rate was observed maximum in T_1 and was minimum in T_4

Similar results were obtained by Lima *et al.* (2001) in cashew where the addition of mineral nutrients and organic fertilizers significantly influenced the height and dry matter weight of aerial parts. The results are also in accordance with the outcome of studies conducted by Jothi *et al.* (2003) in tomato where the application of biogas slurry gave more vegetative growth.

With respect to number of leaves, the effect of treatments did not show any significant difference. The number of leaves produced per month was the maximum in T_1 (9.62) in the month of January. The average number of leaves per month was maximum in T_1 with 7.10. The minimum number of leaves of 4.12 per month was observed in T_3 (POP + AMF) in the month of April. The length of leaf, breadth of leaf and area of leaf also showed no significant difference among various treatments. The leaf length, breadth and area were the maximum in the vines supplied with farmyard manure, biogas slurry and groundnut cake slurry and minimum in T_3 (POP + AMF). The maximum length of leaf of 15.25 cm was observed in T_2. But rate of growth was observed maximum in T_6 (Control - POP) during the months of December and January. The maximum breadth of leaf and the rate of growth were observed in T_2. The area of leaf was also maximum in T_2.

Fig.2. Effect of organics and inorganics on growth of vine



The results are in accordance with that of the studies conducted by Khandkar and Nigam (1996) in ginger where the farmyard manure application increased the number of leaves and tillers per plant. The results of the investigations by Rajwade *et al.* (2000) in potato are also in agreement with the results of the present study. They have observed that application of 10 – 20 t of biogas slurry per ha and 75 per cent of NPK dose (150 kg N, 120 kg P_2O_5 and 80 kg K_2O ha^{-1}) resulted in better dry matter accumulation, leaf area index and crop growth rate.

The internodal length was not significantly influenced by the various treatments tried. However, the rate of growth of internodes was maximum in vines supplied with farmyard manure and biogas slurry. The number of nodes was not significantly influenced by the treatments tried. Maximum number of nodes of 9.62 per month was produced by T_1 (POP + Biogas slurry). The girth of vine also did not show any significant difference among the treatments tried. The maximum growth rate of 0.18 cm was recorded by T_1 in the month of June and the minimum growth rate was observed in control plants. Duration of leaf emergence to maturity was less in vines which received farmyard manure, biogas slurry and groundnut cake slurry. The duration observed was more in T_4 (POP + vermicompost + vermiwash).

Number of aerial roots also did not show any statistical significance. Even though it was not significant, it showed an increasing trend. The rate of growth of aerial roots was maximum in T_5 (POP + 17: 17: 17 complex). The result is in accordance with the report of Guzeman (2001) which says spraying of one per cent solution of fertilizer complex (17: 17: 17) once a month enhances growth and flowering in vanilla. Similar observations were made by Sobhana and Rajeevan (1995) in the orchid, *Cymbidium traceanum*, where spraying with NPK 17: 17: 17 complex at weekly intervals could increase the number of shoots and leaves.

The results revealed that most of the vegetative characters observed except the vine length did not show any significant effect on the treatments tried. Even though the vegetative characters showed non significance, they all showed an increasing trend throughout the experiment. The organic manures might have improved the physical condition of the soil to which they were added, and the improvement in mineral uptake brought about by this might have contributed towards the increased vine length and other vegetative characters.

The results of growth analysis are in accordance with the results obtained by Stephen (2002) in black pepper where the application of organics and biofertilizers did not show any significance with respect to vegetative characters like height of bearing column, canopy spread, number of laterals and spikes, internodal length, leaf area as well as spike and berry characters.

Similar studies were made in ginger by Chengat (1997) where the responses of all organic manures tried were better. With respect to height of the plant, poultry manure and *Azospirillum* + 75 per cent nitrogen were found superior. But significant variation did not exist with regard to number of tillers per plant and number of leaves per tiller.

Studies conducted by Shasidhara *et al.* (1998) in chilli revealed that application of organic inputs like farmyard manure, vermicompost and biogas slurry had no significant influence on dry pod yield.

5.2 CHEMICAL ANALYSIS

5.2.1 Foliar Nutrients

The treatments did not show any statistical significance with respect to foliar nitrogen and phosphorous. However, T_3 (POP + AMF) registered the

highest value for foliar nitrogen and phosphorous contents. The foliar potassium content showed significant difference among treatments.

The maximum value for nitrogen observed was 2.983 per cent in the case of plants supplied with farmyard manure and AMF (Fig. 3). The highest phosphorous content observed was 0.243 per cent (Fig. 4). The treatment T_5 (POP + 17: 17: 17 complex) recorded the maximum potassium content, which was on par with T_1, T_6 and T_4 (Fig. 5) The results are in accordance with the results of the studies of Madhaiyan *et al.* (2001) where the application of orchid mycorrhizal fungi increased the plant nutrient contents like N, P and K.

