# STUDIES ON SEED GERMINATION AND SUBSEQUENT SEEDLING GROWTH OF PAPAYA (*Carica papaya* L.) cv. PUSA NANHA

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**(FRUIT SCIENCE)**

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**ANANTHARAJUPET - 516 105, Y.S.R DISTRICT, ANDHRA PRADESH**

**Dr. Y.S.R. HORTICULTURAL UNIVERSITY**

**JULY, 2014**

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**BY**

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**B.Sc. (Hons.) Horticulture**


**THESIS SUBMITTED TO**

**Dr.Y.S.R. HORTICULTURAL UNIVERSITY IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF**

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**(FRUIT SCIENCE)**



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**JULY, 2014**

# DECLARATION

**I, Ms. CH. PRATIBHA,** hereby declare that the thesis entitled "**STUDIES ON SEED GERMINATION AND SUBSEQUENT SEEDLING GROWTH OF PAPAYA (*Carica papaya* L.) cv. PUSA NANHA"** submitted to Dr. Y.S.R. Horticultural University, Venkataramannagudem, for the Degree of **Master of Science in Horticulture** (FRUIT SCIENCE) is the result of original research work done by me. I declare that no material contained in the thesis has been published earlier in any manner.

**Place:** ANANTHARAJUPET

**Date:**

**Name: CH. PRATIBHA**

**ID.No: AHM/12-09**

## CERTIFICATE

**Ms. CH. PRATIBHA** has satisfactorily prosecuted the course of research and that the thesis entitled **"STUDIES ON SEED GERMINATION AND SUBSEQUENT SEEDLING GROWTH OF PAPAYA (*Carica papaya* L.) cv. PUSA NANHA"** submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination.

I certify that neither the thesis nor its part there of has been previously submitted by her for a degree of any University.

Date: **(Dr. K. SWARAJYA LAKSHMI)**

Place: ANANTHARAJUPET MAJOR ADVISOR

# CERTIFICATE

This is to certify that the thesis entitled **"STUDIES ON SEED GERMINATION AND SUBSEQUENT SEEDLING GROWTH OF PAPAYA (*Carica papaya* L.) cv. PUSA NANHA"** submitted in partial fulfillment of the requirements for the degree **MASTER OF SCIENCE IN HORTICULTURE (Fruit Science)** of **Dr.Y.S.R. Horticultural University, Venkataramannagudem**, is a record of the bonafide research work carried out by **Ms. CH. PRATIBHA** under our guidance and supervision.

No part of the thesis has been submitted by the student for any other degree or diploma. The published part and all the assistance received during the course of the investigations have been duly acknowledged by the author of the thesis.

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***(Ch. Pratibha)***

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# LIST OF SYMBOLS AND ABBREVIATIONS

| | | |
|---|---|---|
| % | : | per cent |
| hrs | : | hours |
| $^0$C | : | degree centigrade |
| L | : | litre |
| CD | : | Critical difference |
| cm | : | Centimeter |
| cv. | : | cultivar |
| M | : | molar |
| mM | : | milli molar |
| $cm^2$ | : | square centimeter |
| *et al*., | : | and others |
| g | : | gram |
| mg | : | milligram |
| $GA_3$ | : | Gibberellic acid |
| $KNO_3$ | : | Potassium Nitrate |
| *i.e.* | : | that is |
| mm | : | millimeter |
| MT | : | metric tonnes |
| ha | : | hectare |
| ppm | : | parts per million |
| RBD | : | Randomised Block Design |
| RH | : | relative humidity |
| SE(m) | : | Standard error mean |
| *viz.,* | : | namely |
| HRS | : | Horticulture research station |
| VAM | : | Vesicular Arbuscular Mycorrhiza |
| PSB | : | Phosphate solubilising Bacteria |
| FYM | : | Farm Yard Manure |

| | | |
|---|---|---|
| etc | : | and so on; and other people/ things |
| pp | : | page number |
| Var. | : | Variety |
| F-test | : | Fishers test |
| No. | : | Number |

| | | |
|---|---|---|
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# ABSTRACT

The present investigation entitled "Studies on seed germination and subsequent seedling growth of papaya (*Carica papaya* L.) cv. Pusa Nanha" was carried out at Horticultural College and Research Institute, Anantharajupet during the year, 2013-14. The experiment was laid out in randomized block design replicated thrice with the objective to study the "Effect of chemical treatments and different growing medias on seed germination and subsequent seedling vigour of papaya (*Carica papaya* L.) cv. Pusa Nanha."

The results indicated that maximum root length and root dry weight and the dry weight of the seedlings were recorded in seed treatment with $GA_3$ 200 ppm for 24 hrs. Whereas, maximum petiole diameter was observed in seed treatment with $GA_3$ 300 ppm for 12 hrs.

The early seed germination, maximum germination percentage, germination index, plant height, number of leaves, number of nodes, leaf area, seedling girth, petiole length, shoot dry weight, vigour index, fresh and dry weight of seedling along with the highest cost benefit ratio were recorded in seed treatment with $GA_3$ 300 ppm for 24 hrs.

The maximum germination percentage, early seed germination, germination index and leaf area were recorded in substrate combination of FYM + Cocopeat + Vermicompost + Soil + Sand (60% + 10% + 10% + 10% + 10%). Whereas, maximum root length and root dry weight was observed in substrate combination of FYM + Cocopeat + Vermicompost + Soil + Sand (10% + 10% + 60% + 10% + 10%) along with the biofertilizer mixture (*Azospirillum*, PSB and *Frateuria aurantia*).

The maximum plant height, number of leaves, number of nodes, seedling girth, petiole length, petiole diameter, shoot dry weight of seedling, fresh weight of seedling, dry weight of seedling and vigour index with the highest cost benefit ratio was recorded in substrate combination of FYM + Cocopeat +

Vermicompost + Soil + Sand (60% + 10% + 10% + 10% + 10%) along with the biofertilizer mixture (*Azospirillum*, PSB and *Frateuria aurantia*).

# Chapter-I

# *Introduction*

# Chapter I

# INTRODUCTION

Papaya (*Carica papaya* Linn.) is an important fruit crop of tropical world and has long been known as wonder fruits of the tropics. It gives higher production of fruits per hectare and income next to banana (Singh, 1990). It belongs to the family Caricaceae and is native of Tropical America (Hofmeyr, 1945). It was introduced into India in the 16$^{th}$ century. It is grown in almost all tropical and subtropical countries of the world and occupies a unique place amongst the fruit crops grown in India. In India it is grown in an area of 132.2 million ha with an annual production of 5381.7 MT/ha and productivity 40.7 MT/ha. In Andhra Pradesh the area is 20.65 million ha with an annual production of 1651.96 MT and productivity 80.0 MT/ ha. (NHB, 2012-13).

The important papaya growing countries in the world other than India are Australia, Hawaii, Brazil, Malaysia, Burma, Sri Lanka and Kenya. In India this crop is cultivated in Andhra Pradesh, Maharashtra, Gujarat, Karnataka, Madhya Pradesh, Bihar, West Bengal, Tamil Nadu, Kerala, Assam and Rajasthan. These states provide ideal climatic conditions for its growth and production. The leading producer of papaya in India is Andhra Pradesh followed by Gujarat, Maharashtra and West Bengal. Papaya has gained popularity during recent years due to its ease of cultivation, wide range of adaptability to diverse soil and climatic conditions, increased demand of fruits, papain and quick returns per unit area.

Papaya is a rich source of carbohydrates, minerals and vitamins. Fruit has gained importance in human diet because of its striking nutritional and medicinal value. Immature fruits of papaya are rich source of papain and proteolytic enzyme which is helpful in protein digestion, tenderizing meat and for medicinal and industrial purpose. Mature fruits are being utilized in the preparation of candy or tutti frutti and ripe fruits are also used in the preparation of ready to serve, jam, fruit bar, ice-cream, soft drinks, flavoring crystallized fruit and syrup etc.

Propagation of papaya is only through seeds as a viable option. The germination of papaya seeds is slow, erratic and incomplete (Chacko and Singh, 1966). The seed is enclosed within a gelatinous sarcotesta (aril or outer seed coat which is formed from the outer integument).Whilst this sarcotesta is reported to prevent germination (Yahiro, 1979). The slow and asynchronous germination is attributed due to the presence of inhibitors (mainly phenolic compounds) in the sarcotesta and seed coat (chow and lin, 1991 and Reyes *et al*. 1980). In addition to inhibitor substances about 20% of papaya seeds are embryoless (Nagao and Furutani, 1986). Dormancy is also observed in seeds from which sarcotesta has been removed (Tokuhisa, 2007). Therefore, freshly extracted seeds are normally cleaned to remove the sarcotesta and washed in running tap water and pre-soaked in various plant growth regulators to enhance the germination percentage and seedling vigour (Chia, 1990). In view of several treatments in improving the seed germination this study was taken up to know the role of different chemicals on seed germination and subsequent seedling vigour.

Commercially papaya is grown from transplants, because of the high cost of seed. Initial growth of papaya seedling is slow and has low competitive ability with weeds (Morales-Payan and Stall, 1997). A papaya transplant is considered ready to be planted in the field when it is 20 cm in height with stem thickness of 1 cm in diameter, with at least four true leaves (Morales-Payan, 1998 and Nishina *et al*. 2000). Papaya transplant production usually takes 35 to 45 days from seedling emergence (Moles-Payan, 1998 and Nishina *et al*. 2000) and transplant quality can be effected by factors such as plant growth regulators, nutrients and substrates (Palmer-Rannie *et al.* 2002). Media composition influences seed germination and quality of the seedlings (Wilson, 2001). A good growth medium provides sufficient anchorage to the plant, serves as a reservoir for nutrients and water, allows oxygen diffusion to the roots (Abad, 2002). The papaya seeds when sown in various substrates along with biofertilizers enhanced seed germination and over all plant performance (Alarcon *et al*. 2002). However, biofertilizers are inputs containing microorganisms which are capable of mobilizing nutritive elements from non usable form to usable form through biological processes (Athani, 2009).

In India, papaya growers (Farmers and Nursery men) produce transplants in a substrate mixture which include soil, FYM and sand. However, there was a limited information on different combination of substrates which can produce healthy and vigorous seedling in India. Hence, the objective of present investigation was to assess possibility of improving seed germination and seedling growth in papaya with the help of different chemicals and substrates along with the biofertilizers.

**Objectives:**

1. To study the effect of seed treatment chemicals on seed germination and subsequent seedling vigour of papaya cv. Pusa Nanha.
2. To study the effect of different subtrates and biofertilizers on seed germination and subsequent seedling vigour of papaya cv. Pusa Nanha.

# Chapter-II

# *Review of Literature*

# Chapter II

# REVIEW OF LITERATURE

Papaya is mainly propagated through seeds. The seeds are covered with sarcotesta, a whitist succulent and translucent material which has been reported to delay germination. The freshly extracted seeds exhibit dormancy when sown immediately and gave only 6% germination (Koyamu, 1951) and papaya growers face many problems in germination due to presence of inhibitors in sarcotesta and seed coat and high seedling mortality due to low growth, low competitive ability of seedlings to weed growth in the nursery. Therefore, attempts were made to accelerate the seed germination and seedling vigour in papaya through the use of some presowing treatments and different substrate combinations along with biofertilizers. Keeping this interest in view, the relevant information on these aspects in papaya as well as in other fruit crops has been reviewed and presented in this chapter.

## 2.1 Effect of seed treatment chemicals on seed germination

Arumugam and Shanmugavelu (1975) revealed that, papaya seeds had the maximum seed germination (94%) when the seeds were treated with 100 ppm thiourea and (92%) with 200 ppm thiourea for 16 hrs.

Hundal and Khajura (1979) reported that, seeds of matchless and sarbati cultivars of peach soaked in $GA_3$ 200 ppm for 24 hrs resulted in highest germination whereas, the cultivars Khurmani and Sufeda recorded better germination in seeds soaked in 5000 and 7000 ppm thiourea for 24 hrs.

Choudhari and Chakrawar (1981) studied the effect of some chemicals on the germination of Kagzi lime seeds and reported that seeds soaked in 40 ppm $GA_3$ and 40 ppm NAA for 12 hrs resulted in highest germination (40.83% and 32.50 % respectively).

Srivastava *et al*. (1984) reported that, sapodilla seeds treated with $GA_3$ 50 ppm had the maximum germination followed by 1 % $KNO_3$ and 1 % thiourea.

Hore and Sen (1985) reported that in Bael seed germination was highest when seeds were treated with $GA_3$ 100 ppm (51.66%) and found to be superior over the untreated seeds.

Rodrfquez *et al*. (1986) stated that, highest seed germination was observed in guava when the seeds were soaked in water for 4 days followed by 24 hrs soaking in 1000 ppm $GA_3$.

Mike *et al*. (1988) conducted experiment on improving germination of papaya seed by density separation, potassium nitrate and gibberellic acid and reported that rate of seedling emergence and germination percentage (87.8 %) was highest in 1.0 M $KNO_3$ treatment followed by 600 ppm $GA_3$ treatment (80.5%).

Ghosh and Sen (1988) studied the effect of seed treatment on germination, seedling growth and longevity of ber seeds and reported that seeds treated with 100 ppm $GA_3$ recorded maximum germination percentage followed by 1% $KNO_3$ treated seeds.

Bal *et al*. (1990) studied the effect of growth regulators and stratification periods on seed germination and seedling growth in wild pear and concluded that 1500 ppm thiourea recorded maximum seed germination (91.7%) followed by 50 ppm $GA_3$ (89.5%).

Chandra and Govind (1990) studied the effect of gibberellic acid, thiourea, ethrel treatments on seed germination of guava and noticed that seeds soaked in 3000 ppm $GA_3$ recorded highest germination (83.2%) followed by seeds soaked in water (80.1%).

Dhankhar and Singh (1996) reported that aonla seeds treated with $GA_3$ 250 ppm and thiourea 250 ppm for 72 hrs showed the significant influence on early germination .

Pawashe *et al*. (1997) revealed that, custard apple seeds had early and highest seed germination when seeds were treated with gibberellic acid 100 ppm for 24 hrs over water soaking for 24 hrs.

Ananthakalaisevi and Dharmalingam (1998) stated that papaya seeds soaked in 100 ppm $GA_3$ solution for 16 hrs showed better germination as compared to untreated seeds.

Padma and Reddy (1998) observed that germination starts earlier and gave highest germination percentage when mango stones were soaked in 0.5 % $KNO_3$ for 24 h.

Helail *et al*. (1999) in their studies on the effect of some pre-sowing treatments on seed germination and growth of papaya, reported that zinc sulphate (1000ppm), $GA_3$ (500ppm) or NAA (100ppm) enhanced germination and reduced the time required to attain 50% germination.

Pandit *et al*. (2001) opined that papaya seeds gave the highest germination under the $GA_3$treatment (2.0mM).

Rajamanickam and Anbu (2001) studied the effect of biofertilizers and growth regulators on seed germination and seedling vigour of aonla and revealed that seeds treated with 200 ppm $GA_3$ for 8 hrs reduced the number of days taken for germination (6.80 days) where as maximum germination percentage (69.33 %) was recorded with 0.5 % KNO3 for 8 hours.

In jackfruit the seeds soaked in 100 ppm gibberellic acid for 24 hrs recorded maximum germination percentage (98.0%) when compared to control. (Maiti *et al*. 2003)

Gunes and Gubbuk (2006) studied the effect of different presowing treatments on seed germination of different papaya cultivars (Sunrise Solo, Red Lady, Tainung, SS-45, BH-65 and Sel- 42) and reported that pretreatment with 250 ppm GA3 for 24 hrs was the best for germination percentage and germination time in Sunrise Solo, Red Lady and Tainung. Soaking of seeds in hot water gave the best result for both seed germination percentage and germination times in SS-45, BH-65 and Sel-42. They also reported that cv. Red Lady seeds treated with 750 ppm GA3 for 24 hrs had the highest germination percentage (97.78%).

Yogeesha *et al*. (2007) conducted experiment on effect of temperature and chemical pre-treatment on seed germination of papaya cultivars ('Surya', 'CO 2' and 'CO 7) and observed that soaking seeds in $GA_3$ at 200 ppm for 48 hrs before sowing greatly improved the germination. $GA_3$ at 200 ppm was found effective at $25^0$C in all cultivars with germination of 85.0, 69.3 and 75.0% in 'Surya', 'CO 2' and 'CO 7' cultivars respectively**.**

Anburani and Shakila (2010) stated that, papaya seeds soaked in $GA_3$ 200 ppm for 12 hrs reduced the time taken for 50% germination (20 days) compared to control.

Babu *et al*. (2010) observed that papaya seeds treated with 100 ppm $GA_3$ increased the germination percentage (66.17%) and also reduced the time taken for germination (29.73 days).

Deb *et al.* (2010) observed that maximum seed germination of papaya (72.2%) was recorded in seeds treated with $GA_3$ at 100 ppm and found superior over the other treatements

Barche *et al.* (2010) reported that, papaya seeds when treated with $GA_3$ 500 ppm for 12 hrs observed the maximum germination (78.50%) and minimum days required for completion of germination (15 days) over control.

Gharge *et al*. (2011) reported that custard apple seeds treated with 500 ppm $GA_3$ for 24 h resulted in early seed germination (18.10 days after sowing) in custard apple.

Padma *et al*. (2013) conducted an experiment on effect of seed treatments to enhance seed viability in papaya cv. Surya and revealed that highest germination (93%) was recorded in 300 ppm $GA_3$ for 12 h followed by 2% $KNO_3$ for 24 h ( 91%).

### 2.1.1 Effect of seed treatment chemicals on seedling vigour

Randhawa and Negi (1964) observed that grape seedlings treated with $GA_3$ 200 ppm for 24 hrs recorded maximum seedling height (24.75 cm) followed by thiourea 0.5% for 24 hrs.

Singh *et al*. (1979) studied the citrus seed germination affected by some chemicals and stated that the seedling attain 9.90 cm height at 100 days of germination with 3000 ppm $KNO_3$ in Jambheri and 15.50 cm in Karna Khatta by the use of $GA_3$ 1000 ppm and maximum dry weight (2.060 g) is obtained when treated with 2000 ppm gibberellic acid for 24 hrs.

Hore and Sen (1985) observed that, bael seed treatment with gibberellic acid 100 ppm for 24 hrs recorded maximum seedling height, stem diameter, fresh weight of seedling and more number of leaves per plant.

Begum *et al*. (1987) found that, papaya seedling had the maximum seedling height and fresh weight when seeds treated with gibberellic acid 100 ppm for 24 hrs when compared to other chemicals.

Palanisamy and Ramamoorthy (1987) reported that presoaking of papaya seeds with GA 100 ppm was found to be effective in breaking the dormancy and recorded maximum root length (16.0 cm), shoot length (6.8 cm) and dry weight of the seedling (0.036 g ) as compared to other chemicals and untreated control.

Singh *et al.* (1989) reported that mosambi seeds treated with 600 ppm $GA_3$ increased the height of seedling (6.05 to 9.23 cm) and number of leaves per plant (9.24 to 13.10).

Chandra and Govind (1990) recorded maximum seedling height (13.15 cm) and more number of leaves per plant (16.70) when guava seeds treated with 3000 ppm $GA_3$.

Ghanta *et al.* (1995) revealed that, papaya seeds treated with potassium nitrate 1.0M recorded maximum plant height, stem girth, number of leaves as compared to water soaking treatment.

Ananthakalaiselvi and Dharmalingam (1998) reported that, papaya seeds treated with 100 ppm $GA_3$ for 16 hrs recorded the maximum plant height, dry matter and root length (4.1 cm) in 14 days old papaya seedlings which was superior over water soking for 16 hrs and untreated seeds.

