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Determining the Effect of Rooting Media and Different Polythene Wrappers on Air Layering of Grape Fruit (*Citrus paradisi*)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The present study aims to investigate the "EFFECT OF ROOTING MEDIA AND DIFFERENT POLYTHENE WRAPPERS ON AIR LAYERING OF GRAPE FRUIT (*Citrus paradisi*')"at The Department of Horticulture, Sam Higginbottom University of Agriculture, Technology and Sciences, Allahabad, during the period 2023-24. The experiment was laid in completely randomized block design with three replications and ten treatment combinations. viz, T_1 (BA1000PPM + BLACK POLYTHENE + SPHAGNUM MOSS) ,T2 (IBA1000PPM + BLACK POLYTHENE + SAWDUST), T3

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(IBA1000PPM + BLACK POLYTHENE + GARDEN SOIL+ SPHAGNUM MOSS),T4 (IBA1000PPM + BLACK POLYTHENE + SPHAGNUM MOSS+ SAWDUST), T5(IBA1000PPM + BLACK POLYTHENE + GARDEN SOIL+ SAWDUST), T6 (IBA1000PPM + WHITE POLYTHENE + SPHAGNUM MOSS), T7 (IBA1000PPM + WHITE POLYTHENE + SAWDUST),T8(IBA1000PPM + WHITE POLYTHENE + GARDEN SOIL + SPHAGNUMMOSS), T9(IBA1000PPM + WHITE POLYTHENE + GARDEN SOIL + SAWDUST),T10(IBA1000PPM + WHITE POLYTHENE + SPHAGNUM MOSS + SAWDUST). On the basis of present experimental findings, it is concluded that treatmentT4(IBA1000PPM + BLACK POLYTHENE + SPHAGNUM MOSS+ SAWDUST) was found to be best in terms of Number of days to root formation (initial rooting), Root length(cm), Root thickness(mm), Number of roots per layer, Survival percentage, Number of new sprouts per layered plant, Number of new leaves per layered plant and length of new shoot(cm) in Grape fruit.Whereas T_9(IBA1000PPM + WHITE POLYTHENE + GARDEN SOIL + SAWDUST) was found to be least in terms of Number of days to root formation (initial rooting), Root length(cm), Survival percentage, Number of new sprouts per layered plant, Number of new leaves per layered plant and Length of new shoots(cm) whereas in Root thickness(mm) and number of roots per layer in Grape fruit.

Keywords: IBA (indole butyric acid); MAP (month after planting).

1. INTRODUCTION

Grapefruit (*Citrus paradisi*), also called pummelo/pomelo, citrus tree of the Rutaceae family. The grapefruit probably originated in Barbados as a hybrid of shaddock (*Citrus grandis*).

“It became well established as a fruit for home consumption in the islands of the West Indies before its culture spread to the American mainland. World production of grapefruit (combined with pomelos) was 9.3 million tonnes, of which 53% was in China, Other significant producers include Vietnam, United States and Mexico” [1].

“It has become popular as breakfast fruit in various parts of the world, and production has expanded to most citrus-growing countries. The grapefruit tree grows to be as large and vigorous as an orange tree; a mature tree may be from 4.5 to 6 meters (15 to 20 feet) high. The foliage is very dense, with leaves dark and shiny green. Most varieties are yellow when ripe. Fruit is usually ready to harvest from October and may continue to bear until May” [1,2,3].

Because of the fruits' high nutritional value and economic importance, citrus is a popular fruit crop grown in more than 100 nations worldwide. Citrus sinensis, Citrus reticulata, Citrus limon, Citrus grandis, and Citrus paradisi are among the major and valuable fruits in the citrus genus, which has a wide range of fruits with pleasant aromas and excellent, distinct flavors [4-6]. Citrus originates from tropical to subtropical regions of Southeast Asia and is a member of the Rutaceae family. Oranges, Mandarins, Grapefruits, Clementines, and Tangerines are the citrus fruits that are best eaten fresh. Oranges and grapefruits are popular breakfast options because they provide wonderful juice. In addition to having a high nutritional value, citrus is a rich source of vitamin C and other macromolecules. The world produces 9504.1 thousand tons of grapefruits, whereas India produces 323.3 thousand tonnes (Anon., 2021). The demand for grapefruit has significantly increased in India in recent years due to increased public awareness of its medicinal effects (Dubey et al., 2013). By lessening the bitterness brought on by the flavonoids limonin and naringin, limonin would increase grapefruit's acceptance among consumers. A grapefruit half offers a variety of nutrients that are essential for a balanced diet; in fact, some specialists view it as an anti-obesity component. One of the main flavanones in grapefruit, naringin, along with hesperidin and rutin, influences glucose and lipid metabolism and corrects hyperglycemia and hyperlipidemia. Lycopene and b-carotene are the two main carotenoids found in grapefruit. Lycopene has the ability to prevent heart disease, cancer, and macular degeneration [7,8].