The results of the studies conducted by Siqueria *et al.* (1995) in coffee support the above findings. AMF inoculation increased seedling growth, phosphorous uptake and seedling survival after transplanting to the field and ultimately the yield. Increased uptake of P, Ca and Mg by AMF inoculated plants has been reported by (Wang *et al.*, 1997) in tea.

Kumari and Balasubramanian (1993) have also observed that combined inoculation of AMF and *Azospirillum* lead to significantly increased uptake of N, P, as well as micronutrients such as Fe, Mn, Cu and Zn in coffee.

The increased foliar P content in T_5 (POP + 17: 17: 17 complex) can be supported by the results of integrated nutrient management studies in betel vine by Mozhiyan and Thamburaj (1998). They were able to obtain highest uptake of N, P, K, Ca and Mg in betel vine with the application of *Azospirillum* along with farmyard manure and N through inorganic way. Sobhana and Rajeevan (1995) reported that plants sprayed with NPK 17: 17: 17 complex at weekly interval @ 10 g l^{-1} could increase the number of shoots and leaves in the orchid, *Cymbidium traceanum*. A fertilizer mixture of (30:30:10) NPK rich in nitrogen was found good for vegetative growth and this mixture was recommended for orchids by Boodley (1981); Linda (1987) and Peter (1990).

Fig.3. Effect of organics and inorganics on foliar N content

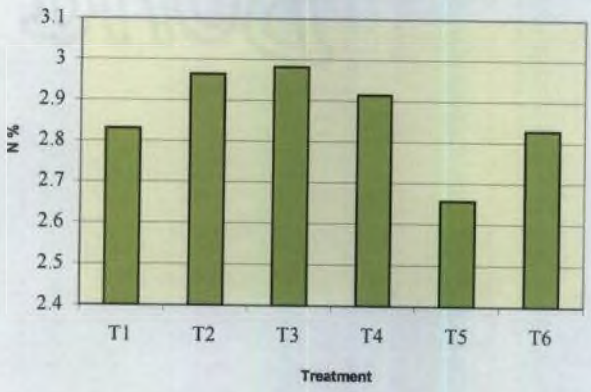


Fig.4. Effect of organics and inorganics on foliar P content

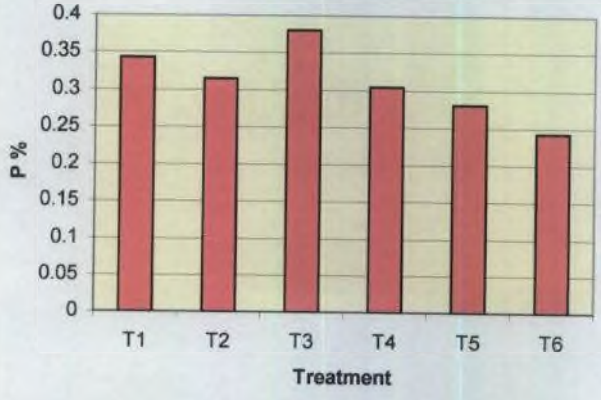
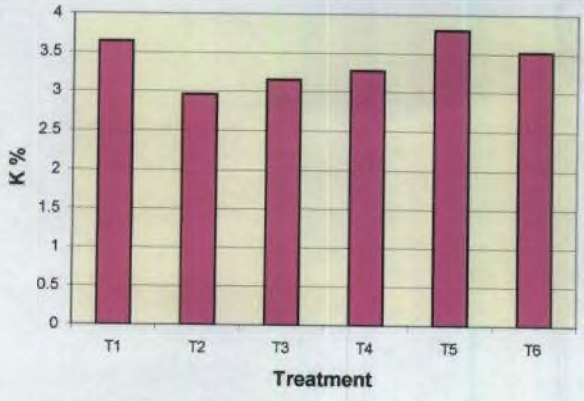


Fig.5. Effect of organics and inorganics on foliar K content



Rajalekshmi (1996) also observed that application of organic manure in the form of vermicompost in soil recorded the highest value for all the available nutrients in the soil.

5.2.2 Foliar Analysis of Carbohydrate, Starch and Phosphatase Activity

Foliar analysis was conducted for total carbohydrate, starch and phosphatase activity. The carbohydrate content was more in vines that received farmyard manure, biogas slurry and groundnut cake slurry. The starch content was maximum (0.81 per cent) in vines in the control plot that is farmyard manure alone. The results are in accordance with the study of Maheswarappa *et al.* (2000) where the application of farmyard manure, NPK combination and vermicompost gave better growth, yield, essential oil and oleoresin contents in *Kaempferia*. The foliar phosphatase activity was maximum in the vines that received farmyard manure and biogas slurry.

