STANDARDIZATION OF GROWTH PROMOTERS FOR MANGOSTEEN (*Garcinia mangostana* L.) SEEDLINGS

By

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THESIS

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DECLARATION

I, hereby declare that this thesis entitled **"Standardization of growth promoters for mangosteen (*Garcinia mangostana* L.) seedlings"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that this thesis entitled **"Standardization of growth promoters for mangosteen (*Garcinia mangostana* L.) seedlings"** is a record of research work done independently by **Ms. Athira A. S.** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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Introduction

1. INTRODUCTION

Mangosteen (*Garcinia mangostana* L.) is a member of the clusiaceae family and popularly known as "queen of tropical fruits" (Fairchild, 1915). The fruit is consumed either in fresh form or in processed forms as canned fruit, juice and preserves. It is an ideal commodity for export, because of the long storage life and durability in transport. The family clusiaceae contains about 35 genera and almost 800 species (Osman and Milan, 2006). The chromosome number of mangosteen has been considered as 2n = 4x = 56-76, 88-90, 96 and 120-130 (Verheij, 1992). *G. mangostana* L. is a polyploid most probably a tetraploid. *G. hombroniana* and *G. malaccensis* are known to be the close relatives of cultivated mangosteen.

It is a humid tropical and sub-tropical evergreen tree originated in Southeast Asia (Malay Peninsula or Malaysia). It is under cultivation in South Asian countries such as Thailand, Malaysia, Philippines, Sri Lanka, Burma, Java, and Borneo (Richards, 1990). Now, small scale cultivation has spread to other tropical countries such as Southern India, Madagascar, Ivory Coast, Australia, Brazil, Central America and Islands of Caribbean (Karp, 2010). The major production area is confined to Eastern and Southern part of Thailand. Ninety per cent of the share in the world market is contributed by Thailand (Pongvinyoo *et al.*, 2015).

Currently the demand for the fruit has increased noticeably both in domestic as well as in export market. As a crop performing well under warm humid tropical climate, farmers of Kerala are very much attracted to the cultivation of mangosteen. It is being cultivated in parts of Pathanamthitta, Kottayam, and Pariyaram region of Thrissur district (Manoj, 2011). Recently popularity of mangosteen has increased among the consumers because of its medicinal properties. Mangosteen contains secondary metabolites such as prenylated and oxygenated xanthones. Antioxidant, antitumoral, anti-inflammatory, antiallergic, antibacterial, antifungal and antiviral are the main activities of xanthones isolated from mangosteen fruits (Pedraza-Chaverri *et al.*, 2008).

Mangosteen is a shade tolerant fruit tree and the young mangosteen seedlings requires shade for their growth. It is very much suited to mixed cropping with other fruit trees such as rambutan (*Nephelium lappaceum*) and durian (*Durio zibethinus*) (Setiawan, 2012).

Although mangosteen is one of the highly prized fruits, its commercial cultivation is limited to certain pockets. The major factors that limit its extensive cultivation is the slow growth of seedlings, long pre-bearing period (8 to 15 years), lack of superior high yielding cultivars, limited climatic adaptability, dormancy of terminal bud and insufficient knowledge about optimal agro techniques. Poor growth of the mangosteen seedlings has been due to the peculiar root system without functional root hairs which leads to poor absorption of nutrients and water from the soil (Wiebel *et al.*, 1992).

Several cultural and chemical methods were experimented to enhance the growth of the mangosteen seedlings. All the attempts had some success in promoting the growth of seedlings. Application of plant growth promoters is one such method to accelerate the growth of mangosteen seedlings. Earlier studies showed that foliar application of nutrients and plant growth promoters had a positive effect on improving the growth of mangosteen seedlings.

Under this context the present study entitled "Standardization of growth promoters for mangosteen (*Garcinia mangostana* L.) seedlings" was undertaken with the objective to identify the ideal combination of different plant growth promoting substances in accelerating the growth of mangosteen seedlings.

Review of literature

2. REVIEW OF LITERATURE

Mangosteen (*Garcinia mangostana* L.) is a broad leaved evergreen tree well adapted to warm humid tropical climate. It is being cultivated mainly in South East Asian countries and is commonly regarded as "queen of tropical fruits" owing to its pleasant taste and nutritional qualities. Long pre-bearing period resulting from extremely slow growth of seedlings, unfavorable climatic factors, intensive labor requirement in harvesting and lack of awareness about the benefits of the crop are the limiting factors for the commercial cultivation of the crop.

Description of the crop, effect of foliar nutrition on seedling growth, effect of different plant growth promoters such as gibberellic acid, thiamine, ascorbic acid on seedling growth are reviewed in this chapter.

2.1 Description of the crop

2.1.1 Morphology of the crop

Mangosteen is an evergreen tropical fruit tree with very slow growth rate. It can grow up to a height of 6 to 25 metre. Branches are arranged symmetrically on the straight growing trunk and the simple leathery leaves are arranged in opposite direction. Yellow latex is present in all plant parts. Flowers are terminal and solitary with four sepals and four petals. Superior ovary is capped with 5 to 8 lobed stigma and surrounded by 14 to 16 staminodes (Lan, 1984). Parthenogenetic fruits are purple violet or deep purple in colour with four to eight white translucent aril segments inside the fruits.

2.1.2 Centre of origin and areas of cultivation

The exact centre of origin of mangosteen is unknown. Different scientists have different opinion about the origin of the crop. Maheshwari (1964) stated that it is believed to be originated from Malay Peninsula or Malaysia. *G. mangostana* thought to have originated from two wild species *G. hombroniana* and *G. malaccensis*

(Richards, 1990). A recent study conducted by Nazre (2014) reported that it is a hybrid of different varieties of *G. malaccensis*.

South East Asian countries such as Thailand, Malaysia, Philippines, Indonesia, Sri Lanka, Myanmar, Borneo and Java have been successfully cultivating mangosteen. Recently the cultivation has been extended to Northern Australia, South America and tropical Africa.

2.1.3 Agro-climatic requirement of the crop

Mangosteen grow very well in deep, fertile, and slightly acidic to neutral (pH 5.5 to 7) soil with good drainage. It needs comparatively high relative humidity of more than eighty per cent and an annual rainfall of 1200 mm or more, without continuous dry period. The crop requires a short dry period of 15 to 30 days to stimulate flowering and then an uninterrupted water supply (Boonklong *et al.* 2006).The ideal temperature for growth of mangosteen ranges from 25^0 to 35^0 C (Yaccob and Tindal, 1995).

2.2 Factors affecting commercial cultivation of mangosteen

Mangosteen is a promising crop under the family clusiaceae. The major deterrent for the large scale cultivation is the very long juvenile phase of the crop. Apomictic seeds of mangosteen used for commercial planting are slow growing both in the nursery and in the field (Hume, 1947; Almeyda and Martin, 1976). Slow growth of mangosteen is mainly due to the poor development of the root system. Highly fragile roots, lack of root hairs and less branching of roots result in poor absorption of nutrients and water from soil (Wiebel, *et al.,* 1992).

Unavailability of superior high yielding varieties, lack of awareness about optimal agro techniques and narrow climatic adaptability of the crop limits its spread of cultivation (Wiebel *et. al.,* 1992). Conventional method of crop improvement by breeding and selection is impossible because of the lack of genetic variation and viable pollen grains in mangosteen (Lan, 1984). Comparatively low carbon acquisition

capacity of the leaves and dormancy of buds at the shoot apex are considered to be the reasons behind the slow growth rate of the mangosteen seedlings (Downton *et al.*, 1990). Accelerating the growth rate of the seedlings is necessary for the extensive cultivation of mangosteen.

2.3 Growth studies

2.3.1 Seed and seed germination

Mangosteen is commercially propagated by apomictic seeds. There is no sexual fertilization involved in the production of seeds. Seeds are produced asexually from nucellar tissue. Seedlings produced from apomictic seeds are genetically uniform and similar to its parent plant (Galang, 1955; Campbell, 1967). Mature seeds are usually 1 to 1.5 cm long, 0.3 to 0.5 cm thick, and 0.5 to 2 cm in width and weight ranges from 0.5 g to 2.0 g per seed. Larger seeds produce strong seedlings with good root system.

Seed germination is hypogeal in nature and have one week of incubation period. Fresh seeds have good viability. Seed shows 91 per cent germination. During seed germination, testa splits and small root arises from one end of the seed. Later plumule emerges from the opposite side of the seed. First pair of leaves are usually produced from the shoot after growing upto 4.0 cm height. Usually a single seedling is produced from a seed, but seeds exhibits 10 per cent polyembryony *i.e.*, two or three even four seedlings may come out from a single seed. Fasciation is another problem observed in mangosteen seedlings. Two seedlings have fused shoot system or three leaves may arise from a single node resulting in incomplete leaf separation (Lan, 1984).

2.3.2 Seedling growth

Quick root development is essential for the early establishment and development of any plant species. Root is a vital plant organ responsible for the uptake of water and nutrients from the soil. Root growth is directly related to shoot growth.

Mangosteen seedlings have poor vigour compared to other fruit trees. The root system of young plants consists of slender tap root and very few lateral roots. Generally the poor root system lead to slow development of the plant. Lack of root hairs and poor branching of the roots reduces the contact with soil and thereby limiting the absorption of nutrients and water from the soil. Duration of juvenile phase can also be influenced by genetic and environment factors.

Masri *et al.* (1998) analyzed root morphological characters of four different fruit plants *viz.* mangosteen, rambutan, cempedak and durian. Based on the study they stated that mangosteen seedlings showed weak root branching and shorter root length. Allocation of dry matter to root was also low in the case of mangosteen compared to other fruit crops. Poor root system led to restricted plant growth in mangosteen seedlings.

Wiebel *et al.* (1992) reported that seedling growth at nursery stage could be enhanced by using suitable potting media, shade, carbondioxide enrichment of the growing environment and application of growth regulators.

Growth of the mangosteen seedlings was studied for a period of 24 months by Rukayah and Zaebedah (1992) to understand the slow growing nature of the plant. They found that the plant height, plant girth, number of leaves and dry matter production were slow upto 12 months. In the case of plant height, only 1.2 to 3 cm increment was noticed in a two months period and regarding leaf production, only two to five leaves were produced. Shoot: root ratio was found to be 6.24 at six months stage and at twenty fourth month it was reduced to 4.94.There was no root hair production during the study period. They concluded that the slow growth of the seedlings could be due to the poor root system with no root hair.

2.4 Effect of foliar nutrition on seedling growth

Foliar nutrition is an efficient method of providing nutrition through leaves. It is an effective method to enhance the nutrient availability to the plants. Nutrients

supplied through foliage are absorbed quickly than through soil application. Foliar nutrition of NPK significantly enhanced the biomass production and improved the yield in plants (Ling and Silberbush, 2002). Foliar nutrition got more attention, as the roots were incapable of absorbing nutrients from the soil. Foliar spray of nitrogen, phosphorus and potassium maintains proper leaf nutrition, carbon balance and also increase the photosynthetic ability of the plants (Ishan *et al.*, 2013). Studies revealed that foliar spraying resulted in increased absorption, assimilation and translocation of nutrients (Shete *et al.*, 2018).

Primary nutrients such as nitrogen, phosphorus and potassium plays an important role in plant growth and development. Nitrogen is essential for the production of amino acids. Amino acid plays an important role in the formation of protoplasm and is therefore necessary for plant growth and development. Nitrogen, a major part of chlorophyll molecule, is also needed for photosynthesis. Nitrogen also improves the quantity and quality of dry matter production in plants.

Phosphorus plays an important role in photosynthesis. It is also helpful for the root development of the plants. Potassium is also important for plant growth, as it act as an enzyme activator and thereby involving in plant metabolism.

Mangosteen responds very well to solid as well as liquid fertilizers. Generally mixtures of fertilizers based on NPK are recommended for the crop. Seedling growth can be enhanced by the application of nitrogenous fertilizers (Osman and Milan, 2006). Salakpetch (2005) reported that application of 16N-16P_2O_5-16K_2O at regular intervals could accelerate the growth of mangosteen seedlings under nursery condition in Thailand.

Manoj (2011) revealed that spraying of nutrient solution of foliar grade 3:1:1 (NPK) at 0.5% along with growth promoters such as GA and IAA were found to be best for improving all growth parameters of mangosteen seedlings.

Goenaga and Rivera (2005) carried out an investigation to determine the effect of different shade levels and fertilizer treatments on growth of mangosteen seedlings. Seedlings were maintained under 0,30,50,70 and 90 per cent artificial shade and applied with 3,6 and 9 g of a 15:4.8:10.8 % (NPK) fertilizer mixture at three, eight and fifteen months after planting. They found that 50 per cent shade and fertilization at a rate of 9 g per plant of a 15:4.8:10.8 % (NPK) fertilizer mixture resulted in adequate growth of mangosteen seedlings. Fertilizer application increased the stem height, stem thickness, leaf area and dry matter production of the seedlings.

2.5 Effect of plant growth promoting substances on seedling growth

Plant growth promoters are chemical substances which helps to stimulate the growth of plants. Plant growth regulators or plant hormones are organic substances produced naturally in higher plants, which regulate the physiological processes in small amounts. Plant hormones play an important role in the growth, differentiation and development of plants. Major plant hormones includes auxin, gibberellic acid, ethylene, cytokinins and absicic acid. Application of growth regulators had reported very good result in fruit crops with respect to growth, yield and quality (Suman *et al.*, 2017). Modification in plant growth and development is possible by changing the levels of hormones applied externally (Manoj, 2011).

Vitamins are organic compounds that are vital for the metabolism of living organisms. Majority of the vitamins act as cofactors and affect the enzymatic reactions.

2.5.1 Gibberellic acid

Giberellic acid is a naturally occurring plant growth hormone produced by fungus *Gibberella fujikori.* Gibberellic acid enhances the stem length and internodal length by increasing the normal cell division and cell enlargement in plants. (Sachs *et al.*, 1959).

Studies on exogenous application of gibberellic acid show its positive impact on early growth of mangosteen. Dormancy of bud at the shoot apex of mangosteen seedlings even under suitable growing conditions is a factor that contributes to slow growth of the seedlings (Downton *et. al.*, 1990). Application of any substance that break the bud dormancy can accelerate the growth of seedlings.

Wiebel *et al.* (1992) stated that GA_3 at lower doses (10 µg) was very effective for breaking the bud dormancy of mangosteen. Foliar application of combination of GA_{4+7} + BA (20 µg) was found to be very effective in breaking the bud dormancy. Application of gibberillic acid on the developing flushes of eight month old unbranched seedlings showed an increase in internodal length. The leaf area of new flushes were found to decrease in plants treated with GA compared to the untreated seedlings.

In order to understand the effect of GA_3 application on pistachio nut seed germination and seedling growth an investigation was conducted by Ak *et al.,* (1995). They soaked the seeds in 125, 250, 500 and 1000 ppm of GA_3 solution for either 24 or 48 hours. Highest germination rate was noticed in 125 ppm GA_3 and 48 hours of soaking. Seedling height and internodal length were the highest in plants treated with 1000 ppm GA_3 and seed soaked for 48 hours. Based on the morphological features, healthy growth of seedlings were observed in plants treated with 250 ppm and 500 ppm GA_3 treatments.

Srisumran *et al.* (1997) carried out an investigation to find out the effect of gibberellic acid at 50, 100, 150, 200 ppm on the growth of one year old mangosteen seedlings. They observed that among the different concentration tried, foliar spraying of 100 ppm of gibberellic acid resulted in maximum stem length (5.05 cm within 36 week) than the untreated seedlings.

Application of GA_3 is very effective in increasing the vegetative growth of many fruit crops. Eel-Kim *et al.* (2003) reported that application of GA_3 at 25, 50 and 100 ppm on Satsuma mandarin resulted in increased number of vegetative shoots.

Gul *et al.* (2006) stated that different gibberellic acid concentration and nitrogen levels had an effect on accelerating the growth of *Araucaria heterophylla* seedlings. Maximum plant height (42.4 cm) was noticed in plants treated with 300 ppm of GA followed by 200 pm of gibberellic acid with 36.4 cm height. Internodal length was also found to be higher in plants treated with GA 300 ppm. They also reported that application of GA had a positive effect on the root characters of *Araucaria heterophylla.*

Application of plant growth regulators such as kinetin at 100 and 400 mg/L and gibberellic acid at 50 mg/L had an influence in inducing sprouting of apical bud in mangosteen seedlings (Moraes *et al.*, 2009).

Promalin (a commercial formulation containing N-(phenyl methyl)-1H –purine 6-amine and $GA_4 + GA_7$) was applied to enhance the growth of mangosteen seedlings. But the application of promalin at different concentration (25,50,75, 100,125 mg/L) on 2.5 year old mangosteen seedlings did not show any significant increase with respect to the growth parameters such as plant height, number of leaves, stem diameter and number of branches (Goenaga, 2010).

Manoj (2011) conducted a study to understand the role of plant growth regulators in enhancing the growth and reducing the pre bearing period of mangosteen seedlings. He found that the treatment containing nutrient solution of NPK @ 0.5 % along with GA_3 100 ppm had significantly superior effect on plant height. Another study done by Yusuf (2002) also reported that gibberellic acid at 150 mg/L had a stimulatory effect on increasing the growth of mangosteen seedlings.

A study conducted by Wahdan *et al.,* (2011) on mango cv. "Succary Abiad" revealed that spraying of GA_3 at 20 ppm one month after full bloom gave high value with respect to shoot length. Application of GA_3 on sapota resulted in earliness in new shoot sprouting, increased shoot length and number of leaves per shoots. (Bhujbal *et al.*, 2012).

Pawar *et al.* (2018) carried out a study to find out the effect of soaking of kokum (*Garcinia indica*) seeds in growth regulators and the further growth of seedlings. From the study it was revealed that soaking seeds in 50 ppm GA solution for 24 hours was superior to all other treatments with respect to the plant height.

Brain *et al.*, (1960) carried out an experiment to investigate the effect of gibberellic acid on the rooting of stem cuttings of pea varieties. They stated that even if gibberellin was effective in stem elongation, it reduces rooting in different varieties of pea plants. It might be due the distribution of essential plant metabolites for extending the shoot portion. Effect of gibberellins on apical shoot growth and basal root production were found to be competitive and opposite in nature.

2.5.2 Thiamine (Vitamin B1)

Vitamin B act as a hormone, it is synthesized in leaves of plants and translocated to roots. Vitamin B acts as a growth factor for the development of roots, and it is a cofactor in different metabolic pathways such as glycolysis, pentose phosphate pathway and tri-carboxylic acid cycle (Krampitz, 1969). It is necessary for the biosynthesis of coenzyme thiamine pyrophosphate, which plays an important role in the metabolism of carbohydrates and fats.

Bonner and Greene (1938) stated that Vitamin B1 had an effect on shoot length elongation. They conducted an experiment on the tung oil tree (*Aleurites fordii*) and observed that plants treated with vitamin B1 1 mg/L showed significant increase in shoot length. After uprooting the plants they found that vitamin B1 applied plants had well developed root system compared to untreated plants.

Horn (1940) conducted an experiment in mangosteen seedlings (10 and 15 months old) to study the accelerated growth of seedlings by spraying water extract of Brewer's yeast. Brewer's yeast is a good source of vitamin B1. He observed that application of water extract of yeast had a beneficial effect on the growth and development of mangosteen plants during first ten months growth period. Ten month

old seedlings showed 75.8 per cent increase in leaf area where as 15 month old seedlings exhibited only 46.8 per cent increase in the leaf area.

A study conducted by Youssef and Talaat, (2003) revealed that foliar application of thiamine increased the growth of rosemary plants (*Rosmarinus officinalis* L.). According to them application of thiamine increased the level of different endogenous growth promoters such as cytokinins and gibberellins. Similar results were also observed in *Syngonium podophyllum* L., in which thiamine spray at 50 ppm significantly increased the plant height, number of leaves, root length, fresh weight of shoot and root (Abdel-Aziz, 2007).