The fruit ranges from 100 to 150 mm (4 to 6 inches) in diameter, its size depending upon the variety and upon growing conditions. Its pulp is usually light yellowish, tender, and very full of juice, with a distinctive mildly acid flavour. Grapefruit juice contains about half the citric acid of lime or lemon juice, and about 50% more citric acid than orange juice [9-11]. Grapefruit is a tropical citrus fruit known for its sweet and somewhat sour taste, It is rich in nutrients, antioxidants and fiber, making it one of the

healthiest citrus fruits. Grapefruit can be propagated through sexual and asexual methods but the sexual method is usually not recommended, because seedlings are not true to type and the juvenile period is too long to bear fruit. The major furanocoumarins present in grapefruit are bergamottin, it inhibits cancer cell growth in humans (Ko et al., 2018). Due to the fura-nocoumarin-induced process in the intestines, which has certain negative effects with some prescription drugs, grapefruit consumption in any form is a worry in fragile elderly people who are on several medications. Red colored grapefruit have lower concentrations of the furocoumarins compared to white colored grapefruit. (Girennavaret al., 2004). Grapefruit also contains sesquiterpenes such as Nootkatone which is more pronounced in the peels of the fruit; responsible for the characteristic taste. It is said to be antioxidative, antifibrotic and also anti-bacterial to gram positive bacteria (Yamaguchi, 2019).

Despite the grapefruit's recent (less than 300 years) history of cultivation, a wide variety of cultivars with varying hues of flesh and peel are currently available; the majority of these resulted from spontaneous or artificial mutations (Louzada and Ramadugu, 2021). Out of all the grapefruit cultivars, "Duncan" grapefruit was thought to be the original source of cultivars and was a necessary cultivar in Florida.Eventually, the cultivar "Marsh," which was almost seedless, took its place before "Ruby Red" took its place. As budsports, "Shambar" and "Thompson" were first created from "Marsh" grapefruit. Naturally occurring budsports and artificial mutations caused "Thompson" to further split into a number of significant colored cultivars. 'Redblush' (which includes 'Ruby', 'Ruby Red', 'Shary Red', 'Curry Red', 'Fawcett Red', 'Red Radiance', and 'Webb's Red blush Seedless'), 'Triumph', 'Paradisi Navel', 'Oroblanco' , 'Foster', etc., are among the other cultivars. The medium-sized, extremely productive NRCC grapefruit 6 type of grapefruit was just released in India by the Central Citrus Research Institute, Nagpur (CCRI). (2019, Anonymous).

Air-layering is a well-known oldest method for vegetative propagation of economically important woody plants. It is a reliable and easy means of propagation, especially in species which are difficult-to-root on cuttings. The retention of desirable characteristics, the creation of uniform rootstock and the ability to mass production of identical plants quickly and efficiently are all advantages of asexual propagation (Adriance and Brison, 1955) and these can be fulfilled through air-layeringPhloroglucinol increases shoot formation and somatic embryogenesis in several horticultural crops. When added to rooting media together with auxin, phloroglucinol further stimulates rooting, most likely because phloroglucinol and its homologues act as auxin synergists or auxin protectors. Synthetic hormones like IBA and NAA are commonly used to promote root development in asexual propagation. IBA is widely used as a root-initiation promoter in agriculture. IBA is a suitable auxin for this type of experiment because it shows a large amount of flexibility when dealing with the range of concentration that can be used.

