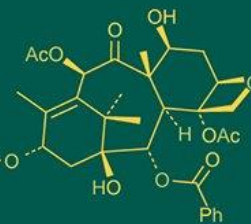
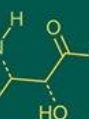
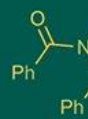


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Efficacy of plant growth regulator and season on rooting, growth and survival of Assam lemon [*Citrus limon* (L.) Burm] stem cuttings

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Abstract

The present investigation was conducted to study the efficacy of plant growth regulator (Indole-3-butyric acid) and season on rooting, growth and survival of Assam lemon [*Citrus limon* (L.) Burm] stem cuttings during the years 2023-24 and 2024-25 at Punjab Agricultural University, Regional Research Station, Gurdaspur. Healthy and mature shoots preferably one year old having thickness of about 1.0 cm were selected in spring (February-March) and rainy (August-September) season from the central and basal part of the branch and hardwood stem cuttings were made of about 15-20 cm in length possessing 6-8 buds. The basal parts (2-3 cm) of all the cuttings were dipped in different concentrations of IBA (indole-3-butyric acid) 250 ppm, 500 ppm, 750 ppm and 1000 ppm for five minutes dip along with control and planted in garden soil + sand + vermicompost + cocopeat (1:1:1:1) medium. It has been resulted that hardwood stem cuttings of Assam lemon treated with IBA 1000 ppm and grown in garden soil + sand + vermicompost + cocopeat (1:1:1:1) media in rainy season showed minimum number of days taken to first sprout with maximum number of the sprouts, sprout length(cm), sprout diameter(mm), number of leaves, leaf length(cm), leaf breadth(cm), rooting (%), number of primary roots, number of secondary roots, longest root length(cm), root diameter(mm), sprouting (%) and survival (%).

Keywords: Hard wood cutting, indole-3-butyric acid, Assam lemon, rooting, growth, survival

1. Introduction

Lemon [*Citrus limon* (L.) Burm.] belongs to the family Rutaceae, is one of the most popular fruits in citrus group in India and around the world as well. Among the citrus species, lemon is one of the important fruit has been cultivated in warm southern slopes of the Himalayas in North-Eastern India and adjacent to Burma, Southern China and Indo-China. Lemon is mainly cultivated in Assam, Bihar, West Bengal, Punjab, Odisha, Maharashtra, Gujrat and Rajasthan on a commercial scale. It is a native of the East Indies and has spread all over the world in tropical and sub-tropical regions and considered as an important species of citrus family. All around the world, it is used for both non-culinary and culinary reasons. Lemon is the leading acid citrus fruit and the third most favoured citrus species next to orange and mandarin, owing to its appealing colour, aroma and flavour (Morton, 1987) ^[36]. Lemon can grow well in a wide variety of soil. It performs well in sandy loam or loamy soil having good drainage. These plants are among the first cultivated fruit crops, having evolved in tropical and subtropical southeast Asia (Chayanika *et al.*, 2011; Das *et al.*, 2021) ^[12, 13]. It has wide adaptability which makes it one of the most promising fruit crops in the world. It flourishes under humid and semi-arid condition and can tolerate heat and cold. Among its many medicinal properties is antiseptic, antioxidant, anti-helminthic, stomachic, constipating, abdominal pain, antiallergic, anti-inflammatory, antiviral, anti-cancerous, and anti-carcinogenic properties (Mante, 2019) ^[32]. Its market-sold candies and flavour-infused drinks give it an abundance of socioeconomic importance (Liu *et al.*, 2012) ^[30]. There are a number of diverse forms of lemon which may slightly differ from each other. Assam lemon, an important variety of lemon is widely grown in the north-eastern parts of India which is a dwarf cultivar and suitable for high density planting (Singh and Singh, 2006) ^[46]. Assam lemon [*Citrus limon* (L.) Burm] widely known as *Kaji Nemu*. Its plant growth like small evergreen shrub with irregular branches and rigid twigs.