Nahed *et al.* (2009) reported that exogenous application of thiamine at 50 ppm, 100 ppm, and 200 ppm on gladiolus (*Gladiolus grandiflora*) plants resulted in increment in all growth characters. Among the different concentration of thiamine, plants which received 100 ppm thiamine exhibited the maximum plant height, number of leaves and nitrogen content. The increase in fresh and dry weight of leaves was found to be 116.4 per cent and 129.6 per cent respectively. Similar results were obtained in dahlia (*Dahlia pinnata* L.) *i.e.* foliar spray of 100 ppm thiamine significantly improve the plant growth (Mahagoub *et al.*, 2011).

Thiamine had significant effect on increasing the rooting in in-vitro propagation of GF677 (Peach ×Almond hybrid).Thiamine at 1.6 mg /L and 2.8 mg/L induced more number of roots (Sepahvand *et al.*, 2012). Spraying B vitamins (B1 + B6 + B12) on sakkoti date palm resulted in an increase in total surface area per palm, total chlorophyll content, N, P, K, Mg and total carbohydrate content in the leaves compared to the untreated plants (control) (Al- Wasfy, 2013).

Ranjbar *et al.* (2014) conducted an experiment to understand the effect of application of thiamine on growth and oil yield of German chamomile (*Matricaria recutita* L.) plants. They treated the plants with 50 and 100 ppm of thiamine. Application of thiamine at 100 ppm exhibited highest value for growth parameters such

as shoot fresh weight and dry weight. But the essential oil yield recovery was maximum with application of 50 ppm of thiamine.

2.5.3. Ascorbic acid (Vitamin C)

Ascorbic acid is produced in higher plants and favors the plant growth and development. It is considered as a growth regulating factor, because it influences many biological processes. In plants, it exist in reduced form as ascorbate in cytosol, chloroplasts, vacuoles, mitochondria and cell wall (Rauten-Kranz *et. al.*, 1994). It plays a key role in photosynthesis and protect the photosynthetic apparatus (chloroplast) from the oxygen radicals formed during photosynthetic activity. Ascorbic acid performs an important role in the metabolism of carbohydrates, fats and proteins. It is considered as a small antioxidant molecule and serves as a primary substrate for the detoxification of reactive oxygen species (ROS), which are injurious to normal plant metabolism. As an enzyme co-factor, ascorbic acid is also involved in process of photosynthesis. As it has a role in the regulation of cell division, differentiation and cell expansion, ascorbic acid stimulate the growth of plants (Smirnoff, 1996). Studies revealed that ascorbic acid could improve the abiotic stress tolerance in plants (Huang *et al.*, 2005; Athar *et al.*, 2008).

Ascorbic acid spray on plants could increase the organic acid excretion from the roots into the soil, which enhance the solubility of nutrients and make it available to the plants (Hanafy-Ahmed, 1996).

Farahat *et al.* (2007) reported that application of ascorbic acid had a positive effect on vegetative growth of Cupressus plants (*Cupressus sempervirens*).Growth parameters such as plant height, stem diameter, number of branches, root length, fresh weight and dry weight of the plants were recorded high with 20 and 40 ppm of ascorbic acid spray. Ascorbic acid (40 ppm) application enhanced the fresh weight of shoots and roots by 25.52 and 16.62 % respectively. Nitrogen content was also found to be higher in plants sprayed with 40 ppm of ascorbic acid.

El-Tohamy *et al.*, (2008) conducted an experiment in brinjal (*Solanum melonogena*) to analyze the effect foliar application of ascorbic acid on growth, yield and physiological responses. They found that application of vitamin C resulted in better growth in terms of plant height, number of leaves, number of branches, fresh and dry weight of the plants.

Application of different concentration of ascorbic acid (50, 100 and 200 ppm) stimulated the growth of gladiolus plants (*Gladiolus grandiflora*). Among the different ascorbic acid concentration greatest plant height, number of leaves, fresh and dry weight of leaves were found in plants treated with 100 ppm of ascorbic acid (Nahed *et al.,* 2009).

Application of a combination antioxidants such as thiamine, ascorbic acid and citric acid on five year old Thomson seedless grape vine showed positive response with respect to shoot length, leaf area, N, P, K content of leaves, fresh and dry weight of leaves. Application of each antioxidant alone also gave higher value for growth parameters compared to antioxidant untreated grape vines (Fayed, 2010).

Mazher *et al.* (2011) carried out an investigation in croton (*Codiaeum variegatum* L.) to analyze the stimulatory effect of ascorbic acid on growth and observed that foliar application of ascorbic acid at 100 and 200 ppm had a significant effect on the growth. Ascorbic acid at 200 ppm was found to be superior to 100 ppm. Growth parameters such as plant height, number of leaves, stem diameter, number of branches, root length, as well as fresh weight, dry weight were higher in ascorbic acid treated plants compared to the control plants (without ascorbic acid application).The percentage increase in plant height and number of leaves was found to be 39.58 per cent and 29.16 per cent respectively compared to the control plants.

Abdulrahman (2013) stated that foliar spray of ascorbic acid on two year old almond (*Prunus amygdalus*) seedlings had a stimulatory effect on the vegetative growth parameters. Highest plant height (90.3 cm) was observed in plants treated with 1000 ppm of ascorbic acid, while primary root length showed a higher value with lower dose *i.e.* 500 ppm of ascorbic acid. Other growth parameters such as stem diameter,

chlorophyll content, leaves dry weight, shoot dry weight showed significantly higher value compared to the control plants (untreated with ascorbic acid).

Two year old olive seedlings were treated with three levels of ascorbic acid concentration such as 250 ppm, 500 ppm and 750 ppm. From the results it could be inferred that application of ascorbic acid at 500 ppm had significantly higher leaf area (7.99 cm^2) than the untreated control plants (5.06 cm^2) (Ibrahim, 2013).

EL-badawy (2013) conducted an experiment to analyze the response of ascorbic acid spray on the growth of ten year old canino apricot trees during the period of 2008 to 2009. From the study it was evident that application of 1000 and 2000 ppm of ascorbic acid spray had a positive impact on growth of apricot trees. The highest number of leaves per shoot were observed with the application 2000 ppm in both the year. Leaf N, P and K content was recorded high in plants treated with 200 ppm of ascorbic acid.

Foliar application of ascorbic acid at 100 ppm on maize plants resulted in higher value with respect to plant height, number of leaves, and LAI (Sahu et al., 1993) .Foliar application of ascorbic acid 0.6 g/L on sunflower plants recorded the greatest plant height, dry matter production and head diameter. N, P and K content of plants also found to be high in plants treated with ascorbic acid (Osman *et al.*, 2014).

Materials and methods

3. MATERIALS AND METHODS

The study entitled "Standardization of growth promoters for mangosteen (*Garcinia mangostana* L.) seedlings" was carried out from April 2018 to April 2019.The present study was conducted with the objective to identify the ideal combination of growth promoters for enhancing seedling growth in mangosteen.

3.1 General details of the experiment

3.1.1 Location and climate

The research work was conducted at Department of Fruit Science, College of Horticulture, Vellanikkara, Thrissur, Kerala. Vellanikkara is located at a latitude of 10^0 54'N and longitude of 76^0 28' E. The area lies 22.25 m above MSL and experiences warm humid tropical climate. The climatological data during the period of the research work are given in figure 1.

3.2 Planting of mangosteen seedlings

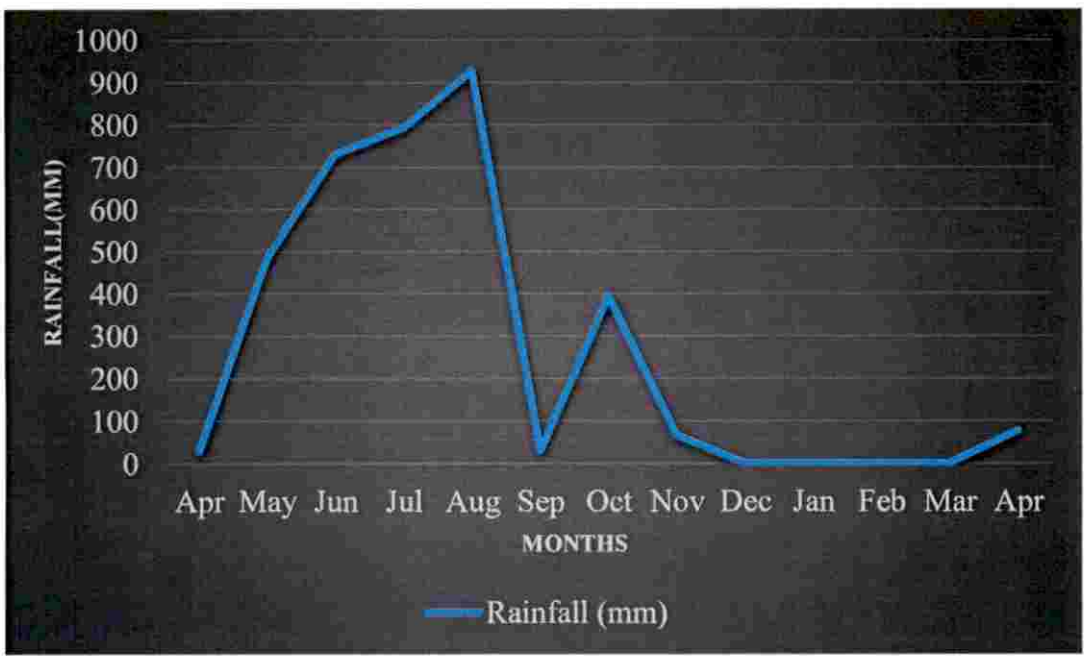
Six month old mangosteen seedlings (Plate 1) with an average initial height of 10 cm were used for planting. Five hundred and ten seedlings were procured from a government authorized private nursery for this purpose.

Seedlings were planted in eight inch pots filled with potting media of soil+ sand+ vermicompost mixture in the ratio 2:1:1. Planting was done on 11^{th} April 2018. Seedlings were kept in a net house cladded with 75 % shade net, in order to provide adequate shade for the growth of seedlings. *Trichoderma viride* 20 g was applied to every pots as a prophylactic measure to control soil borne diseases.

3.2.1 Management of seedlings

Watering was done at regular intervals during the entire study period. Incidence of leaf spot, leaf blight and occasional attack of leaf eating caterpillar, rust were

a) Maximum and minimum temperature recorded during the study period



b) Rainfall recorded during the study period

Figure 1. Meteorological data during the study period (2018 April - 2019 April)

detected in the seedlings. These were managed by appropriate application of plant protection measures.

3.3 Experimental details

The experiment was laid out in completely randomized block design with three replications. In each replication ten plants were maintained per treatment.

3.3.1 Treatments

Foliar spray of NPK (30:10:10) at 0.5% and 1% along with gibberellic acid (300 ppm), ascorbic acid (100 ppm) and thiamine (100 ppm) were given at monthly intervals during the entire study period (from April 2018 to April 2019) .

T1- NPK (3:1:1) @ 0.5%

T2- NPK (3:1:1) 0. 5 % + GA_3 300 ppm

T3- NPK (3:1:1) 0.5% + Thiamine 100 ppm

T4- NPK (3:1:1) 0.5 % + Ascorbic acid 100 ppm

T5- NPK (3:1:1) 0.5 % + GA_3 300 ppm+ Thiamine 100 ppm

T6- NPK (3:1:1) 0. 5 % + GA_3 300 ppm + Ascorbic acid 100 ppm

T7- NPK (3:1:1) 0. 5 % + Thiamine 100 ppm + Ascorbic acid 100 ppm

T8- NPK (3:1:1) 0. 5 + GA_3 300 ppm +Thiamine 100 ppm + Ascorbic acid 100 ppm

T9- NPK (3:1:1) @ 1.0 %

T10- NPK (3:1:1) 1.0% + GA_3 300 ppm

T11- NPK (3:1:1) 1.0% + Thiamine 100 ppm

T12- NPK (3:1:1) 1.0% + Ascorbic acid 100 ppm

T13- NPK (3:1:1) 1.0% + GA_3 300 ppm + Thiamine 100 ppm

Plate 1. Six month old mangosteen seedlings

Plate 2. General view of the experimental field

T14- NPK (3:1:1) 1.0% + GA_3 300 ppm + Ascorbic acid 100ppm

T15- NPK (3:1:1) 1.0% + Thiamine 100 ppm + Ascorbic acid 100 ppm

T16- NPK (3:1:1) 1.0% + GA_3 300 ppm + Thiamine 100 ppm + Ascorbic acid 100 ppm

T17- Control

3.4 Observations

Growth characters such as plant height, plant spread, number of leaves, length of leaf, breadth of leaves, total leaf area, inter nodal length, number of branches were recorded at three months interval.

Observations on root parameters such as number of roots, length of the longest root, root spread, shoot: root ratio and number of root hairs (if any) were measured 12 months after planting. Fresh weight of plants, dry weight and Leaf Area Index (LAI) were also measured.

3.4.1 Growth characters of seedlings

a) Plant height

Seedling height was noted from the collar region to the tip of the main stem using a metre scale and expressed in centimetre.

b) Internodal length

Internodal length is the distance between two proximate nodes. It was measured using a metre scale and expressed in centimetres.

c) Plant spread

Spread of the plant in East - West and North - South directions were measured, average was worked out and denoted in centimeter.

d) Number of leaves

The total number of leaves found at the time of each observation were counted and recorded.

e) Length and breadth of leaves

Fully opened leaves were selected for this purpose. Length was taken from base of petiole to the tip of the leaf and recorded in centimetre. Breadth of leaf was measured at the middle of the leaf and noted in centimetre.

f) Total leaf area

Leaf area was calculated by multiplying the length, the breadth and the factor (0.62) and average was expressed in cm^2. The factor was pre standardized for this purpose, by taking hundred leaves and length and breadth of the leaves were measured. The leaf area for the corresponding leaf was measured by leaf area meter to work out the factor value. Thus the factor value (0.62) was derived using the formula.

Factor = (leaf area / length × breadth)

Using the factor value, the leaf area was calculated.

g) Number of branches

Branches produced from the main stem at the time of each observation was observed.

3.4.2 Root characters of the seedlings

a) Number of roots

Seedlings were uprooted from the pots carefully, after removing the potting media and total number of roots were counted.

b) Length of longest root

Length of longest root was measured from collar region to the tip of the root using a meter scale and noted in centimetre.

c) Root spread

The maximum root spread was measured and noted in centimetre.

d) Shoot: root ratio

Mangosteen seedlings were cut at the collar region and after separating root portion from shoot, weight of the respective portions were recorded and expressed in gram. Shoot: root ratio was calculated by using the equation given below.

Shoot: root ratio = Fresh weight for shoots (top of the plant) / fresh weight for roots

e) Number of root hairs

Roots were observed for the presence of root hairs.

3.4.3 Physiological parameters

a) Fresh weight of plants

Twelve months after planting, three seedlings from a treatment were uprooted, washed well and after draining the water, fresh weight of shoots, roots and whole plant were recorded separately using an electronic balance and the average weight was represented in gram.

b) Dry weight of plants

After recording the fresh weight, the plants were dried in an oven with temperature retained at 80 ± 5^{0} C till the weight of the sample remained constant. The dry weight of the samples were recorded and average expressed in gram.

c) Leaf Area Index

Leaf Area Index (LAI) was computed using the equation

$$LAI = \frac{\text{Total leaf area of the seedlings}}{\text{Land area occupied by the seedlings}}$$

3.4.4 Nutrient content (N, P, and K) of the plants

Nutrient analysis of plant was done 12 months after planting. Plants were uprooted and dried first under shade and then in hot air oven at 80 ± 5^{0} C. Dry weight of the samples were taken before plant analysis. The dried plant samples were ground and then chemically analyzed for major nutrients such as N, P, and K using the standard procedure given below.

Sl. No.	Parameter	Method
1	N (kg/ha)	Microkjeldahl digestion and distillation method (Jackson, 1958)
2	P (kg/ha)	Vanadomolybdophosphoric yellow colour method (Jackson, 1958)
3	K (kg/ha)	Flame photometry (Piper,1966)

3.4.4.1 Nutrient uptake by the plants

Nutrient uptake was estimated by multiplying the nutrient content with the dry weight of respective plant sample and expressed in mg/plant

$$\text{Nutrient uptake} = \frac{\text{Nutrient content (\%)} \times \text{dry weight (mg)}}{100}$$

3.4.5 Analysis of nutrient content of potting medium

Initial N, P and K status of the potting medium was estimated. Samples were shade dried and were analyzed as per the procedures given below.

Sl. No	Parameter	Method	Quantity	Rating
1	Organic carbon (%)	Walkley and Black method (Jackson, 1958)	1.03	Medium
2	N (kg/ha)	Alkaline permanganate method (Subbiah and Asija, 1956)	320.48	Medium
3	P (kg/ha)	Bray – 1 extractant ascorbic acid reductant method (Watnabe and Oslen, 1965)	123.67	High
4	K (kg/ha)	Neutral normal ammonium acetate extractant flame photometry (Jackson,1958)	211.79	Medium

3.5 Statistical analysis

Data for vegetative characters were statistically analyzed by applying analysis of covariance (ANCOVA) as per the design adopted in the experiment with the help of online statistical package R console. Data for root characters, physiological parameters and nutrient uptake were analyzed by using online statistical package WASP. 2.

Results and Discussion

4. RESULTS AND DISCUSSION

The results obtained from the study entitled " Standardization of growth promoters for mangosteen (*Garcinia mangostana* L.) seedlings" are enumerated and discussed below.

4.1 Effect of nutrients and plant growth promoters on growth characters of mangosteen seedlings

4.1.1 Plant height (cm) (3, 6, 9, 12 months after planting)

Height of mangosteen seedlings differed significantly at three, six, nine and twelve month after planting. Table 1 shows the effect of application of nutrients and different plant growth promoters on height of mangosteen seedlings.

After three months of growth, T_6 (NPK (3:1:1) 0. 5 % + GA_3 300 ppm + ascorbic acid 100 ppm) showed the maximum height (28.07 cm) which was on par with T_2 (NPK (3:1:1) 0. 5 % + GA_3 300 ppm) with a height of 25.76 cm. Plants under all other treatments including control were significantly shorter than T_6 and T_2. The lowest value of height was observed in T_4 (NPK (3:1:1) 0.5 % + ascorbic acid 100 ppm) (12.07 cm), which was on par with many treatments (T_3, T_{11}, T_{15}, T_9, T_1, T_{12}, T_7, T_{13}) including control.

At six months stage also plant height was more in T_6 (28.96 cm) which was on par with the treatments T_{14} (28.23 cm) (NPK (3:1:1) 1.0% + GA_3 300 ppm + ascorbic acid 100 ppm) and T_2 (27.17 cm). Plant height was the lowest (13.15 cm) for T_4 (NPK (3:1:1) 0.5 % + ascorbic acid 100 ppm).

After ninth months also the same trend was observed, the highest value (30.92 cm) for plant height being observed in T_6 followed by T_2 (30.49 cm) and T_{14} (29.51

cm), which were statistically on par with T_6. The lowest height was recorded in T_4 (14.59 cm).

Plant height at twelve months after planting was maximum for T_6 (33.32 cm) followed by T_2 (31.72 cm) and T_{14} (30.97 cm), which were found to be statistically on par. Lowest plant height of 16.12 cm was observed in T_4 (NPK (3:1:1) 1.0% +ascorbic acid 100 ppm) (Fig. 1).