Pampanna and Sulikeri (1999) studied the growth of sapota seedlings influenced by presowing seed treatment with growth regulators and found that seeds soaked in 400 ppm $GA_3$ resulted in highest shoot length (10.65 cm), root length (6.73) and more number of leaves per seedling (6.62).

Vincent and Thandapani (2000) studied the effect of storage containers and growth regulators on seed performance of papaya and reported that seeds treated with GA 200 ppm recorded highest vigour index (1339) and dry matter production (160mg per 10 seedlings) compared to control.

Dabhi *et al.* (2000) studied the effect of $GA_3$, kinetin and thiourea on seed germination and seedling growth of aonla and reported that seeds treated with 200 ppm $GA_3$ found most effective in increasing seedling height (23.26 cm).

Gholap *et al*. (2000) studied the effect of plant growth regulators seedling growth of aonla and revealed that 200 ppm $GA_3$ was found significantly superior with respect to seedling height (27.63 cm), stem girth of seedlings (0.86 cm) and number of roots per seedlings (24.00) followed by thiourea 200 ppm.

Pandit *et al*. (2001) reported that papaya seeds gave maximum plant height, more number of leaves and dry weight (0.800 g) when treated with $GA_3$ (2.0mM) compared to control.

Ratan and Reddy (2004) reported that custard apple seeds treated with $GA_3$ 400ppm for 12 hrs recorded the longer roots (12.23 cm) where as maximum leaf area (93.33 $cm^2$) followed by thiourea 0.5%.

Anburani and Shakila (2010) studied the influence of seed treatment on the seedling growth of papaya and revealed that seeds soaked in $GA_3$ 200 ppm for 12 hrs recorded the maximum root length (8.4 cm), shoot length (14.9cm) and vigour index (1826) followed by seed treatment with thiourea 2000 ppm for 12 hrs.

Barche *et al.* (2010) studied the response of seed treatment on germination, growth, survivability and economics on papaya (*Carica papaya*) Cv. Hybrid Mayuri and revealed that the maximum seedling height (12.41 cm),

stem diameter (0.27 cm), more number of leaves (7.23) and cost-benefit ratio (1:2.7) were observed when seeds soaked in gibberellic acid at 500 ppm for 12 hrs, while maximum plant spread (11.10 cm) was observed when soaked in $KNO_3$ at 0.2%.

Deb *et al* (2010) conducted experiment on improvement of seed germination and seedling growth of papaya through different pre-sowing seed treatments and reported that $GA_3$ at 2000 ppm was found best in respect to seedling growth (52.32 cm), seedling height (5.18 cm) and seedling girth.

Kadam *et al.* (2010) studied the effect of plant growth regulators and potassium nitrate on growth of seedling of Kagzi lime and concluded that $GA_3$ 150 ppm resulted in maximum seedling height (18.82 cm), more number of leaves per plant (26.62) and fresh weight (25.89 g) and dry weight of shoots (14.46 g).

Sehrawat *et al*. (2011) studied the influence of priming treatments on vigour and viability of papaya seeds and revealed that freshly extracted seeds when treated with 1000 ppm $GA_3$ exhibited maximum seedling length (14 cm) followed by 500 ppm $GA_3$.

Meena *et al.* (2003) studied the effect of seed treatment with gibberellic acid on growth parameters of different papaya cultivars viz., Honey Dew, Coorg Honey Dew, Farm Sel – 1 and Hybrid Madhu and reported that 100 ppm $GA_3$ significantly increased the seedling height (17.83 cm), stem diameter (0.417 cm), number of leaves per plant (10.08), fresh weight (11.54 g) and dry weight of seedling (1.30 g ).

Supe *et al.* (2012) conducted an experiment on seed germination and seedling growth of amla and concluded that seeds soaked in 750 ppm $GA_3$ for 24 hrs combined with Azospirillum recorded maximum shoot length (12.0 cm), root length (18.5 cm), number of leaves per seedling ( 15.7).

Patil *et al*. (2012) studied the effect of growth regulators and chemicals on seedling growth of Rangpur lime under laboratory conditions and concluded

that 150 ppm $GA_3$ recorded maximum shoot length (4.37 cm), root length (2.82 cm), fresh weight of seedling ( 96.25 g), dry weight of seedling (14.68g ), vigour index (705.19) and least number of days taken for germination (3.34 days).

Anjanawe *et al*. (2012) conducted an experiment on effect of plant growth regulators on seed germination and seedling vigour of papaya cv. Barwani Red and reported that maximum plant height (17.41cm), stem diameter(0.441cm), number of leaves per plant (10.42), average leaf area (41.28 sq.cm), fresh weight of stem and leaves (13.45g), dry weight of stem and leaves (1.036 g), number of primary roots per plant (8.83), number of lateral roots per primary root (76.32), length of the longest root (25.36 cm) and diameter of the thickest root (0.343 cm), were found superior with the application of 200ppm $GA_3$.

### 2.2.1 Effect of substrates on seed germination

Bisla *et al*. (1984) reported that growth media containing sand + soil + organic manure (1:1:1) gave highest germination (74.74%) and better seedling growth in ber seeds.

Yamanishi *et al.* (2004) conducted an experiment on growth of papaya seedlings (cultivars Sunrise Solo and Tainung) in growth medium and concluded that germination occurred in 12 and 14 days after sowing with highest germination rate (92.18%) in media combination of Osmocote + Humus and composted cattle manure.

Lopes *et al*. (2007) studied the germination and vigor of passion fruit seeds in different substrate and reported that the medium soil + sand (1:1) is found better with maximum speed of emergence of the seedlings and germination percentage.

Okeyo and Ouma (2008) studied the effect of washing and media in papaya seeds and found maximum germination with top soil and washing of papaya seeds.

Bihari *et al.* (2009) studied the effect of growing media on seed germination of aonla and reported that soil + sand + FYM (1:1:1) gave the highest seed germination percentage (74.00 %).

Bharti *et al.* (2009) conducted an experiment on effect of growing media on seed germination, rate of seed germination, transplanting success and seedling mortality in Aonla and reported that soil, sand and FYM (1:1:1) yielded highest percentage (74.00) of seed germination.

Andrade *et al*. (2011) studied the seed germination of *Litchi chinensis* Sonn. in different growing media viz., vermiculite, washed sand, filter paper, rice hull and sphagnum and observed the fast and highest germination with the combination of washed sand and rice hull among the different growing media.

Suketi *et al*. (2011) stuided the influence of different growing medias on seed germination and seedling growth of papaya genotypes ( IPB 3, IPB 4 and IPB 9) and reported that papaya seed germination is highest (70%) in the growing media mixture of soil, manure, and rice husk charcoal and germination index is 70.91% in IPB 3 genotype.

Parasana *et al.* (2013) investigated the effect of different growing medias on germination of mango (*Mangifera indica* L.) cultivar under net house conditions and they concluded that among the different growing medias soil + sand + FYM (2: 1: 1) is found to be the most effective for better germination (77.33) at 180 days after sowing.

Bhardwaj *et al*. (2013) studied the effect of growing media on seed germination and seedling growth of papaya cv. Red Lady. They concluded that the treatment containing vermicompost + sand + pond soil (1:1:1) with 2 cm cocopeat on top of the polybags is found best with maximum speed of seedling emergence (493.34), highest germination percent (92.71 %), highest seed vigour (89.33), maximum germination index (7.18), germination value (25.58), least time required for imbibitions (9.37 days) and minimum germination period (3.22 days).

### 2.2.2 Effect of substrates on seedling vigour

Pomper *et al*. (2002) investigated the growth enhancement of container grown papaya seedlings as influenced by media type, root-zone temperature and fertilization regime and concluded that among the different growing medias, sand and sphagnum peat (1:1) is found to be good for enhancing plant height (10.1 cm), leaf number ( 36.95), and total plant dry weight ( 3.07 g).

Khan *et al*. (2006) observed the maximum plant height, stem diameter and number of leaves per seedling of rough lemon (*Citrus jambhiri* L.) in the media consisting of sand + peat (1:1).

Pio *et al.* (2007) pointed out the performance of different substrates for the development of pears seedlings and reported that seeds sown in vermiculite with substrate soil and sand with the ratio of 40 % each showed higher length and dry mass of seedlings.

Rahman *et al.* (2007) studied the effect of different soil media on peach seed germination an5d seedling growth and reported that maximum seedling height (98.67 cm) and girth (5.24 cm) was observed in combination of FYM + sawdust.

Pereira *et al*. (2008) conducted experiment on growth of papaya seedlings in growing media with kaolin and concluded that seeds sown in sacks of polyethylene with a capacity of 1 L containing a mixture of manure (60%), soil (30%), kaolin (30%) and sand (10%) increased the growth of seedlings compared to other treatments.

Costa *et al*. (2010) conducted experiment on papaya seedling formation in three sizes of polyethylene bags and six substrates and found that vermiculite fertilized with 14% organic compost was the best for the maximum growth of papaya seedlings.

Suresh *et al.* (2010) studied the efficiency of PSM (*Bacillus megatherium* + *Aspergillus awamori*) and VAM (*Glomus mosseae* + *G. fasciculatum*) biofertilizers with graded levels of phosphorus ($P_2O_5$ at 50, 100,

150 and 200 g) on growth of papaya and reported the maximum plant height (192.67 cm), girth (24.00 cm) and total number of leaves per seedling (25.17) in VAM + 200 g $P_2O_5$.

Rajamanickam *et al.* (2010) studied the nursery management in papaya var. Co2 and concluded that potting mixture treated with vermicompost gave maximum seedling height (28.50 cm) and seedling diameter (0.639cm), petiole length (6.410 cm), petiole diameter (0.186 cm), number of leaves per seedling (11.65), shoot dry weight (1.254 g), root length (29.715 cm), root dry weight (0.392 g) and root shoot ratio (0.340).

Indriyani *et al*. (2011) conducted an experiment on the effect of planting media on growth of pine apple seedlings and reported that treatment containing soil + manure (1:1) gave maximum plant height ( 39.06 cm), more number of leaves per plant (36.95) and seedling wet weight (24.9g).

Parasana *et al.* (2013) investigated the effect of different growing medias on seedling growth of mango under net house conditions and they concluded that among the different growing medias maximum seedling height ( 51.13 cm), more number of leaves per plant (15.22), shoot and root length ( 51.13 cm and 36.17 cm), stem gith (4.07 cm), fresh and dry weight of seedling (28.79g and 18.90 g) as well as survival percent of seedling (76.67 %) were recorded in soil + sand + FYM (2: 1: 1) at 180 days after sowing.

# Chapter- III

# *Materials and Methods*

# Chapter III

# MATERIAL AND METHODS

The experiment "Studies on seed germination and subsequent seedling growth of papaya *(Carica papaya* L.*)* cv. Pusa Nanha." was carried out at Horticultural College and Research Institute, Anantharajupet during the year 2013-14. The details of materials used, methods followed and experimental techniques adopted during the course of investigation are given below.

## 3.1 Geographical location of experimental site

The experimental site is located at Horticultural College and Research Institute, Anantharajupet which falls under tropical zone with an average rainfall of 700 mm and is situated at an altitude of 162 meters (531 feet) above mean sea level. The geographical situation is $13.98^0$N latitude and $79.40^0$E longitude.

## 3.2 Weather conditions

The meteorological data pertaining to weekly mean rainfall, sunshine hours average minimum and maximum temperature and relative humidity recorded during the period of experimentation (November 2013 to January 2014) are presented in the Appendix I.

## 3.3 Seed material

Fully ripened, yellowish orange coloured fresh fruits of papaya Cv. Pusa Nanha from papaya plot existing in HRS, Ananthajupet were selected for this experiment. The fruits were cut longitudinally using a knife and seeds were extracted by scooping out with hand. The seeds are rubbed with ash for removing the gelatinous sarcotesta and are washed in running water and dried under shade.

## 3.4 Experimental details

### 3.4.1 Treatment details of experiment - 1

Effect of chemical treatments on seed germination and subsequent seedling vigour of papaya *(Carica papaya* L.*)* cv. Pusa Nanha.

| | |
|---|---|
| **$T_1$** - Tap water for 12 hrs | **$T_{11}$** - $KNO_3$ 2000 ppm for 12 hrs |
| **$T_2$** - Tap water for 24 hrs | **$T_{12}$** - $KNO_3$ 2000 ppm for 24 hrs |
| **$T_3$** - $GA_3$ 100 ppm for 12 hrs | **$T_{13}$** - $KNO_3$ 3000 ppm for 12 hrs |
| **$T_4$** - $GA_3$ 100 ppm for 24 hrs | **$T_{14}$** - $KNO_3$ 3000 ppm for 24 hrs |
| **$T_5$** - $GA_3$ 200 ppm for 12 hrs | **$T_{15}$** - Thiourea 2000 ppm for 12 hrs |
| **$T_6$** - $GA_3$ 200 ppm for 24 hrs | **$T_{16}$** - Thiourea 2000 ppm for 24 hrs |
| **$T_7$** - $GA_3$ 300 ppm for 12 hrs | **$T_{17}$** - Thiourea 3000 ppm for 12 hrs |
| **$T_8$** - $GA_3$ 300 ppm for 24 hrs | **$T_{18}$** - Thiourea 3000 ppm for 24 hrs |
| **$T_9$** - $KNO_3$ 1000 ppm for 12 hrs | **$T_{19}$** - Thiourea 4000 ppm for 12 hrs |
| **$T_{10}$** - $KNO_3$ 1000 ppm for 24 hrs | **$T_{20}$** - Thiourea 4000 ppm for 24 hrs |
| | **$T_{21}$** - Control |

#### 3.4.1.1 Preparation of solution of growth substances

##### 3.4.1.1.1 $GA_3$ 100 ppm solution:

10 mg of $GA_3$ was dissolved in little absolute ethyl alcohol solution and then made up to 100 ml with distilled water to get 100ppm of $GA_3$ solution.

##### 3.4.1.1.2 $GA_3$ 200 ppm solution:

20 mg of $GA_3$ was dissolved in little absolute ethyl alcohol solution and then made up to 100 ml with distilled water to get 200ppm of $GA_3$ solution.

#### 3.4.1.1.3 $GA_3$ 300 ppm solution:

30 mg of $GA_3$ was dissolved in little absolute ethyl alcohol solution and then made up to 100 ml with distilled water to get 300ppm of $GA_3$ solution.

#### 3.4.1.1.4 $KNO_3$ 1000 ppm solution:

100 mg of $KNO_3$ solution is dissolved in a small quantity of water and the volume was made up to 100ml by adding distilled water to get 1000ppm $KNO_3$ solution.

#### 3.4.1.1.5 $KNO_3$ 2000 ppm solution:

200mg of $KNO_3$ solution is dissolved in a small quantity of water and the volume was made up to 100ml by adding distilled water to get 2000ppm $KNO_3$ solution.

#### 3.4.1.1.6 $KNO_3$ 3000 ppm solution:

300mg of $KNO_3$ solution is dissolved in a small quantity of water and the volume was made up to 100ml by adding distilled water to get 3000ppm $KNO_3$ solution .

#### 3.4.1.1.7 Thiourea 2000 ppm solution:

200mg of thiourea solution is dissolved in a small quantity of water and the volume was made up to 100ml by adding distilled water to get 2000ppm thiourea solution.

#### 3.4.1.1.8 Thiourea 3000 ppm solution:

300mg of thiourea solution is dissolved in a small quantity of water and the volume was made up to 100ml by adding distilled water to get 3000ppm thiourea solution.

#### 3.4.1.1.9 Thiourea 4000 ppm solution:

400mg of thiourea solution is dissolved in a small quantity of water and the volume was made up to 100ml by adding distilled water to get 4000ppm thiourea solution.

### 3.4.1.2 Preparation of potting mixture

The experiment was carried out by sowing seeds in 15 x 6 cm size polythene bags. The bags were filled with potting mixture containing two parts soil, one part fine sand and one part well decomposed FYM.

### 3.4.1.3 Seed treatments and sowing of seeds

Sound and healthy seeds were selected and soaked in solution of different concentration of chemicals for 12 and 24 hours as per the treatments and were sown in polythene bags of 15 x 6 cm size which were properly filled and labeled with tags.

### 3.4.2 Treatment details of experiment - 2

Effect of different growing medias on seed germination and subsequent seedling growth of papaya *(Carica papaya L.)*cv. Pusa Nanha.

$T_1$ – FYM + Cocopeat + Vermicompost + Soil + Sand
(60% + 10% + 10% + 10% + 10% )

$T_2$ – FYM + Cocopeat + Vermicompost + Soil + Sand
(10% + 60% + 10% + 10% + 10% )

$T_3$ – FYM + Cocopeat + Vermicompost + Soil + Sand
(10% + 10% + 60% + 10% + 10% )

$T_4$ – FYM + Cocopeat + Vermicompost + Soil + Sand
(10% + 10% + 10% + 60% + 10% )

$T_5$ – FYM + Cocopeat + Vermicompost + Soil + Sand
(10% + 10% + 10% + 10% + 60% )

$T_6$ – FYM + Cocopeat + Vermicompost + Soil + Sand
(20% + 20% + 20% + 20% + 20% )

$T_7$ – Soil + FYM + Sand (50% + 25% + 25%)

$T_8$ – $T_1$ + Biofertilizer Mixture

$T_9$ – $T_2$ + Biofertilizer Mixture

$T_{10}$ – $T_3$ + Biofertilizer Mixture

$T_{11}$ – $T_4$ + Biofertilizer Mixture

$T_{12}$ – $T_5$ + Biofertilizer Mixture

$T_{13}$ – $T_6$ + Biofertilizer Mixture

$T_{14}$ – $T_7$ + Biofertilizer Mixture

Note : Biofertilizer mixture (5g *Azospirillum* + 5g Phosphate Solubilizing Bacteria + 5g *Frateuria aurantia)* in each polybag along with potting mixture.

### 3.4.2.2 Preparation of potting mixture

Media components viz, cocopeat, vermicompost, FYM, soil and sand were procured and mixed in different proportions as per the treatments mentioned.

### 3.4.2.3 Sowing of seeds

Fresh seeds of papaya were sown in polybags of 15 x 6 cm in size which were properly filled with different potting mixture prepared as per the treatments.

## 3.5 Nursery management

### 3.5.1 Watering

Watering was done immediately after sowing of seeds in polythene bags using rosecan and maintained proper moisture level through out the experimental period. The polybags were watered everyday.

### 3. 5.2 Weeding

Hand weeding was done at regular intervals to keep the experimental site clean and free from weeds.

### 3. 5.3 Plant protection

Necessary plant protection measures were followed to prevent pest incidence.

## 3.6 Details of observations

### 3.6.1 Germination attributes

The observations pertaining to germination viz, number of days taken for germination, germination percentage and germination index were recorded daily .

#### 3.6.1.1 Number of days taken for germination:

The treatment wise seed sown in polythene bag were observed daily for recording the observations on seed germination since the date of sowing. Then the number of days required for germination was calculated.

#### 3.6.1.2 Germination percentage :

After completion of entire germination the percentage of germination was calculated based on formulae mentioned below.

$$\text{Germination percentage} = \frac{\text{Number of seeds germinated}}{\text{Total number of seeds sown}} \text{ X } 100$$

#### 3.6.1.3 Germination Index :

Number of seedlings emerging daily are counted from the day of sowing till the time germination was completed. Thereafter a germination index was computed by using the following formulae

$$\text{Germination Index (GI)} = \frac{n}{d}$$

Where n = No. of seedlings emerging on day ‘d’

d = day after planting

### 3.6.2 Growth attributes

For recording the growth observations five randomly selected plants were tagged as a observational plants from each treatment and recorded the observations once at the end of experiment i.e; 60 days after sowing.

#### 3.6.2.1 Seedling height (cm)

The height of five randomly selected plants was measured from the tip of polythene bags to the growing tip expressed in centimeter. A meter scale was used for this purpose. It was measured for all the five plants and later on averaged.