2. MATERIALS AND METHODS

The present investigation was carried out in the department of Horticulture, Sam Higginbottom Institute of Agriculture, Technology and Sciences which is located in Prayagraj and it is situated in the south-east part of Uttar Pradesh 2023- 24 India. Prayagraj falls under agroclimatic zone IV which is named as “middle Gangetic plains” the site of experiment is located at 25.57º N latitude 81.51º E longitude and 98 meter above the sea level the temperature falls down as low as 4-5ºc during winter, the average rainfall in this area is around 798.900 mm annually with maximum concentration during July to September with few showers and drizzles in winter also.

Randomized Block Design was used to set up the experiment, and ten treatments were reproduced three times. The ten treatments consist of T1 (IBA1000PPM + BLACK POLYTHENE + SPHAGNUMMOSS) , T2 (IBA1000PPM + BLACK POLYTHENE + SAWDUST), T3 (IBA1000PPM + BLACK POLYTHENE + GARDEN SOIL+ SPHAGNUMMOSS), T4 (IBA1000PPM + BLACK POLYTHENE + SPHAGNUM MOSS+ SAWDUST), T5 (IBA1000PPM + BLACK POLYTHENE + GARDEN SOIL+ SAWDUST) , T6 (IBA1000PPM + WHITE POLYTHENE + SPHAGNUM MOSS), T7 (IBA1000PPM + WHITE POLYTHENE + SAWDUST), T8 (IBA1000PPM + WHITE POLYTHENE + GARDEN SOIL + SPHAGNUMMOSS), T9 (IBA1000PPM + WHITE POLYTHENE + GARDEN SOIL + SAWDUST), T10 (IBA1000PPM + WHITE POLYTHENE + SPHAGNUM MOSS + SAWDUST). IBA were applied at the time of layering as a rooting media.

Table 1. Treatment details

Treatment symbol	Treatment Combination
T_1	Black polythene +Sphagnummoss
T_2	Black polythene + Sawdust
T_3	Black polythene + Garden soil + Sphagum moss
T_4	Black polythene + Sphagummoss + Sawdust
T_5	Black polythene + Garden soil + Sawdust
T_6	White Polythene +Sphagnummoss
T_7	White Polythene + Sawdust
T_8	White Polythene + Garden soil + Sphagummoss
T_9	White Polythene + Garden soil + Sawdust
T_{10}	White Polythene + Sphagummoss + Sawdust

** IBA 1000 ppm were used with all treatments as a rooting media during the experiment*

2.1 Observations Recorded

The successfully rooted air layers were transplanted in polybags under nursery conditions and three sprouted plants of both white polythene and black polythene rooted layers were selected randomly from each treatment in each replication. These three plants were labeled for recording the observations throughout the study.

2.1.1 Root parameters

2.1.1.1 Success in rooting percentage

The number of rooted air-layers was counted after detachment of air layered twigs from the mother plants. The data were compiled and success in rooting percentage was calculated by the following formula:

$$\frac{Number\ of\ rooted\ air\ layers}{Total\ no,of\ layers} \times 100$$

2.1.1.2 Number of days to root formation (initial rooting)

Observations were recorded for the number of days taken for the formation of first adventious root(s) from the day of layering to the day of visibility of first root inside the different polythene layering.

2.1.1.3 Days to complete rooting

Observations were recorded for the number of days taken to complete full root development on air layered stems i.e., from the day of layering to the day of detachment from the mother plant.

2.1.1.4 Root length (cm)

The observations were recorded with the help of scale at time when detachment of air layered stems from the mother plant. The length of primary root was measured from base up to tip.

2.1.1.5 Root thickness (mm)

The observations were recorded with the help of vernier calipers at the time when detachment of air layered stems from the mother plant. The diameter of root was measured from center of root.

2.1.1.6 Number of roots per layering

The observations were recorded by counting the number of adventious roots formed at the time of detachment of layering from the mother plant

2.1.2 Shoot parameters

2.1.2.1 Number of new sprouts per layer (1MAP, 2MAP, 3MAP, 4MAP)

Numbers of new sprouts were counted at 30, 60, 90 & 120 days intervals after planting of air layers into polybags by taking three random samples from each treatment under each replication.