Plant height is an indication of growth and development of the seedlings. Among the different treatments tried in the experiment, treatment T_6 (NPK (3:1:1) 0. 5 % + GA_3 300 ppm + ascorbic acid 100 ppm) showed significantly greater plant height during the entire study period and recorded a maximum height of 33.32 cm at twelve months after planting. Height of the plants showed a significant increase even within three months after application of treatments. From the result, it was evident that treatments containing gibberellic acid (GA_3) exhibited significantly greater plant height *viz.* T_6 (33.32 cm), T_2 (31.72 cm) (NPK (3:1:1) 0.5 % + GA_3 300 ppm) and T_{14} (30.97 cm) (NPK (3:1:1) GA_3 300 ppm + ascorbic acid 100 ppm) than other treatments. Gibberellic acid is known to enhance shoot elongation, cell division and cell expansion. GA reduces the cell osmotic potential and thereby increases the uptake of water into the cell, leading to the expansion of the cell. It is also involved in the process of cell wall extension (Ishida and Katsumi, 1992). Wiebel *et al.* (1992) revealed that judicious application of gibberellins could accelerate the growth of mangosteen seedlings. The results of the study was also in conformity with the findings of Srisumran *et al.* (1997), where application of 100 ppm of gibberellic acid was effective for improving the plant height of mangosteen seedlings.

4.1.2 Internodal length (cm) (3, 6, 9, 12 months after planting)

Influence of application of nutrients and growth promoters on internodal length is represented in Table 2. At three months stage, T_6 (NPK (3:1:1) 0. 5 % + GA_3 300 ppm + ascorbic acid 100 ppm) showed the maximum internodal length (8.51 cm),

which was significantly different from all other treatments including control plants. The lowest internodal length (1.10 cm) was observed in T_{12} (3:1:1) 1 % + ascorbic acid 100 ppm), which was on par with majority of treatments including the control plants.

At six months stage also, T_6 showed the highest internodal length (8.74 cm) among the treatments. The lowest value (1.10 cm) was observed in T_{12}, which was on par with T_{11} (1.14 cm), T_9 (1.52 cm), T_4 (1.56 cm), T_7 (1.57 cm), T_1 (1.57 cm), T_3 (1.82 cm) and T_{17} (1.86 cm)

After nine months, the maximum internodal length was recorded by T_6 (9.11 cm), which was significantly different from all other treatments including control plants. T_{11} (NPK (3:1:1) 1.0% + thiamine 100 ppm) recorded the lowest value (1.45 cm) for internodal length.

At the end of twelfth month, T_6 had the maximum internodal length (9.44 cm), which was significantly different from all the other treatments. The lowest value (1.45 cm) was noticed in T_{11} (Fig. 1).

Treatments containing GA_3 showed the maximum value with respect to plant height. Similar trend was observed in internodal length also, because it is a factor related to plant height. It was observed that application of thiamine and ascorbic acid was not prominent in enhancing the internodal length. But application of gibberellic acid alone or in combination with ascorbic acid and thiamine markedly increased the internodal length. Treatment T_6 (NPK (3:1:1) 0. 5 % + GA_3 300 ppm + ascorbic acid 100 ppm) was found to be superior to all other treatments and recorded the maximum internodal length of 9.44 cm at the end of twelfth month. This is in conformity with the findings of Wiebel *et al.*, (1992) that the application of GA_3 results in doubling of internodal length compared to the untreated plants. This result again confirm the role of gibberellic acid on stem elongation.

Table 1. Effect of nutrients and growth promoters on height of mangosteen seedlings (cm)

Treatments	At the time of planting	3 months	6 months	9 months	12 months
T_1	9.86	13.09^{fg}	15.56^{efg}	17.73^{fg}	19.14^{def}
T_2	9.73	25.76^{ab}	27.17^{ab}	30.49^{ab}	31.72^{ab}
T_3	9.47	12.31^{g}	14.86^{fg}	17.65^{fg}	18.58^{def}
T_4	9.98	12.07^{g}	13.15^{g}	14.59^{g}	16.12^{f}
T_5	11.05	22.45^{c}	24.81^{bc}	25.20^{cd}	27.94^{b}
T_6	12.63	28.07^{a}	28.96^{a}	30.92^{a}	33.32^{a}
T_7	11.47	14.39^{fg}	16.87^{efg}	18.50^{efg}	21.11^{de}
T_8	11.29	19.14^{d}	22.45^{cd}	26.17^{bcd}	27.94^{b}
T_9	11.22	12.77^{fg}	15.21^{efg}	16.38^{fg}	17.66^{ef}
T_{10}	11.31	17.89^{de}	21.54^{cd}	25.40^{cd}	27.22^{bc}
T_{11}	11.25	12.56^{g}	13.70^{g}	14.67^{g}	17.00^{ef}
T_{12}	12.17	14.20^{fg}	15.18^{efg}	16.28^{fg}	17.55^{ef}
T_{13}	10.43	14.69^{fg}	18.79^{de}	22.14^{de}	22.77^{cd}
T_{14}	9.37	23.14^{bc}	28.23^{ab}	29.51^{abc}	30.97^{ab}
T_{15}	9.13	12.64^{fg}	15.98^{efg}	18.28^{efg}	20.66^{def}
T_{16}	10.27	15.67^{ef}	17.59^{ef}	19.30^{ef}	20.42^{def}
T_{17}	10.43	12.89^{fg}	15.03^{fg}	16.19^{fg}	18.10^{def}
CD 0.05 %		3.18	3.72	4.33	4.66

T_1 - NPK (3:1:1) 0.5%
T_2 - NPK (3:1:1) 0. 5% + GA_3
T_3 - NPK (3:1:1) 0.5% + TH
T_4 - NPK (3:1:1) 0.5% + AA
T_5 - NPK (3:1:1) 0.5% + GA_3 + TH
T_6 - NPK (3:1:1) 0. 5% + GA_3 + AA
T_7 - NPK (3:1:1) 0. 5% + TH + AA
T_8 - NPK (3:1:1) 0. 5% + GA_3 + TH +AA
T_9 - NPK (3:1:1) 1.0%
T_{10} - NPK (3:1:1) 1.0% + GA_3
T_{11} - NPK (3:1:1) 1.0% + TH
T_{12} - NPK (3:1:1) 1.0% + AA
T_{13} - NPK (3:1:1) 1.0% + GA_3 + TH
T_{14} - NPK (3:1:1) 1.0% + GA_3 + AA
T_{15} - NPK (3:1:1) 1.0% + TH + AA
T_{16} - NPK (3:1:1) 1.0% + GA_3 + TH + AA
T_{17} - control

* TH - Thiamine, AA - Ascorbic acid

Table 2. Effect of nutrients and growth promoters on internodal length (cm) of mangosteen seedlings

Treatments	At the time of planting	3 months	6 months	9 months	12 months
T_1	1.52	1.42^{f}	1.57^{fg}	1.66^{ef}	2.42^{ef}
T_2	1.95	6.48^{bc}	7.03^{bc}	7.04^{b}	7.17^{b}
T_3	1.82	1.56^{f}	1.82^{fg}	1.86^{ef}	1.92^{ef}
T_4	1.98	1.31^{f}	1.56^{fg}	1.60^{ef}	1.60^{f}
T_5	0.87	5.73^{c}	6.61^{bcd}	7.49^{b}	7.59^{b}
T_6	1.39	8.51^{a}	8.74^{a}	9.11^{a}	9.44^{a}
T_7	1.29	1.52^{f}	1.57^{fg}	1.67^{ef}	2.09^{ef}
T_8	1.10	6.03^{c}	6.12^{cd}	7.29^{b}	8.17^{b}
T_9	1.55	1.33^{f}	1.52^{fg}	1.68^{ef}	1.68^{f}
T_{10}	1.09	6.13^{bc}	6.95^{bc}	7.67^{b}	7.67^{b}
T_{11}	0.99	1.13^{f}	1.14^{g}	1.45^{f}	1.45^{f}
T_{12}	0.98	1.10^{f}	1.10^{g}	1.50^{f}	1.50^{f}
T_{13}	0.99	4.59^{d}	5.86^{d}	5.95^{c}	5.95^{c}
T_{14}	0.80	6.95^{b}	7.08^{b}	7.59^{b}	7.59^{b}
T_{15}	0.83	1.63^{f}	2.20^{f}	2.51^{e}	2.84^{e}
T_{16}	1.03	3.67^{e}	3.81^{e}	4.81^{d}	4.83^{d}
T_{17}	0.95	1.71^{f}	1.86^{fg}	2.02^{ef}	1.98^{ef}
CD (0.05%)		0.90	0.94	0.97	1.06

T_1 - NPK (3:1:1) 0.5%
T_2 - NPK (3:1:1) 0. 5% + GA_3
T_3 - NPK (3:1:1) 0.5% + TH
T_4 - NPK (3:1:1) 0.5% + AA
T_5 - NPK (3:1:1) 0.5% + GA_3 + TH
T_6 - NPK (3:1:1) 0. 5% + GA_3 + AA
T_7 - NPK (3:1:1) 0. 5% + TH + AA
T_8 - NPK (3:1:1) 0. 5% + GA_3 + TH +AA
T_9 - NPK (3:1:1) 1.0%
T_{10} - NPK (3:1:1) 1.0% + GA_3
T_{11} - NPK (3:1:1) 1.0% + TH
T_{12} - NPK (3:1:1) 1.0% + AA
T_{13} - NPK (3:1:1) 1.0% + GA_3 + TH
T_{14} - NPK (3:1:1) 1.0% + GA_3 + AA
T_{15} - NPK (3:1:1) 1.0% + TH + AA
T_{16} - NPK (3:1:1) 1.0% + GA_3 + TH + AA
T_{17} - Control

* TH - Thiamine, AA - Ascorbic acid

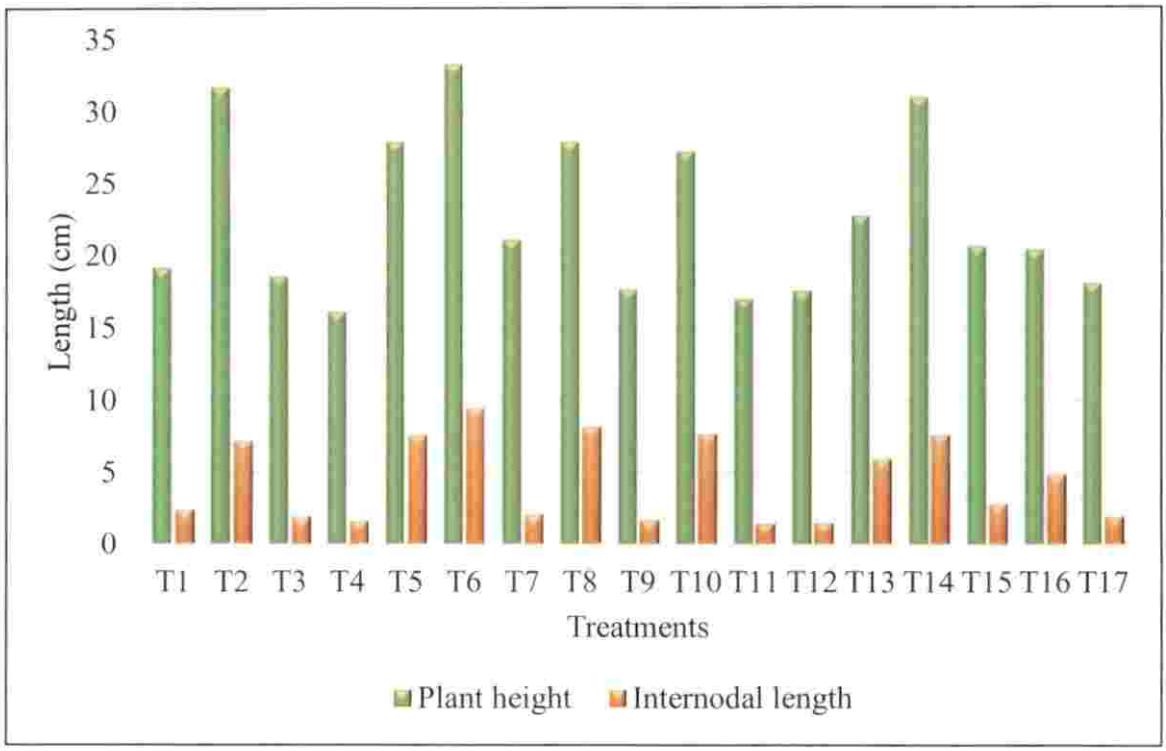


Figure 2. Effect of nutrients and growth promoters on height and internodal length of mangosteen seedlings twelve months after planting

T_1 - NPK (3:1:1) 0.5%
T_2 - NPK (3:1:1) 0. 5% + GA_3
T_3 - NPK (3:1:1) 0.5% + TH
T_4 - NPK (3:1:1) 0.5% + AA
T_5 - NPK (3:1:1) 0.5% + GA_3 + TH
T_6 - NPK (3:1:1) 0. 5% + GA_3 + AA
T_7 - NPK (3:1:1) 0. 5% + TH + AA
T_8 - NPK (3:1:1) 0. 5% + GA_3 + TH +AA
T_9 - NPK (3:1:1) 1.0%
T_{10} - NPK (3:1:1) 1.0% + GA_3
T_{11} - NPK (3:1:1) 1.0% + TH
T_{12} - NPK (3:1:1) 1.0% + AA
T_{13} - NPK (3:1:1) 1.0% + GA_3 + TH
T_{14} - NPK (3:1:1) 1.0% + GA_3 + AA
T_{15} - NPK (3:1:1) 1.0% + TH + AA
T_{16} - NPK (3:1:1) 1.0% + GA_3 + TH + AA
T_{17} - control

*TH – Thiamine, AA – Ascorbic acid

4.1.3 Plant spread (cm) (3, 6, 9, 12 months after planting)

The plant spread significantly differed at three, six, nine and twelve month stages. Changes in plant spread after the application of nutrients and plant growth promoters is presented in Table 3.

At three months stage T_1 (NPK (3:1:1) 0.5 %) recorded the maximum plant spread of 24.84 cm, but it was statistically on par with the control plants (23.03 cm) and T_3 (22.94 cm). T_{10} (NPK (3:1:1) 1.0% + GA_3 300 ppm) recorded the minimum plant spread of 13.19 cm, which was statistically on par with T_{16} (NPK (3:1:1) 1.0% + GA_3 300 ppm +thiamine 100 ppm + ascorbic acid 100 ppm) (13.28 cm), T_{14} (13.98 cm), T_5 (14.49 cm), T_2 (14.68 cm) and T_8 (14.72 cm).

Sixth months after planting T_1 (NPK (3:1:1) 0.5 %) showed the maximum plant spread (30.26 cm), which was significantly different from all other treatments including control plants. The lowest plant spread (13.58 cm) was noticed in T_{10}, followed by T_{16} (13.97 cm) and T_8 (15.27 cm).

After nine months also T_1 recorded the maximum plant spread (32.45 cm) which was statistically on par with T_{12} (30.19 cm). The lowest plant spread (14.83 cm) was observed in the treatment T_{10}, which was on par with T_{16} (15.75 cm), T_8 (16.66 cm) and T_2 (16.77 cm).

At twelve months period also, T_1 (NPK (3:1:1) 0.5 %) was found to be superior than other treatments with respect to plant spread, but it was statistically on par with T_3 (NPK (3:1:1) 0.5 % + thiamine 100 ppm) (32.94 cm),T_{12} (32.89 cm), T_{15} (31.83 cm) and T_4 (31.59 cm). The treatment T_{10} (NPK (3:1:1) 1.0 % + GA_3 300 ppm) recorded the lowest value for plant spread which was on par with T_{10} (15.00 cm), T_{16} (15.75 cm), T_2 (17.08 cm), T_8 (17.67 cm), T_{13} (17.92 cm) and T_5 (18.00 cm) (Fig. 2).

Plant spread showed significant variation after six months onwards. At six months stage T_1 (NPK (3:1:1) 0.5 %) exhibited an overall superiority with respect to plant spread. At nine and twelfth months, treatments T_1, T_3, T_4, T_{12}, T_{15} recorded

greater plant spread. However comparatively higher plant spread (34.27 cm) was noticed with treatment T_1 (NPK (3:1:1) 0.5 %) at the end of twelve months. This might be due to the spraying of NPK foliar mixture (30:10:10) at monthly intervals at the optimum concentration the crop needed which might have provided adequate quantity of primary nutrients enhancing the overall growth of the plants. A study conducted by Dhillon *et al.*, (2009) in pomegranate revealed that NPK fertilization could improve growth parameters including canopy spread. Manoj (2011) also reported that application of nutrient solution - foliar grade of NPK (3:1:1) - 0.5 % had a positive effect on leaf breadth and length, ultimately contributing to plant spread. Plants with greater spread could intercept more sunlight and thereby enhancing the photosynthetic rate. Increase in photosynthetic rate in turn affected the overall growth of the plants. Eventhough NPK (3:1:1) 0.5 % was found to be superior with respect plant spread, NPK (3:1:1) 1% was significantly inferior in enhancing the plant spread. Perhaps for mangosteen, the optimum dose of NPK might be less than 1 per cent. The lowest plant spread during the entire period of observation was noticed in T_{10} (NPK (3:1:1) 1.0% + GA_3 300 ppm). This might be due to the reduced leaf growth in treatments with GA_3. Plant spread is proportional to the leaf growth of any plant. Wiebel *et al.* (1992), have reported reduced leaf area for mangosteen treated with GA.

4.1.4 Number of leaves (3, 6, 9, 12 months after planting)

During the third month after planting, number of leaves varied from 7.13 to 11.60 (Table 4). More number of leaves (11.60) were observed in the treatment T_7 (NPK (3:1:1) 0.5 % + thiamine 100 ppm + ascorbic acid 100 ppm). However T_7 was statistically on par with T_1 (11.53), T_3 (11.40), T_{17} (11.00), T_4 (10.75), T_{12} (10.68) and T_{15} (10.58). The treatment T_{16} had the lowest number of leaves (7.13), which was on par with T_{10} (7.38), (NPK (3:1:1) 1.0 % + GA_3 300 ppm + thiamine 100 ppm + ascorbic acid 100 ppm).

At sixth month after planting, T_{17} (control plants) showed the highest number of leaves (14.13) which was on par with T_1 (13.55), T_{15} (13.44), T_3 (13.27), T_7 (12.80). The lowest value was noticed in T_{16} (7.60) (NPK (3:1:1) 1.0% + GA_3 300 ppm + thiamine 100 ppm + ascorbic acid 100 ppm).

In ninth month after planting, plants received treatment T_1 (NPK (3:1:1) 0.5 %) had more number of leaves (14.69), which was on par with T_3 (14.58), T_{15} (14.55), T_{17} (14.46) and T_7 (14.00).The lowest value was observed in T16 (7.67), followed by T_{10} (8.15), T_5 (9.11), T_8 (9.20). These treatments were statistically on par with each other.

Twelve month after planting also T_{17} (control plants) recorded higher number of leaves (15.11), which was on par with T_1 (15.05), T_3 (14.78), T_{15} (14.67) and T_7 (14.00). Less number of leaves were observed in T_{16} (7.67).

From the study it could be inferred that application of plant growth promoters had no significant effect on number of leaves produced in mangosteen seedlings, as number of leaves recorded in control plants was on par with T_1 (3:1:1) 0.5 % at the end of twelfth month after planting. The lowest number of leaves was observed in plants treated with NPK (3:1:1) 1.0 % + GA_3 300 ppm + thiamine 100 ppm + ascorbic acid 100 ppm (T_{16}). Application of NPK 1% along with combination of gibberellic acid, thiamine and ascorbic acid were found to be inhibitory for leaf production.