5.3 INDUCTION OF PARTHENOCARPY

The results showed that the treatments significantly influenced the parthenocarpic development of beans. The application of growth regulators both 2,4- D and GA showed 100 per cent fruit set in both flower bud swabbing treatment and floral spray treatment. In general, the colour of beans varied from light green to dark green. It was found that the beans dried off before reaching maturity. Both straight and curved beans were observed in all the treatments. With respect to length and volume, hand pollinated (control) beans were on par with the superior treatment PT_2 (2,4-D – 0.20 mg flower bud swabbing) as shown in Plate. 6. The weight and girth wure maximum in hand pollinated beans. The hand pollinated beans were found superior to the growth regulator treated beans. Among the growth regulators, 2,4-D (Plate. 7) was found superior to GA (Plate. 8).

Plate 6. Development of beans four months after swabbing with 2,4-D (0.2mg)

Plate 7. Development of beans four months after spraying with 2,4-D (300 ppm)

Plate 8. Development of beans four months after swabbing with GA (0.2 mg)

Plate 9. Development of beans four months after hand pollination

The length of beans was more in PT_2 (2,4-D – 0.20 mg flower bud swabbing), which was on par with PT_3, PT_4, PT_7, PT_8 and PT_9 (Fig. 6). The maximum girth of beans was observed in PT_9. The treatments PT_1, PT_2, PT_3, PT_4 and PT_6 were on par. The length and girth of beans showed an increasing trend till the seventh week and almost stopped after the eighth week.

The volume of beans was maximum in PT_2 (2,4-D – 0.20 mg flower bud swabbing), which was on par with hand pollinated beans (Fig. 7). The average value for volume was 5.142 cc. The hand pollinated beans recorded the maximum weight (Fig. 8) of 7.481 g, which was significantly superior to all other treatments (Plate. 9).

Biochemical analysis was conducted to find out the content of precursor of vanillin. The precursor of vanillin varied among the treatments and the highest content was observed in PT_2. The minimum value was observed in PT_5.

The results of the present study could be supported by observations made by Gregory *et al.* (1967) in vanilla. The application of growth regulators like 2,4-D, dicamba (2-methoxy-3, 6-dichloro benzoic acid), and IAA induce development of parthenocarpic fruits and give high percentage of fruit set. The application of 0.1 mg of 2,4-D in lanolin paste around the base of calyx resulted in fruit set which although weighing less, were similar in size to those from hand pollinated flowers.

The results obtained were also in accordance with studies in vanilla by Nair and Mathew (1969). Spraying 2,4,5-T at a concentration of 100 to 500 ppm and GA at 20-100 ppm on the previous day or the day of flower opening induced fruit set. Most of the beans dropped before maturity and the size of the surviving beans were only one fourth to one third of the beans obtained by hand pollination.

