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Effect of Cutting Size, Cutting Position, and Indole-3-Butyric Acid (Iba) on Rooting and Growth of *Dalbergia Sissoo* Cuttings

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ABSTRACT

In the present study, the effect of cutting size, position and different levels of growth hormone on the macropropagation and growth of plantlets in Dalbergia sissoo were evaluated. Clone 5 of Dalbergia sissoo from the clonal hedge orchard maintained at Research Farm of the Department of Forestry and Natural Resources, Punjab Agricultural University, Ludhiana was selected due to its vigorous growth, healthy juvenile shoots and superior rooting potential making it suitable for preparing the cuttings to examine the effect of cutting size, position and different levels of IBA treatment and changes in associated physiological traits during adventitious root formation. The vermiculite filled in trays (90 cc) were used as rooting medium. The cuttings of different sizes (4 cm, 7 cm and 10 cm) were treated with 4 hormonal treatments (0 ppm, 1000 ppm, 2000 ppm and 3000 ppm IBA) and were planted in the mist chamber conditions. The significant differences were found among cutting sizes and IBA levels for rooting and growth traits. The 7 cm cutting size showed the maximum rooting percentage (70.50 %) which was statistically at par with 4 cm cutting size (70 %) and 2000 ppm had the highest rooting percentage (74.45 %) which was statistically similar to 1000 ppm IBA level (73.33 %). The cuttings from different positions (top, middle and basal) were treated with 3 hormonal treatments (0 ppm, 1000 ppm and 2000 ppm IBA) and were planted in the mist chamber conditions. Cuttings taken from middle portion had maximum rooting (66.67 %). With regard to IBA levels, maximum rooting was observed at 2000 ppm treatment (66.67 %) which was statistically similar to 1000 ppm IBA level (64.17 %). A significant increase in all the metabolic activities was noted due to IBA. Total soluble sugars, starch content and total carbohydrates declined over time in all cuttings. For such decrease it has been suggested that hydrolytic enzymes release into the rooting zone of cuttings stored carbohydrates, primarily starch and sugars, where they are used to supply the energy required for cellular differentiation and division. The current research also revealed that stored carbohydrates were used in shoot cuttings during adventitious root development. Nitrogen content started to increase in the early stage and reached highest level on day 55 of planting, followed by decline at 80th day of planting. Overall these findings suggested that exogenous application of IBA may have activated carbohydrate metabolism.

INTRODUCTION

Trees being an integral part of biosphere are pillars for sustaining life on earth. Trees provide certain direct and indirect benefits. In addition to the useful purposes, such as timber, plywood, fuelwood, fruits, fodder, and fiber; the intangible advantages, such as oxygen production, air quality improvement, climate change mitigation, water conservation, soil preservation, atmospheric carbon sequestration, and wildlife assistance are priceless. The forest and tree cover in India accounts for about 25.17 per cent of the geographical area of the country (FSI 2023).

Diversification in rice-wheat crop rotation has strongly been advocated in irrigated agro-ecosystem (Chauhan *et al* 2009b). Appropriate policy actions are needed to address the stagnation in agricultural productivity and promote sustainable growth in the agricultural sector. Agroforestry offers a viable option for crop diversification, as it is both economical and sustainable. However, the successful adoption of agroforestry depends on the timely availability of quality planting material of suitable tree species. Apart from the exotic tree species like *Eucalyptus*, poplar etc, shisham also provide good economic returns to the farmers.

Dalbergia sissoo Roxb., commonly known as shisham, tahli, sissoo etc. is an indigenous timber tree species, belonging to the family Fabaceae, sub-family Faboideae (Saha *et al* 2013). It is a large deciduous tree with thick, rough, grey bark and crooked stem attaining height upto 30 m and girth upto 2.4 m. *Dalbergia sissoo* grows best on well-drained, porous soils, whereas its growth is adversely affected on heavy clay. It is widely grown under agroforestry and farm forestry conditions, as the competition for nutrients and water with crops do not occur due to its deep root system. In neighbouring nations, it is found in Afghanistan, Bangladesh, Bhutan, Pakistan, Nepal, Malaysia and Myanmar. Farmers grow it on the boundaries of their fields and on agricultural lands in Punjab in combination with gram, cotton, maize, peas, mustard, rapeseed, wheat and sugarcane. It frequently found at elevation of 900 m, but it can also go as high as 1500 m (Shukla 2002). It has the ability to fix atmospheric nitrogen, and can accumulate good amount of organic matter rich in nitrogen which improves the soil fertility. Its high quality sawn timber is perfect raw material for furniture manufacturing and building construction. The leaves are used as fodder and green manure.