Table 3. Effect of nutrients and growth promoters on spread (cm) of mangosteen seedlings

Treatments	At the time of planting	3 months	6 months	9 months	12 months
T_1	14.28	24.84^{a}	30.26^{a}	32.45^{a}	34.27^{a}
T_2	13.14	14.68^{gh}	16.37^{fg}	16.77^{ghi}	17.08^{fg}
T_3	14.88	22.94^{ab}	26.19^{bc}	27.74^{bcde}	32.94^{ab}
T_4	13.94	18.29^{de}	26.81^{bc}	27.52^{cde}	31.59^{ab}
T_5	13.87	14.49^{gh}	16.85^{efg}	17.69^{fgh}	18.00^{efg}
T_6	14.58	17.12^{ef}	18.50^{e}	20.14^{f}	20.31^{e}
T_7	13.00	22.69^{b}	27.41^{b}	28.96^{bc}	30.00^{bc}
T_8	12.53	14.72^{gh}	15.27^{gh}	16.66^{ghi}	17.67^{efg}
T_9	13.33	19.26^{d}	23.09^{d}	25.65^{e}	26.83^{d}
T_{10}	13.09	13.19^{h}	13.58^{h}	14.83^{i}	15.00^{g}
T_{11}	14.14	20.21^{cd}	24.81^{cd}	26.28^{de}	28.00^{cd}
T_{12}	12.98	21.69^{bc}	26.38^{bc}	30.19^{ab}	32.89^{ab}
T_{13}	13.70	15.51^{fg}	16.80^{efg}	17.31^{gh}	17.92^{efg}
T_{14}	14.37	13.98^{gh}	17.47^{ef}	18.87^{fg}	18.87^{ef}
T_{15}	12.58	19.66^{d}	25.71^{bc}	28.65^{bcd}	31.83^{ab}
T_{16}	12.39	13.28^{h}	13.97^{h}	15.75^{hi}	15.75^{g}
T_{17}	14.30	23.03^{ab}	25.44^{bc}	26.26^{de}	28.32^{cd}
CD 0.05 %		1.97	2.01	2.47	3.10

T_1 - NPK (3:1:1) 0.5%
T_2 - NPK (3:1:1) 0. 5% + GA_3
T_3 - NPK (3:1:1) 0.5% + TH
T_4 - NPK (3:1:1) 0.5% + AA
T_5 - NPK (3:1:1) 0.5% + GA_3 + TH
T_6 - NPK (3:1:1) 0. 5% + GA_3 + AA
T_7 - NPK (3:1:1) 0. 5% + TH + AA
T_8 - NPK (3:1:1) 0. 5% + GA_3 + TH +AA
T_9 - NPK (3:1:1) 1.0%
T_{10} - NPK (3:1:1) 1.0% + GA_3
T_{11} - NPK (3:1:1) 1.0% + TH
T_{12} - NPK (3:1:1) 1.0% + AA
T_{13} - NPK (3:1:1) 1.0% + GA_3 + TH
T_{14} - NPK (3:1:1) 1.0% + GA_3 + AA
T_{15} - NPK (3:1:1) 1.0% + TH + AA
T_{16} - NPK (3:1:1) 1.0% + GA_3 + TH + AA
T_{17} - Control

*TH - Thiamine, AA - Ascorbic acid

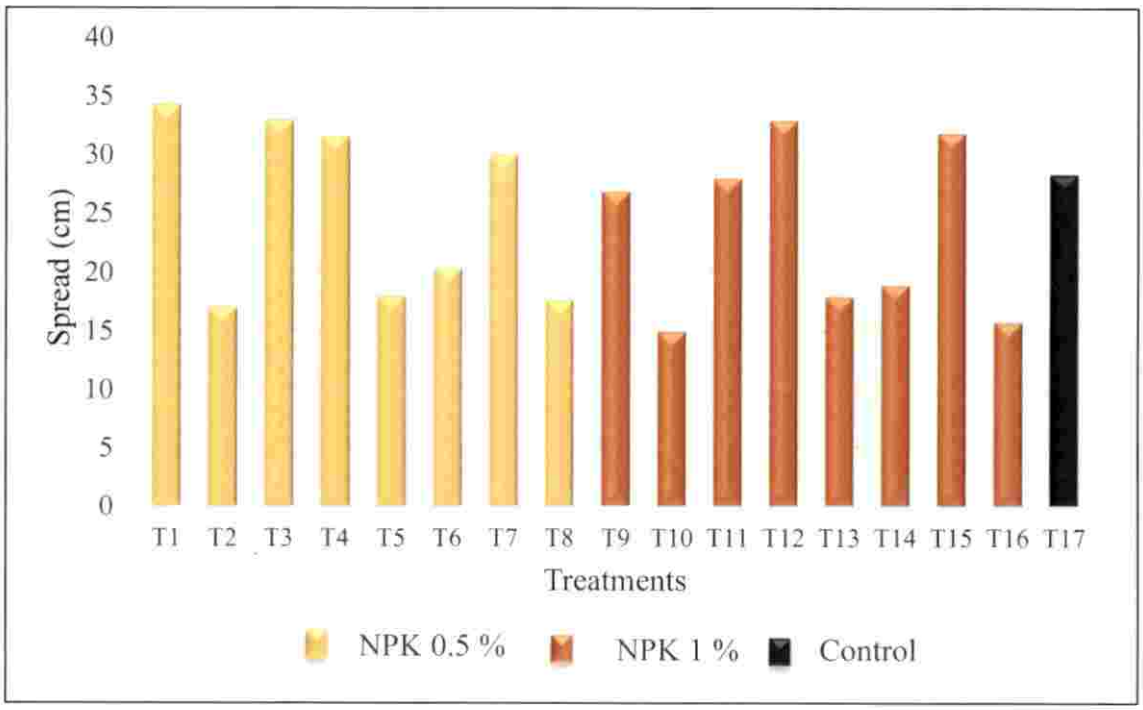


Figure 3. Effect of nutrients and plant growth promoters on spread of mangosteen seedlings twelve months after planting

T_1 - NPK (3:1:1) 0.5%
T_2 - NPK (3:1:1) 0. 5 % + GA_3
T_3 - NPK (3:1:1) 0.5% + TH
T_4 - NPK (3:1:1) 0.5 % + AA
T_5 - NPK (3:1:1) 0.5 % + GA_3 + TH
T_6 - NPK (3:1:1) 0. 5% + GA_3 + AA
T_7 - NPK (3:1:1) 0. 5 % + TH + AA
T_8 - NPK (3:1:1) 0. 5 % + GA_3 + TH +AA
T_9 - NPK (3:1:1) 1.0%
T_{10} - NPK (3:1:1) 1.0% + GA_3
T_{11} - NPK (3:1:1) 1.0% + TH
T_{12} - NPK (3:1:1) 1.0% + AA
T_{13} - NPK (3:1:1) 1.0% + GA_3 + TH
T_{14} - NPK (3:1:1) 1.0% + GA_3 + AA
T_{15} - NPK (3:1:1) 1.0% + TH + AA
T_{16} - NPK (3:1:1) 1.0% + GA_3 + TH +AA
T_{17} - control

*TH - Thiamine, AA - Ascorbic acid

Table 4. Effect of nutrients and growth promoters on number of leaves on mangosteen seedlings

Treatments	At the time of planting	3 months	6 months	9 months	12 months
T_1	8.53	11.53^{ab}	13.55^{a}	14.69^{a}	15.05^{a}
T_2	7.53	10.13^{c}	10.13^{fg}	10.13^{de}	10.13^{f}
T_3	7.87	11.40^{ab}	13.27^{abc}	14.58^{a}	14.78^{a}
T_4	7.87	10.75^{abc}	11.97^{bcde}	12.24^{c}	12.78^{cde}
T_5	8.33	8.47^{d}	9.03^{ghi}	9.11^{efg}	9.50^{fg}
T_6	8.33	10.53^{bc}	11.40^{def}	11.42^{cd}	11.75^{e}
T_7	7.73	11.60^{a}	12.80^{abcd}	14.00^{ab}	14.00^{abc}
T_8	7.80	8.60^{d}	8.70^{ghi}	9.20^{efg}	9.20^{fg}
T_9	7.80	10.53^{bc}	11.81^{cde}	11.90^{c}	12.03^{de}
T_{10}	6.93	7.38^{e}	8.15^{hi}	8.15^{fg}	8.15^{gh}
T_{11}	7.20	10.20^{c}	10.83^{ef}	11.98^{c}	12.67^{cde}
T_{12}	6.80	10.68^{ab}	11.53^{def}	12.52^{bc}	13.28^{bcd}
T_{13}	7.13	8.62^{d}	9.33^{gh}	9.33^{ef}	9.33^{fg}
T_{14}	7.87	10.20^{c}	11.78^{cde}	11.78^{c}	11.78^{e}
T_{15}	7.87	10.58^{ab}	13.44^{ab}	14.55^{a}	14.67^{ab}
T_{16}	7.47	7.13^{de}	7.60^{i}	7.67^{g}	7.67^{h}
T_{17}	10.43	11.00^{abc}	14.13^{a}	14.46^{a}	15.11^{a}
CD 0.05 %		1.06	1.48	1.59	1.43

T_1 - NPK (3:1:1) 0.5%
T_2 - NPK (3:1:1) 0. 5% + GA_3
T_3 - NPK (3:1:1) 0.5% + TH
T_4 - NPK (3:1:1) 0.5% + AA
T_5 - NPK (3:1:1) 0.5% + GA_3 + TH
T_6 - NPK (3:1:1) 0. 5% + GA_3 + AA
T_7 - NPK (3:1:1) 0. 5% + TH + AA
T_8 - NPK (3:1:1) 0. 5% + GA_3 + TH
T_9 - NPK (3:1:1) 1.0%
T_{10} - NPK (3:1:1) 1.0% + GA_3
T_{11} - NPK (3:1:1) 1.0% + TH
T_{12} - NPK (3:1:1) 1.0% + AA
T_{13} - NPK (3:1:1) 1.0% + GA_3 + TH
T_{14} - NPK (3:1:1) 1.0% + GA_3 +
T_{15} - NPK (3:1:1) 1.0% + TH + AA
T_{16} - NPK (3:1:1) 1.0% + GA_3 + TH
T_{17} - Control

*TH – Thiamine, AA – Ascorbic acid

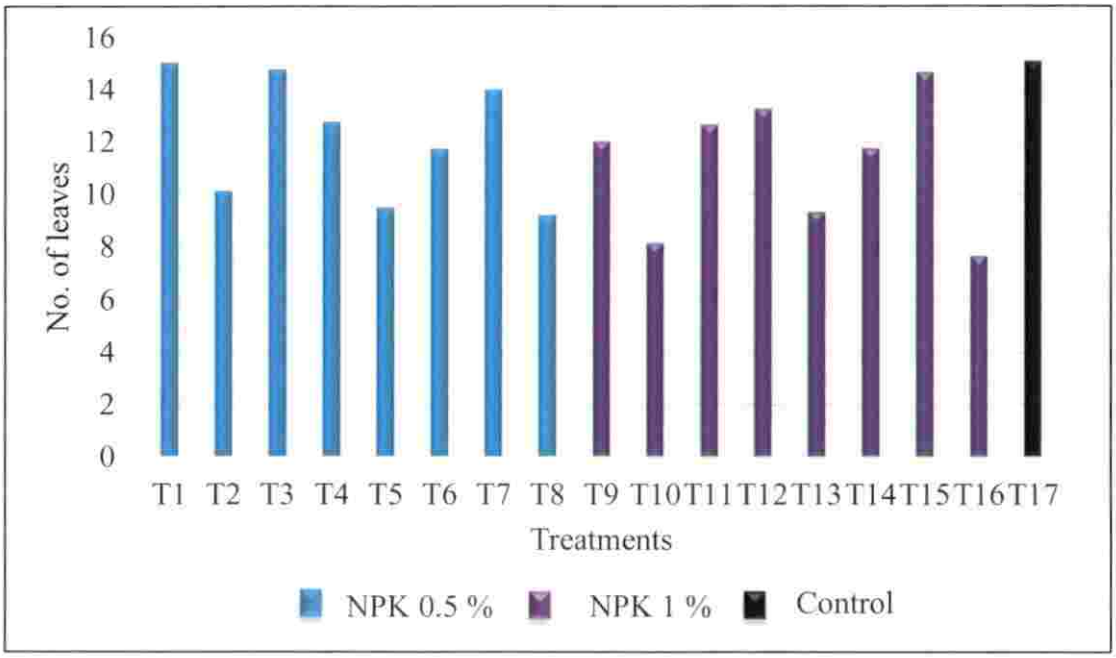


Figure 4. Effect of nutrients and growth promoters on number of leaves of mangosteen seedlings twelve months after planting

T_1 - NPK (3:1:1) 0.5%
T_2 - NPK (3:1:1) 0. 5 % + GA_3
T_3 - NPK (3:1:1) 0.5% + TH
T_4 - NPK (3:1:1) 0.5 % + AA
T_5 - NPK (3:1:1) 0.5 % + GA_3 + TH
T_6 - NPK (3:1:1) 0. 5% + GA_3 + AA
T_7 - NPK (3:1:1) 0. 5 % + TH + AA
T_8 - NPK (3:1:1) 0. 5 % + GA_3 + TH +AA
T_9 - NPK (3:1:1) 1.0%
T_{10} - NPK (3:1:1) 1.0% + GA_3
T_{11} - NPK (3:1:1) 1.0% + TH
T_{12} - NPK (3:1:1) 1.0% + AA
T_{13} - NPK (3:1:1) 1.0% + GA_3 + TH
T_{14} - NPK (3:1:1) 1.0% + GA_3 + AA
T_{15} - NPK (3:1:1) 1.0% + TH + AA
T_{16} - NPK (3:1:1) 1.0% + GA_3 + TH +AA
T_{17} - control

*TH - Thiamine, AA - Ascorbic acid

4.1.5 Leaf length (cm) (3, 6, 9, 12 months after planting)

At three months of planting T_9 (NPK (3:1:1) 1.0 %) showed the highest value (12.27 cm) for leaf length (Table 4). It was on par with T_{17} (control plants) (12.14 cm), T_1 (NPK (3:1:1) 0.5 %) (11.13 cm), T_3 (NPK (3:1:1) 0.5 % + thiamine 100 ppm) (10.95 cm), T_7 (NPK (3:1:1) 0. 5 % + thiamine 100 ppm + ascorbic acid 100 ppm) (10.93 cm), T_{12} (10.92 cm) and T_{15} (10.66 cm).The lowest value (7.36 cm) was recorded in T_{16} (NPK (3:1:1) 1.0 % + GA_3 300 ppm + thiamine 100 ppm + ascorbic acid 100 ppm).

During sixth month, T_1 NPK (3:1:1) 1.0%) showed the maximum leaf length (14.75 cm), which was statistically on par with T_{17} (14.72 cm), T_{15} (13.71 cm), T_3 (13.51 cm), T_9 (13.25 cm) and T_{12} (13.19 cm). The lowest value (7.83 cm) for leaf length was noticed in T_{16}.

Nine months after planting also stage T_1 showed maximum leaf length (16.59 cm) which was on par with T_{17} (15.20 cm). All other treatments were significantly lower than T_1 and T_{17}. The lower value was noticed in T_{16} (8.31 cm), which was on par with T_{10} (8.55 cm), T_5 (9.62 cm), T_{14} (9.64 cm) and T_2 (9.86 cm)

T_1 (NPK (3:1:1) 0.5 %) showed the highest value (17.30 cm) for length of leaf, twelve months after planting followed by T_3 (17.06 cm), T_{15} (16.54 cm) and T_4 (16.25 cm). T_{16} had the lowest value (8.31 cm), which was on par with T_{10} (8.55) and T_{14} (9.64 cm) (Fig. 3).

Treatment T_1 (NPK (3:1:1) 0.5 %) showed highest value at the end of twelfth month. It might be ascribed to the effect of nitrogen in promoting the vegetative growth of the plants. In general foliar application of NPK at higher concentration of 1 per cent along with combination of different plant growth promoters such as GA_3, thiamine and ascorbic acid was found to reduce leaf growth in terms of leaf length and this become more prominent when in combination with GA_3.

4.1.6 Breadth of leaves (cm) (3, 6, 9, 12 months after planting)

The effect of nutrients and plant growth promoters on breadth of leaves is presented in Table 5. At three months stage, T_1 recorded the highest value (4.18 cm) for breadth of leaves, which was statistically on par with control plants (T_{17}) (3.82 cm). The treatment T_{16} NPK (3:1:1) 1.0% + GA_3 300 ppm + thiamine 100 ppm + ascorbic acid 100 ppm) recorded the lowest value (2.61 cm) with respect to breadth of leaves.

After six months of planting also, T_1 (NPK (3:1:1) 0.5 %) showed the maximum leaf breadth (4.49 cm) followed by T_{17} (4.40 cm), these treatments were statistically on par with each other. The lowest leaf breadth was observed in T_{16} (2.71 cm), which war on par with T_{10} (2.81 cm), T_{13} (2.85 cm), T_8 (2.85 cm), T_2 (2.93 cm) T_{14} (3.00 cm) and T_5 (3.03 cm).

At ninth month of planting, among all the treatments T_1 (4.91 cm) and T_{17} (4.45 cm) showed higher and comparable leaf breadth. The lowest leaf breadth (2.76 cm) was observed in T_{16} (NPK (3:1:1) 1.0% + GA_3 300 ppm + thiamine 100 ppm + ascorbic acid 100 ppm).

Twelve months after planting also, T_1 recorded the highest leaf breadth (5.11 cm) followed by T_{17} (4.96 cm), T_4 (4.93 cm), T_{15} (4.89 cm), T_7 (4.82 cm) and T_3 (4.64 cm) and these treatments were statistically on par with each other. The lowest value for leaf breadth (2.76 cm) was recorded in T_{16} (NPK (3:1:1) 1.0% + GA_3 300 ppm + thiamine 100 ppm + ascorbic acid 100 ppm).

The value of leaf breadth varied from 2.76 cm to 5.11 cm twelve months after planting. Leaf breadth is not much influenced by foliar spray of nutrients and growth promoters as comparable values were observed for NPK 0.5 % spray and control. However application of GA_3 resulted in narrow leaves. This may be due to the translocation of photosynthates for cell elongation as evident from increased plant height in GA_3 300 ppm spray.