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It is known for its high growth vigour and long, sharp spines located in the leaf axils. Leaves are bright green, aromatic, and ovate-lanceolate with slightly serrated edges. Primarily flowers during spring (February-March) and autumn (September-October), with some fruiting throughout the year. The flowers are small, often borne in clusters (corymbs) or singly. They feature five white petals, numerous stamens, and appear throughout the year, with a strong, distinctive fragrance. Fruits bear in cluster are generally oblong-ovate to elongated, with a prominent nipple (mammiiform or acute) at the apex and a bumpy or smooth rind, with a distinctive aroma. Rind is thin to thick, pale green to yellow when ripe, and leathery. The juice vesicles are short and stout, providing high acidity. Assam lemon is famous for being largely seedless or having very few seeds, although environmental factors can influence this. Citrus fruits, which are also excellent sources of citric acid, flavonoids, phenolic, pectin, limonoids, ascorbic acids, and other nutrients, are widely known for their dietary, nutritional, therapeutic, and cosmetic qualities (Dugo and Giacomo, 2002; Kumar *et al.*, 2010) [14, 27]. According to recent studies, assam lemons are rich in a number of significant chemicals, such as citric acid, ascorbic acid, pectin, flavonoids, and others, which support their antioxidant qualities and other medicinal qualities (Gogoi, 2021; Khatiwora *et al.*, 2017) [17, 22]. It is an evergreen plant with dark green leaves; leaf lamina is lanceolate in shape with brevipetiolate attachment and dentate margin. Individual flowers are large, hermaphrodite and purple-tinged in the bud and on the lower surface of petals. Anthers are also yellow in colour (Singh and Singh, 2006) [46]. Many flowers are staminate (sterile male) because of pistil abortion, the incidence of which varies greatly from bloom to bloom and season to season (Reuther *et al.*, 1967) [40]. Assam lemon is found to be comparatively bigger in size than the normally grown lemon and hence, contain higher amount of juice. The fruit, zest, roots, leaves and juice are widely used in culinary, beverages, industries and medicines (Barua and Bharadwaj, 2017) [7]. Assam lemon has the character of being able to bear fruits in many flushes making it available throughout the year with two peak season (February-March and September-October). It is a dwarf cultivar and suitable for high density planting (Singh and Singh, 2006) [46]. Lemon is usually propagated by seeds which are commonly polyembryonic in nature, resulting in both zygotic and nucellar individuals. Lemon propagation by cuttings is considered an alternative technique, providing high quality planting material, especially as plants with limited seed availability, such as low seed producing cultivars, and recalcitrant nature of seed. Plant growth regulators, such as indole-3-butyric acid (IBA), naphthalene acetic acid (NAA) and 6-Benzylaminopurine (BAP), are frequently used to promote shooting and rooting in cuttings (Hartmann *et al.*, 2002; Sharma *et al.*, 2013; Verma, 2013) [19, 43, 51]. Different growing media that are well aerated, well drained and with good water retention are used in establishing crop plantlets (Bhosale *et al.*, 2014; Rymbai and Reddy, 2010) [8, 41]. Auxin plays a role in the differentiation of vascular tissues and the creation of callus tissue. It has been demonstrated that IBA (indole-3-butyric acid) is the most successful root-promoting agent in lemon and lime cultivars (Khursheed and Abdul, 2003) [23]. The best material for general use is probably indole-3-butyric acid because it is safe for plants to consume at varying

doses, which promotes the germination of numerous plant species (Hartmann and Kester, 1990) [20]. Cultivar difference and weather condition also affect rooting in various fruit plant cuttings (Mishra and Singh, 1984) [35]. Therefore, it is essential to maximize the production and keeping in mind about its good demand production of genuine and quality planting material is a pre-requisite. It is always important for the fruit growers to have the best quality planting material. Although the studies on the effect of plant growth regulators on rooting of stem cuttings in citrus have been investigated over the years, but the studies on the effect of rooting hormone on stem cuttings in citrus especially in Assam lemon in particular is scarce. Keeping in view, the present investigation was undertaken to evaluate optimum dose rooting hormone in relation to seasonal variation for faster multiplication of good quality plants lemon plants to meet the demand of the fruit growers.

2. Materials and Methods

2.1 Experimental site

The present investigation on “Efficacy of plant growth regulator (Indole-3-butyric acid) and season on rooting, growth and survival of Assam lemon [*Citrus limon* (L.) Burm] stem cuttings” was conducted during the years 2023-24 and 2024-25 at Punjab Agricultural University, Regional Research Station, Gurdaspur in sub-montaneous regions of Punjab which is situated between 32°3' N latitude, 75°22' E longitude and has an altitude of about 257 m from mean sea level having humid subtropical and dry winter climate. The submountain zone of Punjab (*kandi* region) features hilly topography with *shivalik* foothills, undulating terrains, and deep, coarse-textured sandy loam to silt loam coarse textured soils.