Fig.6. Effect of growth regulators on length of beans

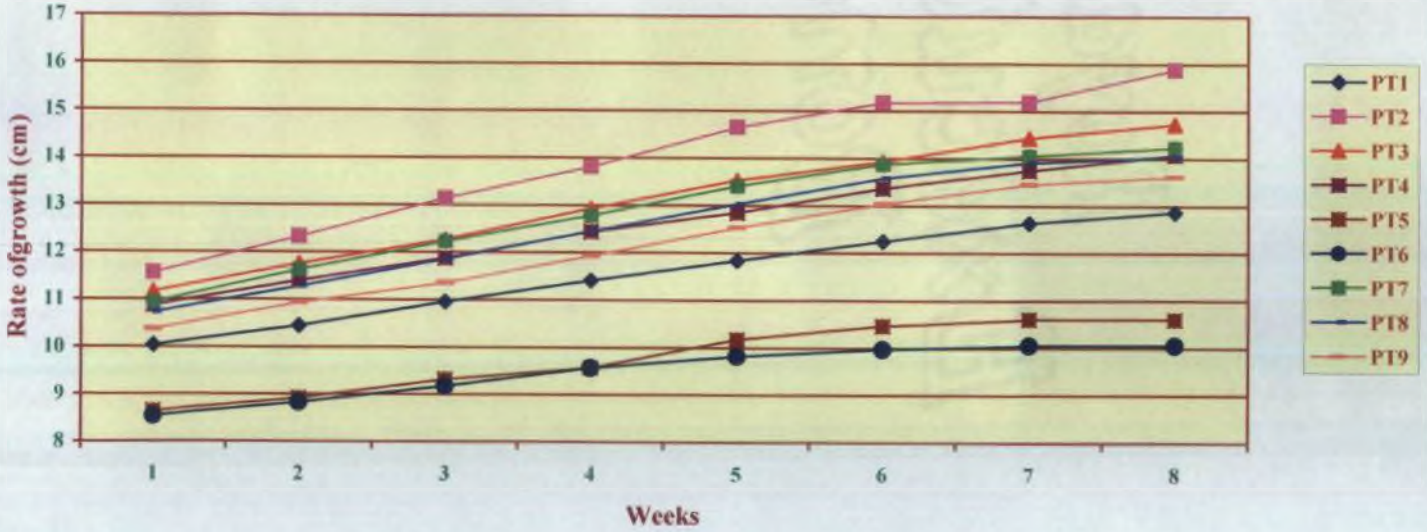


Fig.7. Effect of growth regulators on final volume of beans

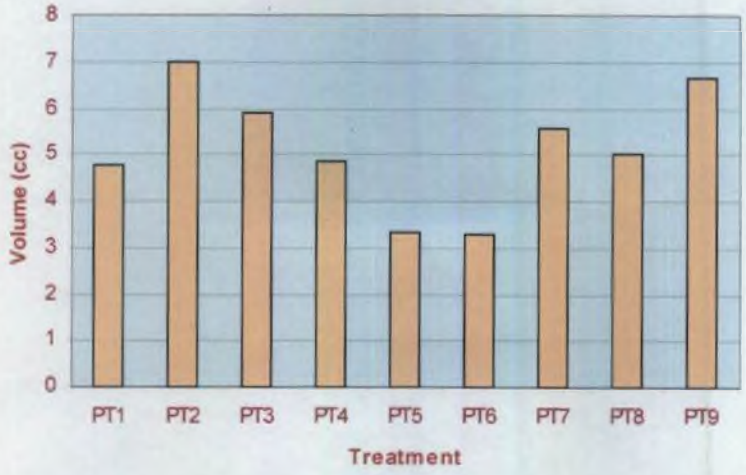
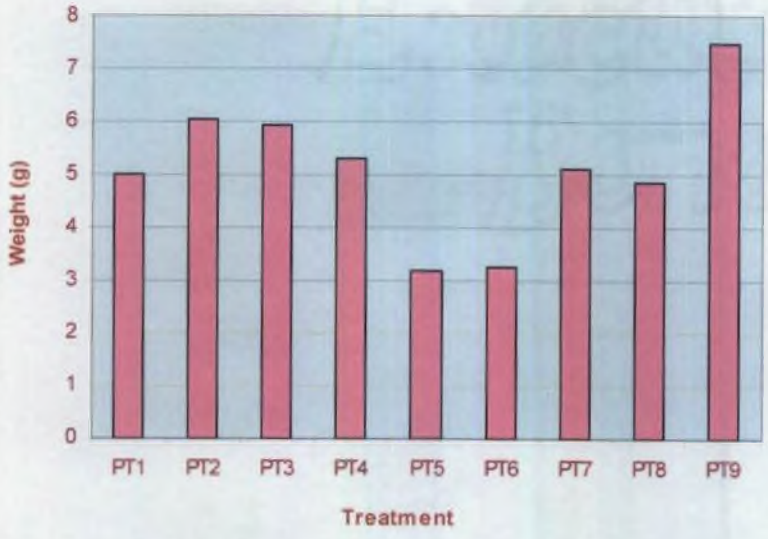


Fig.8. Effect of growth regulators on final weight of beans



The studies in *Lagenaria siceraria* by Yu (1999) also is in support of the result of the present study. Unpollinated ovaries treated with the growth regulators NAA and GA showed high activity in parthenocarpy and NAA and GA induced parthenocarpic fruit set. But they could not induce parthenocarpic fruits of normal size.

Tofanelli *et al.* (2003) produced parthenocarpic fruits in chilli (*Capsicum baccatum*) with the application of GA_3. The percentage of parthenocarpic fruits increased but decreased the fruit production and reduced the fruit quality.

Swabbing of flower bud expressed a negative result of shedding within two weeks in gibberellic acid application. Whereas in all other treatments elongation was observed in the treated beans. The total weight was recorded maximum in the hand pollinated beans in which seeds may also be contributed to the quantity. So the results suggest that the hormone application in flower bud may not be suitable for the production of quality beans.