#### 3.6.2.2 Girth of seedling (mm)

Stem diameter of randomly selected five plants was recorded with the help of vernier calliper and the average was calculated.

#### 3.6.2.3 Root length (cm)

Among five seedlings the length of root was measured from the point of initiation of root to the tip of the root with the help of a meter scale and average root length was calculated.

#### 3.6.2.4 Number of leaves per seedling

The total number of fully grown leaves per seedlings were recorded for all the five plants and average was calculated.

#### 3.6.2.5 Number of nodes per seedling

The total number of nodes per seedlings were counted for all the five plants and average was calculated.

#### 3.6.2.6 Petiole length (cm)

Among five seedlings the length of petiole was measured with the help of a meter scale and average length was calculated.

### 3.6.2.7 Petiole diameter (mm)

Petiole diameter of five plants was measured with the help of verneer callipeers and the average was calculated.

### 3.6.2.8 Leaf area ($cm^2$)

For measurement of leaf area, 5 fully grown, physiologically matured leaves were randomly selected in each treatment. The maximum length and breadth of individual leaves were taken and their product was calculated. Leaf area was measured in square centimeters as suggested by Saidha and Rao (1985).

$$A = (L \times B) K$$

Where A = Actual leaf area

L = maximum length of leaf

B = maximum breadth of leaf

K = Leaf area constant

From the above the equation, the constant K was estimated by using the formula

$$K = \frac{\text{Actual leaf area}}{\text{Apparent leaf area}}$$

### 3.6.2.9 Shoot dry weight

Using destructive method all the five tagged plants shoots are collected and placed in paper bags and then dried in a oven for 24 hrs at $60^0$ C. After drying, the dry weight of shoot was measured from electronic balance and average weight calculated.

### 3.6.2.10 Root dry weight

Using destructive method all the five tagged plants roots are collected and placed in paper bags and then dried in a oven for 24 hrs at $60^0$ C. After drying, the dry weight of root was measured from electronic balance and average weight calculated.

### 3.6.2.11 Fresh weight of seedling (g)

The fresh weight of five plants is measured with the electronic balance and average weight calculated.

### 3.6.2.12 Dry weight of seedling (g)

The seedlings which were selected for fresh weight were dried in oven at $60^o$ C for 48 hours. After drying, the dry weight of seedling was measured from electronic balance and average weight calculated.

### 3.6.2.13 Vigour index

The vigour index is calculated by using the following formulae

Vigour index = Germination percentage x Total length of seedling (mm)

### 3.6.3 Cost benefit ratio

The benefit cost ratio was worked out by using the data on papaya seedlings, selling rate, cost of inputs and total cost of cultivation.

## 3.7 Statistical analysis

The experimental data were statistically analyzed by following the standard procedures of Panse and Sukhatme, 1985. Significance was tested by 'F' value at 5 per cent level of probability. Critical difference (CD) values were calculated wherever the F test was found to be significant and treatment comparisons were made. The results have been depicted graphically where ever necessary.

# Chapter-IV

# *Results and Discussion*


Plate 1. Overview of experimental plot

# Chapter IV

# RESULTS AND DISCUSSION

An experiment on "Studies on seed germination and subsequent seedling growth of papaya (*Carica papaya* L.) cv.Pusa Nanha" was carried during the year 2013-2014 at Horticultural College and Research Institute, Anantharajupet and the observations made in the present study on various parameters under different chemical treatments and substrates combinations along with biofertilizers were tabulated. The results along with discussion are presented below.

## 4.1 Effect of seed treatment chemicals on seed germination

### 4.1.1 Effect of seed treatment chemicals on number of days taken for germination

Observations recorded on days required for germination of seed in papaya as influenced by various seed treatments are presented in Table.4.1 and graphically depicted in Fig.1. The data clearly indicated that minimum number of days taken for germination was recorded in seed treatment with $GA_3$ 300 ppm for 24 hrs ($T_8$) (12.33 days) which was found to be on par with $GA_3$ 300 ppm for 12 hrs, ($T_7$) (14 days), while the maximum days required for germination was recorded in control ($T_{21}$) (30.33 days).

The papaya seeds treated with $GA_3$ prior to sowing gave an early seed germination. This might be due to the fact that, $GA_3$ plays an important role in two stages of germination one at initial enzyme induction and other in activation of reserve food mobilizing system which help in enhancement of germination (Jha *et al*. 1997). The above results are conformity with Barche *et al.* (2010), Anburani and Shakila (2010) and Dhinesh Babu *et al.* (2010) in papaya.

### 4.1.2 Effect of seed treatment chemicals on germination percentage

The seed treatments significantly influenced the germination of papaya seeds (Table.4.1 and Fig.1). The maximum germination percentage (88.89%) was recorded in $GA_3$ 300 ppm for 24 hrs ($T_8$) followed by Thiourea 4000 ppm for 24 hrs ($T_{20}$) (85.55%) whereas, minimum germination percentage was recorded in control ($T_{21}$) (48.89%).

Maximum germination percentage was recorded when seeds soaked in $GA_3$ might be due to the fact that $GA_3$ involved in the activation of cytological enzymes which stimulates α – amylase enzyme that converts insoluble starch into soluble sugars and it also initiates the radical growth by removing some metabolic blocks (Babu *et al*.2010). $GA_3$ also plays an important role in leaching out of the inhibitors which in turn helps in breaking the seed dormancy. Thiourea 4000 ppm for 24 hrs was found to be the next best seed treatment in increasing germination percentage, this might be due to its deactivating capacity of certain inihibitors present in the seed (Thomas, 1997). The results are conformity with the findings reported by veeraragavathatham *et al.* (1980), Pandit *et al*. (2001), Anburani and Shakila (2010), Deb *et al.* (2010) and Barche *et al*. (2010) in papaya.

### 4.1.3 Effect of seed treatment chemicals on germination index

The seed germination index in papaya as influenced by various seed treatments are presented in Table.4.1 and Fig.1. The highest seed germination index was noticed in $GA_3$ 300 ppm for 24 hrs ($T_8$) (2.90) which was found to be significantly superior over all the other treatments whereas, minimum germination index was recorded in control ($T_{21}$) (0.79). The maximum germination index with $GA_3$ might be due to its influence in early germination and increased percent germination. The results are in conformity with findings of Rajamanickam and Anbu (2001) in aonla.

**Table 4.1. Effect of different seed treatment chemicals on number of days taken for germination, germination percentage and germination index.**

| | Treatments | No. of days taken for germination | Germination percentage | Germination Index |
|---|---|---|---|---|
| $T_1$ | Tap water for 12 hrs | 26.67 | 53.33 | 1.15 |
| $T_2$ | Tap water for 24 hrs | 25.33 | 57.77 | 1.18 |
| $T_3$ | $GA_3$ 100 ppm for 12 hrs | 19.00 | 68.89 | 1.14 |
| $T_4$ | $GA_3$ 100 ppm for 24 hrs | 17.00 | 66.66 | 1.56 |
| $T_5$ | $GA_3$ 200 ppm for 12 hrs | 16.00 | 76.66 | 1.95 |
| $T_6$ | $GA_3$ 200 ppm for 24 hrs | 15.67 | 74.44 | 1.92 |
| $T_7$ | $GA_3$ 300 ppm for 12 hrs | 14.00 | 80.00 | 1.54 |
| $T_8$ | $GA_3$ 300 ppm for 24 hrs | 12.33 | 88.89 | 2.90 |
| $T_9$ | $KNO_3$ 1000 ppm for 12 hrs | 22.33 | 58.89 | 1.37 |
| $T_{10}$ | $KNO_3$ 1000 ppm for 24 hrs | 21.33 | 63.33 | 1.42 |
| $T_{11}$ | $KNO_3$ 2000 ppm for 12 hrs | 22.33 | 66.66 | 1.45 |
| $T_{12}$ | $KNO_3$ 2000 ppm for 24 hrs | 20.00 | 66.66 | 1.59 |
| $T_{13}$ | $KNO_3$ 3000 ppm for 12 hrs | 19.67 | 68.89 | 1.45 |
| $T_{14}$ | $KNO_3$ 3000 ppm for 24 hrs | 15.33 | 72.22 | 1.74 |
| $T_{15}$ | Thiourea 2000 ppm for 12 hrs | 20.67 | 68.89 | 1.83 |
| $T_{16}$ | Thiourea 2000 ppm for 24 hrs | 20.33 | 73.33 | 1.93 |
| $T_{17}$ | Thiourea 3000 ppm for 12 hrs | 25.00 | 66.66 | 1.41 |
| $T_{18}$ | Thiourea 3000 ppm for 24 hrs | 23.00 | 76.66 | 1.77 |
| $T_{19}$ | Thiourea 4000 ppm for 12 hrs | 27.00 | 71.11 | 1.43 |
| $T_{20}$ | Thiourea 4000 ppm for 24 hrs | 26.00 | 85.55 | 1.88 |
| $T_{21}$ | Control | 30.33 | 48.89 | 0.79 |
| | **SEm±** | **0.609** | **1.585** | **0.189** |
| | **CD (P=0.05)** | **1.748** | **4.546** | **0.543** |

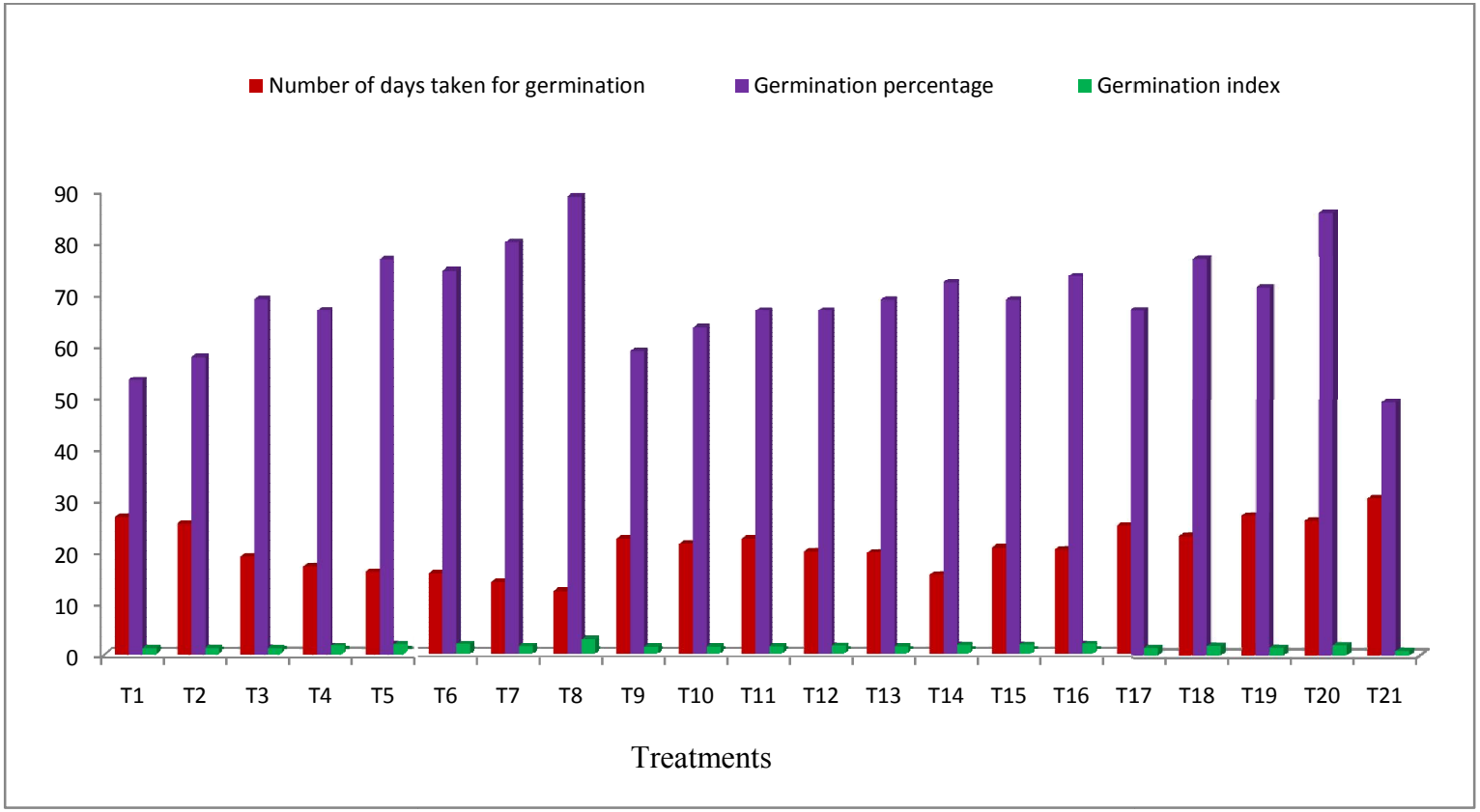


**Fig.1 Effect of different seed treatment chemicals on number of days taken for germination, germination percentage and germination index**

### 4.1.4 Effect of seed treatment chemicals on seedling growth performance

#### 4.1.4.1 Effect of seed treatment chemicals on seedling height

The data on seedling height of papaya as influenced by various seed treatments are presented in Table.4.2 and Fig.2. The highest seedling height was noticed in $GA_3$ 300 ppm for 24 hrs ($T_8$) (9.65 cm) which was found to be significantly superior over all the treatments whereas, minimum seedling height was recorded in control ($T_{21}$) (6.33 cm).

The maximum seedling height in $GA_3$ treated seeds might be due to the effect of gibberellic acid in increasing the osmotic uptake of nutrients and thereby causing cell elongation (Shanmugavelu, 1966) reflects in greater intermodal length, ultimately resulting in increase in plant height. These results are in conformity with Begum *et al*. (1987), Palanisamy and Ramamoorthy (1987), Barche *et al*. (2010), Babu *et al.* (2010) in papaya.

#### 4.1.4.2 Effect of seed treatment chemicals on seedling girth

The girth of papaya seedlings influenced by various seed treatments are presented in Table.4.2 and Fig. 2. The maximum seedling girth was noticed in $GA_3$ 300 ppm for 24 hrs ($T_8$) (9.01 mm) which was found to be significantly superior over all the other treatments whereas, minimum seedling girth was recorded in control ($T_{21}$) (5.40 mm).

The maximum seedling diameter with $GA_3$ treatment may be due to its vital role in stimulation of cambium and its immediate cell progeny, which increase the stem girth, as observed by Dhankhar and Singh (1996) in aonla. The above results are conformity with Pawshe *et al*. (1997) in custard apple, Pandit *et al*. (2001) and Barche *et al*. (2010) in papaya.

#### 4.1.4.3 Effect of seed treatment chemicals on root length

The root length in papaya as influenced by various seed treatments are presented in Table.4.2 and Fig.3. The maximum root length was noticed in

**Table 4.2. Effect of different seed treatment chemicals on seedling height, seedling girth and root length**

| | Treatments | Seedling height (cm) | Seedling girth (mm) | Root length(cm) |
|---|---|---|---|---|
| $T_1$ | Tap water for 12 hrs | 7.56 | 6.55 | 10.62 |
| $T_2$ | Tap water for 24 hrs | 7.75 | 6.04 | 11.25 |
| $T_3$ | $GA_3$ 100 ppm for 12 hrs | 8.58 | 6.23 | 13.92 |
| $T_4$ | $GA_3$ 100 ppm for 24 hrs | 8.97 | 6.64 | 14.44 |
| $T_5$ | $GA_3$ 200 ppm for 12 hrs | 8.93 | 8.14 | 15.14 |
| $T_6$ | $GA_3$ 200 ppm for 24 hrs | 9.35 | 8.71 | 15.30 |
| $T_7$ | $GA_3$ 300 ppm for 12 hrs | 9.33 | 8.27 | 14.56 |
| $T_8$ | $GA_3$ 300 ppm for 24 hrs | 9.65 | 9.01 | 15.09 |
| $T_9$ | $KNO_3$ 1000 ppm for 12 hrs | 6.69 | 6.64 | 10.43 |
| $T_{10}$ | $KNO_3$ 1000 ppm for 24 hrs | 7.15 | 6.57 | 10.09 |
| $T_{11}$ | $KNO_3$ 2000 ppm for 12 hrs | 6.77 | 6.66 | 10.55 |
| $T_{12}$ | $KNO_3$ 2000 ppm for 24 hrs | 6.96 | 7.82 | 11.65 |
| $T_{13}$ | $KNO_3$ 3000 ppm for 12 hrs | 7.05 | 7.50 | 12.70 |
| $T_{14}$ | $KNO_3$ 3000 ppm for 24 hrs | 7.35 | 7.97 | 12.83 |
| $T_{15}$ | Thiourea 2000 ppm for 12 hrs | 8.40 | 6.85 | 10.59 |
| $T_{16}$ | Thiourea 2000 ppm for 24 hrs | 8.07 | 7.76 | 10.62 |
| $T_{17}$ | Thiourea 3000 ppm for 12 hrs | 8.15 | 7.35 | 13.87 |
| $T_{18}$ | Thiourea 3000 ppm for 24 hrs | 8.29 | 7.76 | 14.13 |
| $T_{19}$ | Thiourea 4000 ppm for 12 hrs | 9.03 | 8.35 | 14.38 |
| $T_{20}$ | Thiourea 4000 ppm for 24 hrs | 9.23 | 8.37 | 14.99 |
| $T_{21}$ | Control | 6.33 | 5.40 | 9.73 |
| | **SEm±** | **0.061** | **0.103** | **0.167** |
| | **CD (P=0.05)** | **0.176** | **0.296** | **0.480** |

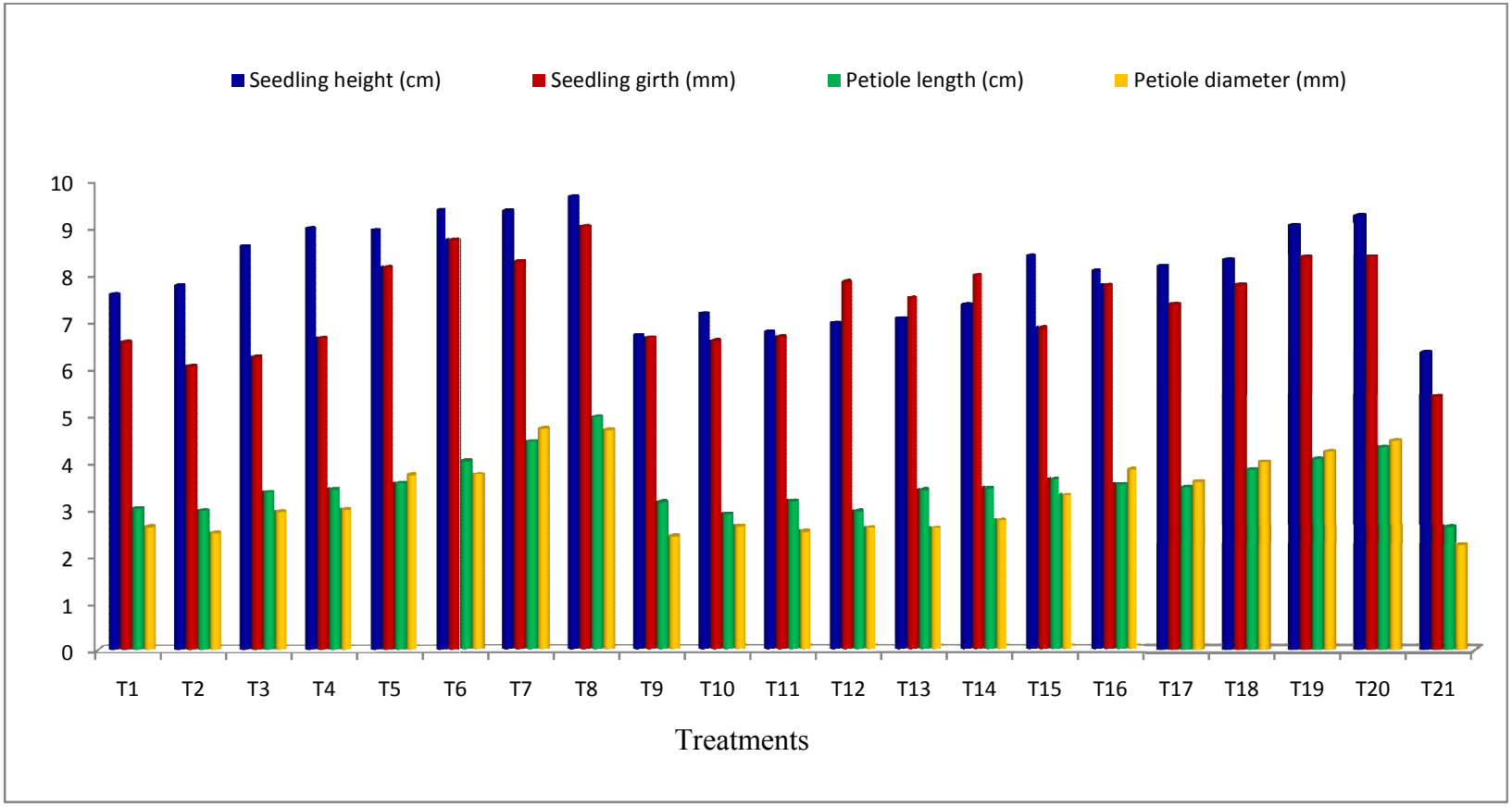


**Fig.2 Effect of different seed treatment chemicals on seedling height, seedling girth, petiole length and petiole diameter**

$GA_3$ 200 ppm for 24 hrs ($T_6$) (15.30 cm) which was found to be at par with $GA_3$ 200 ppm for 12 hrs ($T_5$) (15.14 cm), $GA_3$ 300 ppm for 24 hrs ($T_8$) (15.09 cm) and Thiourea 4000 ppm for 24 hrs ($T_{20}$) (14.99cm) whereas, minimum root length was recorded in control ($T_{21}$) (9.73cm).