2.2 Planting material and preparation of growth media

Assam lemon (4-5 years old plants) grown in the orchard were selected for this experiment on the basis of their uniformity in appearance, growth habit, free from visual symptoms of pests and disease occurrence. Healthy and mature shoots preferably one year old having thickness of about 1.0 cm were selected in spring (February-March) and rainy (August-September) season from the central and basal part of the branch and hardwood stem cuttings were made of about 15-20 cm in length possessing 6-8 buds. Leaves were completely removed from the cuttings with the help of secateur to reduce the transpiration loss. A slanting cut was given at the upper side and a slight slanting cut also was given at the lower end to provide a large surface area to encourage the rooting in cuttings. The basal parts (2-3 cm) of all the cuttings were dipped in different concentrations of IBA 250 ppm, 500 ppm, 750 ppm and 1000 ppm for five minutes dip along with control (Hartmann *et al.*, 2002) [19]. After this, these treated and un-treated cutting were planted in garden soil + sand + vermicompost: cocopeat (1:1:1:1) medium. This experiment was conducted in spring and rainy seasons.

2.3 Experimental design

The experiment was performed in a two way analysis of variance in completely randomized block design with three replication. The treated cuttings were planted in the polythene bags containing garden soil + sand + vermicompost + cocopeat (1:1:1:1) medium and kept under the shade of a tree. The medium was prepared well and

drenched with chloropyriphos solution to avoid the attack of termites. The holes for planting the cuttings were made in the poly bags with the help of iron rod so as to avoid any damage to cuttings. While planting, about 2/3rd portion of the cuttings were buried in the rooting medium, leaving 1/3rd portion exposed to the environment.

2.4 Observations recorded

Observation regarding days to first sprout, number of sprouts, sprout length(cm), sprout diameter(mm), number of leaves, leaf length(cm), leaf breadth(cm), rooting (%), number of primary roots, number of secondary roots, root length(cm), root diameter(mm), sprouting(%) and survival (%) were recorded after planting of cutting.

2.5 Statistical analysis

The recorded data were statistically analyzed by using two-way analysis of variance (ANOVA) with Completely Randomized Design (CRBD) as suggested by Gomez and Gomez (2010) ^[18]. Experimental data was statistically analyzed by using SPSS-30 software.

3. Results

3.1 Number of days taken for sprouting

From Table1, it has been noted that rainy season plantation of Assam lemon cuttings treated with IBA 1000 ppm grown in garden soil + sand + vermicompost + cocopeat(1:1:1:1) medium recorded the minimum days for sprouting (7.02) as compared to spring season plantation(13.32) and maximum days for sprouting were observe in control treatment in both the seasons.

3.2 Number of sprouts

Assam lemon cuttings treated with IBA1000 ppm and planted in garden soil + sand + vermicompost + cocopeat (1:1:1:1) medium during rainy season recorded maximum (22.16) number of sprouts per cuttings as compare to spring season (15.54) and control treatment was recorded minimum number of sprouts in both rainy and spring season planted cuttings (Table1).

3.3 Sprout length (cm) and sprout diameter (mm)

From the Table 1, Assam lemon cutting treated with 1000 ppm IBA and planted in soil + sand + vermicompost + cocopeat (1:1:1:1) medium during rainy season produced longest sprout length (16.56 mm) with highest sprout diameter (3.51 mm) as compared to spring season planted cuttings and the control treatment cuttings retained shortest sprout length with lowest sprout diameter in both the seasons.

3.4 Number of leaves

Maximum number of leaves (21.16) were observed in rainy season planted Assam lemon cuttings which were treated with IBA 1000 ppm grown in soil + sand + vermicompost + cocopeat (1:1:1:1) media as compared to spring season planted cuttings(15.10) and the control treatment cuttings produced lowest number of leaves in both the seasons (Table1).

3.5 Leaf length (cm) and leaf breadth (cm)

It has been noted that leaf length and breadth of Assam lemon were varied significantly among different IBA

treatments (Table 1). Maximum mean leaf length (9.02 cm) and breadth (5.15 cm) were recorded in treatment IBA 1000 ppm treated cuttings grown in soil + sand + vermicompost + cocopeat (1:1:1:1) in rainy season planted cuttings as compared to spring season plantation and minimum value of these parameters were noted in control treatment in both seasons.