2.1.2.2 Number of new leaves (1MAP, 2MAP, 3MAP, 4MAP)

Numbers of new leaves were counted at 30, 60, 90 & 120 days intervals after planting of air layers into polybags by taking three random samples from each treatment under each replication.

2.1.2.3 Length of new shoots (cm) (1MAP, 2MAP, 3MAP, 4MAP)

Length of new leaves were measured by using a scale at 30, 60, 90 & 120 days intervals after planting of air layers into polybags by taking

three random samples from each treatment under each replication.

2.1.3 Plant survival percentage (%)

After transplantation in polybags survival percentage was calculated by using the following formula:

$$\frac{Number\ of\ survived\ plants}{Total\ no.transplanted} \times 100$$

2.1.4 Cost of Cultivation (Rs.)

The cost of cultivation refers to the total expenses incurred in growing. It encompasses all the costs associated with various inputs and activities involved in the cultivation process.

2.1.5 Gross income (Rs.)

Gross return, also known as gross revenue, refers to the total income generated. Gross return is calculated by multiplying the quantity of agricultural produce sold by its selling price per unit.

Here's the formula for calculating gross return:

Gross Return = Quantity of Produce Sold × Selling Price per Unit

2.1.6 Net income (Rs.)

Net return refers to the profit remaining after deducting all expenses, including production costs and overhead, from the gross revenue generated.

The formula for calculating net return is:

Net Return=Gross Return − Total Production Costs − Overhead Expenses

2.1.7 B:C ratio

The Benefit-Cost Ratio (B:C ratio) is a financial metric used to assess the profitability or economic viability of an investment or project. B:C ratio is commonly used to evaluate the returns generated.
The B:C ratio is calculated by dividing the total benefits of the investment by the total costs:

$$B{:}C\ Ratio\ = \frac{Total\ Benefits}{Total\ Costs}$$

3. RESULTS AND DISCUSSION

3.1 Effect of Treatments on Number of Days for Root Formation and Complete Rooting

The minimum number of days for root formation (initial rooting) was observed in treatment T4 (IBA1000ppm + BLACK POLYTHENE + SPHAGNUMMOSS+ SAWDUST) recorded [29.42 days] from over all other treatments. where-as Treatment T9 (IBA1000ppm + White Polythene + Garden soil + Sawdust) was found to be maximum number of days [42.00] days Days taken to rooting was found gradually increased with decrease in the IBA concentration.

The minimum number of days to complete rooting was observed intreatment T4 (IBA1000 ppm + BLACK POLYTHENE + SPHAGNUMMOSS + SAWDUST) recorded [39.83 days] over all other treatments. where-as Treatment T9 (IBA1000ppm + White Polythene + Garden soil + Sawdust) found non- significantly maximum number of days to complete rooting [48.37 days].

This might be due to the wound response signaling pathways are initiated at the location of the wound (ring site) as a part of plant protection mechanism to induce the formation of callus at the wound site and due to using of Black polythene wrappers which decrease the transpiration rate and by the use of Sphagnum moss and Sawdust which help the layering to maintain moisture level. Application of auxin (IBA) at wound site leads to adventitious root formation. These adventitious roots may then develop into new root primordia and eventually form a complete root system.

3.2 Effect of Treatments on Success and Survival Rates of air Layers

The maximum success percent in Grapefruit was observed in treatment T4 (IBA1000ppm + BLACK POLYTHENE + SPHAGNUM MOSS+ SAWDUST) [91.67%], followed by treatment T5 (IBA1000PPM + BLACK POLYTHENE + GARDEN SOIL+ SAWDUST) [75%]

Table 2. Number of days to root formation (initial rooting) And Complete Rooting as affected by various treatments in Grapefruit