The maximum root length was recorded under the $GA_3$ treatment might be due to reason that shoot growth result in production of photosynthatates which is translocated through phloem to the root zone might be responsible for increase in root length. Similar results are obtained in accordance with the results of earlier worker Palanisamy and Ramamoorthy (1987), Ananthakalaiselvi and Dharmalingam (1998) and Anburani and Shakila (2010) in papaya. Wittwer and Bukovac (1958) have also reported that GA at lower concentration initiate the growth of the roots whereas higher concentration has little effect on root growth.

#### 4.1.4.4 Effect of seed treatment chemicals on number of leaves per seedling

The effect of chemical treatments on number of leaves per seedlings are presented in Table.4.3 and Fig.3. The highest number of leaves was noticed in $GA_3$ 300 ppm for 24 hrs ($T_8$) (11.07) which was found to be on par with $GA_3$ 300 ppm for 12 hrs ($T_7$) (10.80) whereas, minimum number of leaves was recorded in control ($T_{21}$) (6.67).

The maximum number of leaves per seedling associated with $GA_3$ might be due to fact that, gibberellic acid increased the osmotic uptake of nutrients causing cell elongation and greater intermodal length which ultimately resulted in production of more number of leaves per seedling. The above results are in conformity with singh (1979) in citrus, Pandit *et al*. (2001) in papaya Barche *et al*. (2010) in papaya.

#### 4.1.4.5 Effect of seed treatment chemicals on leaf area of seedling

The effect of chemical treatments on leaf area of seedlings are presented in Table.4.3 and Fig.3. The maximum leaf area was noticed in $GA_3$ 300 ppm for 24 hrs ($T_8$) (31.49 $cm^2$) which was found to be on par with $GA_3$ 300 ppm

for 12 hrs ($T_7$) (30.19cm$^2$) whereas, minimum leaf area was recorded in control, $T_{21}$ (17.32 cm$^2$).

The maximum leaf area associated in $GA_3$ seed treatment might be due to the fact that activity of gibberellic acid at apical meristem result in more production and accumulation of nucleoprotein responsible for increasing leaf initiation and leaf expansion. Similar effect of $GA_3$ on leaf area was noticed by Simao *et al*. (1960) and Sen and Ghanti (1976) in papaya.

#### 4.1.4.6 Effect of seed treatment chemicals on petiole length of seedling

The effect of chemical treatments on petiole length of papaya seedlings are presented in Table.4.3 and Fig.2. The highest petiole length was noticed in $GA_3$ 300 ppm for 24 hrs ($T_8$) (4.95cm) which was found to be significantly superior over all the other treatments whereas, minimum petiole length was recorded in control, $T_{21}$ (2.61cm).

The maximum petiole length in $GA_3$ treated seeds might be due to its involvement in increasing cell elongation resulted in rapid increase in petiole length. Similar results are in accordance with the results of earlier worker Zhao *et al*. (2004) in papaya and Maiti *et al*. (2003) in jack fruit.

#### 4.1.4.7 Effect of seed treatment chemicals on number of nodes per seedling

The effect of chemical treatments on number of nodes per papaya seedlings are presented in Table.4.4 and Fig.3. The highest number of nodes was noticed in $GA_3$ 300 ppm for 24 hrs ($T_8$) (13) which was found to be significantly superior over all the other treatments whereas, minimum number of nodes was recorded in control, $T_{21}$ (7.33).

The maximum number of nodes per seedling in $GA_3$ treatmented seeds might be due to the fact that, gibberellic acid play an important role in cell division, cell elongation and cell multiplication which reflect in maximum

**Table 4.3. Effect of different seed treatment chemicals on number of leaves per seedling, leaf area and petiole length**

| | Treatments | No. of leaves per seedling | Leaf area ($cm^2$) | Petiole length(cm) |
|---|---|---|---|---|
| $T_1$ | Tap water for 12 hrs | 7.27 | 18.78 | 3.00 |
| $T_2$ | Tap water for 24 hrs | 7.40 | 18.44 | 2.96 |
| $T_3$ | $GA_3$ 100 ppm for 12 hrs | 9.47 | 20.18 | 3.35 |
| $T_4$ | $GA_3$ 100 ppm for 24 hrs | 9.47 | 24.77 | 3.41 |
| $T_5$ | $GA_3$ 200 ppm for 12 hrs | 10.00 | 27.49 | 3.55 |
| $T_6$ | $GA_3$ 200 ppm for 24 hrs | 10.00 | 29.37 | 4.01 |
| $T_7$ | $GA_3$ 300 ppm for 12 hrs | 10.80 | 30.19 | 4.43 |
| $T_8$ | $GA_3$ 300 ppm for 24 hrs | 11.07 | 31.49 | 4.95 |
| $T_9$ | $KNO_3$ 1000 ppm for 12 hrs | 8.00 | 18.80 | 3.14 |
| $T_{10}$ | $KNO_3$ 1000 ppm for 24 hrs | 8.00 | 19.68 | 2.89 |
| $T_{11}$ | $KNO_3$ 2000 ppm for 12 hrs | 8.40 | 19.59 | 3.16 |
| $T_{12}$ | $KNO_3$ 2000 ppm for 24 hrs | 8.33 | 19.76 | 2.95 |
| $T_{13}$ | $KNO_3$ 3000 ppm for 12 hrs | 8.27 | 21.20 | 3.39 |
| $T_{14}$ | $KNO_3$ 3000 ppm for 24 hrs | 8.47 | 21.51 | 3.42 |
| $T_{15}$ | Thiourea 2000 ppm for 12 hrs | 8.80 | 26.10 | 3.63 |
| $T_{16}$ | Thiourea 2000 ppm for 24 hrs | 9.00 | 23.89 | 3.52 |
| $T_{17}$ | Thiourea 3000 ppm for 12 hrs | 8.93 | 28.89 | 3.47 |
| $T_{18}$ | Thiourea 3000 ppm for 24 hrs | 8.93 | 29.84 | 3.85 |
| $T_{19}$ | Thiourea 4000 ppm for 12 hrs | 9.27 | 28.58 | 4.07 |
| $T_{20}$ | Thiourea 4000 ppm for 24 hrs | 10.53 | 30.03 | 4.32 |
| $T_{21}$ | Control | 6.67 | 17.32 | 2.61 |
| | **SEm±** | **0.178** | **0.461** | **0.073** |
| | **CD (P=0.05)** | **0.512** | **1.322** | **0.208** |

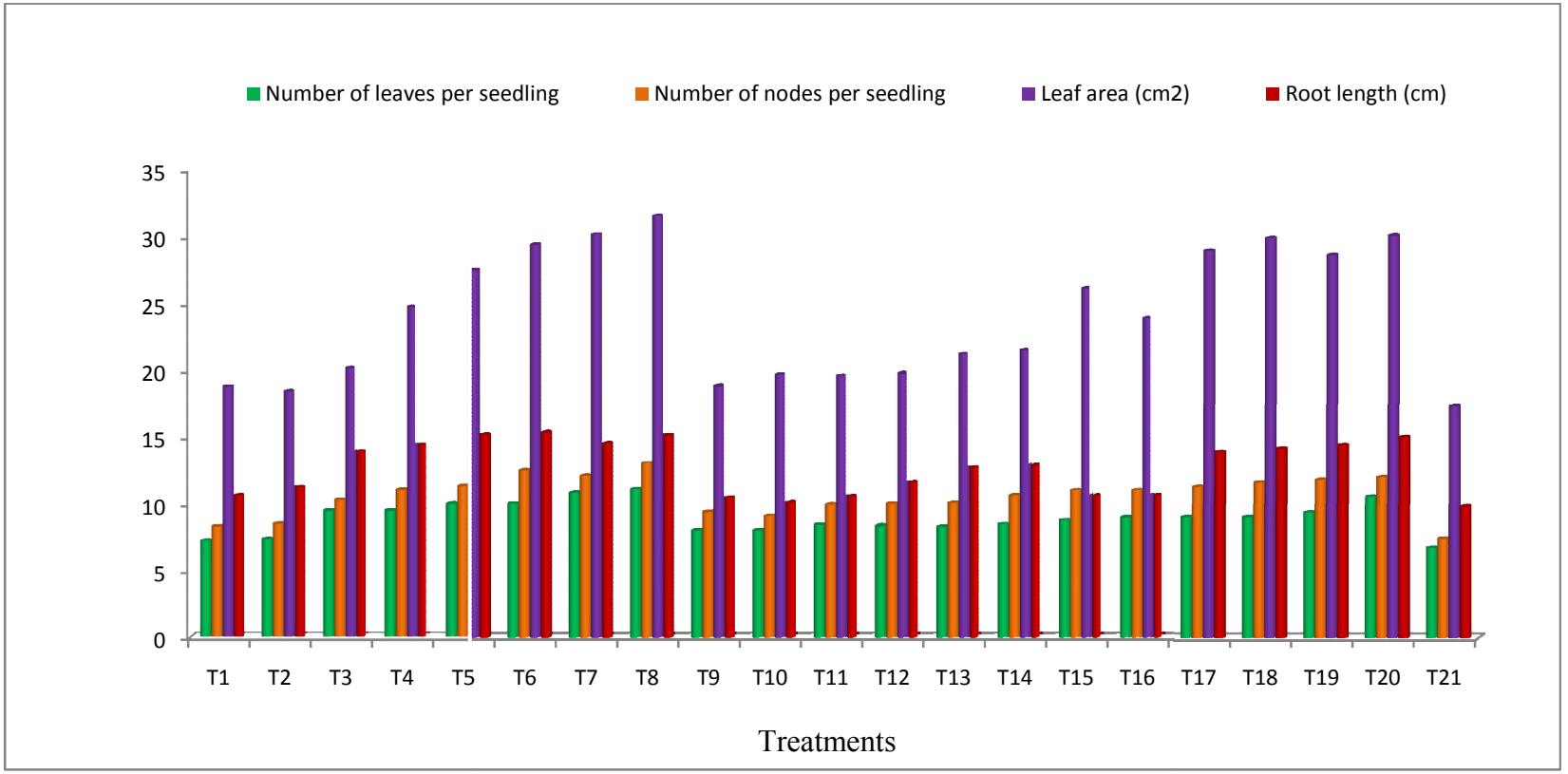


**Fig.3 Effect of different seed treatment chemicals on number of leaves per seedling, number of nodes per seedling, leaf area and root length**

number of nodes per seedling. The results are in conformity with the Pawshe *et al*. (1997) in custard apple.

#### 4.1.4.8 Effect of seed treatment chemicals on petiole diameter of seedling

The effect of chemical treatments on petiole diameter of seedlings are presented in Table.4.4. and Fig.2. The highest petiole diameter was noticed in $GA_3$ 300 ppm for 12 hrs ($T_7$) (4.70mm) which was found to be on par with $GA_3$ 300 ppm for 24 hrs ($T_8$) (4.68mm) where as, minimum petiole diameter was recorded in control treatment (2.23cm).

The maximum petiole diameter associated with $GA_3$ probably due to involvement of to $GA_3$ in mobilizing the reserve foods to the growing apices (Nanda and purohit, 1965). The results obtained are in accordance with the results of earlier worker Dhankhar and Singh(1996), Gholap *et al*. (2000) in aonla and *Deb et al.* (2010) in papaya.

#### 4.1.4.9 Effect of seed treatment chemicals on fresh weight of seedling

The effect of chemical treatments on fresh weight of seedlings are presented in Table.4.4 and Fig.4. The highest fresh weight was noticed in $GA_3$ 300 ppm for 24 hrs ($T_8$) (5.78g) which was found to be significantly superior over all the other treatments whereas, minimum fresh weight was recorded in control ($T_{21}$) (2.90g).

The maximum fresh weight with $GA_3$ seed treatment might be due to rapid growth of seedling with increase in plant height, number of leaves, leaf area and stem diameter which inturn resulted in maximum fresh weight of seedlings. The results are in conformity with Begum *et al*. (1987) and Pandit *et al*. (2001) in papaya and Walse (2005) in aonla.

**Table 4.4. Effect of different seed treatment chemicals on number of nodes per seedling, petiole diameter and fresh weight of seedling**

| | Treatments | No. of nodes per seedling | Petiole diameter(mm) | Fresh weight of seedling (g) |
|---|---|---|---|---|
| $T_1$ | Tap water for 12 hrs | 8.33 | 2.61 | 3.65 |
| $T_2$ | Tap water for 24 hrs | 8.53 | 2.48 | 3.72 |
| $T_3$ | $GA_3$ 100 ppm for 12 hrs | 10.27 | 2.94 | 4.11 |
| $T_4$ | $GA_3$ 100 ppm for 24 hrs | 11.00 | 2.98 | 4.43 |
| $T_5$ | $GA_3$ 200 ppm for 12 hrs | 11.33 | 3.73 | 4.61 |
| $T_6$ | $GA_3$ 200 ppm for 24 hrs | 12.47 | 3.73 | 5.05 |
| $T_7$ | $GA_3$ 300 ppm for 12 hrs | 12.07 | 4.70 | 5.23 |
| $T_8$ | $GA_3$ 300 ppm for 24 hrs | 13.00 | 4.68 | 5.78 |
| $T_9$ | $KNO_3$ 1000 ppm for 12 hrs | 9.40 | 2.42 | 3.94 |
| $T_{10}$ | $KNO_3$ 1000 ppm for 24 hrs | 9.13 | 2.62 | 3.96 |
| $T_{11}$ | $KNO_3$ 2000 ppm for 12 hrs | 9.93 | 2.51 | 4.33 |
| $T_{12}$ | $KNO_3$ 2000 ppm for 24 hrs | 10.00 | 2.59 | 4.33 |
| $T_{13}$ | $KNO_3$ 3000 ppm for 12 hrs | 10.07 | 2.58 | 4.53 |
| $T_{14}$ | $KNO_3$ 3000 ppm for 24 hrs | 10.60 | 2.76 | 4.21 |
| $T_{15}$ | Thiourea 2000 ppm for 12 hrs | 11.00 | 3.28 | 4.45 |
| $T_{16}$ | Thiourea 2000 ppm for 24 hrs | 11.00 | 3.85 | 4.62 |
| $T_{17}$ | Thiourea 3000 ppm for 12 hrs | 11.27 | 3.59 | 4.82 |
| $T_{18}$ | Thiourea 3000 ppm for 24 hrs | 11.60 | 4.01 | 4.93 |
| $T_{19}$ | Thiourea 4000 ppm for 12 hrs | 11.80 | 4.23 | 5.29 |
| $T_{20}$ | Thiourea 4000 ppm for 24 hrs | 12.00 | 4.46 | 5.46 |
| $T_{21}$ | Control | 7.33 | 2.23 | 2.90 |
| | **SEm±** | **0.172** | **0.083** | **0.026** |
| | **CD (P=0.05)** | **0.493** | **0.238** | **0.075** |

#### 4.1.4.10 Effect of seed treatment chemicals on shoot dry weight of seedling

The effect of chemical treatments on shoot dry weight of seedlings are presented in Table.4.5 and Fig.4. The highest shoot dry weight was noticed in $GA_3$ 300 ppm for 24 hrs ($T_8$) (0.6g) which was found to be on par with $GA_3$ 300 ppm for 12 hrs ($T_7$) (0.58g), Thiourea 4000 ppm for 24 hr ($T_{20}$) (0.56g), $GA_3$ 200 ppm for 24 hrs ($T_6$) (0.54g), whereas, minimum shoot dry weight was recorded in control, $T_{21}$ (0.22g).

The maximum shoot dry weight of seedling was associated in seeds treated with $GA_3$ prior to sowing might be due to role of $GA_3$ in increased shoot growth and accumulation of carbohydrates matter in shoots resulted in maximum shoot dry weight. Veeraragavathatham *et al*. (1980) also reported increased shoot dry weight in $GA_3$ treated papaya seeds.

#### 4.1.4.11 Effect of seed treatment chemicals on root dry weight of seedling

The effect of chemical treatments on root dry weight are presented in Table.4.5 and Fig.4. The highest root dry weight was noticed in $GA_3$ 200 ppm for 24 hrs ($T_6$) (0.32g) which was found to be on par with $GA_3$ 200 ppm for 12 hrs ($T_5$) (0.30g), $GA_3$ 300 ppm for 24 hrs ($T_8$) (0.28), whereas, minimum root dry weight was recorded in control ($T_{21}$) (0.11g).

The maximum root dry weight was associated in seedlings treated with $GA_3$ prior to sowing, which might be due to the increase in root length and more translocation of carbohydrates to roots increases the root dry weight. The above results are in conformity with Veeraragavathatham *et al*. (1980) in papaya.

