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Effect of plant growth regulators and different growing media on propagation of fruit crops

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Abstract
Plant growth regulators, also known as phytohormones, are biosynthesized organic compounds that have an influence on physiological and biochemical processes within plants. But they can also be synthesised in artificially in laboratories. On the basis of their structural similarities and their effects on plant physiology, there are several recognised classes of plant growth regulators, including auxins, cytokinins, gibberllins, ethylene, and abscissic acid. One of the most common asexual methods of fruit production is the vegetative mode. Fruit production is currently being hampered by a number of issues, including cutting's failure to root or shoot formation. Any substrate that promotes the growth of roots and shoots is referred to as a growing medium. Perlite, cocopeat, vermiculite, peat moss, and composted materials are some of the many growth mediums utilised in the production of fruit. A procedure for producing high-quality planting material for fruit crops may be developed using the interplay between plant growth regulators and the growing medium.

Keywords: Fruit crops, plant growth regulators, growing media

Introduction
As the world community favors all-inclusive strategies for nutrition improvement, there is a strong demand for the cultivation of economically significant fruit crops. The nation's need for horticultural goods has been steadily rising over time. This is primarily caused by the growth in population, household income, and increased concern for nutritional security. Along with increasing the food production our focus should also be on product quality. The quality of the planting material is one of the most crucial factors influencing the high yield of fruit crops. Fruit crops, which are often perennial in nature, need extreme caution in variety selection, quality planting material and use of appropriate technologies for mass multiplication of plant material. Asexual propagation is an effective way to sustain the progeny of seedless fruit plants like banana, pineapple, fig, grape, guava, and lemon and to cultivate true to type fruit plants with uniform growth and quality. In order to get rid of soil-borne diseases and pests the use of soilless growing media is becoming more and more popular. In order to serve as adequate soil substitutes, different soilless media are now being used across the world (Thakur and Shylla, 2018) [25]. The growth of a strong, fibrous root system and the quality of the seedling produced will both benefit from a good growing medium (Kumar, 2015) [11]. To promote consistent emergence, growth, and development of plant material, the selected growing medium must contain adequate nutrients, retain moisture, and provide proper aeration (Mathowa *et al.*, 2017) [13]. The use of plant growth regulators will accelerate germination, shorten the germination period, and boost germination rate. They can also encourage the production of hydrolyzing enzymes, including amylase and protease, which can hydrolyze food and could be utilized for the growth of an embryo. Additionally, to achieve a high survival rate, growing medium and growth regulators are frequently utilised nowadays (Voruganti *et al.*, 2022) [27].

Pomegranate (*Punica granatum* L.)
A healthy and well-developed root system for pomegranate trees is extremely important as it facilitates improved field establishment, which is achieved through the application of appropriate plant growth regulator in order to prevent the high mortality of rooted cuttings under field conditions. Netam *et al.* (2020) [15] studied the impact of different growing media on rooting and survival percentage of pomegranate cuttings cv. Super Bhagwa under Chhattisgarh plains condition and reported that sand and Cocopeat with a ratio of 1:1 showed significantly higher survival percentage (80.61%), maximum number of roots per cuttings