5.3 IMPROVING VANILLIN CONTENT OF BEANS

5.3.1 Curing and Quality of Beans

The growth regulators NAA, IBA and Kinetin significantly influenced the quality of beans in terms of physical and biochemical parameters. The cured beans were dark brown to black in colour without scars and blemishes. The beans were flexible and supple after slow drying. But most of the beans remained non flexible after the conditioning period.

The weight of the beans reduced significantly after the curing process (Fig. 9) The weight was found to reduce to half of the fresh weight after sun drying. The weight after slow drying was reduced to about one third of the weight recorded after sun drying. After three months of conditioning, there was no

Fig.9. Effect of growth regulators on weight of beans during curing

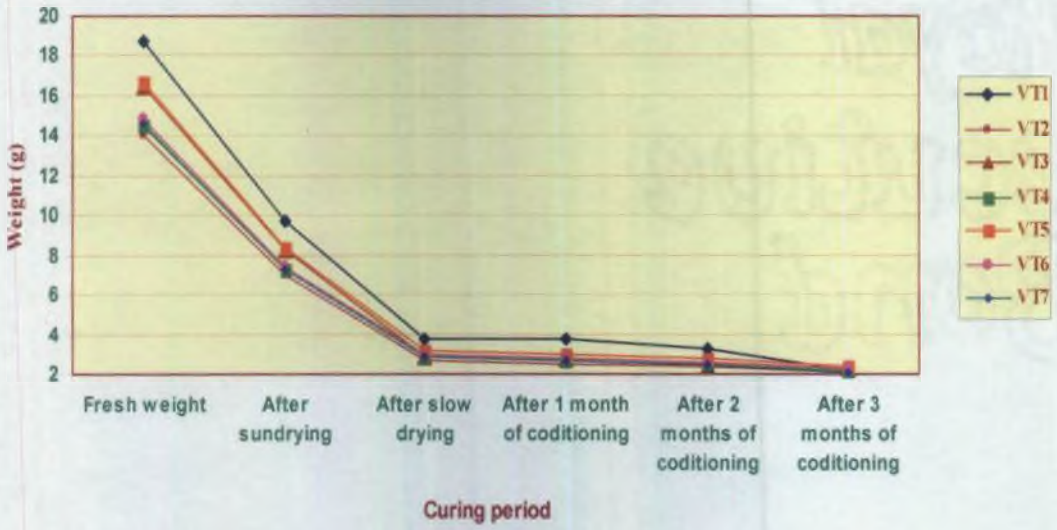
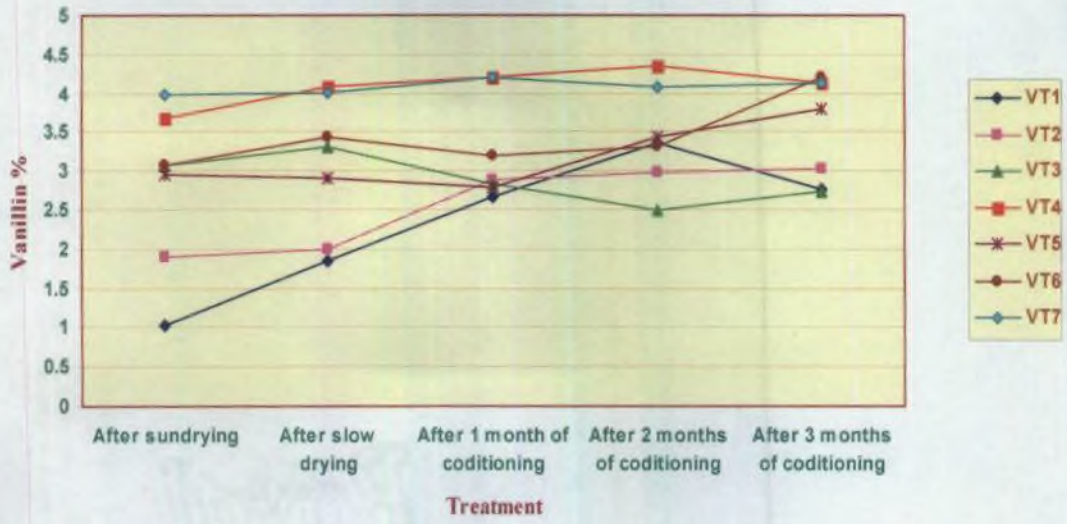


Fig.10. Effect of growth regulators on vanillin content of beans



significant difference among treatments in respect of bean weight. The percentage reduction in weight also varied among treatments. After sun drying VT_2 recorded the highest percentage reduction in weight and after slow drying VT_4 recorded the highest percentage reduction. After conditioning the percentage reduction in weight was less in all treatments except in VT_1 where the percentage was more (46.15)

The moisture content and curing percentage varied among the treatments. The highest moisture content was observed in VT_3 (IBA– 100 ppm). The highest curing percent was recorded by VT_6. The low curing percent and the non flexible nature of the beans after curing could be due to the high temperature which prevailed during the curing process.