3.6 Rooting percent, number of primary roots and number of secondary roots

From Table 2, it has been noted that maximum rooting percentage (95.26), number of primary roots (22.36) and number of secondary roots (36.18) were noted in Assam lemon cuttings treated with IBA 1000 ppm and planted in soil + sand + vermicompost + cocopeat (1:1:1:1) growth media in rainy season planted cuttings as compared to spring season plantation and minimum value of these parameters were noted in control in the both seasons.

3.7 Root length (cm) and root diameter (mm)

Maximum root length (24.17 mm) and root diameter (1.85 mm) were reported in Assam lemon cuttings treated with IBA 1000 ppm and planted in soil + sand + vermicompost + cocopeat (1:1:1:1) growth media in rainy season plantation as compared to the spring season plantation. Lowest value of these root growth characteristics were noted in control treatment in spring and rainy season(Table2) .

3.8 Sprouting (%) and survival (%)

Assam lemon cuttings treated with IBA 1000 ppm and planted in garden soil + sand + vermicompost + cocopeat (1:1:1:1) medium recorded maximum sprouting(86.47%) and survival (87.32%) in rainy season planted cuttings as compared to spring season and but the control treatment was recorded minimum sprouting and survival percentage in both seasons (Table2).

4. Discussion

4.1 Number of days taken for sprouting

Number days taken to sprouts varied significantly among different IBA treatments and season. Chandramouli (2001) ^[11] observed that the increase in the concentration of IBA significantly decreased the number of days to first sprouting of cuttings and earliness in sprouting might be due to better utilization of stored carbohydrates, nitrogen and other factors with the help of growth regulators. The earliest number of days taken to first bud sprouting may be caused by the downward transfer of carbohydrates and auxin build-up inside of cuttings for the completion of physiological processes. Kour *et al.*, (2006) ^[24] and Priya *et al.*, (2008) ^[39] supports the idea that specialized media specifically a blend of soil, sand and vermicompost create an ideal environment for these processes. This combination provides the structural aeration and nutrient density required to trigger early sprouting and improve the overall percentage of successful cuttings. Similarly, Maurya *et al.*, (2022) ^[33] noted minimum days taken to first sprouting in lemon cuttings prepared during rainy season with IBA 2000 ppm and planted in media combination of soil + peat moss + sand. Lalhruaitluanga *et al.*, (2022) ^[29] also reported the minimum number of days taken to sprout in Assam lemon stem cuttings under IBA 800 ppm + soil + sand + vermicompost + cocopeat (1:1:1:1) treatment.

4.2 Number of sprouts

The data presented on average length of sprout per cutting revealed that there was significant effect of growing media, growth regulators and growing seasons on number of sprouts per cutting. The positive effects of cocopeat on sprout length might be due to better root growth in cocopeat medium which led to the increase in the growth of sprouts. This might be due to better moisture availability and higher temperature in rainy season which increased the nutrient absorption capacity of the cuttings and ultimately leading to better growth. This may also be due to higher net assimilation rate on account of better growth leading to the production of endogenous metabolites earlier in optimum level enabling early bud initiation and thereby better survival. Further, vermicompost in comparison to farmyard manure used for polybag mixture contained higher level of nutrients. Increase in sprouting percentage may be due to better utilization of stored carbohydrate, nitrogen and other factor with the aid of growth regulator. Similarly Kumar and Kumar (2022) [26] reported that Pant lemon cuttings treated with IBA 1800 ppm and grown in garden Soil + sand + vermicompost (1:1:1) produced maximum percentage of sprouting. Amrutha and Patel (2025) [2] also noted that exogenous application of IBA 1500 ppm to Dragon fruit cuttings with growth media combination of soil + sand + cocopeat reported maximum number of sprouts. Tanwar *et al.*, (2020) [50] also reported IBA 2000 ppm treated cuttings of pomegranate cultivar Bhagwa and grown in coco peat + perlite + vermiculite recorded highest number of sprouts per cutting. Similarly, Singh *et al.*, (2015) [49] reported that spring planted lemon cuttings was found superior regarding number of sprout per cutting and number of primary roots per cutting Maurya *et al.*, (2022) [33] noted highest number of sprouts in lemon cuttings prepared during rainy season treated with IBA 2000 ppm and planted in media combination of soil + peat moss + sand.