Traditionally, *Dalbergia sissoo* is propagated by planting seedlings and suckers (Bari *et al* 2008). Owing to its nitrogen fixing nature, high commercial value, multifarious uses and its large scale mortality in northern region in the past years there is an urgent need for undertaking large scale afforestation of this tree species. Elite plants selected from natural populations or obtained through breeding initiatives are multiplied through the widespread use of vegetative propagation in horticulture, forestry, and agriculture. The tree population is extremely heterozygous and vegetative propagation facilitates the fastest possible utilisation of genetic gains. The proper environment, genetic component and the physiological status of cuttings are necessary for vegetative propagation to be successful (Afzal *et al* 2005). Clonal propagation techniques have been developed in *Dalbergia sissoo* to maintain uniformity in field plantations and increasing the production by producing genetically superior plants (Husen 2004). For the production of high quality timber and faster tree development, it is important to standardise clonal propagation technique through selection of elite clones from which the shoot cuttings are to be collected. Clones are abundant in nature and have long been employed as a tool for domestication, as well as in large scale forest operations.

The most significant cutting types are stem cuttings, which are divided into four classes based on the type of wood used to make cuttings: softwood, hardwood, semi-hard wood cuttings and herbal cuttings. The top and basal cuttings of plant have different chemical composition. In cuttings from various parts of the shoot, variations in root development have been noted. In many cases, the maximum rooting has been developed in cuttings derived from the bottom sections of the shoot. However, in other species where soft wood cuttings are employed, the upper shoots have maximum rooting. Most likely, the rooting agents are concentrated more in the buds than in lower cuttings, where cell differentiation is also reduced. Even though various substances including CO, acetylene and ethylene have been employed for rooting of stem cuttings. IAA and NAA, commercially derived forms of auxin, have a significant impact on cutting rooting (Rahbin *et al* 2012).

Adventitious root growth in cuttings offer a wide range of practical applications in forestry and there is significant commercial interest from the perspective of tree improvement (Husen 2008). Various environmental factors such as hormones (particularly auxin), carbohydrates and mineral salts, all influence and govern the production of adventitious roots in *Dalbergia sissoo* (Kumar *et al* 2022). The positions from which cuttings are obtained have an impact on the overall quality, rooting potential, following growth habit, mean number of roots per cutting and mean length of shoot per cutting. Cutting size is also considered important since smaller the cutting size the greater the productivity of cuttings per stock plant.

The most promising method for producing high quality planting material in large quantities while requiring minimal preparation is adventitious root development in juvenile cuttings from vegetative multiplication gardens (Husen 2004). All the tree species do not respond equally to hormonal treatments (Nanda and Anand 1970). Since the rooting of cuttings is a complex process and is affected by various external as well as internal factors like season of lopping the cutting, various growth regulators and their concentration. Auxins have been demonstrated to influence a variety of processes in plant growth and development, including cell division, cell elongation, and differentiation. Auxins applied to shoot cuttings serve a critical role in metabolic changes throughout the initiation, emergence, and development of root primordial. Auxin in high concentrations, on the other hand, inhibits root elongation and promotes the production of adventitious roots. Carbohydrate content in cuttings is vital for rooting, and it was accumulated at the cuttings' base throughout the adventitious root development process (Bakshi and Kaur 2018). Auxin aids in the mobilisation of carbohydrates in the leaves and upper stem, as well as improving transport to the rooting zone (Altman and Wareing 1975).

IBA level, size and position of cuttings on shoots all influence clonal propagation of shisham. Keeping in view these factors, importance of shisham as valuable timber species and urgent need to standardise vegetative propagation techniques at species level for mass multiplication of planting stock.

MATERIAL AND METHODS

Location and climate of experimental site

The experiment was laid out in the mist chamber, Research farm of Department of Forestry and Natural Resources, Punjab Agricultural University, Ludhiana, India. The region, which is in the central region of Punjab, is located at 247 metres above sea level and lies at 30°50" N latitude and 75°52" E longitude. A long wet season from July to early September and a long dry season from late September to early June characterize the subtropical to tropical climate. The warmest months are May and June, while the coldest months are December and January.

Collection of Clonal material

Clone 5 of *Dalbergia sissoo* from the clonal hedge orchard maintained at Research Farm of the Department of Forestry and Natural Resources, Punjab Agricultural University, Ludhiana was selected for collecting the shoots in order to make cuttings of different sizes viz 4 cm, 7 cm and 10 cm and uniform size from different positions viz top, middle and base.

Time of cuttings collection

The cuttings of *Dalbergia sissoo* were taken in the April month from the healthy mature trees growing in the Research Farm of Department of Forestry and Natural Resources, Punjab Agricultural University, Ludhiana.