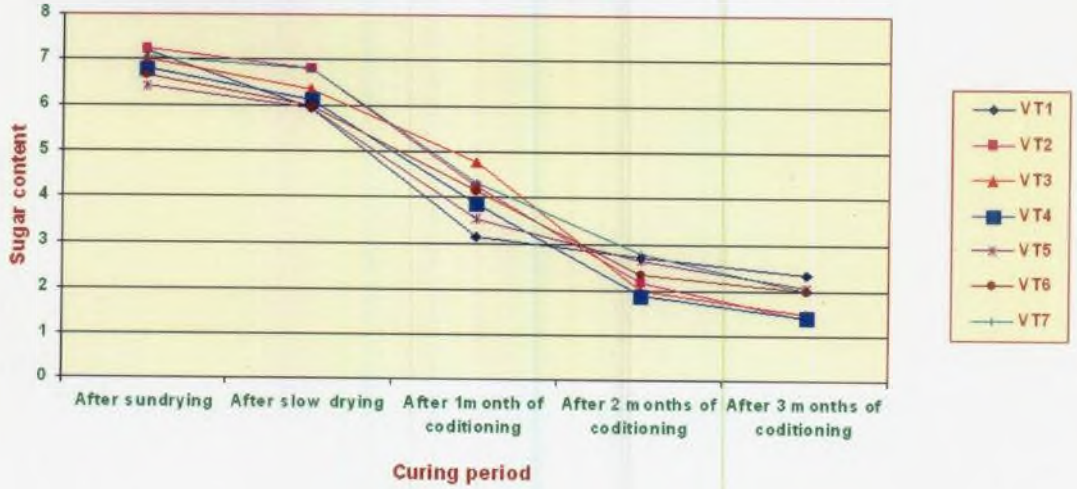
The vanillin content varied among the treatments during the curing process (Fig. 10). Even though the vanillin content increased during the curing process, a definite increasing or decreasing trend was not observed in any of the treatments. After sun drying, high vanillin content was observed in VT_7 (control –water spray), which was on par with VT_4. The treatment VT_4 registered the highest value for vanillin content after slow drying. VT_6 recorded the highest vanillin content (4.20 per cent) among the treatments after conditioning which was on par with VT_4, VT_5 and VT_7. The average vanillin content among the treatments was 3.54 per cent.

The phenol and sugar contents also varied during the curing period and followed a trend somewhat same as that of vanillin content. The content of phenol increased during curing (Fig.11). The average content after sun drying was 24.64 mg g^{-1}, which was found to increase, and attained a value of 30.60 mg g^{-1} after conditioning. After curing the phenol content was high in VT_6 (39.85mg g^{-1}).

The sugar content tends to reduce during the curing period (Fig.12). The average sugar content among the treatments after sun drying was 6.90 per cent

Fig.11. Effect of growth regulators on phenol content of beans

Fig.12. Effect of growth regulators on sugar content of beans



was reduced to 1.81 per cent after conditioning. The highest sugar content after curing was recorded by VT_1 (NAA – 100 ppm) and least content was observed in beans treated with IBA 200 ppm.

From the analytical data it was observed that even though the trend of vanillin content was not same during curing, the percentage of vanillin at the final stage of curing was high for all treatments. The phenol content showed somewhat same trend as that of vanillin content which is an indication of the involvement of enzymes during the course of curing. The sugar percentage has decreased during curing period.

Sun drying period seems to be an important deciding stage of vanillin content of the cured beans (Table 26). At this stage the sugar may be converted to glycosides.

The analytical results show that VT_4, VT_5 and VT_6 treatments showed a low content of sugar in the sun drying period when compared to the control where VT_5 showed low sugar than VT_4 and VT_6. At this stage IBA 200 ppm, Kinetin 100ppm and 200 ppm each might have influenced the conversion of sugar to glycosides and ultimately resulted in a high content of vanillin.

It may also be noted that the variation of sugar content from control was high in VT_4, VT_5 and VT_6 treatments. The variation in sugar percentage was higher than control during slow drying, one month after conditioning (except in VT_3), two months after conditioning and three months after conditioning (except in VT_1 andVT_5). It can also be inferred that the enzymatic process of vanillin production might have initiated at a high rate from slow drying stage onwards which may have a direct influence in the reduction of sugar content.