#### 4.1.4.12 Effect of seed treatment chemicals on dry weight of seedling

The effect of chemical treatments on dry weight of seedlings are presented in Table.4.5 and Fig.4. The highest dry weight was noticed in $GA_3$ 300 ppm for 24 hrs ($T_8$) (0.88g) which was found to be on par with $GA_3$ 200 ppm for 24 hrs ($T_6$) (0.85g), $GA_3$ 300 ppm for 12 hrs ($T_7$) (0.83g), Thiourea 4000 ppm for

**Table 4.5 Effect of different seed treatment chemicals on shoot dry weight, root dry weight and dry weight of seedling**

| | Treatments | Shoot dry weight (g) | Root dry weight (g) | Dry weight of seedling (g) |
|---|---|---|---|---|
| $T_1$ | Tap water for 12 hrs | 0.28 | 0.14 | 0.42 |
| $T_2$ | Tap water for 24 hrs | 0.24 | 0.16 | 0.40 |
| $T_3$ | $GA_3$ 100 ppm for 12 hrs | 0.45 | 0.21 | 0.66 |
| $T_4$ | $GA_3$ 100 ppm for 24 hrs | 0.46 | 0.23 | 0.70 |
| $T_5$ | $GA_3$ 200 ppm for 12 hrs | 0.48 | 0.30 | 0.77 |
| $T_6$ | $GA_3$ 200 ppm for 24 hrs | 0.54 | 0.32 | 0.85 |
| $T_7$ | $GA_3$ 300 ppm for 12 hrs | 0.58 | 0.25 | 0.83 |
| $T_8$ | $GA_3$ 300 ppm for 24 hrs | 0.60 | 0.28 | 0.88 |
| $T_9$ | $KNO_3$ 1000 ppm for 12 hrs | 0.30 | 0.12 | 0.42 |
| $T_{10}$ | $KNO_3$ 1000 ppm for 24 hrs | 0.29 | 0.11 | 0.41 |
| $T_{11}$ | $KNO_3$ 2000 ppm for 12 hrs | 0.31 | 0.13 | 0.44 |
| $T_{12}$ | $KNO_3$ 2000 ppm for 24 hrs | 0.42 | 0.17 | 0.59 |
| $T_{13}$ | $KNO_3$ 3000 ppm for 12 hrs | 0.41 | 0.18 | 0.59 |
| $T_{14}$ | $KNO_3$ 3000 ppm for 24 hrs | 0.46 | 0.19 | 0.65 |
| $T_{15}$ | Thiourea 2000 ppm for 12 hrs | 0.48 | 0.13 | 0.61 |
| $T_{16}$ | Thiourea 2000 ppm for 24 hrs | 0.49 | 0.14 | 0.64 |
| $T_{17}$ | Thiourea 3000 ppm for 12 hrs | 0.50 | 0.22 | 0.73 |
| $T_{18}$ | Thiourea 3000 ppm for 24 hrs | 0.51 | 0.21 | 0.73 |
| $T_{19}$ | Thiourea 4000 ppm for 12 hrs | 0.53 | 0.24 | 0.76 |
| $T_{20}$ | Thiourea 4000 ppm for 24 hrs | 0.56 | 0.26 | 0.82 |
| $T_{21}$ | Control | 0.22 | 0.10 | 0.32 |
| | **SEm±** | **0.022** | **0.015** | **0.027** |
| | **CD (P=0.05)** | **0.063** | **0.043** | **0.076** |

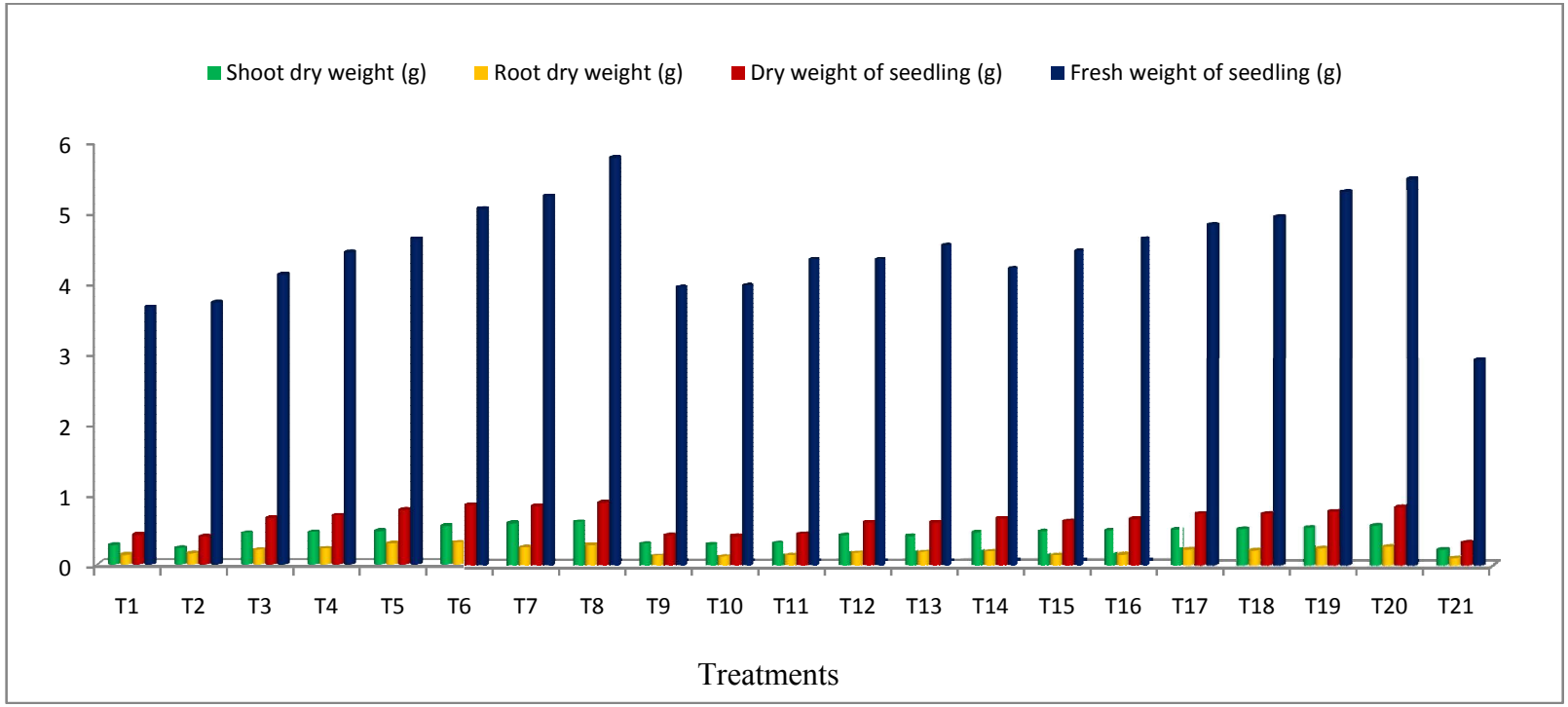


**Fig.4 Effect of different seed treatment chemicals on shoot dry weight, root dry weight, dry weight of seedling and fresh weight of seedling**

24 hrs ($T_{20}$) (0.82g) whereas, minimum dry weight was recorded in control ($T_{21}$) (0.34g).

The maximum dry weight of seedling with $GA_3$ might be due to involvement of gibberellic acid in mobilizing, translocation and accumulation of water and nutrients transported at higher rate which might have promoted more production of photosynthetic products in various plant parts might have resulted in increased total dry weight of seedling. Similar effect of $GA_3$ on dry weight of seedling were reported by Dhankar and Singh (1996), Palanisamy and Ramamoorthy (1987), Ananthakalaiselvi and Dharmalingam (1998), Anburani and Shakila (2010) and Pandit *et al*. (2001) in papaya.

#### 4.1.4.13 Effect of seed treatment chemicals on vigour index of seedling

The effect of different seed treatments on vigour index of papaya seedlings are presented in Table.4.6 and Fig.5. The highest vigour index was noticed in $GA_3$ 300 ppm for 24 hrs ($T_8$) (8574.90) which was found to be significantly superior over all the other treatments whereas, minimum vigour index was recorded in control, $T_{21}$ (3094.31).

The vigour index of seedlings is directly dependent on germination percentage and seedling length. The hike in vigour index in $GA_3$ seed treatment might be due to the direct influence on the extensive growth of seedlings probably by increased mobilization of reserve foods to growing apices. Begum *et al.* (1983) showed linear response of vigour index with the increase in the concentration of $GA_3$ in papaya. The results are in line with the findings of Anburani and Shakila (2010) and Dhinesh babu *et al.* (2010) in papaya.

### 4.1.5 Effect of seed treatment chemicals on Benefit cost ratio

The highest benefit cost ratio (Table.4.7) was recorded when seeds treated with $GA_3$ 300 ppm for 24 hrs ($T_8$) (2.57) followed by $GA_3$ 200 ppm for 24 hrs ($T_7$) (2.21) compared to the other treatments in the papaya cv. Pusa Nanha whereas, least benefit cost ratio was observed in control ($T_{21}$) (1.12).

**Table.4.6. Effect of different seed treatment chemicals on Vigour index**

| | Treatments | Vigour index |
|---|---|---|
| $T_1$ | Tap water for 12 hrs | 4033.08 |
| $T_2$ | Tap water for 24 hrs | 4475.65 |
| $T_3$ | $GA_3$ 100 ppm for 12 hrs | 5908.03 |
| $T_4$ | $GA_3$ 100 ppm for 24 hrs | 5977.03 |
| $T_5$ | $GA_3$ 200 ppm for 12 hrs | 6844.14 |
| $T_6$ | $GA_3$ 200 ppm for 24 hrs | 6956.91 |
| $T_7$ | $GA_3$ 300 ppm for 12 hrs | 7459.02 |
| $T_8$ | $GA_3$ 300 ppm for 24 hrs | 8574.90 |
| $T_9$ | $KNO_3$ 1000 ppm for 12 hrs | 3925.18 |
| $T_{10}$ | $KNO_3$ 1000 ppm for 24 hrs | 4525.98 |
| $T_{11}$ | $KNO_3$ 2000 ppm for 12 hrs | 4510.44 |
| $T_{12}$ | $KNO_3$ 2000 ppm for 24 hrs | 4639.10 |
| $T_{13}$ | $KNO_3$ 3000 ppm for 12 hrs | 4852.28 |
| $T_{14}$ | $KNO_3$ 3000 ppm for 24 hrs | 5305.17 |
| $T_{15}$ | Thiourea 2000 ppm for 12 hrs | 5787.59 |
| $T_{16}$ | Thiourea 2000 ppm for 24 hrs | 5915.06 |
| $T_{17}$ | Thiourea 3000 ppm for 12 hrs | 5435.01 |
| $T_{18}$ | Thiourea 3000 ppm for 24 hrs | 6355.83 |
| $T_{19}$ | Thiourea 4000 ppm for 12 hrs | 6425.15 |
| $T_{20}$ | Thiourea 4000 ppm for 24 hrs | 7894.59 |
| $T_{21}$ | Control | 3094.31 |
| | **SEm±** | **129.212** |
| | **CD (P=0.05)** | **370.679** |

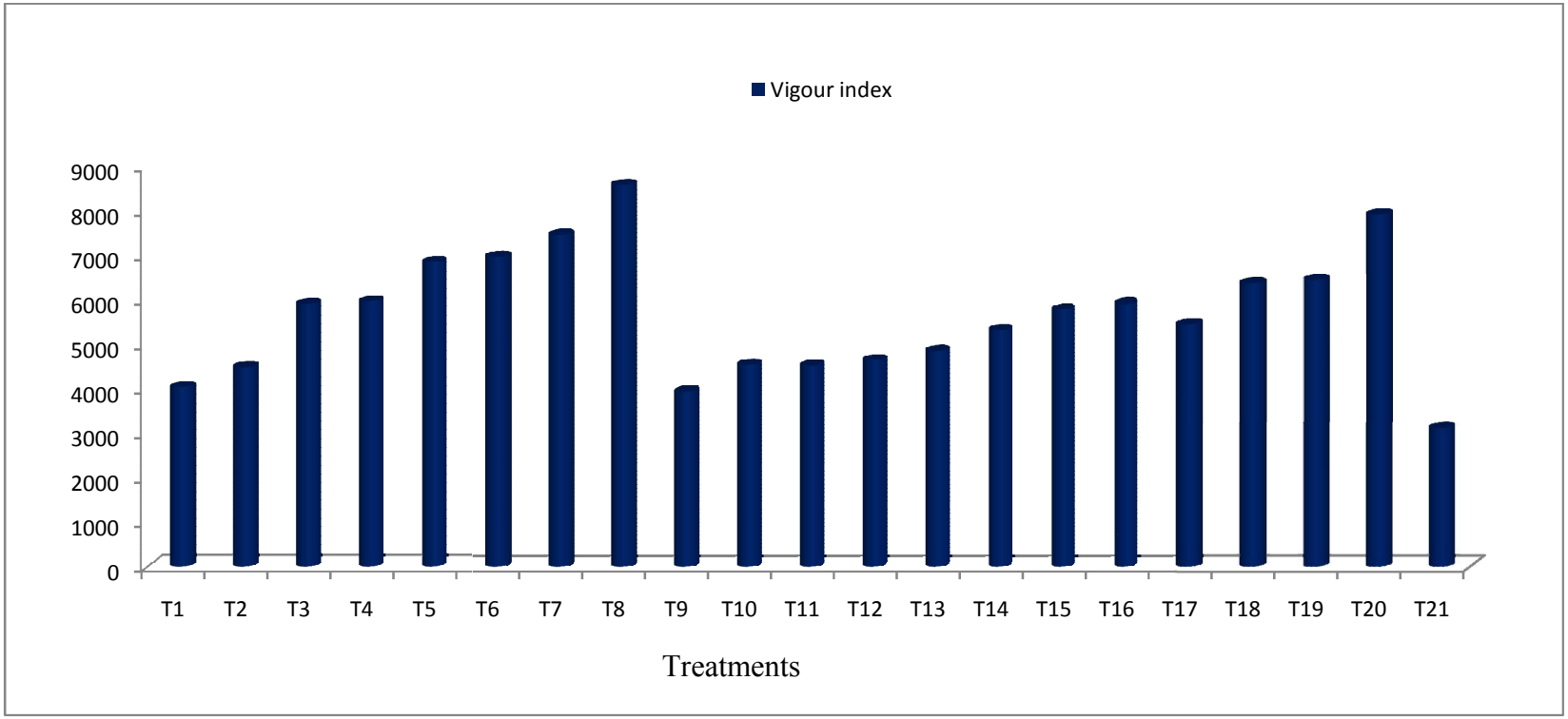


**Fig.5 Effect of different seed treatment chemicals on vigour index**

**Table 4.7. Effect of different seed treatment chemicals on Cost benefit ratio for the production of 1000 papaya seedlings**

| | Treatments | Total production cost (Rs) | Gross returns (Rs) | Net returns (Rs) | Benefit: cost ratio |
|---|---|---|---|---|---|
| $T_1$ | Tap water for 12 hrs | 120.00 | 258.00 | 138.00 | 1.15 |
| $T_2$ | Tap water for 24 hrs | 120.00 | 261.00 | 141.00 | 1.18 |
| $T_3$ | $GA_3$ 100 ppm for 12 hrs | 121.65 | 290.00 | 168.35 | 1.38 |
| $T_4$ | $GA_3$ 100 ppm for 24 hrs | 121.65 | 298.50 | 175.85 | 1.45 |
| $T_5$ | $GA_3$ 200 ppm for 12 hrs | 122.30 | 301.00 | 178.70 | 1.46 |
| $T_6$ | $GA_3$ 200 ppm for 24 hrs | 122.30 | 344.00 | 221.70 | 1.81 |
| $T_7$ | $GA_3$ 300 ppm for 12 hrs | 123.00 | 396.00 | 273.00 | 2.22 |
| $T_8$ | $GA_3$ 300 ppm for 24 hrs | 123.00 | 440.00 | 317.00 | 2.58 |
| $T_9$ | $KNO_3$ 1000 ppm for 12 hrs | 122.00 | 297.50 | 175.50 | 1.44 |
| $T_{10}$ | $KNO_3$ 1000 ppm for 24 hrs | 122.00 | 301.00 | 179.00 | 1.47 |
| $T_{11}$ | $KNO_3$ 2000 ppm for 12 hrs | 124.00 | 308.00 | 184.00 | 1.48 |
| $T_{12}$ | $KNO_3$ 2000 ppm for 24 hrs | 124.00 | 340.00 | 216.00 | 1.74 |
| $T_{13}$ | $KNO_3$ 3000 ppm for 12 hrs | 126.25 | 348.00 | 221.75 | 1.76 |
| $T_{14}$ | $KNO_3$ 3000 ppm for 24 hrs | 126.25 | 352.00 | 225.75 | 1.79 |
| $T_{15}$ | Thiourea 2000 ppm for 12 hrs | 120.50 | 304.50 | 183.75 | 1.52 |
| $T_{16}$ | Thiourea 2000 ppm for 24 hrs | 120.75 | 308.00 | 187.25 | 1.55 |
| $T_{17}$ | Thiourea 3000 ppm for 12 hrs | 121.50 | 344.00 | 222.50 | 1.83 |
| $T_{18}$ | Thiourea 3000 ppm for 24 hrs | 121.50 | 348.00 | 226.50 | 1.86 |
| $T_{19}$ | Thiourea 4000 ppm for 12 hrs | 122.25 | 387.00 | 264.50 | 2.16 |
| $T_{20}$ | Thiourea 4000 ppm for 24 hrs | 122.25 | 391.50 | 269.25 | 2.20 |
| $T_{21}$ | Control | 120.00 | 255.00 | 135.00 | 1.13 |


Plate 2a. Roots of papaya seedlings under different chemical treatments


Plate 2b. Roots of papaya seedlings under different chemical treatments

## 4.2 Effect of different substrates on seed germination

### 4.2.1 Effect of different substrates on number of days taken for germination.

The data on days required for germination of papaya seeds affected by various substrates are presented in Table.4.8 and Fig.6. The data clearly indicated that comparatively lesser days required for seed germination was observed in FYM + Cocopeat + Vermicompost + Soil + Sand (60% + 10% + 10% + 10% + 10%) ($T_1$) (16.67 days) which is found to be significantly superior over all the other treatments, while the maximum days required for germination were recorded in Soil + FYM + Sand (50% + 25% + 25%) along with 5g *Azospirillum* + 5g PSB + 5g *Frateuria aurantia* ($T_{14}$) (28.67 days).

The papaya seeds sown in substrate combination with FYM gave an early seed germination. This might be due to the reason that media containing organic matter posses organic acid within them which improves the soil structure and texture which increases the metabolic activity in germinating seed. Therefore, more available moisture and some acids help in minimum days required for germination. These results are in agreement with the findings of Neelam *et al*. (2001) and Lopes *et al*. (2007) in passion fruit, Shergill *et al*. (1992) in ber.

### 4.2.2 Effect of different substrates on germination percentage

The seed germination percentage in papaya as influenced by various substrates are presented in Table.4.8 and Fig.6. The maximum percentage of seed germination was noticed in FYM + Cocopeat + Vermicompost + Soil + Sand (60% + 10% + 10% + 10% + 10%) ($T_1$) (87.73 %) which was found to be significantly superior over all the other treatments whereas, minimum germination percentage was recorded in Soil + FYM + Sand (50% + 25% + 25%) along with 5g *Azospirillum* + 5g PSB + 5g *Frateuria aurantia* ($T_{14}$) (51.10 %).

The papaya seeds sown in substrate combination with FYM gave maximum seed germination might be due to its Cation exchange capacity for

retention of nutrients, good water holding capacity as well as sufficient porousity, So that permitting adequate moisture and exchange of gases between growth media and the embryo which is essential for rapid and uniform germination of seeds. These results are in agreement with the findings of Narayan *et al*. (2008) and Bihari *et al*. (2009) in Aonla.

### 4.2.3 Effect of different substrates on germination index

The seed germination index in papaya as influenced by various substrates are presented in Table.4.8 and Fig.6. The highest seed germination index was noticed in FYM + Cocopeat + Vermicompost + Soil + Sand (60% + 10% + 10% + 10% + 10%) ($T_1$) (3.15) significantly superior over all the other treatments whereas, minimum germination index was recorded in Soil + FYM + Sand (50% + 25% + 25% ) along with 5g *Azospirillum* + 5g PSB + 5g *Frateuria aurantia* ($T_{14}$) (1.13). This is due to the reason that germination index is directly dependent on days required for germination and germination percentage. These results are in agreement with the findings of Bhardwaj *et al*. (2013) in papaya.