(32.44), Length of roots per cuttings (30.37 cm), diameter of roots per cuttings (1.52 mm), fresh weight of roots per cuttings (4.15 g) and dry weight of roots per cuttings (1.55 g) in comparison to other growing media. Rajkumar *et al.* (2017) [18] reported that perlite with combination of vermiculite medium showed better results in terms of rooting (82.33 per cent), number of roots (32.67 per cutting), fresh and dry weight of roots (0.61 mg and 2.08 mg), shoots per cutting (80.33) and survival percentage (76.0 per cent) than the other medium used. Better water holding capacity and nutrient availability as well as the release of enough nutrients and appropriate aeration in the root zone of the cuttings may be responsible for the improvement in survival percentage. Seiar (2017) [21] showed that highest sprouting percentage (68.00%), highest rooting percentage (60.40%), maximum number of sprouts (2.09), maximum diameter of sprout (0.59cm), longest roots (18.9cm) and maximum diameter of root (1.62mm) were recorded in cuttings treated with IBA 1500ppm along with NAA 1500ppm, whereas, longest sprout (34.50cm), highest number of primary roots (10.30) and secondary roots (62.70), maximum fresh weight of sprout (9.03g), maximum dry weight of shoot (4.66g), highest fresh weight of root (2.70g) and the highest dry weight of root (1.63g) per cutting was recorded with IBA 1500ppm along with NAA 1000ppm. In general, the root and shoot parameters responded better to the application of larger quantities of growth regulators than to low concentrations. A likely cause might be improved nutritional uptake by the plant, supported by growth regulators, of nitrogen, carbohydrates, and other nutrients.

Acid Lime (*Citrus aurantifolia*)

Acid lime is often propagated by seeds, however this approach has the drawbacks of non-uniform offspring and a high risk of viral disease contamination. Citrus plants must be vegetatively propagated (*via.* cuttings, budding, grafting, and layering) to have the desired characteristics of the mother plant and to be free from pest and diseases. According to Malakar *et al.* (2019) [12], the minimum days taken to sprout (16.83 days) was reported in the treatment (C_3 Hardwood cutting + M_1 Sand + G_0 IBA 0 ppm). Further, C_3 Hardwood cutting+ M_4 Cocopeat + G_1 IBA 500 ppm) gave the best results with respect sprouted percentage of cuttings (47.22 per cent), sprouts number (4.6, 24.00 and 7.40) at 30, 60 and 90 DAP respectively. The findings of their study can be utilised for producing high-quality acid lime planting material through cuttings. Meshram *et al.* (2015) [14] showed that the germination percentage (81.63%) was found maximum with application of GA_3 @ 200 ppm (81.63 cm) which was found at par with the application of NAA @ 40 ppm (79.36 cm). The highest germination percentage in GA_3 @ 200 ppm is due to fact that the synthesis of amino acids in plants is accelerated, which is indirectly exhibited by enhanced growth of citrus plants and their parts.

Karonda (*Carissa carandas* L.)

Cutting-based vegetative propagation is advantageous for maintaining good agronomic traits and promoting the growth and multiplication of true-to-type plants. Since the use of growth regulators results in more and better root formation per cutting, therefore different growth regulators *viz.* IBA and NAA have been utilised to boost the percentage of rooting. The accelerated hydrolysis of carbohydrates, accumulation of metabolites at the application site, synthesis of new proteins, cell expansion, and cell division are the causes of the increase in the percentage of rooting in cuttings treated with IBA (Singh *et al.*, 2011) [24]. Prajwala *et al.* (2019) [17] showed that among growth regulator treatments, IBA @ 8000 ppm was found best and in case of interaction effects it was found that the combination of semi-hardwood cuttings of green fruited and IBA @ 8000 ppm was observed to be significantly superior with respect to rooting parameters. They reported that the highest percentage of rooting cuttings (43.48%), survival percentage of rooting cuttings (33.82%), maximum roots per cutting (5.25) and recorded the highest value (7.69 cm) length of the longest root was found in IBA @ 8000 ppm. Galav *et al.* (2019) [7] concluded that root: shoot ratio, survival rate, and growth characteristics of karonda seedlings are all strongly influenced by the growing medium. Growing medium Soil: Sand: FYM: Vermicompost: Perlite in the ratio of 2:1:1:1:1, outperformed all other growing media in terms of germination, growth characteristics, and root: shoot ratio, and survival rate. The results showed that the lowest days taken for initiation of germination (7.00 days) was recorded in Soil: Sand: FYM: Vermicompost: Perlite in the ratio 2:1:1:1:1 respectively. Maximum seedling height (29.00 cm), leaves per plant (19.11), root length (6.06 cm) were recorded Soil: Sand: FYM: Vermicompost: Perlite in the ratio of 2:1:1:1:1 respectively. The increase of growth parameters in G_{10} (soil: sand: FYM: Vermicompost: perlite 2:1:1:1:1 v/v) is because it provides more nutrition to seedlings which resulted in increment to plant height, leaves per and plant, root length. Lower clay content, pH, compactness, which improve drainage, aeration, water holding capacity and highest nutrients uptake by root system respectively results in highest plant height in growing media Soil: Sand: FYM: Vermicompost: perlite 2:1:1:1:1 respectively.