Root Formation (INITIAL) & Complete Rooting			
	Treatment Combination	**No of Days for Root Initation**	**No of Days for Complete Rooting**
T1	IBA1000PPM + BLACK POLYTHENE + SPHAGNUMMOSS	39.08	44.00
T2	IBA1000PPM + BLACK POLYTHENE + SAWDUST	31.00	42.57
T3	IBA1000PPM + BLACK POLYTHENE + GARDEN SOIL+ SPHAGNUMMOSS	32.33	45.47
T4	IBA1000PPM + BLACK POLYTHENE + SPHAGNUM MOSS+ SAWDUST	29.42	39.83
T5	IBA1000PPM + BLACK POLYTHENE + GARDEN SOIL+ SAWDUST	31.42	43.50
T6	IBA1000PPM + WHITE POLYTHENE + SPHAGNUM MOSS	34.67	41.97
T7	IBA1000PPM + WHITE POLYTHENE + SAWDUST	31.50	44.00
T8	IBA1000PPM + WHITE POLYTHENE + GARDEN SOIL + SPHAGNUMMOSS	35.42	46.20
T9	IBA1000PPM + WHITE POLYTHENE + GARDEN SOIL + SAWDUST	42.00	48.37
T10	IBA1000PPM + WHITE POLYTHENE + SPHAGNUM MOSS + SAWDUST	37.58	43.40
	F-TEST	**S**	**S**
	S.E. (m) (+)	**1.91**	**0.96**
	C D (5%)	**5.67**	**2.85**
	C V	**9.60**	**3.77**

Whereas The Treatment T9 (IBA1000ppm + White Polythene + Garden soil + Sawdust) was found significantly the lowest [50%] success percent.

The maximum survival percent was observed in treatment T4 (IBA1000ppm + BLACK POLYTHENE + SPHAGNUM MOSS+ SAWDUST) [91.67%] from over all other treatments followed by T5 (IBA1000PPM + BLACK POLYTHENE + GARDEN SOIL+ SAWDUST) [75%].

Where-as Treatment T9 (IBA1000ppm + White Polythene + Garden soil + Sawdust) was found significantly lowest [50%] survival percent.

The Success and survival percentage of layers in treatments is T4 (IBA1000ppm + BLACK POLYTHENE + SPHAGNUM MOSS+ SAWDUST) maximum and this might be due to a greater number of roots and root length in these treatments, which could have caused the absorption of nutrients and water from the soil, ultimately resulting in high survival rate. It also might be probably due to the fact that rooting co factors and their balance with auxin and nutritive substances like Vermicompost and Gardensoil. The response of above growing media might be due to a greater number of roots and subsequently, increased root length at this concentration which could have caused the better absorption of nutrients, food material and moisture from the soil, ultimately resulted in high survival percentage of layers.

3.3 Effect of Treatments on Number of New Sprouts

The maximum number of new sprouts was observed in treatment T_4 (IBA1000ppm + BLACK POLYTHENE + SPHAGNUM MOSS+ SAWDUST) [6.33(1MAP), 7.00(2MAP), 7.33 (3MAP), 6.67(4MAP)] followed by T2 (IBA1000PPM + BLACK POLYTHENE + SAWDUST) [4.00(1MAP), 5.00(2MAP), 5.67 (3MAP), 5.33(4MAP).

Table 3. Success percentage and Survival Percentage of the layers as effected by various treatments in Grapefruit

Treatment	Treatment Combination	Success %	Survival %
T1	IBA1000PPM + BLACK POLYTHENE + SPHAGNUM MOSS	66.67	58.33
T2	IBA1000PPM + BLACK POLYTHENE + SAWDUST	75.00	66.67
T3	IBA1000PPM + BLACK POLYTHENE + GARDEN SOIL+ SPHAGNUM MOSS	66.67	58.33
T4	IBA1000PPM + BLACK POLYTHENE + SPHAGNUM MOSS+ SAWDUST	91.67	91.67
T5	IBA1000PPM + BLACK POLYTHENE + GARDEN SOIL+ SAWDUST	75.00	75.00
T6	IBA1000PPM + WHITE POLYTHENE + SPHAGNUM MOSS	75.00	75.00
T7	IBA1000PPM + WHITE POLYTHENE + SAWDUST	58.33	58.33
T8	IBA1000PPM + WHITE POLYTHENE + GARDEN SOIL + SPHAGNUM MOSS	75.00	58.33
T9	IBA1000PPM + WHITE POLYTHENE + GARDEN SOIL + SAWDUST	50.00	41.67
T10	IBA1000PPM + WHITE POLYTHENE + SPHAGNUM MOSS + SAWDUST	58.33	58.33
	F-TEST	**S**	**S**
	S.E. (m) (+)	**6.15**	**7.03**
	C D (5%)	**18.27**	**20.88**
	C V	**15.40**	**18.97**