### 4.2.4 Effect of different substrates on seedling growth parameters

#### 4.2.4.1 Effect of different substrates on seedling height

As evident from (Table.4.9 and Fig.7) the maximum seedling height in papaya was noticed in FYM + Cocopeat + Vermicompost + Soil + Sand (60% + 10% + 10% + 10% + 10%) along with 5g *Azospirillum* + 5g PSB + 5g *Frateuria aurantia* ($T_8$) (15.09 cm), which was found to be on par with FYM + Cocopeat + Vermicompost + Soil + Sand (60% + 10% + 10% + 10% + 10%) ($T_1$) (14.81 cm) and found to be significant over rest of the treatments whereas, minimum seedling height was recorded in Soil + FYM + Sand (50% + 25% + 25% ) ($T_7$) (6.45 cm).

The tallest papaya seedlings are observed in the media combination with FYM along with the Biofertilizer mixture might be due to the fact that substrates improves the soil physical properties and releases the nitrogen slowly and also supplies all other micronutrients essential for the plant growth (Cooke,

**Table 4.8. Effect of different substrates on number of days taken for germination, germination percentage and germination index**

| | Treatments | No. of days taken for germination | Germination percentage (%) | Germination index |
|---|---|---|---|---|
| $T_1$ | FYM + Cocopeat + Vermicompost + Soil + Sand (60% + 10% + 10% + 10% + 10% ) | 16.67 | 87.73 | 3.15 |
| $T_2$ | FYM + Cocopeat + Vermicompost + Soil + Sand (10% + 60% + 10% + 10% + 10% ) | 21.00 | 63.30 | 1.91 |
| $T_3$ | FYM + Cocopeat + Vermicompost + Soil + Sand (10% + 10% + 60% + 10% + 10% ) | 19.00 | 79.97 | 2.55 |
| $T_4$ | FYM + Cocopeat + Vermicompost + Soil + Sand (10% + 10% + 10% + 60% + 10% ) | 20.00 | 75.50 | 2.37 |
| $T_5$ | FYM + Cocopeat + Vermicompost + Soil + Sand (10% + 10% + 10% + 10% + 60% ) | 21.33 | 66.63 | 1.82 |
| $T_6$ | FYM + Cocopeat + Vermicompost + Soil + Sand (20% + 20% + 20% + 20% + 20% ) | 19.67 | 78.87 | 2.31 |
| $T_7$ | Soil + FYM + Sand (50% + 25% + 25%) | 26.33 | 53.30 | 1.34 |
| $T_8$ | $T_1$ + Biofertilizer Mixture | 18.67 | 83.30 | 2.57 |
| $T_9$ | $T_2$ + Biofertilizer Mixture | 24.33 | 58.87 | 1.63 |
| $T_{10}$ | $T_3$ + Biofertilizer Mixture | 21.00 | 73.30 | 2.00 |
| $T_{11}$ | $T_4$ + Biofertilizer Mixture | 21.33 | 67.73 | 1.89 |
| $T_{12}$ | $T_5$ + Biofertilizer Mixture | 25.00 | 62.20 | 1.55 |
| $T_{13}$ | $T_6$ + Biofertilizer Mixture | 22.67 | 69.97 | 1.96 |
| $T_{14}$ | $T_7$ + Biofertilizer Mixture | 28.67 | 51.10 | 1.13 |
| | **SEm±** | **0.663** | **1.256** | **0.092** |
| | **CD (P=0.05)** | **1.937** | **3.671** | **0.269** |

Note : Biofertilizer mixture (5g *Azospirillum* + 5g PSB + 5g *Frateuria aurantia)* in each polybag along with potting mixture.

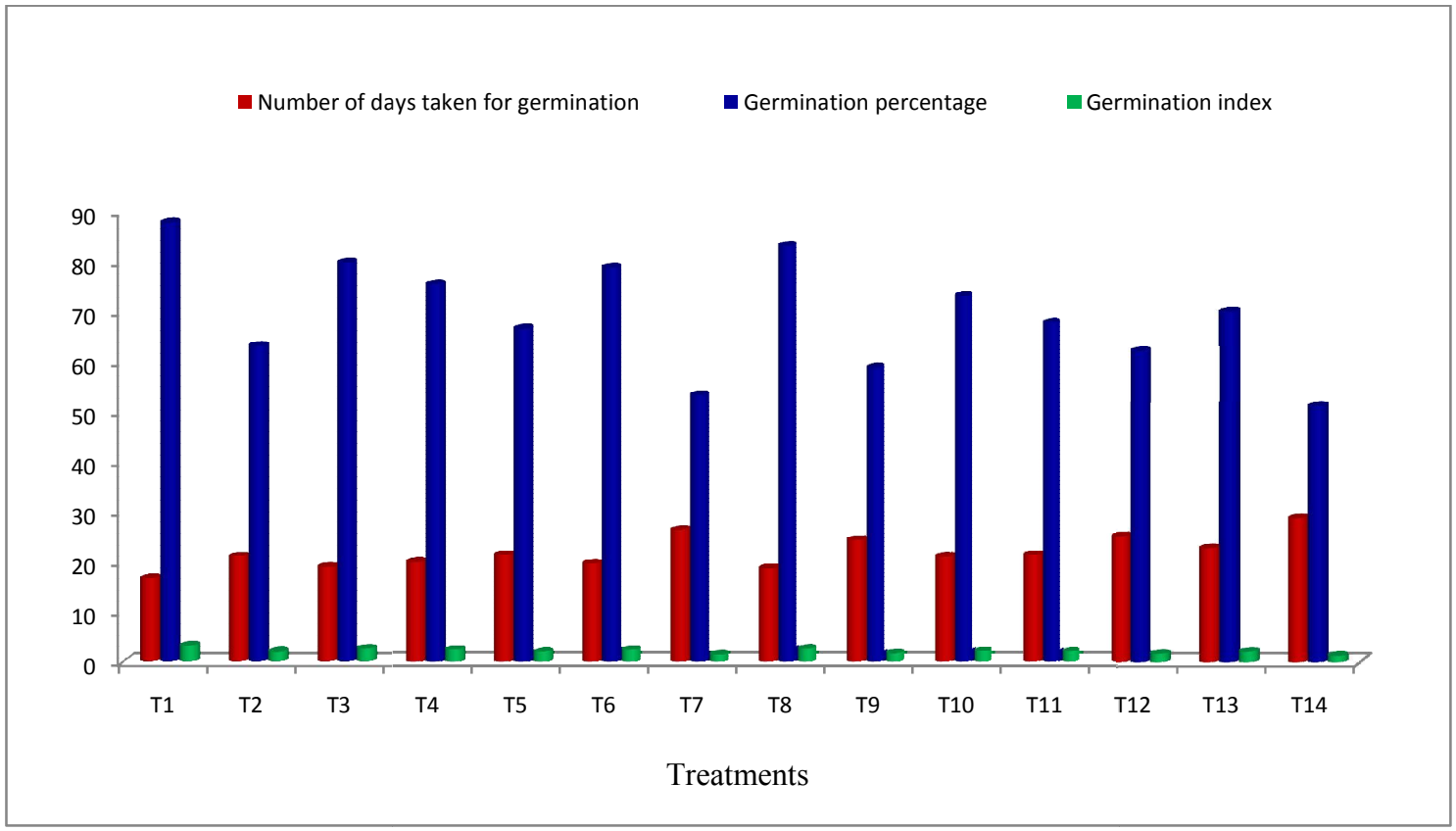


**Fig.6 Effect of different substrates on number of days taken for germination, germination percentage and germination index**

1967). Similar results were reported by Conover *et al*. (1981). The notable improvement with respect to growth parameters with the use of biofertilizers such as *Azospirillum*, PSB and *Frateuria aurantia* and organic amendments may be attributed due to role of *Azospirillum* besides nitrogen fixation, secretes plant growth promoting substances like IAA, cytokinins and gibberellins which might have improved the nutrient absorption capacity of the plant roots. Phosphate solubilizing bacteria have been reported to produce organic acids which lower the soil pH thus increasing the uptake of soluble soil phosphorus, indicating their role for solubilization and soil fertilization. On the other hand, Potassium plays an important role in the growth and development of plants. It activates enzymes, maintains cell turgor, enhances photosynthesis, reduces respiration, helps in transport of sugars and starches, helps in nitrogen uptake and is essential for protein synthesis . The results are in conformity with similar findings of Costa *et al*. (2010) and Suresh *et al*. (2010) in papaya.

#### 4.2.4.2 Effect of different substrates on seedling girth

The seedling girth in papaya as influenced by various substrates are presented in Table.4.9 and Fig.7. The highest seedling girth was noticed in FYM + Cocopeat + Vermicompost + Soil + Sand (60% + 10% + 10% + 10% + 10%) along with the 5g *Azospirillum* + 5g PSB + 5g *Frateuria aurantia* ($T_8$) (9.16 mm), which was found to be on par with FYM + Cocopeat + Vermicompost + Soil + Sand (60% + 10% + 10% + 10% + 10%) ($T_1$) (9.07 mm) and FYM + Cocopeat + Vermicompost + Soil + Sand (10% + 10% + 60% + 10% + 10%) along with 5g *Azospirillum* + 5g PSB + 5g *Frateuria aurantia* ($T_{10}$) (8.76 mm) whereas, minimum seedling girth was recorded in Soil + FYM + Sand (50% + 25% + 25% ) along with 5g *Azospirillum* + 5g PSB + 5g *Frateuria aurantia* ($T_{14}$) (5.49 mm).

The promising effect of FYM alone and its combination with biofertilizers might be attributed to its richer nutritional status which enhanced photosynthetic activity resulted in more plant stored material, thereby increasing the seedling girth. Similar results were reported by Henley, (1974). The growth enchancement by biofertilizers may be due to the production of growth regulators

**Table 4.9. Effect of different substrates on seedling height, seedling girth and root length**

| | Treatments | Seedling height(cm) | Seedling girth(mm) | Root length (cm) |
|---|---|---|---|---|
| $T_1$ | FYM + Cocopeat + Vermicompost + Soil + Sand (60% + 10% + 10% + 10% + 10% ) | 14.81 | 9.07 | 15.07 |
| $T_2$ | FYM + Cocopeat + Vermicompost + Soil + Sand (10% + 60% + 10% + 10% + 10% ) | 7.60 | 6.10 | 10.37 |
| $T_3$ | FYM + Cocopeat + Vermicompost + Soil + Sand (10% + 10% + 60% + 10% + 10% ) | 13.15 | 8.39 | 15.01 |
| $T_4$ | FYM + Cocopeat + Vermicompost + Soil + Sand (10% + 10% + 10% + 60% + 10% ) | 10.72 | 7.21 | 12.53 |
| $T_5$ | FYM + Cocopeat + Vermicompost + Soil + Sand (10% + 10% + 10% + 10% + 60% ) | 10.30 | 6.84 | 11.26 |
| $T_6$ | FYM + Cocopeat + Vermicompost + Soil + Sand (20% + 20% + 20% + 20% + 20% ) | 11.46 | 7.01 | 12.93 |
| $T_7$ | Soil + FYM + Sand (50% + 25% + 25%) | 6.45 | 5.51 | 9.49 |
| $T_8$ | $T_1$ + Biofertilizer Mixture | 15.09 | 9.16 | 15.4 |
| $T_9$ | $T_2$ + Biofertilizer Mixture | 7.79 | 6.00 | 10.56 |
| $T_{10}$ | $T_3$ + Biofertilizer Mixture | 13.55 | 8.76 | 16.61 |
| $T_{11}$ | $T_4$ + Biofertilizer Mixture | 12.69 | 7.72 | 14.44 |
| $T_{12}$ | $T_5$ + Biofertilizer Mixture | 11.01 | 7.57 | 12.32 |
| $T_{13}$ | $T_6$ + Biofertilizer Mixture | 12.39 | 8.21 | 13.81 |
| $T_{14}$ | $T_7$ + Biofertilizer Mixture | 6.65 | 5.49 | 9.66 |
| | **SEm±** | **0.123** | **0.132** | **0.28** |
| | **CD (P=0.05)** | **0.36** | **0.386** | **0.819** |

Note : Biofertilizer mixture (5g *Azospirillum* + 5g PSB + 5g *Frateuria aurantia)* in each polybag along with potting mixture.

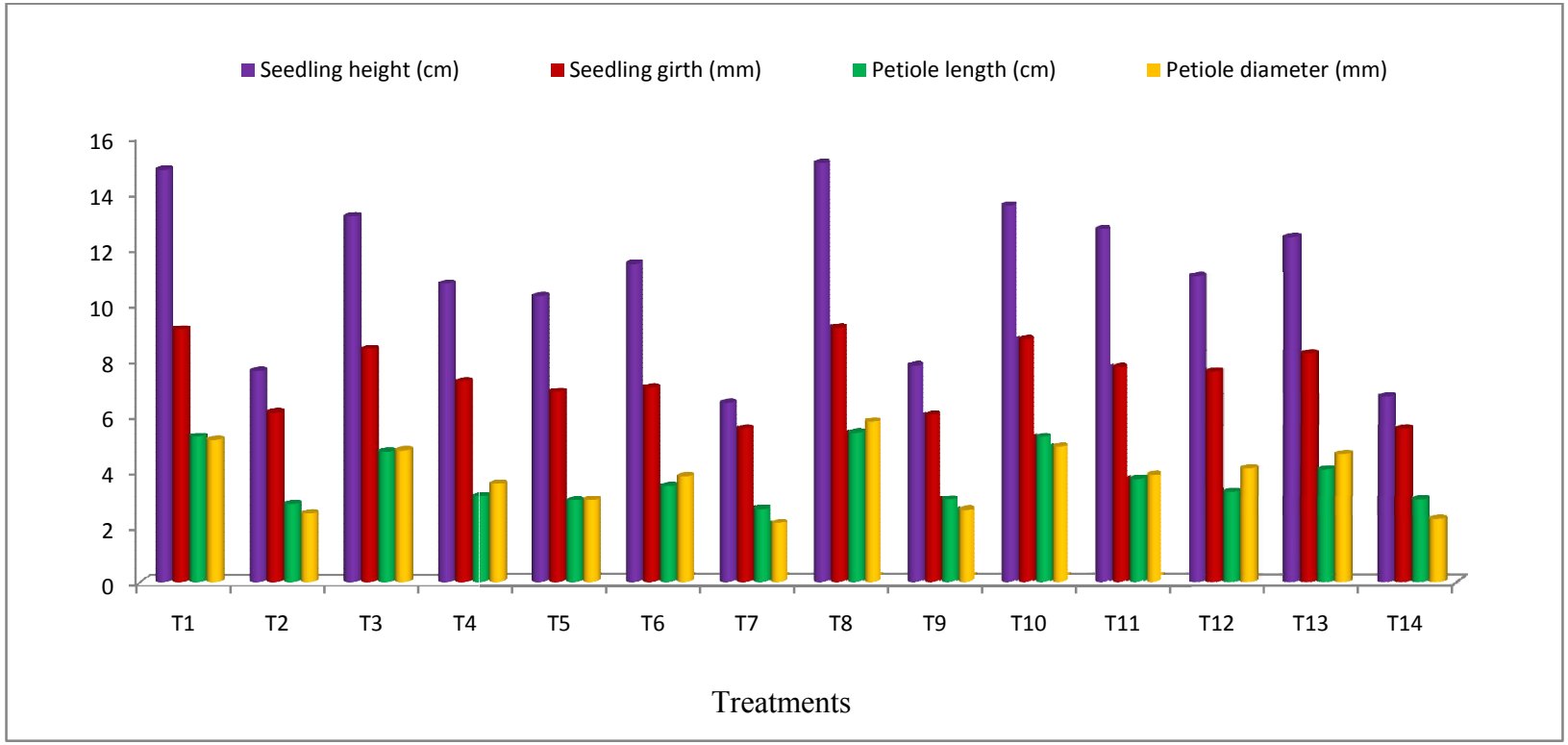


**Fig.7 Effect of different substrates on seedling height, seedling girth, petiole length and petiole diameter**

as well as to nitrogen fixation, Bashan and Levanony (1990). The results are in conformity with similar findings of Rajamanickam *et al*. (2010) in papaya

### 4.2.4.3 Effect of different substrates on root length of seedling

The root length in papaya as influenced by various substrates are presented in Table.4.9 and Fig.8. The highest root length was observed in FYM + Cocopeat + Vermicompost + Soil + Sand (10% + 10% + 60% + 10% + 10%) along with the 5g *Azospirillum* + 5g PSB + 5g *Frateuria aurantia* ($T_{10}$) (16.61 cm), which was found to be significantly superior over all the other treatments whereas, minimum root lenght was recorded in Soil + FYM + Sand (50% + 25% + 25% ) ($T_7$) (9.49 cm).

The maximum root length was recorded under the media combination of vermicompost along with the Biofertilizer mixture, this might be due to fact that vermicompost is reported to have bioactive principles which are considered to be beneficial for root growth and this has been hypothesized to result in greater root intiation, increased biomass, enhanced growth and development (Bachman and Metzger, 2008) and also balanced composition of nutrients (Zaller, 2007). The possible reason in the relative enhancement of root length by biofertilizers may be related to PSB which releases phosphorus essential for root growth. The results are in conformity with similar findings of Rajamanickam *et al*. (2010) in papaya.

### 4.2.4.4 Effect of different substrates on number of leaves per seedling

The data on number of leaves per seedling in papaya as influenced by various substrates are presented in Table.4.10 and Fig.8. The highest number of leaves was observed in FYM + Cocopeat + Vermicompost + Soil + Sand (60% + 10% + 10% + 10% + 10%) along with the 5g *Azospirillum* + 5g PSB + 5g *Frateuria aurantia* ($T_8$) (15.07) which is found to be on par with FYM + Cocopeat + Vermicompost + Soil + Sand (60% + 10% + 10% + 10% + 10%) ($T_1$) (14.40) whereas, minimum number of leaves was recorded in Soil + FYM + Sand

(50% + 25% + 25% ) along with 5g *Azospirillum* + 5g PSB + 5g *Frateuria aurantia* ($T_{14}$) (7.20).

The maximum number of leaves was recorded under the media combination with FYM along with the Biofertilizer mixture, this might be due to fact that phenolic compounds formed from organic matter have favourable effect on initiation of more number of leaves per seedling (Whitehead, 1963). The results are in conformity with the Rajamanickam *et al*. (2010) in papaya and Parasana *et al*. (2013) in mango.

### 4.2.4.5 Effect of different substrates on leaf area of seedling

The effect of substrates on leaf area of papaya seedlings are presented in Table.4.10 and Fig.8. The maximum leaf area was observed in FYM + Cocopeat + Vermicompost + Soil + Sand (60% + 10% + 10% + 10% + 10%) ($T_1$) (40.21 $cm^2$) which was found to be on par with FYM + Cocopeat + Vermicompost + Soil + Sand (60% + 10% + 10% + 10% + 10%) along with the 5g *Azospirillum* + 5g PSB + 5g *Frateuria aurantia* ($T_8$) (40.12$cm^2$) and FYM + Cocopeat + Vermicompost + Soil + Sand (10% + 10% + 60% + 10% + 10%) along with the 5g *Azospirillum* + 5g PSB + 5g *Frateuria aurantia* ($T_{10}$) (39.08 $cm^2$) whereas, minimum leaf area was recorded in Soil + FYM + Sand (50% + 25% + 25% ) ($T_7$) (15.43 $cm^2$).

The maximum leaf area was recorded under the media combination with FYM might be due to the fact that substrates provide nutrional factors which improves photosynthetic efficiency causing greater synthesis, translocation and accumulation of carbohydrates in plants responsible for increasing leaf expansion (Morard, 1974). Similar results were obtained by Khan *et al.* (2006) in citrus.