Table 5. Effect of nutrients and growth promoters on leaf length (cm) of mangosteen seedlings

Treatments	At the time of planting	3 months	6 months	9 months	12 months
T_1	7.49	11.13^{ab}	14.75^{a}	16.59^{a}	17.30^{a}
T_2	7.20	8.84^{defg}	9.45^{de}	9.86^{cde}	10.05^{g}
T_3	6.99	10.95^{ab}	13.51^{abc}	14.43^{b}	17.06^{ab}
T_4	6.67	9.20^{cdef}	12.97^{bc}	13.93^{b}	16.25^{abcd}
T_5	6.48	8.72^{defg}	9.00^{def}	9.62^{cde}	9.78^{gh}
T_6	6.76	9.77^{bcde}	10.39^{d}	11.02^{c}	11.50^{f}
T_7	6.45	10.93^{ab}	12.99^{bc}	14.59^{b}	15.64^{cde}
T_8	5.85	8.51^{efg}	9.36^{def}	10.23^{cd}	10.64^{fg}
T_9	6.25	12.27^{a}	13.25^{abc}	13.92^{b}	15.44^{cde}
T_{10}	6.07	7.49^{fg}	8.50^{ef}	8.55^{de}	8.55^{hi}
T_{11}	6.14	10.40^{bcd}	11.99^{c}	13.51^{b}	14.50^{e}
T_{12}	5.82	10.92^{ab}	13.19^{abc}	14.43^{b}	15.10^{de}
T_{13}	5.67	8.84^{defg}	9.50^{de}	10.17^{cd}	10.17^{fg}
T_{14}	6.40	8.50^{efg}	9.17^{def}	9.64^{cde}	9.64^{ghi}
T_{15}	6.03	10.66^{abc}	13.71^{ab}	14.25^{b}	16.54^{abc}
T_{16}	6.49	7.36^{g}	7.83^{f}	8.31^{e}	8.31^{i}
T_{17}	6.85	12.14^{a}	14.72^{a}	15.20^{ab}	15.87^{bcd}
CD (0.05%)		1.72	1.57	1.72	1.35

T_1 - NPK (3:1:1) 0.5%
T_2 - NPK (3:1:1) 0. 5% + GA_3
T_3 - NPK (3:1:1) 0.5% + TH
T_4 - NPK (3:1:1) 0.5% + AA
T_5 - NPK (3:1:1) 0.5% + GA_3 + TH
T_6 - NPK (3:1:1) 0. 5% + GA_3 + AA
T_7 - NPK (3:1:1) 0. 5% + TH + AA
T_8 - NPK (3:1:1) 0. 5% + GA_3 + TH +AA
T_9 - NPK (3:1:1) 1.0%
T_{10} - NPK (3:1:1) 1.0% + GA_3
T_{11} - NPK (3:1:1) 1.0% + TH
T_{12} - NPK (3:1:1) 1.0% + AA
T_{13} - NPK (3:1:1) 1.0% + GA_3 + TH
T_{14} - NPK (3:1:1) 1.0% + GA_3 +
T_{15} - NPK (3:1:1) 1.0% + TH + AA
T_{16} - NPK (3:1:1) 1.0% + GA_3 + TH + AA
T_{17} - Control

*TH – Thiamine, AA – Ascorbic acid

Table 6. Effect of nutrients and growth promoters on leaf breadth (cm) of mangosteen seedlings

Treatments	At the time of planting	3 months	6 months	9 months	12 months
T_1	3.01	4.18^{a}	4.49^{a}	4.91^{a}	5.11^{a}
T_2	2.81	2.69^{g}	2.93^{de}	3.06^{efg}	3.28^{f}
T_3	2.81	3.52^{bc}	3.77^{b}	4.06^{bc}	4.64^{abc}
T_4	2.60	3.19^{cdef}	3.67^{bc}	4.10^{bc}	4.93^{ab}
T_5	2.73	2.92^{defg}	3.03^{de}	2.96^{efg}	3.17^{f}
T_6	2.80	3.21^{cde}	3.21^{cd}	3.38^{de}	3.40^{ef}
T_7	2.69	3.62^{bc}	3.84^{b}	4.07^{bc}	4.82^{ab}
T_8	2.41	2.73^{fg}	2.85^{de}	3.14^{efg}	3.27^{f}
T_9	2.51	3.62^{bc}	3.78^{b}	3.91^{c}	3.97^{de}
T_{10}	2.36	2.78^{efg}	2.81^{de}	2.85^{fg}	2.85^{f}
T_{11}	2.55	3.65^{bc}	3.66^{bc}	3.74^{cd}	4.10^{cd}
T_{12}	2.37	3.59^{bc}	3.77^{b}	4.02^{bc}	4.31^{bcd}
T_{13}	2.52	2.78^{efg}	2.85^{de}	2.96^{efg}	2.96^{f}
T_{14}	2.55	2.77^{efg}	3.00^{de}	3.30^{def}	3.30^{f}
T_{15}	2.45	3.37^{bcd}	3.59^{bc}	3.73^{cd}	4.89^{ab}
T_{16}	2.72	2.61^{g}	2.71^{e}	2.76^{g}	2.76^{f}
T_{17}	2.98	3.82^{ab}	4.40^{a}	4.45^{ab}	4.96^{a}
CD (0.05%)		0.46	0.47	0.51	0.64

T_1 - NPK (3:1:1) 0.5%
T_2 - NPK (3:1:1) 0. 5% + GA_3
T_3 - NPK (3:1:1) 0.5% + TH
T_4 - NPK (3:1:1) 0.5% + AA
T_5 - NPK (3:1:1) 0.5% + GA_3 + TH
T_6 - NPK (3:1:1) 0. 5% + GA_3 + AA
T_7 - NPK (3:1:1) 0. 5% + TH + AA
T_8 - NPK (3:1:1) 0. 5% + GA_3 + TH +AA
T_9 - NPK (3:1:1) 1.0%
T_{10} - NPK (3:1:1) 1.0% + GA3
T_{11} - NPK (3:1:1) 1.0% + TH
T_{12} - NPK (3:1:1) 1.0% + AA
T_{13} - NPK (3:1:1) 1.0% + GA3 + TH
T_{14} - NPK (3:1:1) 1.0% + GA3 + AA
T_{15} - NPK (3:1:1) 1.0% + TH + AA
T_{16} - NPK (3:1:1) 1.0% + GA3 + TH + AA
T_{17} - Control

*TH – Thiamine, AA – Ascorbic acid

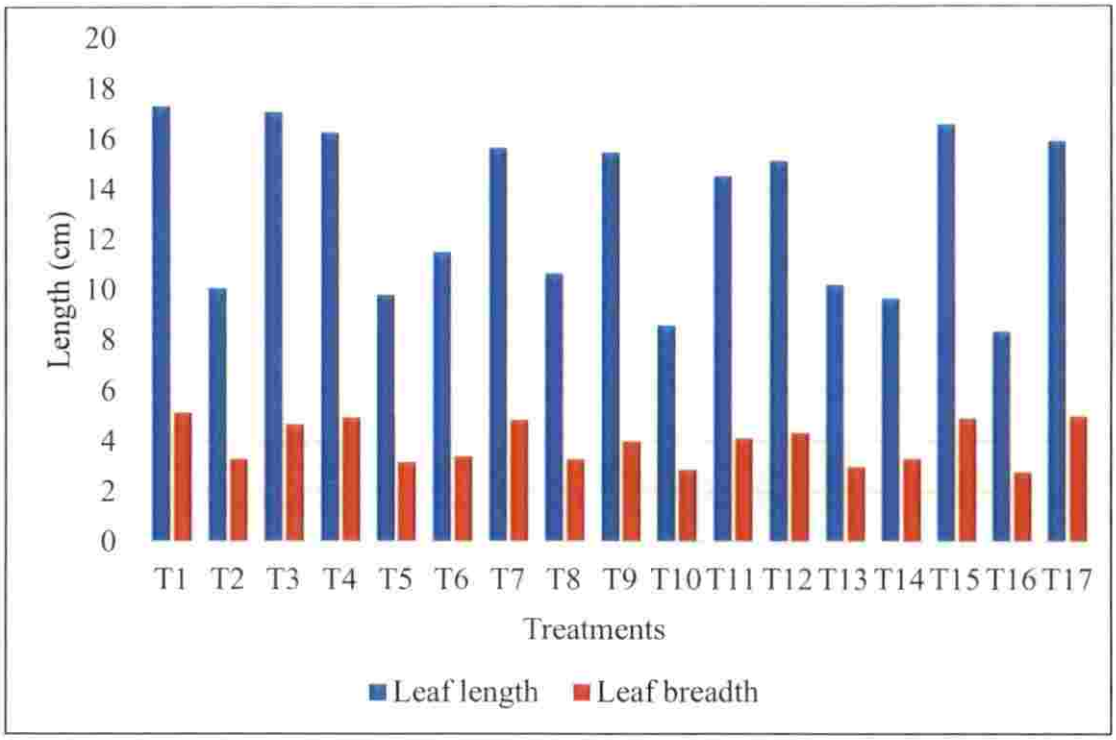


Figure 5. Effect of nutrients and growth promoters on leaf length and breadth of mangosteen seedlings twelve months after planting

T_1 - NPK (3:1:1) 0.5%
T_2 - NPK (3:1:1) 0. 5 % + GA_3
T_3 - NPK (3:1:1) 0.5% + TH
T_4 - NPK (3:1:1) 0.5 % + AA
T_5 - NPK (3:1:1) 0.5 % + GA_3 + TH
T_6 - NPK (3:1:1) 0. 5% + GA_3 + AA
T_7 - NPK (3:1:1) 0. 5 % + TH + AA
T_8 - NPK (3:1:1) 0. 5 % + GA_3 + TH +AA
T_9 - NPK (3:1:1) 1.0%
T_{10} - NPK (3:1:1) 1.0% + GA_3
T_{11} - NPK (3:1:1) 1.0% + TH
T_{12} - NPK (3:1:1) 1.0% + AA
T_{13} - NPK (3:1:1) 1.0% + GA_3 + TH
T_{14} - NPK (3:1:1) 1.0% + GA_3 + AA
T_{15} - NPK (3:1:1) 1.0% + TH + AA
T_{16} - NPK (3:1:1) 1.0% + GA_3 + TH +AA
T_{17} - control

*TH - Thiamine, AA - Ascorbic acid

Table 7. Effect of nutrients and growth promoters on total leaf area (cm^2) of mangosteen seedlings

Treatments	At the time of planting	3 months	6 months	9 months	12 months
T_1	118.93	336.02^{a}	556.30^{a}	742.88^{a}	826.45^{a}
T_2	96.50	151.90^{fgh}	176.17^{ef}	190.51^{gh}	208.92^{ef}
T_3	95.81	274.99^{abcd}	417.76^{b}	534.12^{bc}	727.56^{ab}
T_4	84.57	196.03^{efg}	353.76^{bc}	433.56^{cde}	634.93^{bc}
T_5	92.22	135.56^{fgh}	155.09^{ef}	163.18^{gh}	184.42^{ef}
T_6	98.47	207.86^{def}	238.46^{de}	263.03^{fg}	284.75^{e}
T_7	83.35	284.26^{abc}	395.87^{bc}	517.37^{bcd}	657.34^{bc}
T_8	68.33	125.09^{gh}	144.83^{ef}	183.04^{gh}	200.05^{ef}
T_9	75.94	290.95^{abc}	365.89^{bc}	401.55^{de}	458.22^{d}
T_{10}	73.02	95.35^{h}	120.42^{f}	123.14^{h}	123.14^{f}
T_{11}	70.31	241.53^{cde}	298.95^{cd}	381.50^{ef}	470.34^{d}
T_{12}	58.22	261.38^{bcde}	358.71^{bc}	455.07^{cde}	538.03^{cd}
T_{13}	63.18	131.66^{gh}	156.72^{ef}	176.60^{gh}	176.60^{ef}
T_{14}	79.55	148.47^{fgh}	199.41^{ef}	230.40^{gh}	230.40^{ef}
T_{15}	73.27	242.17^{cde}	424.07^{b}	488.67^{cde}	741.92^{ab}
T_{16}	82.33	86.32^{h}	101.09^{f}	109.07^{h}	109.07^{f}
T_{17}	137.49	320.04^{ab}	577.46^{a}	616.32^{ab}	739.97^{ab}
CD (0.05%)		73.09	98.75	126.57	134.54

T_1 - NPK (3:1:1) 0.5%
T_2 - NPK (3:1:1) 0. 5% + GA_3
T_3 - NPK (3:1:1) 0.5% + TH
T_4 - NPK (3:1:1) 0.5% + AA
T_5 - NPK (3:1:1) 0.5% + GA_3 + TH
T_6 - NPK (3:1:1) 0. 5% + GA_3 + AA
T_7 - NPK (3:1:1) 0. 5% + TH + AA
T_8 - NPK (3:1:1) 0. 5% + GA_3 + TH +AA
T_9 - NPK (3:1:1) 1.0%
T_{10} - NPK (3:1:1) 1.0% + GA_3
T_{11} - NPK (3:1:1) 1.0% + TH
T_{12} - NPK (3:1:1) 1.0% + AA
T_{13} - NPK (3:1:1) 1.0% + GA_3 + TH
T_{14} - NPK (3:1:1) 1.0% + GA_3 + AA
T_{15} - NPK (3:1:1) 1.0% + TH + AA
T_{16} - NPK (3:1:1) 1.0% + GA_3 + TH + AA
T_{17} - Control

*TH - Thiamine, AA - Ascorbic acid

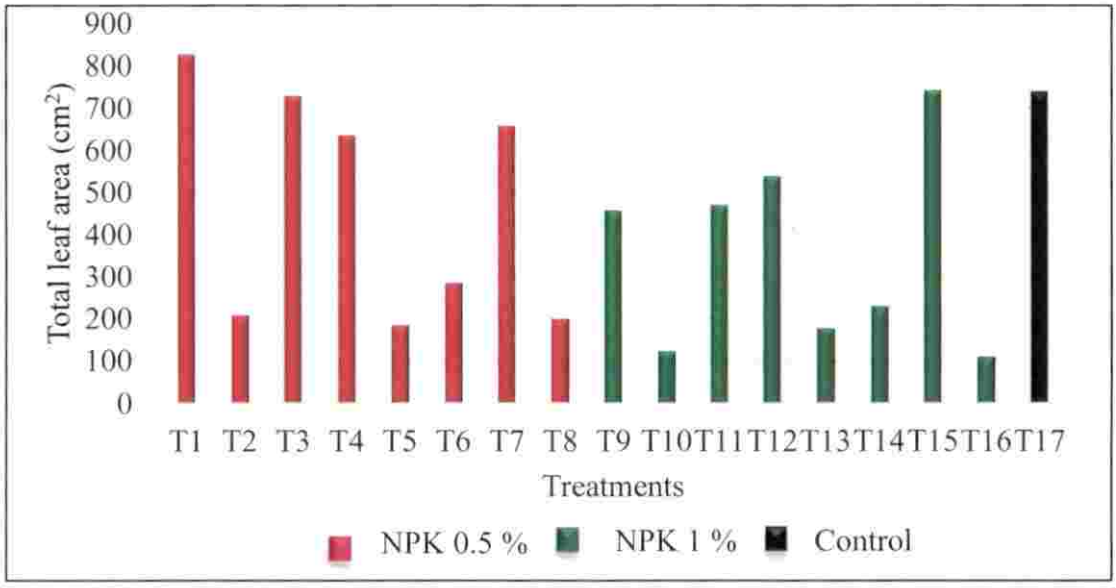


Figure 6. Effect of nutrients and growth promoters on total leaf area of mangosteen seedlings twelve months after planting

T_1 - NPK (3:1:1) 0.5%
T_2 - NPK (3:1:1) 0. 5 % + GA_3
T_3 - NPK (3:1:1) 0.5% + TH
T_4 - NPK (3:1:1) 0.5 % + AA
T_5 - NPK (3:1:1) 0.5 % + GA_3 + TH
T_6 - NPK (3:1:1) 0. 5% + GA_3 + AA
T_7 - NPK (3:1:1) 0. 5 % + TH + AA
T_8 - NPK (3:1:1) 0. 5 % + GA_3 + TH +AA
T_9 - NPK (3:1:1) 1.0%
T_{10} - NPK (3:1:1) 1.0% + GA_3
T_{11} - NPK (3:1:1) 1.0% + TH
T_{12} - NPK (3:1:1) 1.0% + AA
T_{13} - NPK (3:1:1) 1.0% + GA_3 + TH
T_{14} - NPK (3:1:1) 1.0% + GA_3 + AA
T_{15} - NPK (3:1:1) 1.0% + TH + AA
T_{16} - NPK (3:1:1) 1.0% + GA_3 + TH +AA
T_{17} - control

*TH - Thiamine, AA - Ascorbic acid

4.1.7 Total leaf area (cm^2) (3, 6, 9, 12 months after planting)

Variation in total leaf area by the application of nutrients and different growth promoters is represented in Table 7. At three months stage, T_1 (NPK (3:1:1) 0.5 %) showed the maximum total leaf area (336.02 cm^2), which was on par with T_{17} (320.04 cm^2), T_9 (290.95 cm^2), T_7 (284.26 cm^2), T_3 (274.99 cm^2). The lowest value was observed in T_{16} (86.32 cm^2).

After six months of planting, T_{17} (control plants) showed the maximum total leaf area (577.46 cm^2), which was significantly on par with T_1 (556.30 cm^2).T_{16} had the lower value (101.09 cm^2) with respect to total leaf area.

At nine months stage T_1 recorded the highest total leaf area (742.88 cm^2) followed by T_{17} (616.32 cm^2), these treatments were statistically on par with each other. The lowest value was noticed in T_{16} (109.07 cm^2) which was on par with T_{10} (123.14 cm^2)

At twelve months stage T_1 recorded the highest total leaf area (826.45 cm^2), which was on par with T_{15} (741.92 cm^2), T_{17} (739.97 cm^2) and T_3 (727.56 cm^2).The lowest value was noticed in T_{16} (109.07 cm^2).

Total leaf area was found to be higher in NPK (3:1:1) 0.5 % (T_1) throughout the study period. Increase in leaf area is positively related to the photosynthetic efficiency of the plant. From the study, it was evident that application of gibberellic acid alone or along with thiamine and ascorbic acid exhibited a lower value of total leaf area than control. Although there is an increase in plant height and internodal length in treatment combinations with GA_3, the length and breadth of leaf was found to be reduced significantly. This might have contributed to the lowest leaf area in treatments involving GA_3. This is in conformity with results of Wiebel *et al.*, (1992) that foliar application of gibberellic acid was effective in breaking bud dormancy and enhancing internodal length in mangosteen seedlings. But the leaf area was found to

be reduced by the application of plant growth regulators (GA and BA). The decrease in leaf area might be due to the diversion of nutrients including carbohydrates for stem elongation than for leaf area expansion.

4.1.8 Number of branches

No branching was observed during the study period. It could be inferred that application of plant growth promoters had no influence on branch production in mangosteen seedlings. Manoj (2011) carried out a study to analyze the effect of different plant growth promoters in accelerating the growth of mangosteen seedlings. He observed the seedlings for a period twelve months and reported that none of the treatments were able to produce branches during the observation period. Mangosteen seedlings normally requires about 26 months for producing first pair of lateral branches (Mansyah *et al.*, 2013).

4.2 Effect of nutrients and growth promoters on root characters of mangosteen seedlings (12 months after planting)

Effect of nutrients and different plant growth promoters on the root characters such as number of roots, length of longest root, root spread, shoot: root ratio are presented in Table 8.

4.2.1 Number of roots

In the case of number of roots, T_1 (NPK (3:1:1) 0.5%) had the maximum number of roots (85.67), which was significantly superior to all other treatments. This was followed by the control with an average of 61.33 number of roots. Lowest number of roots were observed in T_8 (NPK (3:1:1) 0. 5 % + GA_3 300 ppm + thiamine 100 ppm + ascorbic acid 100 ppm) with 10.00 number of roots, which was on par with T_{16} (13), T_{14} (14.67), T_{10} (16), T_5 (21.67).

Rapid root development is essential for growth and development of any plant species. Mangosteen has very poor root system consisting of a slender tap root and few

T_6 - NPK (3:1:1) 0. 5 % + GA_3 300 ppm + AA 100 ppm

T_4 - NPK (3:1:1) 0.5 % + Ascorbic acid 100 ppm

Plate 3. Effect of nutrients and growth promoters on height of mangosteen seedlings

Control

T_1 - NPK 0.5 %

Plate 4. Effect of nutrients and growth promoters on spread of mangosteen seedlings

laterals. The root system is highly fragile also. Absence of root hairs is another feature. Hence, any treatment that can improve the root branching and root spread is critical for accelerating the growth and establishment of the plant. In the present study, it was found that the number of roots was significantly higher for T_1 (NPK 3:1:1 0. 5 %) when compared to its higher concentration (1 per cent). Perhaps, foliar nutrition of major nutrients *viz*. N, P and K at 0.5 % was optimum for maintaining carbon balance, root development and plant growth. The higher concentration of NPK 3:1:1 at 1 %, was probably inhibitory for the production of more number of roots. In this context, the soil nutrient status of N, P and K also should be taken into consideration, which recorded a medium rating for N and K and high for P. This might be the reason for the better performance with regard to the number of roots in lower NPK concentration and also in control. Plants sprayed with combination of various growth regulator and vitamins also recorded poor performance even than control with respect to number of roots. This might be due to the stress caused by the combination of various nutrients and growth promoters given simultaneously through foliar spray to the seedlings. Brain *et al.* (1960) revealed that even if gibberellin was effective in stem elongation, it reduces rooting in different varieties of pea plants. It may be also due the distribution of essential plant metabolites for extending the shoot portion. Effect of gibberellins on apical shoot growth and basal root production were found to be competitive and opposite in nature. There are reports that gibberellic acid reduces root growth, root: shoot ratio (Little and loach, 1975).

4.2.2 Length of longest root (cm)

There was no significant difference with respect to length of longest root. Even though the maximum length of root was observed in T_3 (26.07 cm) followed by T_1 (25.50 cm).The lowest value (14.57 cm) was recorded by T_{13} (NPK (3:1:1) 1.0% + GA_3 300 ppm + thiamine 100 ppm).