Sugar content can be considered as an indicator for fixing an index of curing period by observing the sugar percentage with respect to hormone

Table 26. Influence of growth regulators on beans at various stages with respect to vanillin content

Treatment	After sun drying	After slow drying	1 month after conditioning	2 months after conditioning	3 months after conditioning	Vanillin content
	Variation of sugar content from control					
VT_1	+ 0.17	- 0.84	- 1.15	- 0.06	+ 0.36	2.78^b
VT_2	+ 0.19	- 0.01	- 0.06	- 0.61	- 0.59	3.03^b
VT_3	- 0.03	- 0.45	+ 0.47	- 0.80	- 0.48	2.73^b
VT_4	- 0.25	- 0.68	- 0.46	- 0.91	- 0.56	4.13^a
VT_5	- 0.61	- 0.83	- 0.77	- 0.12	+ 0.08	3.80^a
VT_6	- 0.38	- 0.80	- 0.16	- 0.45	- 0.01	4.20^a

VT_1 - NAA – 100 ppm
VT_2 - NAA – 200 ppm
VT_3 - IBA – 100 ppm
VT_4 - IBA – 200 ppm
VT_5 - Kinetin - 100 ppm
VT_6 - Kinetin – 200 ppm
VT_7 - Control (water spray)

application. It is observed that the vanillin content was low and sugar content was high in VT_5 at a particular period of curing and if the curing is continued for a specific period the sugar might have converted to vanillin and a product of high vanillin could be obtained.

The results are in accordance with that of the studies conducted by Jayachandran and Sethumadhavan (1988) in ginger. They reported that kinetin at 50 ppm increased contents of volatile oil, non volatile ether extract and starch in ginger.

The results obtained by Funk and Brodelius (1990) in vanilla are also supportive of the results of the present investigations. They reported that NAA at 0.5 or 1.0 mg per litre enhanced the formation of extractable phenolics in cell suspension cultures of *Vanilla planifolia*. Kinetin at 0.5 mg per litre and BA at 0.2, 0.5 or 1.0 mg per litre favoured lignin biosynthesis in vanilla. Funk and Brodelius (1992) also reported kinetin induced vanillic acid formation in cell suspension cultures of *Vanilla planifolia*.

Geetha (1981) observed that by the application of 150 ppm of NAA, the oleoresin content of pepper berries was increased. Belakbir *et al.* (1988) reported that GA_3 increased fruit ascorbic acid and citric acid concentrations and Biozyme increased fruit fructose, sucrose, carotenoid and lycopene concentrations in *Capsicum annuum*, which also support the results of the present studies.

SUMMARY

6. SUMMARY

The experiment on "Growth, development and quality of vanilla (*Vanilla planifolia* Andrews) as influenced by organics and growth regulators" was conducted at College of Horticulture, Vellanikkara during 2002-2004. Three experiments were conducted to study the effect of organics inputs on growth of vine, to induce parthenocarpic beans through the application of growth regulators and to improve the vanillin content of beans.

The experiment on growth analysis was conducted to study the effect of organic inputs on growth of vine. This experiment was laid out in Randomised Block Design, with six treatments each replicated eight times.

Vegetative characters observed like the number of leaves, leaf length, breadth of leaf, girth of vine, number of nodes, internodal length, duration of leaf emergence to maturity and number of aerial roots failed to produce significant difference among treatments except for the length of vine. The rate of growth of vine showed significant differences during two stages of growth *i.e* in December and February. During December, T_1 (POP + biogas slurry) recorded the maximum growth rate of 58.62 cm and during February, T_2 (POP + biogas slurry + groundnut cake slurry) recorded the maximum growth rate.

Foliar nutrients exhibited significant treatment differences with respect to foliar potassium content. The treatment did not show any statistical significant difference with respect to foliar nitrogen and phosphorous. The vines which receive POP + 17: 17: 17 complex spray recorded the highest value for potassium (3.80 per cent). The highest value for nitrogen and phosphorous, 2.98 per cent and 0.380 per cent respectively was registered by T_3 (POP + AMF).

Biochemical analysis was conducted for total carbohydrate, starch and phosphatase activity. The carbohydrate content was more in vines of T_2 (POP + biogas slurry + groundnut cake slurry). The starch content was maximum in vines of control (POP alone) and the foliar phosphates activity was maximum in T_1 (POP + biogas slurry).

The second experiment for parthenocarpic study was laid out in completely randomised design with nine treatments. In each treatment three inflorescences were selected per vine and fifteen buds per inflorescence were given the treatment. The results revealed that the treatments significantly influenced the parthenocarpic development of beans. In flower bud swabbing and floral bud spraying treatments, growth regulators 2,4-D and GA showed hundred per cent fruit set with light green to dark green beans. But the inflorescences treated with GA (flower bud swabbing), some beans dropped off after set.