### 4.2.4.6 Effect of different substrates on petiole length of seedling

The data pertaining to petiole length as influenced by various substrates are presented in Table.4.10 and Fig.7. The maximum petiole length was observed in FYM + Cocopeat + Vermicompost + Soil + Sand (60% + 10% + 10% + 10% + 10%) along with the 5g *Azospirillum* + 5g PSB + 5g *Frateuria aurantia* ($T_8$) (5.36 cm) which was found to be on par with FYM + Cocopeat +

Vermicompost + Soil + Sand (60% + 10% + 10% + 10% + 10%) ($T_1$ ) (5.23 cm) and FYM + Cocopeat + Vermicompost + Soil + Sand (10% + 10% + 60% + 10% + 10%) along with the 5g *Azospirillum* + 5g PSB + 5g *Frateuria aurantia* ($T_{10}$) (5.21 cm) whereas, minimum petiole length was recorded in Soil + FYM + Sand (50% + 25% + 25%) ($T_7$) (2.63 cm).

The maximum petiole length was recorded under the media combination of along with the Biofertilizer mixture, this might be due to fact that all substrates supplemented with manure and biofertilizers significantly influenced seedling height and petiole length perhaps because this combination provides adequate nutrients and enhances both the physical properties and water holding capacity (Soegiman,1982). Similar results was also reported by Supriyanto *et al*. (1990) on orange seedlings.

### 4.2.4.7 Effect of different substrates on number of nodes per seedling

The number of nodes per seedling in papaya as influenced by various substrates are presented in Table.4.11 and Fig.8. The highest number of nodes was observed in FYM + Cocopeat + Vermicompost + Soil + Sand (60% + 10% + 10% + 10% + 10%) along with the 5g *Azospirillum* + 5g PSB + 5g *Frateuria aurantia* ($T_8$) (17.13), which was found to be significantly superior over all the other treatments whereas, minimum number of nodes was recorded in Soil + FYM + Sand (50% + 25% + 25% ) ($T_7$) (9.00).

The maximum number of nodes was recorded under the media combination with FYM along with the Biofertilizer mixture, this might be due to fact that FYM mixed with various substrates, affects physical, chemical and biological properties of the soil as the organic matter acts as a glue for soil aggregration and is a source of soil nutrients. Soil aggregration improves permeability and air flow in the polybags which might have increased more number of nodes per seedling (Karama and Manwan, 1990). The results are in conformity with the Suresh *et al*. (2010) in papaya.

**Table 4.10. Effect of different substrates on number of leaves per seedling, leaf area and petiole length**

| | Treatments | No. of leaves per seedling | Leaf area ($cm^2$) | Petiole length (cm) |
|---|---|---|---|---|
| $T_1$ | FYM + Cocopeat + Vermicompost + Soil + Sand (60% + 10% + 10% + 10% + 10% ) | 14.40 | 40.21 | 5.23 |
| $T_2$ | FYM + Cocopeat + Vermicompost + Soil + Sand (10% + 60% + 10% + 10% + 10% ) | 8.93 | 18.30 | 2.80 |
| $T_3$ | FYM + Cocopeat + Vermicompost + Soil + Sand (10% + 10% + 60% + 10% + 10% ) | 13.27 | 33.32 | 4.70 |
| $T_4$ | FYM + Cocopeat + Vermicompost + Soil + Sand (10% + 10% + 10% + 60% + 10% ) | 10.87 | 22.48 | 3.08 |
| $T_5$ | FYM + Cocopeat + Vermicompost + Soil + Sand (10% + 10% + 10% + 10% + 60% ) | 9.40 | 20.09 | 2.91 |
| $T_6$ | FYM + Cocopeat + Vermicompost + Soil + Sand (20% + 20% + 20% + 20% + 20% ) | 10.53 | 30.50 | 3.45 |
| $T_7$ | Soil + FYM + Sand (50% + 25% + 25%) | 8.33 | 15.43 | 2.63 |
| $T_8$ | $T_1$ + Biofertilizer Mixture | 15.07 | 40.12 | 5.36 |
| $T_9$ | $T_2$ + Biofertilizer Mixture | 8.73 | 19.49 | 2.97 |
| $T_{10}$ | $T_3$ + Biofertilizer Mixture | 13.60 | 39.08 | 5.21 |
| $T_{11}$ | $T_4$ + Biofertilizer Mixture | 11.93 | 26.06 | 3.71 |
| $T_{12}$ | $T_5$ + Biofertilizer Mixture | 10.27 | 23.04 | 3.25 |
| $T_{13}$ | $T_6$ + Biofertilizer Mixture | 11.27 | 33.26 | 4.05 |
| $T_{14}$ | $T_7$ + Biofertilizer Mixture | 7.20 | 16.90 | 2.95 |
| | **SEm±** | **0.291** | **0.563** | **0.092** |
| | **CD (P=0.05)** | **0.852** | **1.647** | **0.27** |

Note : Biofertilizer mixture (5g *Azospirillum* + 5g PSB + 5g *Frateuria aurantia)* in each polybag along with potting mixture.

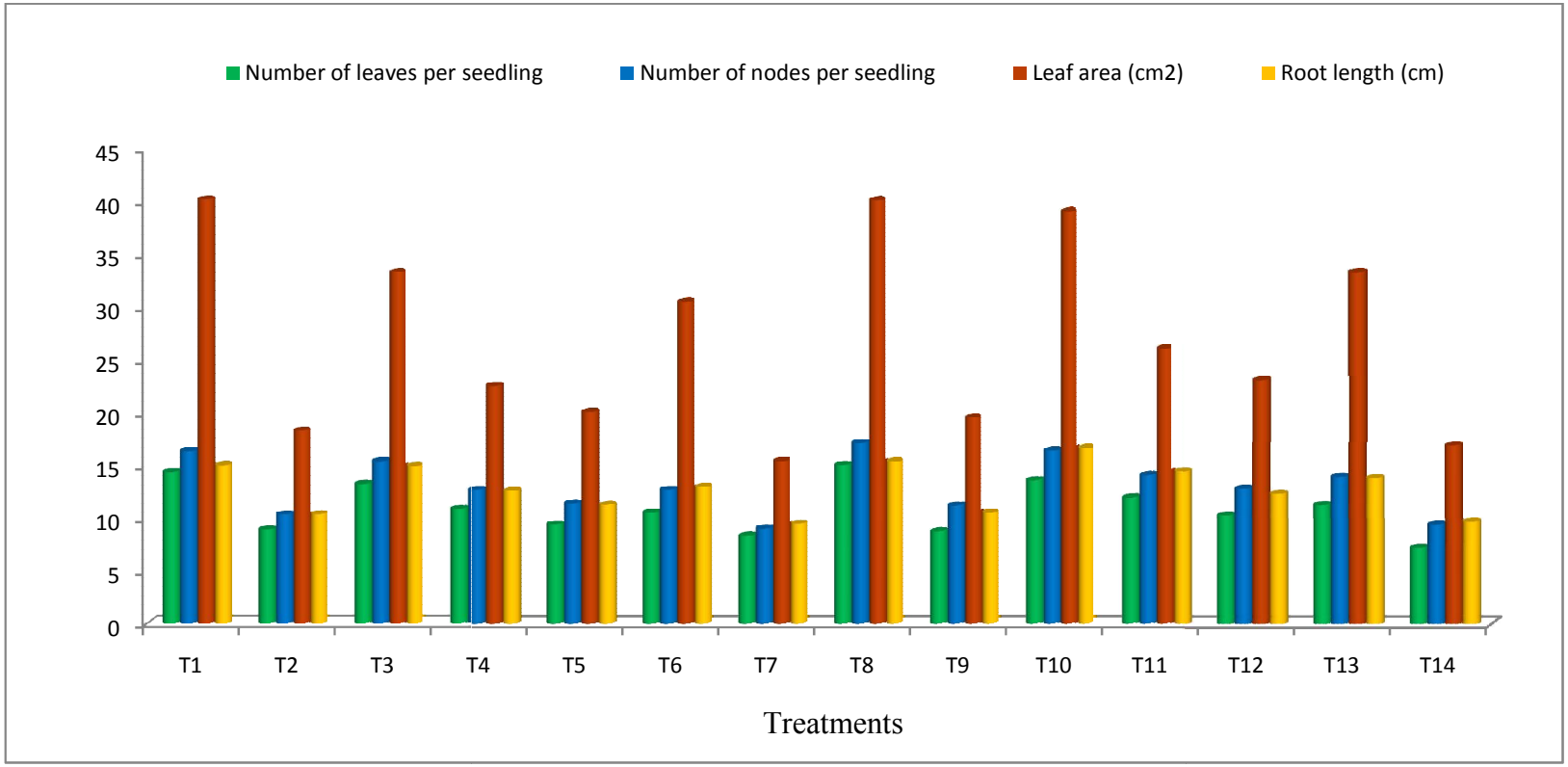


**Fig.8 Effect of different substrates on number of leaves per seedling, number of nodes per seedling, leaf area and root length**

### 4.2.4.8 Effect of different substrates on petiole diameter of seedling

The petiole diameter in papaya as influenced by various substrates are presented in Table.4.11 and Fig.7. The maximum petiole diameter was observed in FYM + Cocopeat + Vermicompost + Soil + Sand (60% + 10% + 10% + 10% + 10%) along with the 5g *Azospirillum* + 5g PSB + 5g *Frateuria aurantia* ($T_8$) (5.77 mm) which was found to be significantly superior over all the other treatments whereas, minimum petiole diameter was recorded in Soil + FYM + Sand (50% + 25% + 25% ) ($T_7$) (2.12 mm).

The maximum petiole diameter was recorded under the media combination with FYM along with the Biofertilizer mixture, this may be due to better nutrient availability in the media leading to higher production of photosynthetically functional leaves which increases petiole diameter (Borah *et al*. 1994). Similar results were obtained by Shergill *et al*. (1992) in ber.

### 4.2.4.9 Effect of different substrates on fresh weight of seedling

The effect of substrates on fresh weight of papaya seedlings are presented in Table.4.11 and Fig.9. The maximum fresh weight was observed in FYM + Cocopeat + Vermicompost + Soil + Sand (60% + 10% + 10% + 10% + 10%) along with the 5g *Azospirillum* + 5g PSB + 5g *Frateuria aurantia* ($T_8$) (7.82 g) which was found to be on par with FYM + Cocopeat + Vermicompost + Soil + Sand (60% + 10% + 10% + 10% + 10%) ($T_1$) (7.60 g) whereas, minimum fresh weight was recorded in Soil + FYM + Sand (50% + 25% + 25%) ($T_7$) (2.22g).

The maximum fresh weight was recorded under the media combination with FYM along with the Biofertilizer mixture, which might be due to fact that substrates improves the physical and chemical properties of the rooting media that increased plant height, number of leaves and stem diameter which causes rapid growth of plant which reflect into maximum fresh weight of seedlings. The above results are conformity with Parasana *et al*. (2013) in mango.

**Table 4.11 Effect of different substrates on number of nodes per seedling, petiole diameter and fresh weight of seedling**

| | Treatments | No. of nodes per seedling | Petiole diameter (mm) | Fresh weight of seedling (g) |
|---|---|---|---|---|
| $T_1$ | FYM + Cocopeat + Vermicompost + Soil + Sand (60% + 10% + 10% + 10% + 10% ) | 16.33 | 5.11 | 7.60 |
| $T_2$ | FYM + Cocopeat + Vermicompost + Soil + Sand (10% + 60% + 10% + 10% + 10% ) | 10.33 | 2.45 | 2.75 |
| $T_3$ | FYM + Cocopeat + Vermicompost + Soil + Sand (10% + 10% + 60% + 10% + 10% ) | 15.40 | 4.74 | 6.69 |
| $T_4$ | FYM + Cocopeat + Vermicompost + Soil + Sand (10% + 10% + 10% + 60% + 10% ) | 12.67 | 3.53 | 5.63 |
| $T_5$ | FYM + Cocopeat + Vermicompost + Soil + Sand (10% + 10% + 10% + 10% + 60% ) | 11.40 | 2.94 | 4.17 |
| $T_6$ | FYM + Cocopeat + Vermicompost + Soil + Sand (20% + 20% + 20% + 20% + 20% ) | 12.67 | 3.80 | 6.09 |
| $T_7$ | Soil + FYM + Sand (50% + 25% + 25%) | 9.00 | 2.12 | 2.22 |
| $T_8$ | $T_1$ + Biofertilizer Mixture | 17.13 | 5.77 | 7.82 |
| $T_9$ | $T_2$ + Biofertilizer Mixture | 11.20 | 2.59 | 3.04 |
| $T_{10}$ | $T_3$ + Biofertilizer Mixture | 16.40 | 4.89 | 7.37 |
| $T_{11}$ | $T_4$ + Biofertilizer Mixture | 14.07 | 3.84 | 5.93 |
| $T_{12}$ | $T_5$ + Biofertilizer Mixture | 12.80 | 4.09 | 4.59 |
| $T_{13}$ | $T_6$ + Biofertilizer Mixture | 13.93 | 4.59 | 6.53 |
| $T_{14}$ | $T_7$ + Biofertilizer Mixture | 9.40 | 2.25 | 2.33 |
| | **SEm±** | **0.197** | **0.091** | **0.09** |
| | **CD (P=0.05)** | **0.577** | **0.266** | **0.263** |

Note : Biofertilizer mixture (5g *Azospirillum* + 5g PSB + 5g *Frateuria aurantia)* in each polybag along with potting mixture.

### 4.2.4.10 Effect of different substrates on shoot dry weight of seedling

The data on shoot dry weight of papaya seedlings are presented in Table.4.12 and Fig.9. The maximum shoot dry weight was observed in FYM + Cocopeat + Vermicompost + Soil + Sand (60% + 10% + 10% + 10% + 10%) along with the 5g *Azospirillum* + 5g PSB + 5g *Frateuria aurantia* ($T_8$) (0.95 g) which was found to be on par with FYM + Cocopeat + Vermicompost + Soil + Sand (60% + 10% + 10% + 10% + 10%) ($T_1$) (0.91 g) and $T_{10}$ (0.88 g) whereas, minimum shoot dry weight was recorded in Soil + FYM + Sand (50% + 25% + 25%) ($T_7$) (0.19g).

The maximum shoot dry weight was recorded under the media combination with FYM along with the Biofertilizer mixture might be due to the increase in shoot growth and more accumulation of carbohydrates matter in shoots resulted in maximum shoot dry weight. The above results are in conformity with Pio *et al* (2007) in pear and Rajamanickam *et al*. (2010) in papaya.

### 4.2.4.11 Effect of different substrates on root dry weight of seedling

The effect of substrates on root dry weight of papaya seedlings are presented in Table.4.12 and Fig.9. The maximum root dry weight was observed in FYM + Cocopeat + Vermicompost + Soil + Sand (10% + 10% + 60% + 10% + 10%) along with the 5g *Azospirillum* + 5g PSB + 5g *Frateuria aurantia* ($T_{10}$) (0.43 g) which was found to be on par with FYM + Cocopeat + Vermicompost + Soil + Sand (60% + 10% + 10% + 10% + 10%) along with the 5g *Azospirillum* + 5g PSB + 5g *Frateuria aurantia* ($T_8$) (0.40g), FYM + Cocopeat + Vermicompost + Soil + Sand (60% + 10% + 10% + 10% + 10%) ($T_1$) (0.38 g) whereas, minimum root dry weight was recorded in Soil + FYM + Sand (50% + 25% + 25% ) ($T_7$) (0.10 g).

The maximum root dry weight was recorded under the media combination with FYM along with the Biofertilizer mixture, which might be due to fact that increase in root length ultimately increases the root dry weight. The above results are conformity with Rajamanickam *et al*. (2010) in papaya.

**Table 4.12. Effect of different substrates on shoot dry weight, root dry weight and dry weight of seedling**

| | Treatments | Shoot dry weight (g) | Root dry weight (g) | Dry weight of seedling (g) |
|---|---|---|---|---|
| $T_1$ | FYM + Cocopeat + Vermicompost + Soil + Sand (60% + 10% + 10% + 10% + 10% ) | 0.91 | 0.32 | 1.23 |
| $T_2$ | FYM + Cocopeat + Vermicompost + Soil + Sand (10% + 60% + 10% + 10% + 10% ) | 0.26 | 0.12 | 0.37 |
| $T_3$ | FYM + Cocopeat + Vermicompost + Soil + Sand (10% + 10% + 60% + 10% + 10% ) | 0.73 | 0.31 | 1.04 |
| $T_4$ | FYM + Cocopeat + Vermicompost + Soil + Sand (10% + 10% + 10% + 60% + 10% ) | 0.46 | 0.20 | 0.66 |
| $T_5$ | FYM + Cocopeat + Vermicompost + Soil + Sand (10% + 10% + 10% + 10% + 60% ) | 0.41 | 0.20 | 0.60 |
| $T_6$ | FYM + Cocopeat + Vermicompost + Soil + Sand (20% + 20% + 20% + 20% + 20% ) | 0.57 | 0.24 | 0.81 |
| $T_7$ | Soil + FYM + Sand (50% + 25% + 25%) | 0.19 | 0.10 | 0.32 |
| $T_8$ | $T_1$ + Biofertilizer Mixture | 0.95 | 0.40 | 1.34 |
| $T_9$ | $T_2$ + Biofertilizer Mixture | 0.39 | 0.16 | 0.54 |
| $T_{10}$ | $T_3$ + Biofertilizer Mixture | 0.88 | 0.43 | 1.31 |
| $T_{11}$ | $T_4$ + Biofertilizer Mixture | 0.56 | 0.22 | 0.78 |
| $T_{12}$ | $T_5$ + Biofertilizer Mixture | 0.47 | 0.24 | 0.71 |
| $T_{13}$ | $T_6$ + Biofertilizer Mixture | 0.69 | 0.28 | 0.96 |
| $T_{14}$ | $T_7$ + Biofertilizer Mixture | 0.20 | 0.11 | 0.31 |
| | **SEm±** | **0.021** | **0.016** | **0.030** |
| | **CD (P=0.05)** | **0.061** | **0.046** | **0.087** |

Note : Biofertilizer mixture (5g *Azospirillum* + 5g PSB + 5g *Frateuria aurantia)* in each polybag along with potting mixture.