4.2.3 Root spread (cm)

Root spread varied significantly among the treatments. T_1 (NPK (3:1:1) 0.5%) showed the maximum root spread of 24.77 cm, which was on par with T_3 (23.30 cm). The lowest value was recorded by T_8 (5.10 cm) followed by T_{10} (6.75 cm), these treatments were on par statistically.T_1 (NPK (3:1:1) 0.5%), T_3 (NPK (3:1:1) 0.5% + thiamine 100 ppm), were found to be the two superior treatments with respect to root spread. It is not only the length of the root that determine the growth and establishment of a plant. Root branching and root spread are important factors that determine the contact of roots with the growing medium, which ultimately decide water and nutrient absorption and thereby growth of plants. The present study revealed that the root spread was significantly high in T_1 (NPK (3:1:1) 0.5%), which was on par with T_3 (NPK (3:1:1) 0.5% + thiamine 100 ppm). N, P and K are inevitable mineral nutrients for the root growth of plants. Thiamine act as a growth factor for the roots (Krampitz, 1969). Foliar application of thiamine at 50 ppm on *Syngonium podophyllum* L. resulted 37.6 % increase with respect to root length (Abdel-Aziz, 2007). Sepahvand *et al.* (2012) also reported that thiamine along with IBA was found to be best for rooting in GF677 (peach ×almond hybrid) in *in-vitro* condition.

4.2.4 Shoot: root ratio

At twelve months stage shoot root ratio varied from 1.60 to 4.64. The treatment T_6 recorded the maximum value (4.64) followed by T_{12} (4.20), T_3 (4.36), T_4 (4.31), T_1 (4.26), T_{17} (4.14), T_7 (3.95), T_8 (3.67) and these treatments were significantly on par with each other. The lowest value (1.60 cm) was noticed in T_{16} (NPK (3:1:1) 1.0% + GA_3 300 ppm + thiamine 100 ppm + ascorbic acid 100 ppm). Shoot: root ratio indicates the relative growth of shoot and root portions in terms of fresh weight, which differed significantly at twelve months after planting. Even though fresh weight of whole plant was low in T_6, shoot: root ratio was found to be high in the same treatment. This is due to the low fresh weight of the root portion compared to the shoot portion.

Table 8. Effect of nutrients and growth promoters on root characters of mangosteen seedlings (12 months after planting)

Treatments	No. of roots Per plants	Length of the longest root(cm)	Root spread(cm)	Shoot: root ratio
T_1	85.67^{a}	25.50	24.77^{a}	4.26^{abc}
T_2	30.00^{fg}	19.83	9.35^{de}	2.27^{fg}
T_3	55.33^{bcd}	26.07	23.30^{a}	4.36^{ab}
T_4	45.00^{cde}	19.73	18.60^{b}	4.31^{abc}
T_5	21.67^{gh}	20.20	11.07^{d}	2.59^{efg}
T_6	34.00^{efg}	15.13	15.60^{bc}	4.64^{a}
T_7	58.00^{bc}	24.43	15.50^{bc}	3.95^{abc}
T_8	10.00^{h}	15.77	5.10^{f}	3.67^{abcd}
T_9	45.33^{cde}	19.20	$17.80b^{c}$	3.45^{bcde}
T_{10}	16.00^{h}	14.90	6.75^{ef}	1.93^{fg}
T_{11}	57.6^{7bc}	21.17	15.50^{bc}	3.50^{bcde}
T_{12}	$42.33d^{ef}$	25.70	15.00^{c}	4.20^{abc}
T_{13}	34.00^{efg}	14.57	15.57^{bc}	2.62^{efg}
T_{14}	14.67^{h}	17.27	11.07^{d}	2.65^{def}
T_{15}	47.33^{cde}	22.20	15.35^{bc}	3.31^{cde}
T_{16}	13.00^{h}	22.63	11.50^{d}	1.60^{g}
T_{17}	61.33^{b}	23.37	18.70^{b}	4.14^{abc}
CD ((0.05%)	13.46	NS	3.47	1.02

T_1 - NPK (3:1:1) 0.5%
T_2 - NPK (3:1:1) 0. 5% + GA_3
T_3 - NPK (3:1:1) 0.5% + TH
T_4 - NPK (3:1:1) 0.5% + AA
T_5 - NPK (3:1:1) 0.5% + GA_3 + TH
T_6 - NPK (3:1:1) 0. 5% + GA_3 + AA
T_7 - NPK (3:1:1) 0. 5% + TH + AA
T_8 - NPK (3:1:1) 0. 5% + GA_3 + TH +AA
T_9 - NPK (3:1:1) 1.0%
T_{10} - NPK (3:1:1) 1.0% + GA_3
T_{11} - NPK (3:1:1) 1.0% + TH
T_{12} - NPK (3:1:1) 1.0% + AA
T_{13} - NPK (3:1:1) 1.0% + GA_3 + TH
T_{14} - NPK (3:1:1) 1.0% + GA_3 + AA
T_{15} - NPK (3:1:1) 1.0% + TH + AA
T_{16} - NPK (3:1:1) 1.0% + GA_3 + TH + AA
T_{17} - Control

*TH – Thiamine, AA – Ascorbic acid

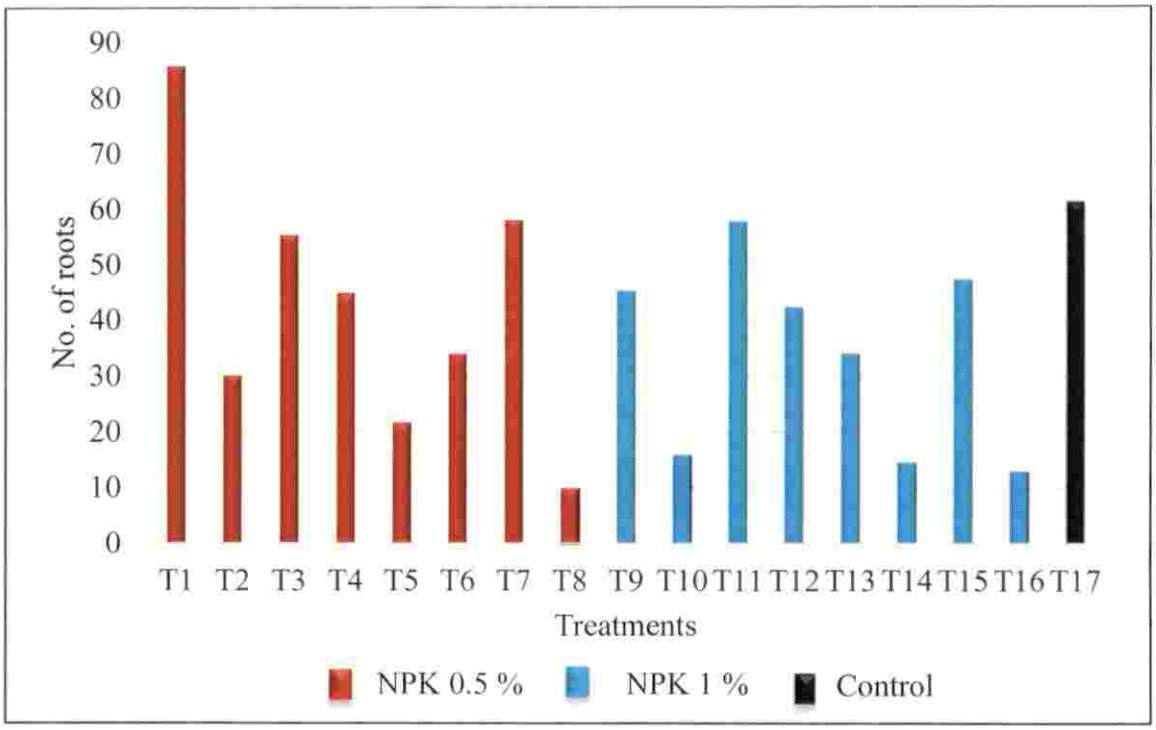


Figure 7. Effect of nutrients and growth promoters on number of roots of mangosteen seedlings twelve months after planting

T_1 - NPK (3:1:1) 0.5%
T_2 - NPK (3:1:1) 0. 5 % + GA_3
T_3 - NPK (3:1:1) 0.5% + TH
T_4 - NPK (3:1:1) 0.5 % + AA
T_5 - NPK (3:1:1) 0.5 % + GA_3 + TH
T_6 - NPK (3:1:1) 0. 5% + GA_3 + AA
T_7 - NPK (3:1:1) 0. 5 % + TH + AA
T_8 - NPK (3:1:1) 0. 5 % + GA_3 + TH +AA
T_9 - NPK (3:1:1) 1.0%
T_{10} - NPK (3:1:1) 1.0% + GA_3
T_{11} - NPK (3:1:1) 1.0% + TH
T_{12} - NPK (3:1:1) 1.0% + AA
T_{13} - NPK (3:1:1) 1.0% + GA_3 + TH
T_{14} - NPK (3:1:1) 1.0% + GA_3 + AA
T_{15} - NPK (3:1:1) 1.0% + TH + AA
T_{16} - NPK (3:1:1) 1.0% + GA_3 + TH +AA
T_{17} - control

*TH - Thiamine, AA - Ascorbic acid

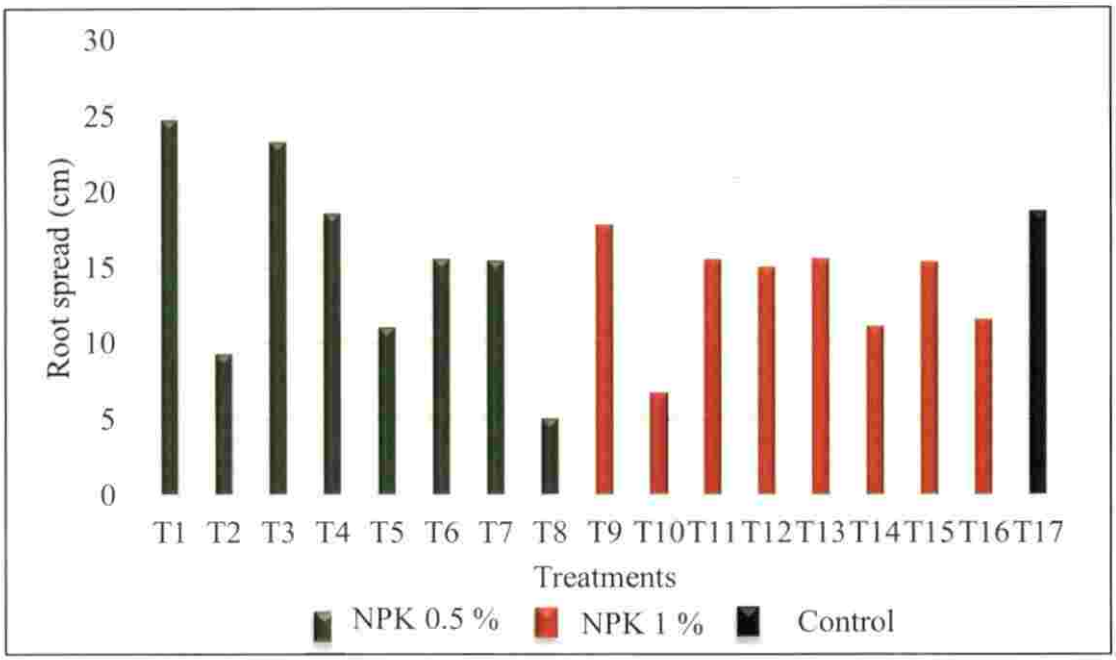


Figure 8. Effect of nutrients and growth promoters on root spread of mangosteen seedlings twelve months after planting

T_1 - NPK (3:1:1) 0.5%
T_2 - NPK (3:1:1) 0. 5 % + GA_3
T_3 - NPK (3:1:1) 0.5% + TH
T_4 - NPK (3:1:1) 0.5 % + AA
T_5 - NPK (3:1:1) 0.5 % + GA_3 + TH
T_6 - NPK (3:1:1) 0. 5% + GA_3 + AA
T_7 - NPK (3:1:1) 0. 5 % + TH + AA
T_8 - NPK (3:1:1) 0. 5 % + GA_3 + TH +AA
T_9 - NPK (3:1:1) 1.0%
T_{10} - NPK (3:1:1) 1.0% + GA_3
T_{11} - NPK (3:1:1) 1.0% + TH
T_{12} - NPK (3:1:1) 1.0% + AA
T_{13} - NPK (3:1:1) 1.0% + GA_3 + TH
T_{14} - NPK (3:1:1) 1.0% + GA_3 + AA
T_{15} - NPK (3:1:1) 1.0% + TH + AA
T_{16} - NPK (3:1:1) 1.0% + GA_3 + TH +AA
T_{17} - control

*TH - Thiamine, AA - Ascorbic acid

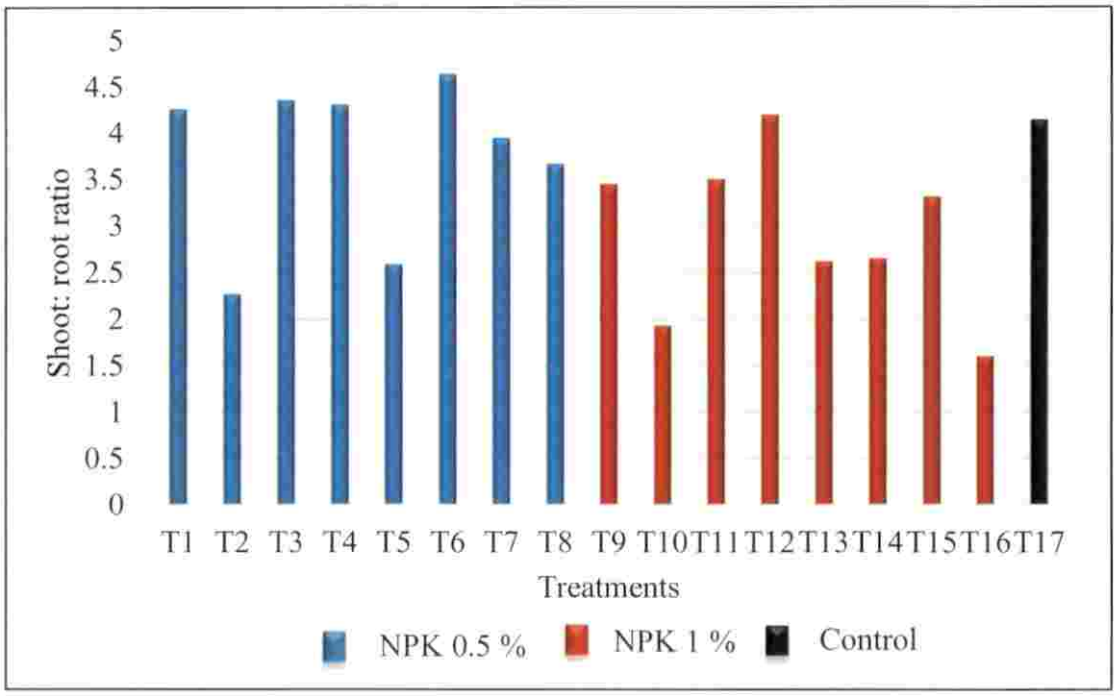


Figure 9. Effect of nutrients and growth promoters on shoot: root ratio of mangosteen seedlings twelve months after planting

T_1 - NPK (3:1:1) 0.5%
T_2 - NPK (3:1:1) 0. 5 % + GA_3
T_3 - NPK (3:1:1) 0.5% + TH
T_4 - NPK (3:1:1) 0.5 % + AA
T_5 - NPK (3:1:1) 0.5 % + GA_3 + TH
T_6 - NPK (3:1:1) 0. 5% + GA_3 + AA
T_7 - NPK (3:1:1) 0. 5 % + TH + AA
T_8 - NPK (3:1:1) 0. 5 % + GA_3 + TH +AA
T_9 - NPK (3:1:1) 1.0%
T_{10} - NPK (3:1:1) 1.0% + GA_3
T_{11} - NPK (3:1:1) 1.0% + TH
T_{12} - NPK (3:1:1) 1.0% + AA
T_{13} - NPK (3:1:1) 1.0% + GA_3 + TH
T_{14} - NPK (3:1:1) 1.0% + GA_3 + AA
T_{15} - NPK (3:1:1) 1.0% + TH + AA
T_{16} - NPK (3:1:1) 1.0% + GA_3 + TH +AA
T_{17} - control

*TH - Thiamine, AA - Ascorbic acid

4.2.5 Number of root hairs

No root hairs were observed till twelve months stage. So it is clear that application of growth promoters along with nutrient solution is not capable for producing root hairs in mangosteen seedlings. Rukayah and Zaebedah, (1992) also got the same result that no root hairs were present in mangosteen seedlings during early stages of growth.

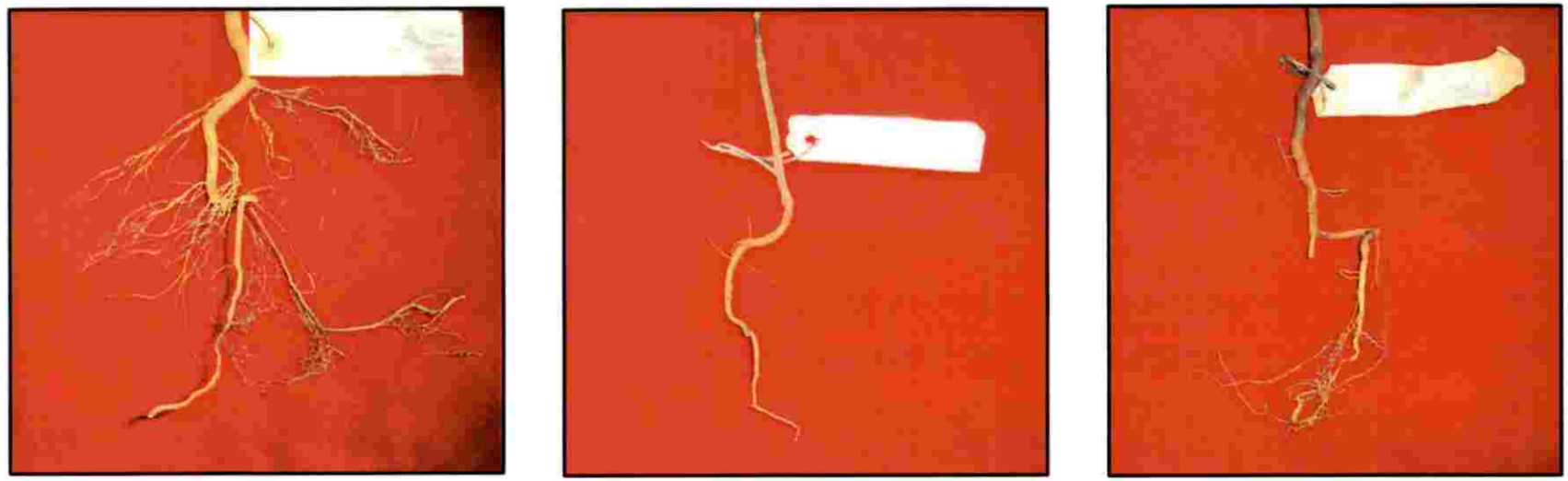
4.3 Effect of nutrients and growth promoters on physiological characters

4.3.1 Fresh and dry weight (g/plant)

During twelve months stage, the plants differed significantly with respect to fresh weight and dry weight (Table 9). In the case of fresh weight of whole plants T_1 (NPK (3:1:1) @ 0.5%) recorded the maximum value (24.48 g), which significantly differed from all other treatments including control plants. Plants received the treatment T_{10} (NPK (3:1:1) 1.0% + GA_3 300 ppm) had the lowest fresh weight (3.62 g), which was statistically on par with T_{16} (4.07 g), T_2 (4.63 g), T_8 (5.83 g), T_{14} (5.93 g), T_5 (6.31 g), T_{13} (6.81 g) (Fig. 4).