4.3 Sprout length (cm) and sprout diameter (mm)

Increase in sprout length and diameter is related to better rooting performance. The cuttings treated with IBA 1000 ppm gave more rooting which facilitated the enhanced nutrient uptake and ultimately increased the shoot length. Similarly, maximum shoot length was reported in IBA 800 ppm treated cuttings of Assam lemon and planted in soil + sand + vermicompost + cocopeat (1:1:1:1) growing media (Lalhruaitluanga *et al.*, 2022) [29]. As a growth promoter IBA promotes cell division, which results in early rooting leading towards efficient absorption of mineral nutrients and hence maximizes shoot length. This might be due to increased concentrations and activity of IBA which be caused hydrolysis and translocation of carbohydrates and nitrogenous substances in the cellular level at the base of cuttings which resulted in accelerated cell elongation and cell division caused extension in shoot length under favourable environmental condition (Singh and Singh, 2011) [47]. The probable cause of increased shoot length might be the better utilization of carbohydrates, nitrogen and other nutrients from media, which had been aided by growth regulators (Babaie *et al.*, 2014) [6]. Likewise Anand and Ajay (2025) [3] reported maximum shoot length in lemon cuttings treated with IBA 1500 ppm and planted in garden soil + sand + FYM (1:1:1) media. Similarly, maximum sprout length and diameter of lemon cuttings treated with IBA 500 ppm grown in soil + sand + FYM in rainy season plantation

(Singh *et al.*, 2016) [48]. Maurya *et al.*, (2022) [33] also noted highest sprout length and diameter of lemon cuttings treated with IBA 2000 ppm during rainy season and planted in media combination of soil + peat moss + sand.

4.4 Number of leaves

The data revealed that number of leaf varied significantly with the application of different IBA concentration. These results align with previous observations by Kumar *et al.*, (2004) [28] and Murkute *et al.*, (2009) [37] confirming that the synergy between hormonal application and a fertile rooting medium accelerates the transition from root initiation to vigorous canopy growth. Indole-3-butyric acid treated cuttings resulted in longer, healthier roots that aid in the absorption of water and nutrients, significantly impacting the cuttings ability to produce more leaves. There may be more roots, branches and plant height with IBA treatment which results in more leaves per cutting (Bowden *et al.*, 2022) [9]. Likewise Kumar *et al.*, (2022) [26] reported that Pant lemon-1 stem cuttings treated with 1800 ppm IBA and grown in garden soil + sand + vermicompost (1:1:1) growth media recorded highest number of leaves per cutting (Jaiwal *et al.*, 2021) [21]. Likewise Ficus cuttings treated with IBA 2000 mg/litre and planted in growing media of sand + cocopeat + vermicompost (1:1:1) was recorded significantly maximum number of leaves (Zala and Masu, 2025) [52]. Maurya *et al.*, (2022) [33] also noted highest number of leaves in lemon cuttings prepared during rainy season, treated with IBA 2000 ppm and planted in media combination of soil + peat moss + sand.

4.5 Leaf length (cm) and leaf breadth (cm)

The data revealed that number of leaf was found significantly with the application of IBA concentration. This may be due to stem cuttings treated with IBA and growth media produced healthier lengthy roots and hence absorbed more nutrients and water contents lead to the synthesis of more carbohydrates in the leaves which might have resulted in elongation of leaves through cell division and cell elongation which resulted in more leaf area per cutting when compared to all other treatments. Similar results were undertaken by Ghosh *et al.*, (2017) [16] in phalsa and Abhinav *et al.*, (2016) [1] in grapes. Mehra *et al.*, (2019) [34] also noted that persimmon cultivar Fuyu cuttings treated with IBA 6000 ppm and planted in soil + FYM (1:2) rooting media resulted highest leaf area.