The length of beans was more in PT_2 (2,4-D- 0.20 mg/flower bud, swabbing) with 15.88 cm and the maximum girth was observed in hand pollinated beans (4.12 cm). The maximum volume was recorded by PT_2 with a value of 6.99 cc and the maximum weight of 7.48 g was recorded by the hand pollinated beans. The precursor of vanillin content was more in beans which received 2,4-D- 0.10 mg flower bud swabbing. From the studies it was revealed that hand pollination is better and hand pollination can be recommended.

The experiment to improve the vanillin content of the beans revealed that the growth regulators significantly influenced the quality of beans. The experiment was laid out on Completely Randomised Design with seven treatments, with fifteen beans in each treatment. The cured beans possess dark brown to black colour without any scars and blemishes. The beans were flexible after slow drying. But most of the beans became non flexible after the conditioning period.

Weight of beans was reduced to half of fresh weight after sun drying and to one third after slow drying. The percentage reduction in weight after sun drying was maximum in VT_2 (NAA – 200 ppm) (50.51) and after slow drying it was maximum in VT_3 (IBA – 100 ppm) (64.86). After curing the percentage reduction was more in VT_1 (NAA – 100 ppm). Moisture content of the beans was more in beans which received NAA 100 ppm spray with a value of 29.95 per cent and the curing per cent was maximum in VT_6 (Kinetin- 200 ppm spray) with 15.50 per cent.

It was observed that the vanillin content varied significantly among the treatments through out the curing period. After sun drying, the hand pollinated beans showed a high vanillin content of 3.98 per cent. After slow drying period VT_4 (IBA – 200 ppm) recorded the highest vanillin content of 4.22 per cent and after conditioning VT_6 (Kinetin – 200 ppm) recorded high vanillin content (4.20 per cent). The phenol content varied among the treatments and showed somewhat same trend as that of vanillin. The highest value for phenol content after curing was showed by beans which received Kinetin 200 ppm spray.

The sugar content showed a reducing trend during the curing period. The sugar content was high after sun drying and VT_2 (NAA – 200 ppm) recorded a highest value of 7.22 per cent, during this time. The sugar content reduced during curing and attained an average value of 1.81 per cent after conditioning and VT_1 (NAA – 100 ppm) and VT_2 (NAA – 200 ppm) recorded the highest and lowest sugar contents respectively.

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* Originals not seen

GROWTH, DEVELOPMENT AND QUALITY OF VANILLA (*Vanilla planifolia* Andrews) AS INFLUENCED BY ORGANICS AND GROWTH REGULATORS

By

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ABSTRACT OF THE THESIS

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ABSTRACT

Investigations on "Growth, development and quality of vanilla (*Vanilla planifolia* Andrews) as influenced by organics and growth regulators" were conducted under three experiments at College of Horticulture, Vellanikkara during 2002-2004. The salient findings are abstracted below:

Vegetative characters such as like the number of leaves, leaf length, breadth of leaf, leaf area, number of nodes, internodal length, girth of vine, duration of leaf emergence to maturity and number of aerial roots failed to exhibit any significant differences among treatments except for the length of vine. With respect to rate of growth of vine the treatment POP + biogas slurry showed maximum growth rate during December and POP+ biogas slurry + groundnut cake slurry showed maximum growth rate during February.

With respect to foliar nutrient content, only potassium showed significant difference among the treatments. The vines which received POP + 17: 17: 17 complex spray recorded the highest value for potassium (3.80 per cent).

The results of the experiment to induce parthenocarpy revealed that the treatments significantly influenced the parthenocarpic development of beans. Both growth regulators 2,4-D and GA recorded cent per cent fruit set. The length and volume of beans were more in PT_2 (2,4-D- 0.20 mg/ flower bud, swabbing). Maximum girth and weight of beans were observed in hand pollinated beans.

The experiment to improve the vanillin content of beans revealed that the growth regulators significantly influenced the quality of beans. The moisture content was recorded maximum in beans sprayed with IBA 100 ppm. It was observed that the vanillin content varied significantly among the treatments through out the curing period. After sun drying, the hand pollinated beans showed a high vanillin content of 3.98 per cent. After slow drying period VT_4 (IBA – 200

ppm) recorded the highest vanillin content of 4.22 per cent and after conditioning VT_6 (Kinetin – 200 ppm) recorded high vanillin content (4.20 per cent). Phenol content after curing was more in beans which received 200 ppm Kinetin spray and the highest sugar content was recorded by VT_1 (NAA – 100 ppm).