In the case dry weight of the plants the treatment T_1 (NPK (3:1:1) 0.5%) had the highest dry weight (9.83 g), which was significantly superior from all other. The lowest dry weight (1.46 g) was noticed in T_{10} (NPK (3:1:1) 1.0% + GA_3 300 ppm), followed by T_{16} (1.70 g), T_8 (2.03 g), T_2 (2.06 g), T_{14} (2.10 g), T_{13} (2.20 g), T_5 (2.26 g), these treatments were on par statistically (Fig. 4).

Plant weight in terms of both fresh and dry weight is a designation of overall growth of the plant. Both fresh and dry weight of the plant differed significantly at twelve months stage. T_1 (NPK (3:1:1) 0.5%) recorded the highest value in terms of fresh and dry weight of the plants. It might be due to the fact that NPK fertilization at optimum concentration had a positive impact on overall growth of the plants (Al-mukthar *et al.*, 1987; Khalid and sheheed, 2015).

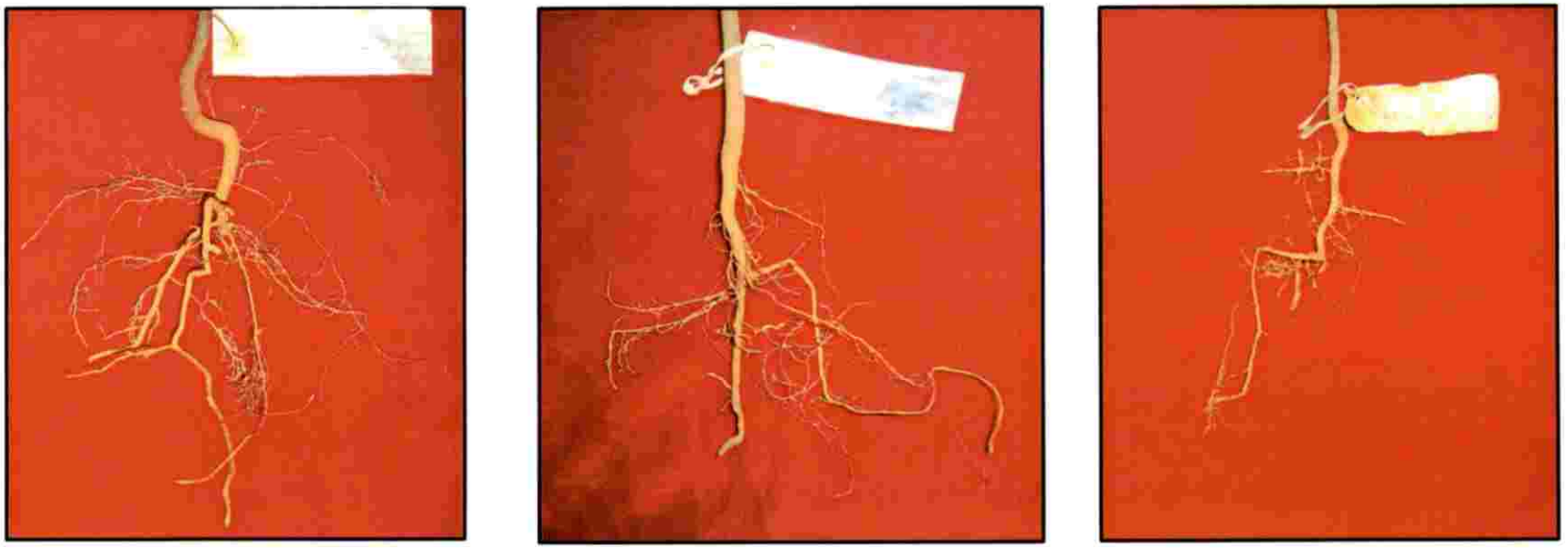


T_1 - NPK 0.5 %

T_8 - NPK 0.5 % + GA3 100 ppm + Thiamine 100ppm + Ascorbic acid 100 ppm

T_{17} - Control

Plate 5. Effect of nutrients and growth promoters on number of roots of mangosteen seedlings (12 MAP)



T_1 - NPK 0.5 %	T_3 - NPK 0.5 % + Thiamine 100 ppm	T_{17} - Control

Plate 6. Effect of nutrients and growth promoters on root spread of mangosteen seedlings (12 MAP)

Table 9. Effect of nutrients and growth promoters on fresh and dry weight of mangosteen seedlings

Treatments	Fresh weight (g/plant)	Dry weight (g/plant)
T_1	24.48^{a}	9.83^{a}
T_2	4.63^{gh}	2.06^{h}
T_3	17.63^{b}	6.78^{bc}
T_4	18.74^{b}	7.70^{b}
T_5	6.31^{gh}	2.26^{gh}
T_6	9.70^{ef}	3.30^{fg}
T_7	16.92^{bc}	6.26^{cd}
T_8	5.83^{gh}	2.03^{h}
T_9	13.57^{d}	4.47^{ef}
T_{10}	3.62^{h}	1.46^{h}
T_{11}	12.86^{d}	4.40^{ef}
T_{12}	14.66^{cd}	6.52^{bcd}
T_{13}	6.81^{fg}	2.20^{gh}
T_{14}	5.93^{gh}	2.10^{h}
T_{15}	12.53^{de}	5.53^{de}
T_{16}	4.07^{gh}	1.70^{h}
T_{17}	17.81^{b}	7.16^{bc}
CD (0.05%)	2.89	1.18

T_1 - NPK (3:1:1) 0.5%
T_2 - NPK (3:1:1) 0. 5% + GA_3
T_3 - NPK (3:1:1) 0.5% + TH
T_4 - NPK (3:1:1) 0.5% + AA
T_5 - NPK (3:1:1) 0.5% + GA_3 + TH
T_6 - NPK (3:1:1) 0. 5% + GA_3 + AA
T_7 - NPK (3:1:1) 0. 5% + TH + AA
T_8 - NPK (3:1:1) 0. 5% + GA_3 + TH +AA
T_9 - NPK (3:1:1) 1.0%
T_{10} - NPK (3:1:1) 1.0% + GA_3
T_{11} - NPK (3:1:1) 1.0% + TH
T_{12} - NPK (3:1:1) 1.0% + AA
T_{13} - NPK (3:1:1) 1.0% + GA_3 + TH
T_{14} - NPK (3:1:1) 1.0% + GA_3 + AA
T_{15} - NPK (3:1:1) 1.0% + TH + AA
T_{16} - NPK (3:1:1) 1.0% + GA_3 + TH + AA
T_{17} - Control

*TH – Thiamine, AA - Ascorbic acid

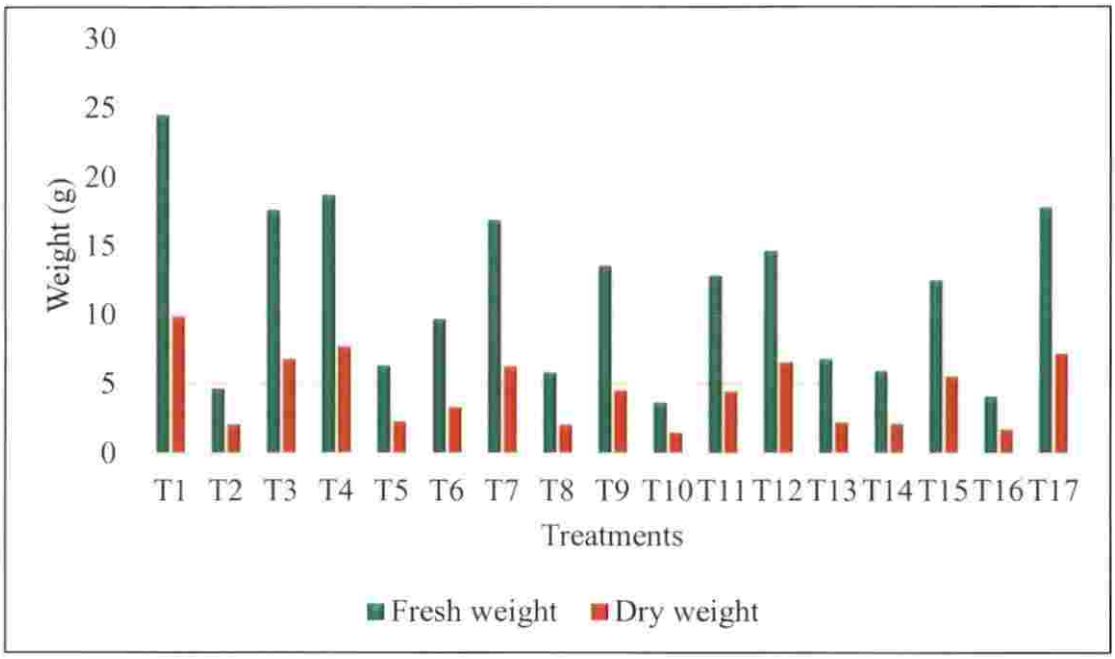


Figure 10. Effect of nutrients and growth promoters on fresh and dry weight of mangosteen seedlings twelve months after planting

T_1 - NPK (3:1:1) 0.5%
T_2 - NPK (3:1:1) 0. 5 % + GA_3
T_3 - NPK (3:1:1) 0.5% + TH
T_4 - NPK (3:1:1) 0.5 % + AA
T_5 - NPK (3:1:1) 0.5 % + GA_3 + TH
T_6 - NPK (3:1:1) 0. 5% + GA_3 + AA
T_7 - NPK (3:1:1) 0. 5 % + TH + AA
T_8 - NPK (3:1:1) 0. 5 % + GA_3 + TH +AA
T_9 - NPK (3:1:1) 1.0%
T_{10} - NPK (3:1:1) 1.0% + GA_3
T_{11} - NPK (3:1:1) 1.0% + TH
T_{12} - NPK (3:1:1) 1.0% + AA
T_{13} - NPK (3:1:1) 1.0% + GA_3 + TH
T_{14} - NPK (3:1:1) 1.0% + GA_3 + AA
T_{15} - NPK (3:1:1) 1.0% + TH + AA
T_{16} - NPK (3:1:1) 1.0% + GA_3 + TH +AA
T_{17} - control

*TH - Thiamine, AA - Ascorbic acid

4.3.2 Leaf Area Index (LAI)

Effect of nutrients and different plant growth promoting substances on Leaf Area Index (LAI) is given in Table 10. LAI varied significantly throughout the study period.

From Table 10, it is clear that though T_1 (NPK (3:1:1) 0.5%) showed the maximum value (1.48) for LAI, many treatments including control had statistically comparable value at 3 months after planting.

Treatment T_{17} (control plants) showed the highest value (2.54) at six months after planting, which was on par with T_1 (2.45).The lowest value (0.44), was observed in T_{16} (NPK (3:1:1) 1.0% + GA_3 300 ppm + thiamine 100 ppm + ascorbic acid) which was on par with T_{10}, T_8, T_5, T_{13}, T_2, T_{14}.

During nine months after planting, T_1 showed the maximum value (3.27) for LAI, followed by T_{17} (2.72) and these treatments were statistically on par with each other.T_{16} recorded the lowest value (0.48) for LAI. The treatments T_{10}, T_5, T_{13}, T_8, T_2 and T_{14} were statistically on par with each other.

At twelve months stage also the treatment T_1 (NPK (3:1:1) 0.5%) was superior with LAI of 3.64, which was on par with T_{15} (3.27), T_{17} (3.26) and T_3 (3.21). The lowest value was observed in T_{16} (NPK (3:1:1) 1.0% + GA_3 300 ppm+ thaimine 100 ppm +ascorbic acid 100 ppm) having LAI of 0.48.

Leaf Area Index (LAI) is the leafiness per ground area of a plant and it is an indication of the photosynthetic capacity. In the present study though T_1 (NPK (3:1:1) 0.5%) showed higher LAI during the entire study period it was comparable to LAI of control plants. A similar trend was observed in terms of total leaf area also. This is because of the fact that there was no significant difference in number of leaves per plant between these treatments. This is in accordance with result of Manoj (2011) that foliar spray of NPK (3:1:1) 0.5% on mangosteen seedlings recorded the highest Leaf Area Index. Higher LAI is an indication for higher dry matter production by the plants. In

cotton plants net photosynthesis of the plants increased with increase in LAI to 3 to 4 (Ludwig *et al.*, 1965).

4.4 Nutrient (N, P, and K) uptake by the plants

Data regarding the nutrient (N, P and K) uptake by the plants twelve months after planting is presented in Table 11. Treatments differed significantly with respect to N, P and K uptake at the end of twelve months. Nutrient uptake by the plant was computed by using nutrient content and dry weight of the respective plant samples. Nutrient content of plants under each treatments are given in Appendix 1.

Nitrogen uptake was the highest (190.10 mg/plant) in T_1 (NPK (3:1:1) 0.5%), which was significantly superior to all other treatment. This might be due to the higher dry weight as well as higher N content in seedlings treated with NPK (3:1:1) 0.5%. The lowest uptake (29.81 mg/ plant) of nitrogen could be seen in T_{10} (NPK (3:1:1) 1% + GA3 300 ppm), which was on par with T_{16}, T_{10}, T_2, T_{13}, T_{14}, T_8, T_5, T_6. Foliar application of NPK (3:1:1) 0.5% (T_1) alone resulted in greater absorption of nitrogen and it might be due to the fact that plants could able to absorb nutrients without any inhibition. Nitrogen is a major constituent of chlorophyll molecule, higher concentration of nitrogen in leaves is an indication of efficient photosynthesis (Haboudane *et al*, 2002).

The phosphorus uptake was highest (5.01 mg plant $^{-1}$) in T_4 (NPK (3:1:1) 0.5% + ascorbic acid 100 ppm), which was statistically on par with T_{12} (4.29 mg plant $^{-1}$). The lowest value (1.46 mg plant $^{-1}$) was noticed in T_{13}, which was on par with T_{10}, T_2, T_3, T_{16}, and T_{14}.

In the case of potassium, higher uptake (120.23 mg plant $^{-1}$) was noticed in T_4 (NPK (3:1:1) 0.5% + ascorbic acid 100 ppm), which was on par with T_3 (103.74 mg plant $^{-1}$) and T_1 (102.66 mg plant $^{-1}$). The lowest value (19.02 mg plant $^{-1}$) of K uptake was noticed in T_{10}, which was on par with T_{13}, T_8, T_{16}, T_5, T_2, T_{14}, and T_6.

Eventhough the potting media had medium range (320.48 kg/ha) of available nitrogen and potassium (211.79 kg/ha), foliar spray of NPK (1 per cent) alone and in combination with other plant growth promoting substances showed significantly lower nitrogen and potassium uptake. This might be because of the stress condition experienced by the plants under these treatments for absorbing nutrients from the potting media. Available phosphorus content was found to be high in the potting media, higher phosphorus uptake was recorded in treatments T_4 (NPK (3:1:1) 0.5 % + ascorbic acid 100 ppm) and T_{12} (NPK (3:1:1) 1.0% + ascorbic acid 100 ppm). All other treatments showed significantly lower value with respect to phosphorus uptake.

Higher uptake of phosphorus and potassium in T_4 (NPK (3:1:1) 0.5 % + ascorbic acid 100 ppm) may be because of the action of ascorbic acid on releasing organic acids from the roots of plants into the soil. These organic acids enhance the solubility of nutrients in the rhizosphere and make it available to the plants (Hanafy-Ahmed, 1995). Nahed *et al.*, (2009) reported that foliar spray of ascorbic acid at 100 ppm and 200 ppm on gladiolus had a stimulatory effect on increasing the uptake of major nutrients. Similar effect was also observed in *Syngonum podophyllum* by the application of ascorbic acid 100 ppm (Abdel-Aziz *et al.*, 2007). In sweet pepper also foliar application of ascorbic acid enhanced the content of major nutrients (Talaat, 2003).

Table 10. Effect of nutrients and growth promoters on Leaf Area Index (LAI) of mangosteen seedlings

Treatments	At the time of planting	3 months	6 months	9 months	12 months
T_1	0.52	1.48^{a}	2.45^{a}	3.27^{a}	3.64^{a}
T_2	0.43	0.67^{fgh}	0.78^{efg}	0.84^{gh}	0.92^{ef}
T_3	0.42	1.21^{abcd}	1.84^{b}	2.35^{bc}	3.21^{ab}
T_4	0.37	0.86^{efg}	1.56^{bc}	1.91^{cde}	2.80^{bc}
T_5	0.41	0.60^{fgh}	0.68^{efg}	0.72^{gh}	0.81^{ef}
T_6	0.43	0.92^{def}	1.05^{de}	1.16^{fg}	1.25^{e}
T_7	0.37	1.25^{abc}	1.75^{bc}	2.28^{bcd}	2.90^{bc}
T_8	0.30	0.55^{gh}	0.64^{efg}	0.81^{gh}	0.88^{ef}
T_9	0.34	1.28^{abc}	1.61^{bc}	1.77^{de}	2.02^{d}
T_{10}	0.32	0.42^{h}	0.53^{fg}	0.54^{h}	0.54^{f}
T_{11}	0.31	1.06^{cde}	1.31^{cd}	1.68^{ef}	2.08^{d}
T_{12}	0.26	1.15^{bcde}	1.58^{bc}	2.01^{cde}	2.37^{cd}
T_{13}	0.28	0.58^{gh}	0.69^{efg}	0.78^{gh}	0.78^{ef}
T_{14}	0.35	0.65^{fgh}	0.88^{def}	1.02^{gh}	1.02^{ef}
T_{15}	0.32	1.07^{cde}	1.87^{b}	2.15^{cde}	3.27^{ab}
T_{16}	0.36	0.38^{h}	0.44^{g}	0.48^{h}	0.48^{f}
T_{17}	0.61	1.41^{ab}	2.54^{a}	2.72^{ab}	3.26^{ab}
CD (0.05%)		0.32	0.43	0.55	0.59

T_1 - NPK (3:1:1) 0.5%
T_2 - NPK (3:1:1) 0. 5% + GA_3
T_3 - NPK (3:1:1) 0.5% + TH
T_4 - NPK (3:1:1) 0.5% + AA
T_5 - NPK (3:1:1) 0.5% + GA_3 + TH
T_6 - NPK (3:1:1) 0. 5% + GA_3 + AA
T_7 - NPK (3:1:1) 0. 5% + TH + AA
T_8 - NPK (3:1:1) 0. 5% + GA_3 + TH +AA
T_9 - NPK (3:1:1) 1.0%
T_{10} - NPK (3:1:1) 1.0% + GA_3
T_{11} - NPK (3:1:1) 1.0% + TH
T_{12} - NPK (3:1:1) 1.0% + AA
T_{13} - NPK (3:1:1) 1.0% + GA_3 + TH
T_{14} - NPK (3:1:1) 1.0% + GA_3 + AA
T_{15} - NPK (3:1:1) 1.0% + TH + AA
T_{16} - NPK (3:1:1) 1.0% + GA_3 + TH + AA
T_{17} - Control