Table 4. Number of new sprouts in a layer per month as effected by various treatments in Grapefruit

No of New Sprouts				
Treatment	**1MAP**	**2MAP**	**3MAP**	**4MAP**
T1	5.00	5.67	4.00	3.67
T2	4.00	5.00	5.67	5.33
T3	2.67	4.33	6.00	5.67
T4	6.33	7.00	7.33	6.67
T5	3.00	4.67	4.67	4.67
T6	2.67	6.67	5.33	3.67
T7	4.33	3.67	6.67	4.00
T8	3.67	5.33	4.33	4.33
T9	2.00	4.00	3.67	3.33
T10	4.67	3.33	5.00	4.33
F-TEST	**S**	**S**	**S**	**S**
S.E. (m) (+)	**0.68**	**0.51**	**0.59**	**0.53**
C D (5%)	**2.01**	**1.52**	**1.75**	**1.57**
C V	**30.58**	**17.88**	**19.30**	**20.08**

**MAP: Month After Planting.*

Where-as Treatment T_9 (IBA1000ppm + White Polythene + Garden soil + Sawdust) [2.001MAP), 4.00(2MAP), 3.67(3MAP), 3.33(4MAP)] was found significantly minimum number of new sprouts

Number of new sprouts per layer followed an increasing pattern with T_4 (IBA1000ppm + BLACK POLYTHENE + SPHAGNUM MOSS+ SAWDUST).

IBA stimulates the growth of new roots from the cut stem. As the roots grow and establish themselves, they provide the plant with the nutrients and water it needs to develop new sprouts. The vermicompost and the garden soil help the plant to provide them a good nutrients and the sphagnum moss and sawdust also supported the plant to maintain moisture level which promotes the plant to produce good number of new sprouts.

Table 5. Number of new leaves in a layer per month as affected by various treatments in Grapefruit

	No. of Leaves			
Treatment	**1MAP**	**2MAP**	**3MAP**	**4MAP**
T1	6.00	7.00	7.33	8.33
T2	4.00	5.00	6.00	7.33
T3	5.67	5.67	6.67	7.67
T4	7.00	8.00	8.00	9.00
T5	4.00	4.00	4.00	5.33
T6	5.00	4.33	5.67	8.67
T7	4.33	6.00	6.00	6.00
T8	4.67	6.00	6.33	6.33
T9	2.67	3.67	3.67	4.67
T10	5.00	4.67	5.00	5.00
F-TEST	**S**	**S**	**S**	**S**
S.E. (m) (+)	**0.58**	**0.57**	**0.62**	**0.82**
C D (5%)	**1.72**	**1.69**	**1.85**	**2.43**
C V	**20.80**	**18.10**	**18.35**	**20.70**

3.4 Effect of Treatments on Number of New Leaves Formation

There was a subsequent increase in the number of new leaves in layers among different treatments, with an increase in months.

The maximum number of new leaves was observed in treatment T4 (IBA1000ppm + BLACK POLYTHENE + SPHAGNUM MOSS+ SAWDUST) [7.00(1MAP), 8.00(2MAP), 8.00 (3MAP), 9.00(4MAP)] overall from other treatments, followed by T1 (IBA1000PPM + BLACK POLYTHENE+SPHAGNUM MOSS), [6.00 (1MAP),7.00(2MAP), 7.33(3MAP), 8.33 (4MAP)].

Where-as Treatment T9 (IBA1000ppm + White Polythene + Garden soil + Sawdust) was found significantly minimum number leaves [2.67(1MAP), 3.67(2MAP), 3.67(3MAP), 4.67 (4MAP).

Vermicompost is a nutrient-rich organic fertilizer that is produced through the process of vermicomposting. This process involves using earthworms to break down organic material, such as food scraps, yard waste, and manure, into a rich soil amendment that is high in beneficial microorganisms, enzymes, and nutrients. This high source of organic nutrients might help the transplanted plant to obtain good amount of nutrition to obtained the the maximum number of new leaves and the effect of green hounce also help the plant to maint temperature and moisture level of the plant which promotes the leaf growth.