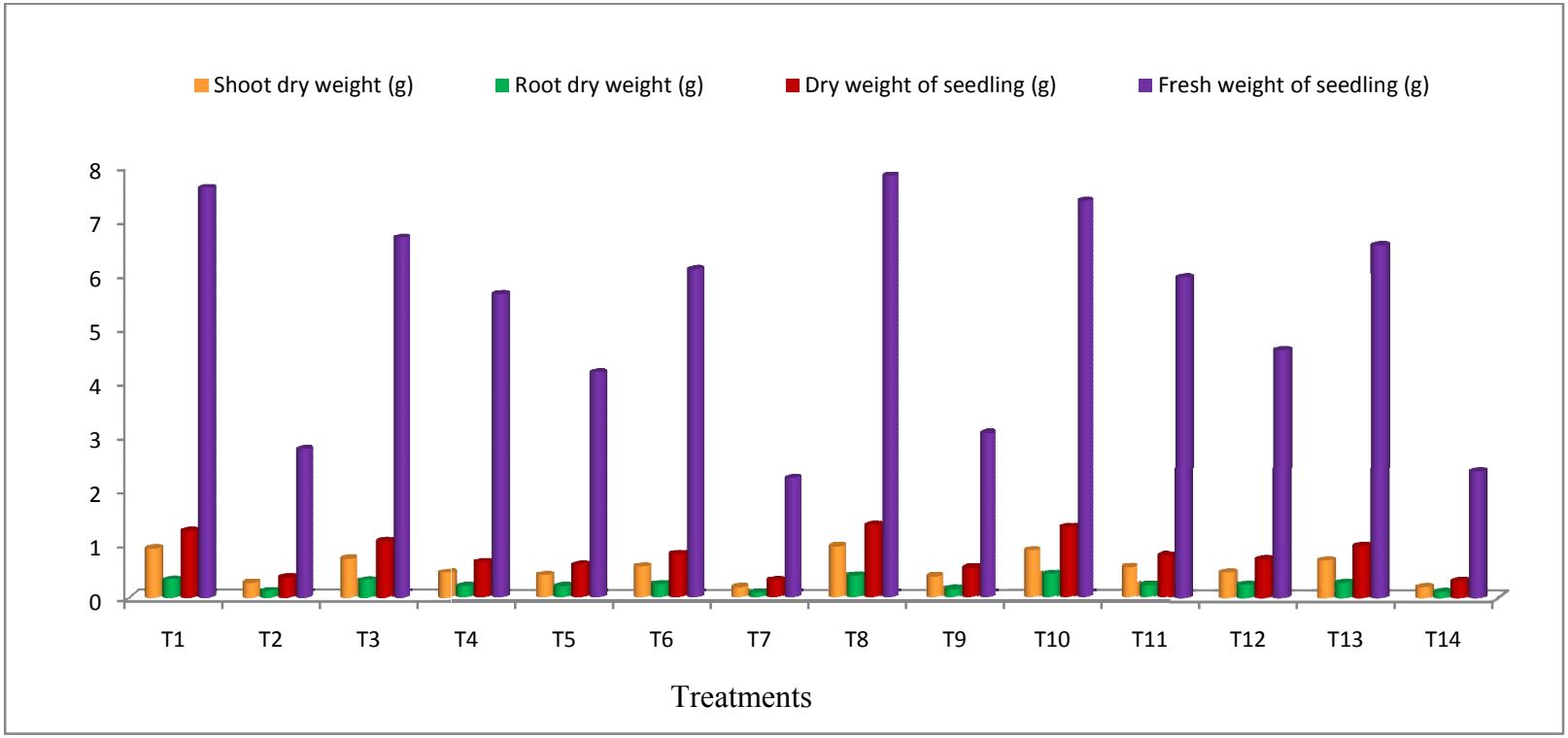


**Fig.9 Effect of different substrates on shoot dry weight, root dry weight, dry weight of seedling and fresh weight of seedling**

### 4.2.4.12 Effect of different substrates on dry weight of seedling

The effect of substrates on dry weight of papaya seedlings are presented in Table.4.12 and Fig.9. The maximum dry weight was observed in FYM + Cocopeat + Vermicompost + Soil + Sand (60% + 10% + 10% + 10% + 10%) along with the 5g *Azospirillum* + 5g PSB + 5g *Frateuria aurantia* ($T_8$) (1.31 g) which was found to be on par with FYM + Cocopeat + Vermicompost + Soil + Sand (10% + 10% + 60% + 10% + 10%) along with the 5g *Azospirillum* + 5g PSB + 5g *Frateuria aurantia* ($T_{10}$) (1.34g) and FYM + Cocopeat + Vermicompost + Soil + Sand (60% + 10% + 10% + 10% + 10%) ($T_1$) (1.28 g) whereas, minimum dry weight was recorded in Soil + FYM + Sand (50% + 25% + 25% ) along with 5g *Azospirillum* + 5g PSB + 5g *Frateuria aurantia* ($T_{14}$) (0.31 g).

The maximum dry weight was recorded under the media combination with FYM along with the Biofertilizer mixture, which might be due to fact that organic matter improves the nutritional status of the media that promotes more production of photosynthetic product and translocated them to various plant parts which might have resulted in more dry weight. Similar results have been reported by Lopes *et al*. (2007) in passion fruit.

### 4.2.4.13 Effect of substrates on vigour index of seedling

The effect of substrates on vigour index of papaya seedlings are presented in Table.4.13 and Fig.10. The maximum vigour index was observed in FYM + Cocopeat + Vermicompost + Soil + Sand (60% + 10% + 10% + 10% + 10%) along with the 5g *Azospirillum* + 5g PSB + 5g *Frateuria aurantia* ($T_8$) (12068.30) which was found to be on par with FYM + Cocopeat + Vermicompost + Soil + Sand (10% + 10% + 60% + 10% + 10%) ($T_3$) (10520.53), FYM + Cocopeat + Vermicompost + Soil + Sand (10% + 10% + 60% + 10% + 10%) along with the 5g *Azospirillum* + 5g PSB + 5g *Frateuria aurantia* ($T_{10}$) (9934.97) and FYM + Cocopeat + Vermicompost + Soil + Sand (60% + 10% + 10% + 10% + 10%) ($T_1$) (9197.17) whereas, minimum vigour

index was recorded in Soil + FYM + Sand (50% + 25% + 25% ) along with 5g *Azospirillum* + 5g PSB + 5g *Frateuria aurantia* ($T_{14}$)(3401).

The maximum vigour index was recorded under the media combination with FYM along with the Biofertilizer mixture, which might be due to fact that seedling vigour index is strongly correlated with germination percentage and seedling length. (Naryana Bhat, 1991 and Sanders *et al*.1975). Similar results have been reported by Bhardwaj *et al*. (2013) in papaya.

### 4.2.5 Effect of different substrates on Benefit cost ratio

The highest benefit cost ratio (Table.4.1) was maximum in substrate combination of FYM + Cocopeat + Vermicompost + Soil + Sand (60% + 10% + 10% + 10% + 10%) along with the 5g *Azospirillum* + 5g PSB + 5g *Frateuria aurantia* ($T_8$) (2.32) followed by FYM + Cocopeat + Vermicompost + Soil + Sand (60% + 10% + 10% + 10% + 10%) ($T_1$) (2.09) compared to the other treatments in papaya cv. Pusa Nanha whereas, minimum benefit cost ratio was found in Soil + FYM + Sand (50% + 25% + 25%) ($T_7$) (1.07).

**Table 4.13. Effect of different substrates on vigour index**

| | Treatments | Vigour index |
|---|---|---|
| $T_1$ | FYM + Cocopeat + Vermicompost + Soil + Sand (60% + 10% + 10% + 10% + 10% ) | 9197.17 |
| $T_2$ | FYM + Cocopeat + Vermicompost + Soil + Sand (10% + 60% + 10% + 10% + 10% ) | 4811.20 |
| $T_3$ | FYM + Cocopeat + Vermicompost + Soil + Sand (10% + 10% + 60% + 10% + 10% ) | 10520.53 |
| $T_4$ | FYM + Cocopeat + Vermicompost + Soil + Sand (10% + 10% + 10% + 60% + 10% ) | 8211.47 |
| $T_5$ | FYM + Cocopeat + Vermicompost + Soil + Sand (10% + 10% + 10% + 10% + 60% ) | 6862.90 |
| $T_6$ | FYM + Cocopeat + Vermicompost + Soil + Sand (20% + 20% + 20% + 20% + 20% ) | 9163.03 |
| $T_7$ | Soil + FYM + Sand (50% + 25% + 25%) | 3438.90 |
| $T_8$ | $T_1$ + Biofertilizer Mixture | 12068.30 |
| $T_9$ | $T_2$ + Biofertilizer Mixture | 4586.07 |
| $T_{10}$ | $T_3$ + Biofertilizer Mixture | 9934.97 |
| $T_{11}$ | $T_4$ + Biofertilizer Mixture | 8600.60 |
| $T_{12}$ | $T_5$ + Biofertilizer Mixture | 6850.87 |
| $T_{13}$ | $T_6$ + Biofertilizer Mixture | 8463.40 |
| $T_{14}$ | $T_7$ + Biofertilizer Mixture | 3401.00 |
| | **SEm±** | **1055.84** |
| | **CD (P=0.05)** | **3086.25** |

Note : Biofertilizer mixture (5g *Azospirillum* + 5g PSB + 5g *Frateuria aurantia)* in each polybag along with potting mixture.

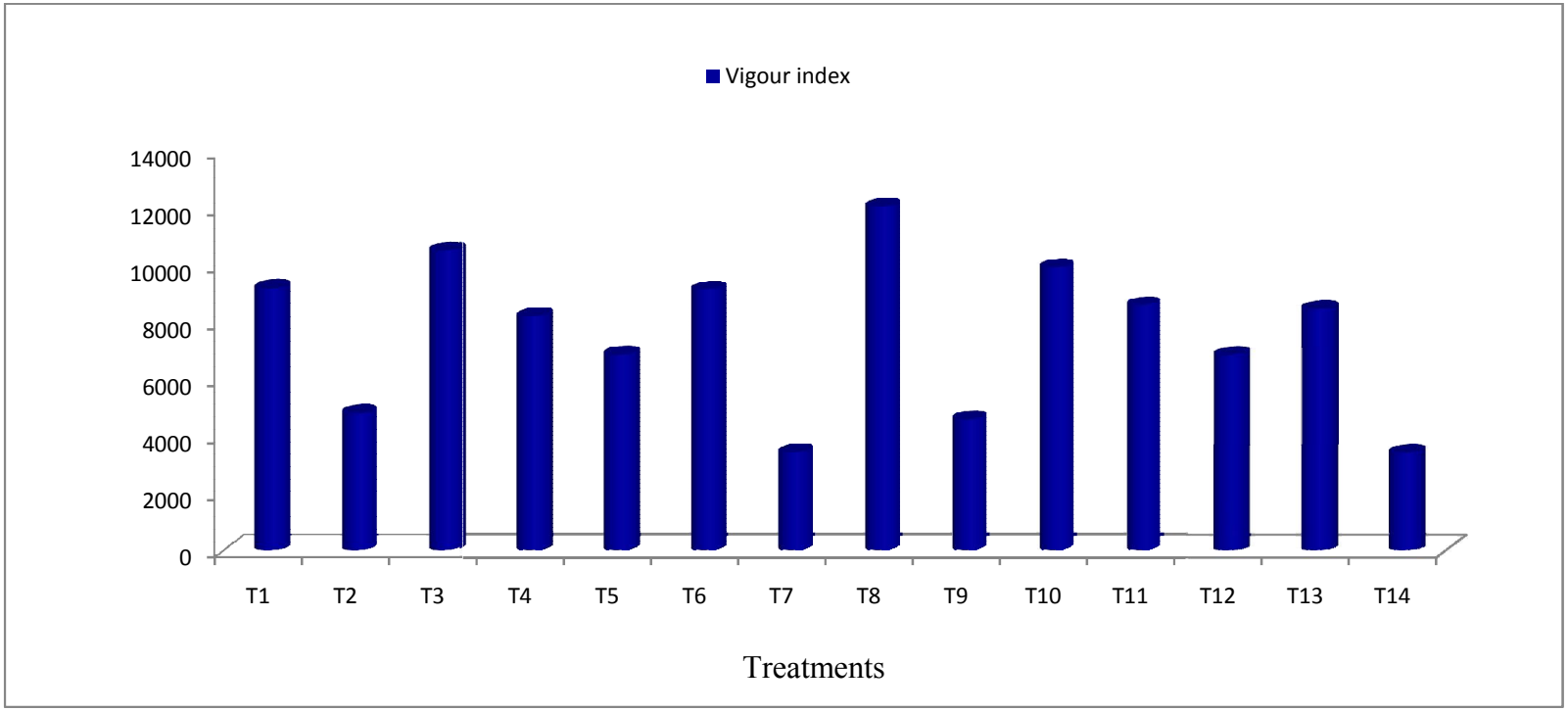


**Fig.10 Effect of different substrates on vigour index**

**Table 4.14. Effect of different substrates on cost benefit ratio of 1000 papaya seedlings**

| | Treatments | Total cost of cultivation | Gross returns | Net returns | Benefit : cost ratio |
|---|---|---|---|---|---|
| $T_1$ | FYM + Cocopeat + Vermicompost + Soil + Sand (60% + 10% + 10% + 10% + 10% ) | 275 | 850 | 575 | 2.09 |
| $T_2$ | FYM + Cocopeat + Vermicompost + Soil + Sand (10% + 60% + 10% + 10% + 10% ) | 411.8 | 968 | 556.2 | 1.35 |
| $T_3$ | FYM + Cocopeat + Vermicompost + Soil + Sand (10% + 10% + 60% + 10% + 10% ) | 316.8 | 924 | 607.2 | 1.91 |
| $T_4$ | FYM + Cocopeat + Vermicompost + Soil + Sand (10% + 10% + 10% + 60% + 10% ) | 259.8 | 738 | 478.2 | 1.84 |
| $T_5$ | FYM + Cocopeat + Vermicompost + Soil + Sand (10% + 10% + 10% + 10% + 60% ) | 278.8 | 765 | 486.2 | 1.74 |
| $T_6$ | FYM + Cocopeat + Vermicompost + Soil + Sand (20% + 20% + 20% + 20% + 20% ) | 298.2 | 704 | 405.8 | 1.36 |
| $T_7$ | Soil + FYM + Sand (50% + 25% + 25%) | 246.3 | 510 | 263.7 | 1.07 |
| $T_8$ | $T_1$ + Biofertilizer Mixture | 375 | 1246 | 871 | 2.32 |
| $T_9$ | $T_2$ + Biofertilizer Mixture | 511.8 | 1232 | 720.2 | 1.40 |
| $T_{10}$ | $T_3$ + Biofertilizer Mixture | 416.8 | 1232 | 815.2 | 1.95 |
| $T_{11}$ | $T_4$ + Biofertilizer Mixture | 359.8 | 1032 | 672.2 | 1.86 |
| $T_{12}$ | $T_5$ + Biofertilizer Mixture | 378.8 | 1092 | 713.2 | 1.88 |
| $T_{13}$ | $T_6$ + Biofertilizer Mixture | 398.2 | 1032 | 633.8 | 1.59 |
| $T_{14}$ | $T_7$ + Biofertilizer Mixture | 346.3 | 729 | 382.7 | 1.10 |

Note : Biofertilizer mixture (5g *Azospirillum* + 5g PSB + 5g *Frateuria aurantia)* in each polybag along with potting mixture.


**Plate 3. Roots of Papaya seedlings under different substrates**

Chapter-V

# *Summary and Conclusions*

# Chapter V

# SUMMARY AND CONCLUSIONS

An experiment entitled "Studies on seed germination and subsequent seedling growth of papaya *(Carica papaya L.)* cv.Pusa Nanha" was carried out at Horticultural College and Research Institute, Anantharajupet during the year 2013-14. The experiment was carried out with 21 different treatments in a randomized block design (RBD) with three replications. The investigation was conducted to find out best chemical seed treatment and substrate combination on seed germination and seedling growth of papaya.

**Experiment-1. "**Effect of chemical treatments on seed germination and subsequent seedling vigour of papaya (*Carica papaya L*.) cv. Pusa Nanha."

An early seed germination (12.33 days) with maximum germination percentage (88.89 %), and germination index (2.90) were recorded when seeds were treated with $GA_3$ 300 ppm for 24 hrs.

The desirable growth of seedling performance in respect of plant height (9.65 cm), number of leaves (11.07), number of nodes (13), leaf area (31.49 $cm^2$), seedling girth (9.01mm), petiole length (4.59 cm), shoot dry weight (0.6 g), fresh weight of seedling (5.78 g) ,dry weight of the seedlings (0.88 g) and vigour index (8574.90) with the highest cost benefit ratio (2.57) were observed in the seedlings which were raised from the seeds treated with $GA_3$ 300 ppm for 24 hrs.

While, amongst the various pretreatments tried, $GA_3$ 200 ppm for 24hrs was found superior for root length (15.30 cm) and root dry weight (0.32 g).

The maximum petiole diameter (4.70 mm) was observed in treatment $GA_3$ 300 ppm for 12 hrs.

**Experiment-2.** "Effect of different growing medias on seed germination and subsequent seedling growth of papaya (*Carica papaya L.*) cv. Pusa Nanha."

An early seed germination (16.67 days) with maximum germination percentage (87.73 %), germination index (3.15) and leaf area (40.21 $cm^2$) were recorded when seeds were sown in treatment combination of FYM + Cocopeat + Vermicompost + Soil + Sand (60% + 10% + 10% + 10% + 10%).

The desirable growth of seedling performance in respect of plant height (15.09 cm), number of leaves (15.07), number of nodes (17.13), seedling girth (9.16 mm), petiole length (5.36 cm), petiole diameter (5.77 mm), shoot dry weight of seedling (0.95), fresh weight of seedling (7.82 g), dry weight of seedling (1.34g) and vigour index (12068.30) with the highest cost benefit ratio (2.32) were observed in the seedlings which were raised from the treatment combination of FYM + Cocopeat + Vermicompost + Soil + Sand (60% + 10% + 10% + 10% + 10% ) along with the biofertilizer mixture (*Azospirillum*, PSB and *Frateuria aurantia*)

While, amongst the various treatment combinations, FYM + Cocopeat + Vermicompost + Soil + Sand (10% + 10% + 60% + 10% + 10% ) along with the biofertilizer mixture (*Azospirillum*, PSB and *Frateuria aurantia*) was found superior for root length (16.61 cm) and root dry weight of seedling (0.43 g).

## Conclusion

Amongst the various pretreatments, $GA_3$ 200 ppm for 24 hrs was found superior for root length and root dry weight of the seedlings. Whereas, maximum petiole diameter was observed in treatment $GA_3$ 300 ppm for 12 hrs.

Amongst the various substrates, FYM + Cocopeat + Vermicompost + Soil + Sand (60% + 10% + 10% + 10% + 10% ) was found superior for early seed germination, maximum germination percentage, germination index and leaf area. Whereas, maximum root length and root dry weight was observed in treatment combination of FYM + Cocopeat + Vermicompost + Soil + Sand (10% + 10% + 60% + 10% + 10%) along with the biofertilizer mixture (*Azospirillum*, PSB and *Frateuria aurantia*).

Hence it is concluded that seeds treated with $GA_3$ 300 ppm for 24 hrs was found superior with early seed germination, maximum germination percentage, germination index, plant height, number of leaves, number of nodes, leaf area, seedling girth, petiole length, fresh weight of seedling, shoot dry weight, dry weight of seedling and vigour index along with the highest cost benefit ratio and the seeds sown in substrate combination of FYM + Cocopeat + Vermicompost + Soil + Sand (60% + 10% + 10% + 10% + 10%) along with the biofertilizer mixture (*Azospirillum*, PSB and *Frateuria aurantia*) was found to be best with maximum plant height, number of leaves, number of nodes, seedling girth, petiole length, petiole diameter, shoot dry weight of seedling, fresh weight of seedling, dry weight of seedling and vigour index with the highest cost benefit ratio.

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# *Appendices*

# Appendix-I

## Weekly meteorological data recorded during the period of study

## (November, 2013-January, 2014)

| Standard week number | Period | TEMPERATURE $^0$C | | R.H (%) | | Rainfall (mm) |
|---|---|---|---|---|---|---|
| | | Maximum | Minimum | Morning 8.00 hrs | Evening 14.00 hrs | |
| 45 | 05-11 NOV | 29.71 | 24.00 | 84.86 | 35.71 | 0.00 |
| 46 | 12-18 | 29.29 | 21.57 | 86.71 | 35.86 | 6.00 |
| 47 | 19-25 | 27.57 | 21.43 | 88.00 | 36.43 | 0.86 |
| 48 | 26-02 DEC | 29.00 | 21.29 | 86.43 | 35.86 | 7.71 |
| 49 | 03-09 | 27.43 | 18.29 | 86.43 | 36.14 | 0.00 |
| 50 | 10-16 | 27.14 | 18.14 | 86.86 | 37.43 | 0.00 |
| 51 | 17-23 | 25.00 | 17.14 | 88.29 | 37.14 | 0.00 |
| 52 | 24-31 | 22.00 | 15.50 | 76.00 | 33.00 | 0.00 |
| 1 | 01-07 JAN | 25.00 | 18.00 | 89.57 | 43.29 | 0.00 |
| 2 | 08-14 | 26.29 | 18.29 | 86.57 | 42.43 | 0.00 |