*TH - Thiamine, AA - Ascorbic acid

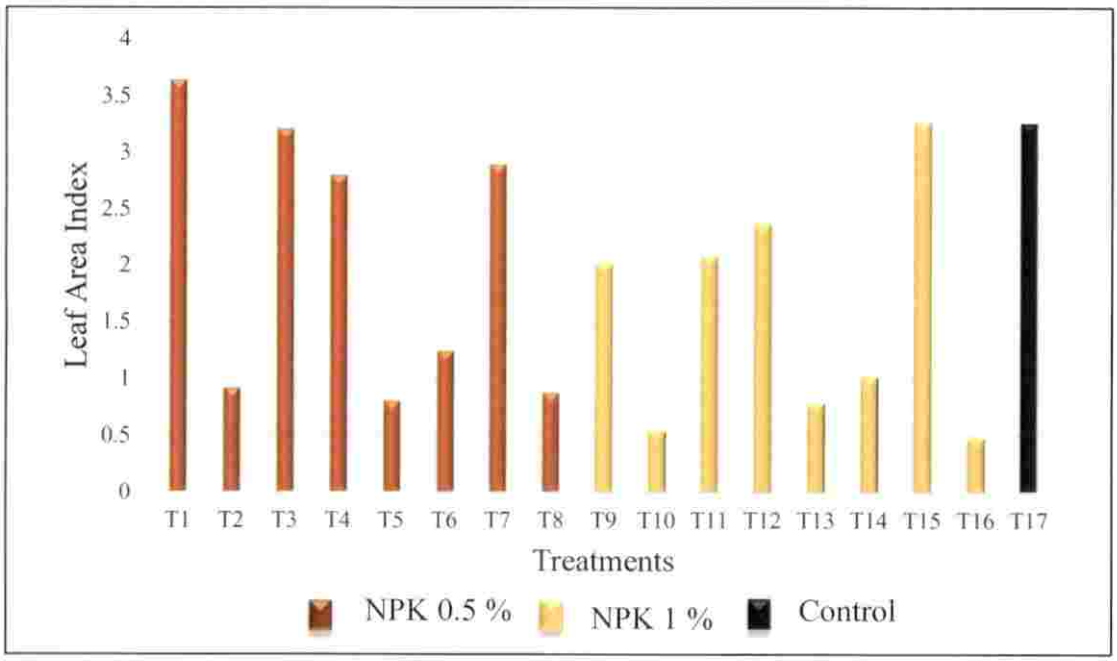


Figure 11. Effect of nutrients and growth promoters on LAI of mangosteen seedlings twelve months after planting

T_1 - NPK (3:1:1) 0.5%
T_2 - NPK (3:1:1) 0. 5 % + GA_3
T_3 - NPK (3:1:1) 0.5% + TH
T_4 - NPK (3:1:1) 0.5 % + AA
T_5 - NPK (3:1:1) 0.5 % + GA_3 + TH
T_6 - NPK (3:1:1) 0. 5% + GA_3 + AA
T_7 - NPK (3:1:1) 0. 5 % + TH + AA
T_8 - NPK (3:1:1) 0. 5 % + GA_3 + TH +AA
T_9 - NPK (3:1:1) 1.0%
T_{10} - NPK (3:1:1) 1.0% + GA_3
T_{11} - NPK (3:1:1) 1.0% + TH
T_{12} - NPK (3:1:1) 1.0% + AA
T_{13} - NPK (3:1:1) 1.0% + GA_3 + TH
T_{14} - NPK (3:1:1) 1.0% + GA_3 + AA
T_{15} - NPK (3:1:1) 1.0% + TH + AA
T_{16} - NPK (3:1:1) 1.0% + GA_3 + TH +AA
T_{17} - control

*TH - Thiamine, AA - Ascorbic acid

Table 11. Effect of nutrients and growth promoters on nutrient uptake (mg/plant) by mangosteen seedlings

Treatments	N uptake	P uptake	K uptake
T_1	190.10^{a}	3.45^{bcd}	102.66^{ab}
T_2	32.81^{f}	1.54^{f}	28.83^{fg}
T_3	97.58^{de}	1.57^{f}	103.74^{ab}
T_4	140.47^{b}	5.01^{a}	120.23^{a}
T_5	45.68^{f}	1.93^{ef}	25.12^{fg}
T_6	49.22^{f}	2.29^{ef}	32.98^{fg}
T_7	83.83^{e}	4.07^{bc}	66.55^{de}
T_8	43.58^{f}	2.03^{ef}	23.67^{fg}
T_9	80.33^{e}	1.99^{ef}	58.57^{de}
T_{10}	29.81^{f}	1.46^{f}	19.02^{g}
T_{11}	90.08^{de}	2.85^{de}	47.35^{ef}
T_{12}	134.18^{bc}	4.29^{ab}	93.20^{bc}
T_{13}	37.81^{f}	1.44^{f}	23.15^{g}
T_{14}	40.15^{f}	1.78^{f}	29.71^{fg}
T_{15}	111.35^{cd}	3.58^{bcd}	81.38^{bcd}
T_{16}	31.71^{f}	1.70^{f}	23.69^{fg}
T_{17}	109.17^{d}	3.26^{cd}	72.59^{cd}
CD (0.05%)	23.22	0.91	24.14

T_1 - NPK (3:1:1) 0.5%
T_2 - NPK (3:1:1) 0. 5% + GA_3
T_3 - NPK (3:1:1) 0.5% + TH
T_4 - NPK (3:1:1) 0.5% + AA
T_5 - NPK (3:1:1) 0.5% + GA_3 + TH
T_6 - NPK (3:1:1) 0. 5% + GA_3 + AA
T_7 - NPK (3:1:1) 0. 5% + TH + AA
T_8 - NPK (3:1:1) 0. 5% + GA_3 + TH + AA
T_9 - NPK (3:1:1) 1.0%
T_{10} - NPK (3:1:1) 1.0% + GA_3
T_{11} - NPK (3:1:1) 1.0% + TH
T_{12} - NPK (3:1:1) 1.0% + AA
T_{13} - NPK (3:1:1) 1.0% + GA_3 + TH
T_{14} - NPK (3:1:1) 1.0% + GA_3 + AA
T_{15} - NPK (3:1:1) 1.0% + TH + AA
T_{16} - NPK (3:1:1) 1.0% + GA_3 + TH + AA
T_{17} - Control

*TH - Thiamine, AA - Ascorbic acid

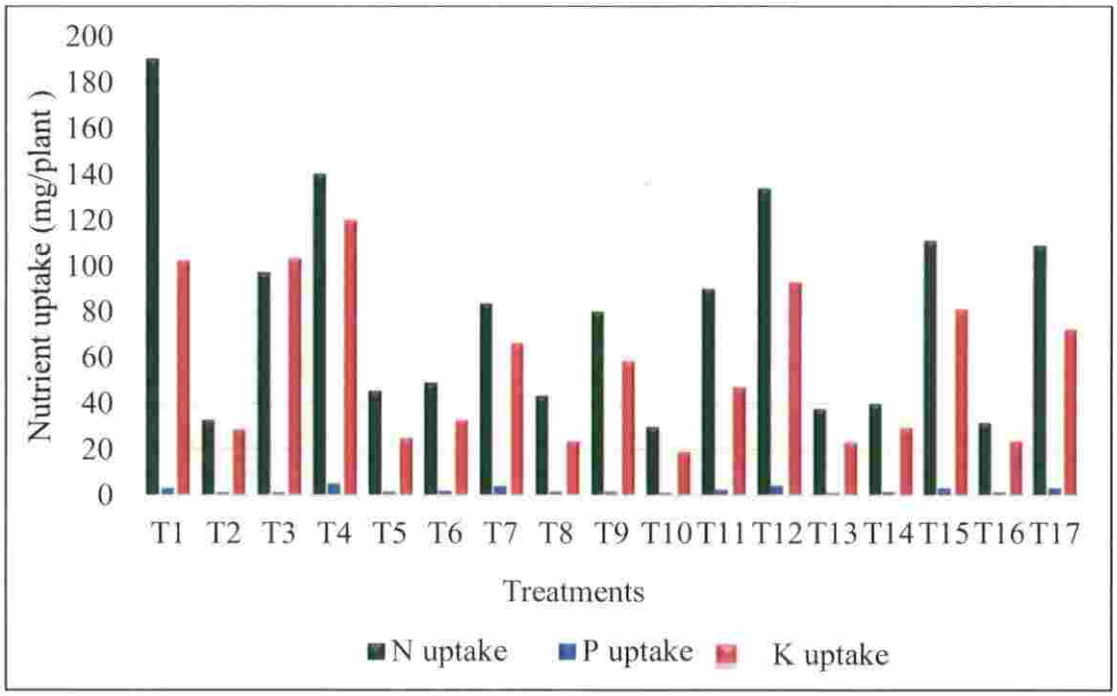


Figure 12. Effect of nutrients and growth promoters on nutrient uptake of mangosteen seedlings twelve months after planting

T_1 - NPK (3:1:1) 0.5%
T_2 - NPK (3:1:1) 0. 5 % + GA_3
T_3 - NPK (3:1:1) 0.5% + TH
T_4 - NPK (3:1:1) 0.5 % + AA
T_5 - NPK (3:1:1) 0.5 % + GA_3 + TH
T_6 - NPK (3:1:1) 0. 5% + GA_3 + AA
T_7 - NPK (3:1:1) 0. 5 % + TH + AA
T_8 - NPK (3:1:1) 0. 5 % + GA_3 + TH +AA
T_9 - NPK (3:1:1) 1.0%
T_{10} - NPK (3:1:1) 1.0% + GA_3
T_{11} - NPK (3:1:1) 1.0% + TH
T_{12} - NPK (3:1:1) 1.0% + AA
T_{13} - NPK (3:1:1) 1.0% + GA_3 + TH
T_{14} - NPK (3:1:1) 1.0% + GA_3 + AA
T_{15} - NPK (3:1:1) 1.0% + TH + AA
T_{16} - NPK (3:1:1) 1.0% + GA_3 + TH +AA
T_{17} - control

*TH - Thiamine, AA - Ascorbic acid

From the study it could be inferred that foliar application of NPK (3:1:1) 0.5% was sufficient to enhance the growth of mangosteen seedlings. Plant spread, length of the leaf, number of roots, root spread, fresh eight, dry weight and nitrogen uptake were found to be higher in this treatment compared to other treatments. No significant increase in growth was observed at higher concentration of nutrients alone and in combination with plant growth promoters like GA_3, thiamine or ascorbic acid. Eventhough plant height and internodal length were found to be higher in plants treated with gibberellic acid, other growth parameters such as leaf area, leaf length, leaf breadth and root parameters were found to be reduced with the application of gibberellic acid.

Summary

5. SUMMARY

The present study on "Standardization of growth promoters for mangosteen (*Garcinia mangostana* L.) seedlings" was carried out in the Department of Fruit Science, College of Horticulture, Vellanikkara during 2018 - 2019 with the objective of identifying the ideal combination of growth promoters for accelerating the growth of mangosteen seedlings. For the study six month old seedlings were planted in eight inch size pots containing soil + sand + vermicompost (2:1:1) media. Planting was done during the month of April 2018.

The experiment was laid out in CRD with seventeen treatments replicated thrice. Treatments included NPK (3:1:1) at 0.5 and 1% along with gibberellic acid (300 ppm), thiamine (100 ppm), ascorbic acid (100 ppm) and the combination of this three. Treatments were applied as foliar spray at monthly intervals during the entire study period (2018 April to 2019 April). Observations on vegetative characters, root characters, physiological parameters were noted at 3, 6, 9, 12 months after planting.

The major findings of the study are summarised as follows:

- Foliar application of nutrients and growth promoters significantly influenced the plant height. Plants receiving treatment NPK (3:1:1) 0. 5 % + GA_3 300 ppm + ascorbic acid 100 ppm (T_6) recorded the highest plant height of 33.32 cm at the end of twelve months, which was on par with NPK (3:1:1) 0. 5 % + GA_3 300 ppm (T_2) and NPK (3:1:1) 1.0% + GA_3 300 ppm + ascorbic acid 100 ppm (T_{14}). Seedlings which received GA_3 spray were found to be taller throughout the study period.
- Internodal length also followed similar trend that of plant height. Application of growth promoters had a significant effect on internodal length. NPK (3:1:1)

0. 5 % + GA_3 300 ppm + ascorbic acid 100 ppm (T_{16}) recorded the highest internodal length at twelve months after planting.

- Plant spread also varied significantly due to nutrients and growth regulator application. Among the treatments NPK (3:1:1) 0. 5 % (T_1) showed the highest plant spread (34.27 cm).
- Foliar application of growth promoters had no significant effect on number of leaves produced in the seedlings. Control plants recorded the highest number of leaves at twelve months after planting, which was on par with NPK (3:1:1) 0. 5 % (T_1).
- NPK (3:1:1) 0. 5 % (T_1) was found to be the best treatment with regard to leaf length and breadth. Significantly lowest leaf length and breadth of was noticed in NPK (3:1:1) 1% + GA_3 (300 ppm) thiamine + ascorbic acid (100 ppm) (T_{16}). In general, treatments involving GA_3 showed lower leaf length and breadth.
- Total leaf area and Leaf Area Index (LAI) differed significantly among the treatments. The highest total leaf area and LAI was recorded in T_1 (NPK (3:1:1) 0.5 %), which was on par with control plants. The lowest leaf area and LAI was found in T_{16} (NPK (3:1:1) 1 % + gibberellic acid 300 ppm+ thiamine 100 ppm + ascorbic acid 100 ppm) among the treatments. In general there was reduction in the total leaf area observed in all treatments that containing GA_3 (300 ppm).
- Branching was not observed during the study period.
- Considering the root characters, NPK (3:1:1) 0. 5 % (T_1) recorded highest value (85.67) of number of roots twelve months after planting. Lowest number of roots were found in NPK (3:1:1) 1 % + gibberellic acid 300 ppm + thiamine 100 ppm + ascorbic acid 100 ppm (T_{16}).
- No significant difference was observed among the treatments with respect to length of the longest root.
- No root hairs were observed even twelve months after planting.

- NPK (3:1:1) 0. 5 % (T_1) and NPK (3:1:1) 0. 5 % + thiamine 100 ppm were the two superior treatments in terms of root spread. The lowest root spread was observed in plants treated with NPK (3:1:1) 0.5 % + gibberellic acid 300 ppm + thiamine 100 ppm + ascorbic acid 100 ppm (T_8).
- Among the treatments, shoot: root ratio was significantly higher for NPK (3:1:1) 0. 5 % + GA_3 300 ppm + ascorbic acid 100 ppm (T_6), NPK (3:1:1) 0.5 % + thiamine 300 ppm (T_3) and NPK (3:1:1) 0.5 % (T_1), these were on par with control.
- Considering the fresh weight and dry weight of seedlings, treatments differed significantly twelve months after planting. In the case of fresh weight NPK (3:1:1) 0. 5 % (T_1) showed significantly higher value (24.48 g). The lowest fresh weight was observed in plants treated with NPK (3:1:1) 0.5 % + gibberellic acid 300 ppm + thiamine 100 ppm + ascorbic acid 100 ppm (T_{16}). In the case of dry weight also NPK (3:1:1) 0. 5 % (T_1) was found to be superior among the treatments, twelve months of planting.
- Considering the uptake of major nutrients *viz.* N, P and K, treatments showed significant variation among the treatments. Nitrogen uptake was found to be highest in NPK (3:1:1) 0. 5 % (T_1), while phosphorus and potassium uptake was recorded higher in plants under NPK (3:1:1) 0. 5 % + ascorbic acid 100 ppm (T_4).
- Among the different treatments tried in the present experiment, NPK (3:1:1) 0. 5 % (T_1) was found to be superior with respect to plant spread, length of leaf, number of roots, root spread, fresh weight, dry weight and nitrogen uptake of plants. Foliar application of NPK (3:1:1) 1 % in combination with growth promoters reduced the overall growth of the seedlings. From the study, it could be inferred that foliar application of NPK (3:1:1) 0. 5 % is adequate for enhancing the growth of mangosteen seedlings.

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Appendices

Appendix 1: Nutrient content (%) of mangosteen seedlings twelve months after planting)

Treatments	N (%)	P (%)	K (%)
T_1	1.96	0.04	1.09
T_2	1.61	0.08	1.42
T_3	1.47	0.03	1.65
T_4	1.89	0.07	1.64
T_5	2.03	0.09	1.20
T_6	1.54	0.08	1.01
T_7	1.4	0.07	1.09
T_8	2.17	0.10	1.21
T_9	1.82	0.05	1.35
T_{10}	2.1	0.10	1.38
T_{11}	2.1	0.07	1.15
T_{12}	2.1	0.07	1.59
T_{13}	1.75	0.07	1.09
T_{14}	1.96	0.09	1.54
T_{15}	2.03	0.07	1.20
T_{16}	1.89	0.10	1.55
T_{17}	1.54	0.05	1.02

STANDARDIZATION OF GROWTH PROMOTERS FOR MANGOSTEEN (*Garcinia mangostana* L.) SEEDLINGS

By

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ABSTRACT OF THE THESIS

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ABSTRACT

Mangosteen (*Garcinia mangostana* L.) is a promising fruit crop for Kerala due to high price and consumer demand. Slow growth of the seedlings and prolonged pre bearing period are the major factors limiting large scale cultivation of mangosteen. In this context, the present study entitled "Standardization of growth promoters for mangosteen (*Garcinia mangostana* L.) seedlings" was carried out in the Department of Fruit Science, College of Horticulture, Vellanikkara during 2018 to 2019. The main objective of the study was to identify the ideal combination of plant growth promoters for enhancing the growth of mangosteen seedlings. The experiment was laid out in CRD with seventeen treatments replicated thrice. In each replication ten plants were maintained per treatment. Six month old seedlings planted in eight inch pots containing a medium composed of soil + sand + vermicompost in 2:1:1 ratio. Foliar application of NPK mixture (3:1:1) at 0.5 % and 1 % and growth promoters such as GA_3 (300 ppm), thiamine (100 ppm), ascorbic acid (100 ppm) were given at monthly intervals during the entire study period (April 2018 to April 2019). Observations on growth characters, root characters, physiological parameters were recorded periodically at different stages of the study.

Growth characters such as plant height, plant spread, number of leaves, length and breadth of leaves, total leaf area and internodal length, number of branches were recorded at quarterly intervals upto twelve months after planting. Significant difference was observed among the treatments with respect to plant height and taller seedlings (33.32 cm) with the longest internode (9.44 cm) were observed in T_6 (NPK (3:1:1) 0. 5 % + GA_3 300 ppm + ascorbic acid 100 ppm. Better plant spread (34.27 cm) was observed in seedlings sprayed with NPK (3:1:1) 0. 5 % (T_1). Application of plant growth promoters had no effect on number of leaves produced by mangosteen seedlings. Control plants recorded the highest number of leaves (15.11), which was statistically on par with NPK (3:1:1) 0. 5 % (T_1). Leaf length was found to be

superior in T1 (NPK (3:1:1) 0. 5 %) at twelve months after planting. However, breadth and total leaf area and Leaf Area Index (LAI) were not influenced by foliar application of nutrients and growth promoters. In general, there was a reduction in all leaf parameters such as number of leaves, leaf length, breadth, total leaf area and LAI in treatments involving GA_3. Application of growth promoters could not induce branching in mangosteen seedlings during the period of study.

Total number of roots (85.67) was the highest in T_1 (NPK (3:1:1) 0. 5 %). Length of the longest root did not show any significant difference among the treatments. However, root spread differed significantly. NPK (3:1:1) 0. 5 % (T_1) and NPK (3:1:1) 0. 5 % + thiamine 100 ppm (T_3) were the two superior treatments with respect to root spread. Treatments involving GA_3 alone and in combination with other growth promoters had an inhibitory effect on root growth and development. Shoot: root ratio was found to be higher (4.64) in T_6 (NPK (3:1:1) 0. 5 % + GA_3 300 ppm + ascorbic acid 100 ppm) which was on par with control plants. Root hairs were absent in the plants even after twelve months of planting.

Highest fresh weight (24.48 g/plant) and dry weight (9.83 g/plant) were noticed in T_1 (NPK (3:1:1) 0. 5 %). Plants were analysed for major nutrients (N, P and K) twelve months after planting. Nitrogen, phosphorus and potassium content in the seedlings ranged from 1.4 % - 2.17 %, 0.03 % - 0.10 % and 1.01 % - 1.65 % respectively. Highest nitrogen uptake (190.10 mg/plant) was found in seedlings applied with NPK (3:1:1) 0. 5 % (T_1). Higher uptake of phosphorus (5.01 mg/plant) and potassium (120.23 mg/plant) was recorded in T_4 (NPK (3:1:1) 0. 5 % + ascorbic acid 100 ppm).

The study clearly indicated that foliar application of NPK (3:1:1) 0.5 % (T_1) at monthly intervals can be recommended for enhancing the growth of mangosteen seedlings, as superior growth parameters were observed in this treatment. No significant increase in seedling growth was noticed with the foliar spray of NPK 1%.