3.5 Effect of Treatments on Length of New Shoot

The data on length of new shoots in a layer per month showed that there were significant differences among the treatments.

There was a subsequent increase in the length of new shoots in layers among different treatments, with an increase in months.

The longest length of shoots was oberved in treatment T4 (IBA1000ppm + BLACK POLYTHENE + SPHAGNUM MOSS+ SAWDUST) [4.17 (1MAP), 4.37(2MAP), 5.33 (3MAP), 8.07(4MAP)] from overall other treatments.

Where-as Treatment T9 (IBA1000ppm + White Polythene + Garden soil + Sawdust) 6 was found significantly shortest length of shoots [3.20 (1MAP), 3.075(2MAP), 4.07(3MAP), 7.17 (4MAP).

IBA is a plant hormone that promotes cell division and elongation, and is often used to stimulate shoot growth. It can stimulate the growth of new cells and help to elongate the shoot. This effect might have resulted in a longer stem or shoot, which made the plant taller and more robust.

3.6 Effect of Treatments on Root Length and Root Thickness

There was subsequent increase in the root length of layers among different treatments.

Table 6. Length of new shoots in a layer per month as affected by various treatments in Grapefruit

New Shoots				
TREATMENT	1MAP	2MAP	3MAP	4MAP
T1	3.87	3.93	5.03	7.67
T2	3.33	3.57	4.83	7.73
T3	3.53	3.73	4.60	7.67
T4	4.17	4.37	5.33	8.07
T5	3.93	3.93	5.03	7.70
T6	3.83	3.93	4.83	7.77
T7	3.80	4.03	4.87	7.77
T8	3.77	3.97	5.07	7.47
T9	3.20	3.07	4.07	7.17
T10	3.83	4.03	5.10	7.57
F-TEST	**S**	**S**	**S**	**S**
S.E. (m) (+)	**0.12**	**0.12**	**0.13**	**0.11**
C D (5%)	**0.37**	**0.36**	**0.38**	**0.33**
C V	**5.75**	**5.42**	**4.60**	**2.50**

Table 7. Root length and Root thickness of layers as affected by various treatments in Grapefruit.

Root Length and Root Thickness			
Treatment	**Treatment Combination**	**Root Length (cm)**	**Root Thickness (mm)**
T1	IBA1000PPM + BLACK POLYTHENE + SPHAGNUMMOSS	8.23	1.30
T2	IBA1000PPM + BLACK POLYTHENE + SAWDUST	7.80	1.29
T3	IBA1000PPM + BLACK POLYTHENE + GARDEN SOIL+ SPHAGNUMMOSS	7.43	1.28
T4	IBA1000PPM + BLACK POLYTHENE + SPHAGNUM MOSS+ SAWDUST	8.47	1.35
T5	IBA1000PPM + BLACK POLYTHENE + GARDEN SOIL+ SAWDUST	7.33	1.29
T6	IBA1000PPM + WHITE POLYTHENE + SPHAGNUM MOSS	8.30	1.33
T7	IBA1000PPM + WHITE POLYTHENE + SAWDUST	7.27	1.31
T8	IBA1000PPM + WHITE POLYTHENE + GARDEN SOIL + SPHAGNUMMOSS	8.07	1.33
T9	IBA1000PPM + WHITE POLYTHENE + GARDEN SOIL + SAWDUST	7.03	1.24
T10	IBA1000PPM + WHITE POLYTHENE + SPHAGNUM MOSS + SAWDUST	7.70	1.31
	F-TEST	**S**	**S**
	S.E. (m) (+)	**0.24**	**0.01**
	C D (5%)	**0.71**	**0.03**
	C V	**5.31**	**1.37**

Effect of treatment T4 (IBA1000ppm + BLACK POLYTHENE + SPHAGNUM MOSS+ SAWDUST) recorded the longest root length [8.47 cm] over all other treatments where-as Treatment T9 (IBA1000ppm + White Polythene + Garden soil + Sawdust) was found significantly shortest root length [7.03]. Root length of layers was found to be longer in treatment 4(IBA1000ppm + BLACK POLYTHENE + SPHAGNUM MOSS+ SAWDUST).

There was subsequent increase in the root thickness of layers among different treatments.