Litchi (*Litchi chinensis* Sonn.)

Poor fruit set, large fruit drop, fruit cracking, and poor fruit quality are among the issues causing the low economic potential of litchi farming in different litchi growing locations. Plant growth regulators have been used for a long time to change the behavior of fruit plants for economic reasons, which includes to regulating vegetative growth, to boost blooming and fruit set, stimulate maturation and ripening and enhance fruit quality. According to reports, growth agents such as gibberellic acid (GA_3), borax, naphthalene acetic acid (NAA), and 2, 4-D have a significant impact on litchi and have shown to be helpful in lowering fruit drop and fruit cracking rates and has helped in boosting fruit quality. Kaur(2020) observed in her experiment that the maximum total length (12.5cm) of first order roots, highest number of roots (35.52), higher survival percentage (95.25), maximum mean root thickness (1.62mm) and the higher root: shoot ratio was registered in IBA 5000 ppm (0.067) and NAA 5000ppm (0.04) Chawla *et al.* (2012) [4] results indicated that application of IBA 5000 ppm treated layers took lesser days to root initiation (25.99 days) and also gave better results with respect to all the parameters studied including rooting percentage (86%), number of first (27.30) and second (41.20) order roots, total length of first order roots (2.14 m), mean root thickness (1.09 mm), fresh (2.89 g) and dry (1.11 g) weight of roots, fresh (46.29 g) and dry (28.00 g) weight of shoot and root: shoot ratio (0.04) of air layer in comparison to all other treatments. This is due to the possibility that the

greater IBA concentration boosted the mobilisation and utilisation of carbohydrates and nitrogen fraction by the developing litchi layers, allowing them to produce more vegetative mass and as a result, more photosynthates, which were then transported to the roots and raised the aforementioned parameter. Chawla and Mehta (2015) [5] noted that litchi orchard soil + FYM + PGPR @ 50g/kg growing media took earlier growth emergence after planting (105.98 days) and also gave better results with respect to survival percentage (90.00%), maximum plant height (10.65 cm), number of leaves/layer (32.30), average leaf area (25.50 cm^2), total leaf area (823.45 cm^2), total root length (14.27 m), chlorophyll content (0.91 mg/ g), fresh and dry weight of roots (8.17 and 3.08 g), fresh and dry weight of shoot (58.03 and 35.30 g), root: shoot ratio on fresh and dry weight basis (0.141 and 0.087), respectively. This is because of the plant's ability to absorb more nutrients from the soil is thought to be enhanced by IAA-producing Plant Growth Promoting Growth Regulators, which are thought to promote root development and length.

Guava (*Psidium guajava* Linn.)