4.6 Rooting percent, number of primary roots and number of secondary roots

Rooting of stem cuttings of Assam lemon was found significantly with the application of IBA concentrations. Auxins initiate synthesis of structural enzyme protein in the formation of adventitious roots, thus increasing the root length through the process of acidification (Andus, 1963) [5]. The various aspects of root development are influenced by IBA such as the formation of adventitious roots, regulation of root apical meristem size, root hair elongation and lateral root development (Frick and Strader, 2018) [15]. The enhanced root length in treatments involving cocopeat and higher IBA concentration may be attributed to the physical and chemical properties of cocopeat. Its low particle density and high specific surface area promote water and nutrient retention, which supports better root elongation. Additionally, the presence of auxins (such as IBA)

stimulates cell elongation and root growth. Likewise Amrutha and Patel (2025) ^[2] also noted that exogenous application of IBA1500 ppm to Dragon fruit stem cuttings with media combination of soil + sand + cocopeat significantly increased the rooting percentage. Likewise, Madhuri *et al.*, (2024) ^[31] observed that treatment combination (IBA 3000 ppm + red earth + vermicompost) to dragon fruit stem cuttings recorded highest number of roots, root length, fresh weight of the roots, dry weight of the roots and root thickness. Tanwar *et al.*, (2020) ^[50] also reported treatment combination comprising IBA 2000 ppm + cocopeat + perlite + vermiculite to pomegranate cultivar Bhagwa recorded highest values in term of percentage of rooted cuttings, survival of rooted cuttings, number of roots per cutting and length of longest roots per cutting. Similarly, Maurya *et al.*, (2022) ^[33] reported highest number of roots per cutting in lemon cuttings prepared during rainy season with IBA 2000 ppm treatment and planted in media combination of soil + peat moss + sand.

4.7 Root length (cm) and root diameter (mm)

Root length and root diameter varied significantly with rooting hormone (IBA) treatment and planting season. The enhanced root length in treatments involving cocopeat and higher IBA concentration may be attributed to the physical and chemical properties of cocopeat. Its low particle density and high specific surface area promote water and nutrient retention, which supports better root elongation. Additionally, the presence of auxins (such as IBA) stimulates cell elongation and root growth. These findings are in close agreement with the results of Porghorban *et al.*, (2014) ^[38] in olive and Araujo *et al.* (2010) ^[4] in Passiflora, who reported that improved substrate texture and porosity facilitated enhanced root growth through better aeration and nutrient mobility. The enhanced rooting observed in the higher IBA concentration and cocopeat containing media may be attributed to rapid hydrolysis of stored polysaccharides in stem cuttings into physiologically active sugars. These sugars provide energy to meristematic tissues, stimulating root primordia initiation (Chander and Kumar, 2023; Singh *et al.*, 2025) ^[10, 45]. Likewise, Tanwar *et al.*, (2020) ^[50] also reported treatment combination comprising IBA 2000 ppm + cocopeat + perlite + vermiculite to pomegranate cultivar Bhagwa recorded highest values in

term of percentage of rooted cuttings, survival of rooted cuttings, number of roots per cutting and length of longest roots per cutting. Kumar and Kumar (2022) ^[26] also reported that the significantly maximum length and diameter of primary root were recorded with the treatment of 800 ppm IBA + garden soil + sand + vermicompost (1:1:1) in stem cutting of lemon cultivar Pant Lemon-1. Similarly, maximum root length and diameter of lemon cuttings were noted with IBA 500 ppm + soil + sand + FYM in rainy season plantation (Singh *et al.*, 2016) ^[48]. Maurya *et al.*, (2022) ^[33] also noted highest root length of lemon cuttings prepared during rainy season treated with IBA 2000 ppm and planted in media combination of soil + peat moss + sand.

4.8 Sprouting and survival percent

Plant growth regulator treatment and growing season had the significant effect on the sprouting and survival of Assam lemon cuttings. Similarly Sharma *et al.*, (2022) ^[44] reported that in Kagzi lime air layering, treatment with IBA1500 ppm and growing media of soil + sphagnum moss significantly increased the survival percentage. Significant effect of growth regulators on survival percentage was due to root induction capacity of auxin and better root growth in rooting media which help in production of adventitious roots and thereby increase in the survival of plants. It also might be probably due to root and root length at this concentration which could have caused the absorption of nutrients and the fact that rooting co-factors and their balance with auxin and nutritive substances. Similarly survival percentage was highest in IBA 2000 ppm treated stem cuttings of pomegranate cultivar Bhagwa planted in cocopeat, perlite and vermicompost (4:1:1) growth media as reported by Saini *et al.*, (2022) ^[42]. Amrutha and Patel (2025) ^[2] also noted maximum sprouting percentage with exogenous application of IBA1500 ppm to dragon fruit cuttings with growth media combination of soil + sand + cocopeat. Similarly, maximum survival percentage of lemon cuttings was noted with IBA 500 ppm + soil + sand + FYM in rainy season plantation (Singh *et al.*, 2016) ^[48]. Likewise, Maurya *et al.*, (2022) ^[33] reported maximum survival and sprouting percentage in lemon cuttings prepared during rainy season with IBA 2000 ppm and planted in media combination of soil + peat moss + sand.