Table 8. Number of roots per layer as affected by various treatments in Grapefruit

No of Roots Per Layer		
Treatment	**Treatment Combination**	**Number of Roots Per Layer**
T1	IBA1000PPM + BLACK POLYTHENE + SPHAGNUMMOSS	8.13
T2	IBA1000PPM + BLACK POLYTHENE + SAWDUST	8.40
T3	IBA1000PPM + BLACK POLYTHENE + GARDEN SOIL+ SPHAGNUMMOSS	9.60
T4	IBA1000PPM + BLACK POLYTHENE + SPHAGNUM MOSS+ SAWDUST	9.83
T5	IBA1000PPM + BLACK POLYTHENE + GARDEN SOIL+ SAWDUST	9.17
T6	IBA1000PPM + WHITE POLYTHENE + SPHAGNUM MOSS	8.73
T7	IBA1000PPM + WHITE POLYTHENE + SAWDUST	8.27
T8	IBA1000PPM + WHITE POLYTHENE + GARDEN SOIL + SPHAGNUMMOSS	8.50
T9	IBA1000PPM + WHITE POLYTHENE + GARDEN SOIL + SAWDUST	8.30
T10	IBA1000PPM + WHITE POLYTHENE + SPHAGNUM MOSS + SAWDUST	9.27
	F-TEST	**S**
	S.E. (m) (+)	**0.29**
	C D (5%)	**0.86**
	C V	**5.67**

Table 9. Total cost of cultivation, Gross return, Net return and B.C ratio

Treatment	Fixed cost (Rs)	Variabe cost (Rs)	Total cost of cultavation/1000 polybags	Selling price (Rs)	Gross return (Rs)	Net return (Rs)	B:C ratio
T1	3556	100	2031.2	70	4666.9	2635.7	2.2
T2	3556	90	2278.7	70	5250	2971.3	2.3
T3	3556	120	2042.3	70	4666.9	2624.6	2.2
T4	3556	140	2823.4	90	8250.3	5426.9	2.9
T5	3556	100	2285	80	6000	3715	2.6
T6	3556	120	2297.5	80	6000	3702.5	2.6
T7	3556	90	1772.2	70	4083.1	2310.9	2.3
T8	3556	120	2297.5	75	5625	3327.5	2.4
T9	3556	80	1515	65	3250	1735	2.1
T10	3556	130	1791.7	75	4374.7	2583	2.4

Effect of treatment T4 (IBA1000ppm + BLACK POLYTHENE + SPHAGNUM MOSS+ SAWDUST) recorded the maximum thickness [0.34 mm] over all other treatments where-as Treatment T9 (IBA1000ppm + White Polythene + Garden soil + Sawdust) was found significantly minimum root thickness [0.26]

This might be due to the layering was carried out on younger mother plants as they affects the thickness and differentiation of the root system Adequate nutrient availability in media and with the use of Black polythene wrappers temperature might have promoted the length of the roots.

3.7 Effect of treatments on number of roots per layers

Effect of treatment T4 (IBA1000ppm + BLACK POLYTHENE + SPHAGNUM MOSS+ SAWDUST) recorded the maximum number of roots [9.83] over all other treatments where-as Treatment T9 (IBA1000ppm + White Polythene + Garden soil + Sawdust) was found significantly minimum no. of roots [8.30].

The higher number of roots may be due to the fact that optimum IBA concentration is the result of less time needed for callus formation and as a result consequent enhanced cambium dedifferentiation, producing numerous cells which will then differentiate to form root cells. It was possibly due to the fact that IBA along with Sphagnummoss, sawdust and Black polythene wrappers accelerates the initiation of root meristem and consequently resulted in the production of the greater number of roots.

4. CONCLUSION

From the present investigation it is concluded that effect of Treatment T_4 i.e., IBA@1000ppm + BLACK POLYTHENE + SPHAGNUM MOSS+ SAWDUST was found to be best in terms of Number of days to root formation (initial rooting), Root length(cm), Root thickness(mm), Number of roots per layer, Success percentage, Survival percentage, Number of new sprouts per layered plant, Number of new leaves per layered plant and length of new shoot(cm) and also have the best BC ratio in Grape fruit under Pryagraj agro-climatic condition.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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