Guava is a prolific fruit with a high ascorbic acid concentration. Guava is used to treat diabetes, hypertension, and diarrhea. In addition to vegetative ways of propagation, guavas may reproduce sexually. Although guava may be effectively grown from seeds, vegetative methods of propagation are preferable since seedling propagation can lead to genetic differences that can have an impact on the fruit's quality, size, and yield. Furthermore, seedling plants need 6-7 years to reach the bearing stage, thus they are utilised to grow rootstocks for budding and grafting (Thapa and Rawat, 2020) [26]. Ali (2018) treated guava cuttings with various IBA (Indole-3-butyric acid) concentrations and recorded that guava stem cuttings treated with IBA at 2000 ppm had a greater survival rate while IBA at 4000 ppm had a higher rooting percentage. Despite the fact that guava is difficult to root, use of auxin has shown promising outcomes in root initiation in stem cutting. Auxin, a plant growth regulator, is used to encourage adventitious root production in guava stem cuttings. Rani *et al.,* (2015) [19] observed that the softwood cutting of guava performed better in all the media compositions i.e. Vermiculite: FYM (1:1), Perlite: FYM (1:1), Sand: FYM (1:1), Vermiculite: Sand: FYM (1:1:1) and Perlite: Sand: FYM (1:1:1), Vermiculite: Sand: FYM (1:1:1) showed highest rooted cuttings (78.69%), number of new shoots per plant (10.42), maximum plant height (26.49 cm), maximum number of leaves per plant (25.08) and maximum stem thickness (1.14 cm). The higher number of shoots is due to more available potassium and magnesium contained in the vermiculite as it has high nutrient holding capacity as compared to perlite.

Jamun (*Syzigium cumini* L. Skeels)

To solve the problem of longer duration for the first flowering and fruiting in trees raised from the seeds, true to type plants need to be cultivated. The easiest and most affordable way to achieve this is by vegetative propagation of Jamun. Bhyravi *et al.* (2022) [3] concluded that the minimum number of days (8.37 DAP), was recorded for sprouting initiation in shoottip cutting planted in Soilrite (75% Irish peat moss and 25% expanded perlite with pH-5.0 to 6.5), the highest sprouting percentage (36.73%) was recorded in Hardwood cuttings planted in Sand and length of longest root (15.43 cm) was found in hardwood cutting planted in soil rite media. Whereas the Hard wood cutting planted in soil rite showed better rooting percentage (44.87%) at 90 DAP. It may be because soil rite medium considerably favoured the length of the longest root owing to auxin compound absorption and translocation in rooted cutting and well-drained media also encouraged the better growth of roots via root penetration. The plant growth regulators like auxins play a vital role in rooting of cuttings as it promotes adventitious rooting of the stem cuttings. Hardwood cutting treated with rootex gave better shoot and root parameters because callus and tissue formation and tissue differentiation is enhanced by the application of auxin. Also, the root primordia gets activated and root formation is enhanced when energy is provided after the polysaccharides present in the mature cuttings get hydrolysed at rapid rate.

Grapes

Cuttings, rooting, budding, layering, and grafts are all methods of grape propagation used in commercial vineyards. Cutting is one of the most common methods of vegetative plant multiplication used in the horticulture sector and is a key method in viticulture. It has many benefits, including being economical, requiring minimal space, being simple, and being quick to disseminate chosen clones or new varieties developed through breeding operations. It keeps true to type varietal traits (Jaleta and Sulaiman, 2019) [9]. Without the growth regulator, the percentages of Prabu Bestari grapevines that were successfully grafted onto the rootstocks of Banjarsari 30, Banjarsari 5 and Banjarsari 8 were, respectively, 75.00%, 75.00% and 83.00%. The proportion of successful grafting was modified by the use of plant growth regulators to 77.25%, 91.50% and 79.00%. Combining plant growth regulators with either Banjarsari 30 or Banjarsari 5 rootstocks increases the proportion of grafting that is successful (Gusti and Agus, 2020) [8]. Shriram *et al.* (2021) [23] reported that the maximum callus diameter (32.99 mm), maximum length of longest roots per cutting (20.11), maximum diameter of root (1.11 mm) and maximum rooting percentage (74.03%) was obtained in 1613 C rootstock treated with 100 ppm IAA. The use of auxin like IAA and IBA may be responsible for more roots since these compounds encouraged cell proliferation and elongation, which improved root growth and resulted in better, relatively large shoots. According to Abhinav *et al.* (2016) [1] in Grape, it was also a result of more cell activity, more food that was produced, and photosynthates, which led to more shoots with larger stem diameter, callus diameter, and root diameter. Shah *et al.* (2021) [22] stated that the highest sprouting percentage (90%), shoot length (30.83cm), number of leaves (18.83), root length (13.66cm), number of roots (49.50) and the most negligible mortality percentage (10%) was found in plants grown in Compost.. This is due to the improved gaseous exchanges, good drainage, the presence of high levels of organic matter, and better water holding capacity which resulted in increased number of roots in compost and sand. These factors also contributed to increased callus cell division, which increased the formation of tissues like phloem, pericycle, and cambium. The conducting tissues of cuttings made a vascular link with these tissues to form the primordial of roots, which led to the development of roots.