Table 1: Effect of IBA and season on shoot and parameters of Assam lemon stem cuttings

Doses of IBA	Days to sprouting		Number of sprouts		Sprout length (cm)		Sprout diameter (mm)		Number of leaves		Leaf length (cm)		Leaf breadth (cm)	
	Spring season	Rainy season	Spring season	Rainy season	Spring season	Rainy season	Spring season	Rainy season	Spring season	Rainy season	Spring season	Rainy season	Spring season	Rainy season
250 ppm	23.15	17.15	7.05	11.36	6.10	7.68	1.60	2.04	8.25	11.16	6.35	7.05	3.41	3.68
500 ppm	20.10	14.24	9.58	13.25	8.02	10.21	1.85	2.42	10.21	14.54	7.12	7.46	3.76	4.05
750 ppm	17.08	11.36	12.16	16.58	10.35	12.04	2.16	2.81	12.46	17.38	7.65	8.25	4.02	4.36
1000 ppm	13.32	7.02	15.54	20.65	13.08	16.56	2.75	3.51	15.10	21.16	8.12	9.02	4.63	5.15
Control	27.10	22.16	5.28	8.02	4.18	6.05	1.02	1.56	5.08	8.23	5.41	6.21	3.05	3.35
CD (5%)	IBA (A): 1.62 Season (B): 1.03 (A x B): NS		IBA (A): 2.10 Season (B): 1.33 (A x B): NS		IBA (A): 1.38 Season (B): 0.87 (A x B): NS		IBA (A): 0.54 Season (B): 0.34 (A x B): NS		IBA (A): 1.75 Season (B): 1.11 (A x B): NS		IBA (A): 0.39 Season (B): 0.25 (A x B): NS		IBA (A): 0.48 Season (B): 0.30 (A x B): NS	

Table 2: Effect of IBA and season on root parameters of Assam lemon stem cuttings

Doses of IBA	Rooting (%)		Number of primary roots		Number of secondary roots		Root length(cm)		Root diameter (mm)		Sprouting (%)		Survival (%)	
	Spring season	Rainy season	Spring season	Rainy season	Spring season	Rainy season	Spring season	Rainy season	Spring season	Rainy season	Spring season	Rainy season	Spring season	Rainy season
250 ppm	56.38	65.54	5.10	10.52	15.23	20.35	7.35	12.21	0.45	0.56	60.46	65.51	61.22	68.25
500 ppm	63.41	72.18	8.75	15.21	18.10	25.14	9.48	15.35	0.86	1.08	66.05	74.28	70.38	76.51
750 ppm	70.15	80.53	11.25	18.44	21.14	29.58	14.52	19.46	1.13	1.32	73.51	80.45	75.56	80.11
1000 ppm	82.36	95.26	16.25	22.36	30.10	36.18	18.15	24.17	1.56	1.85	80.25	86.47	82.14	87.32
Control	30.25	45.38	3.15	7.36	11.42	15.24	4.10	9.03	0.12	0.21	40.25	50.24	36.18	45.12
CD (5%)	IBA (A): 10.98 Season (B): 6.94 (A x B): NS		IBA (A): 1.95 Season (B): 1.23 (A x B): NS		IBA (A): 2.08 Season (B): 1.32 (A x B): NS		IBA (A): 2.11 Season (B): 1.33 (A x B): NS		IBA (A): 0.21 Season (B): 0.13 (A x B): NS		IBA (A): 2.74 Season (B): 1.73 (A x B): NS		IBA (A): 2.88 Season (B): 1.82 (A x B): NS	

5. Conclusion

The treatment combination of 1000 ppm IBA + garden soil + sand + vermicompost + cocopeat (1:1:1:1) to the hardwood stem cuttings of Assam lemon [*Citrus limon* (L.) Burm] during the months of rainy season (September-October) found best for rooting, growth and survival percentage. This treatment combination gave the significant response in respect to all the shoot and root growth parameters. Moreover, the above mentioned treatment combination lead to faster multiplication of true to type and elite planting material availability of Assam lemon nursery plants to the fruit growers of the region.

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