Apple

Studies on isolated apple shoots indicate that the cytokinins that are transported in the xylem sap from rootstock to scion play a significant role in regulating shoot growth. Therefore, any impact of rootstock or inters tock on these growth regulators is likely to be more significant than any impact on the phloridzin, gibberellins, or ABA of the sap. The solute of the xylem sap, including the cytokinins, appears to be depleted during the graft unions of dwarfing rootstocks or interstocks with the scion. Wani *et al.,* (2016) [28] found that IBA 1000 ppm gave the best response in respect of all the parameters studied *viz.*, maximum number of roots per cutting (3.93), girth of the thickest root (1.38 mm), length of the longest root (4.47 cm), percentage of rooting per cutting (45.37), survival percentage of rooted cuttings (60.00) number of leaves per cutting (2.27), number of secondary branches per cutting (1.87) cutting and number of leaves per secondary branch (4.60). Padhan *et al.* (2019) [16] reported that the maximum survival percentage (100%) of low chilling variety of Apple, in term of days to bud break (10.00), maximum number of leaves (32.50) at 120 DAS was noticed in growing media Vermicompost +LC+FYM in the ratio of 2:1:1respectively. This is because of vermicompost helps in improving media physical properties *viz*. bulk density, water holding capacity, porosity and also improve biological properties.

Fig (*Ficus carica*)

Asexual propagation of fig can be achieved through stem cuttings. The exogeneous application of plant growth regulators like auxins tend to improve rooting in cuttings by breaking the cytokinin induced apical root dominance. Apart from this the endogeneous concentration of plant hormones influences root intiation. A study on the effects of IBA and NAA treatments on the hard wood cuttings of Fig cv. Dinakar was conducted by. There were ten different treatments used, and the treatment of IBA At 1000 ppm + NAA @ 1000 ppm produced the highest root to shoot ratio, rooting percentage, shoot growth, and survival percentage (82.5%). Additionally, it was noted that the same treatment increased the induction of rooting (58.66%) as reported by Dahale *et al.* (2018) [6]. Mehmood *et al.* (2020) [29] studied on responses of Fig cuttings (*Ficus Carica*) to different sowing dates and potting media and observed that the maximum length of root (9.8cm), maximum shoot thickness (1.4cm) and maximum number of leaves (4.1) was found in farm yard manure whereas, minimum was noted in soil i.e. control. This is because cuttings planted in farm yard manure emerge earliest among other cuttings due to farm yard manure having high porosity and greater availability of moisture and nutrients, which in turn stimulates the physiological activity of fig cuttings and causes their leaves to emerge earlier than in other growing media.

Conclusion

This review paper examines the effect of growing media used in soilless culture. As they represent one of the main solutions for soil problems, have positive effects on the environment and improve fertilizer and water-use efficiency. This is especially the case in various area where shortage of good quality water is a major constraint in protected cultivation. At present, a relatively small proportion of growing media which are very important for a good start to plant cultivation and can be used for the production of quality plant material. In addition to growing media, plant growth regulators play a major role as their application results in initiation of rooting and shooting during propagation of fruit crops. Now-a-days, growing media along with plant growth regulators can be used to develop a protocol for production of quality planting material of fruit crops through various modes of vegetative propagation.

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