Preparation of cuttings

During April shoots were collected from current year growth in the morning. Branches with thumb thickness of approximately one year were selected. Insect and disease free shoots were selected for making cuttings. Care was taken to ensure that the bark remained intact while preparing the cuttings. To improve the surface area for nutrient absorption and to expose more meristematic tissues, the lower end is cut close to the node in a slanting manner. Leaves were removed from cuttings to reduce water loss due to transpiration. A slanting cut was made on the upper end of the cutting to prevent fungal attack. Put the stem cuttings in water until planting time and the cuttings were treated immediately. The vermiculite filled in hyco trays (90 cc) used as rooting medium. The planted cuttings were placed in mist chamber having temperature of 35°C±2°C and relative humidity of 75±5 per cent.

Analysis of total soluble sugars, starch and total carbohydrate

The total soluble sugar was estimated as per the methodology given by Dubois *et al* (1956). The residual left over after extracting all of the soluble sugar was used to estimate the amount of starch. The total starch content was estimated as per the methodology given by McCready *et al* (1958). By multiplying sugar content by a factor of 0.9, starch content was calculated. Total carbohydrate is the sum total of total soluble sugars (mg glucose/g DW) estimated by Dubois *et al* (1956) and starch content (mg starch/g DW) estimated by McCready *et al* (1958).

Statistical analysis

Analysis of the data through standard statistical procedures was undertaken according to the guidelines defined for completely randomized factorial design. Analysis of variance, variability parameters and critical difference (CD) were calculated for the presentation and interpretation of the results of the present study (Panse and Sukhatme 1989).

RESULTS

Effect of cutting size and IBA level on the rooting and growth traits of shisham cuttings

Sprouting percentage has very crucial role to predict the behaviour of the tree if it is to be propagated by asexual method of shoot cutting. With respect to data in table 1, cutting size 7 cm cutting size showed maximum sprouting percentage (86.67 % after 55 days of planting) and minimum sprouting percentage was recorded in 10 cm (73.33 % after 55 days of planting). After 55 days of planting, maximum sprouting percentage was observed in 1000 ppm IBA level (87.77 %) which was statistically at par with control treatment (83.33 %). Interaction between both factors even after 55 days of interval showed non-significant results. The data showed that among IBA levels, 2000 ppm had the highest rooting percentage (74.45 %) after 85 days of planting which was statistically similar to 1000 ppm IBA level (73.33 %) and the lowest rooting percentage was observed in 3000 ppm IBA level (58.89 %). The 7 cm cutting size showed maximum rooting (70.50 % after 85 days of planting) which was statistically at par with 4 cm cutting size (70 % after 85 days of planting). The interaction for cutting size and IBA level found to be non-significant. The data of shoot length in table 1 for three different sizes was found to be significant. The 10 cm cutting size had the longest shoots (12.21 cm) which was statistically similar to 7 cm cutting size (11.69 cm) and 4 cm cutting size had the shortest shoots (10.26 cm). No significant variation was found for interaction between cutting size and IBA level for shoot length. The cuttings treated with IBA 2000 ppm had the longest roots (10.54 cm). It was followed by cuttings treated with 1000 ppm (8.91 cm) and 3000 ppm (8.67 cm) and the lowest value was noted in control (7.45 cm). Among sizes, 7 cm cutting size had the longest roots (10.14 cm) and the shortest roots were observed in 10 cm cutting size (7.48 cm). With regard to interaction between cutting size and IBA level, the results were found to be non-significant. The data for roots per cutting in table 1 revealed that *Dalbergia sissoo* cuttings with 7 cm size (20.65) exhibited the highest number of roots per cutting and the least value was observed in 10 cm cutting size (13.60). Shoot and root dry biomass also varied significantly among different cutting sizes. Dry shoot biomass varied from 0.37 g to 0.93 g and dry root biomass varied from 254.9 mg to 430.1 mg.(fig 3)(fig 4)(fig 5)

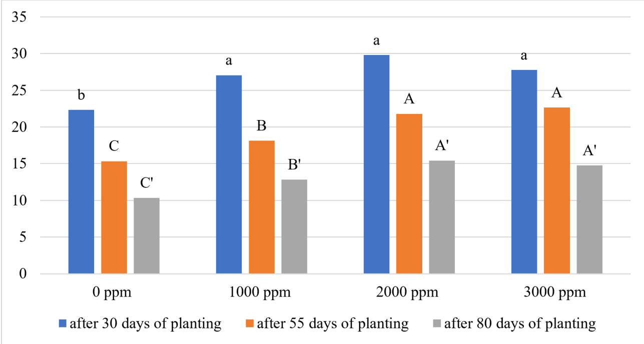

Figure 3: Effect of day of sampling and IBA level in metabolic activities of leaf tissues during rooting of Dalbergia sissoo cuttings. Each bar represents mean (a) Starch content (mg glucose/g DW) of different sizes of cutting

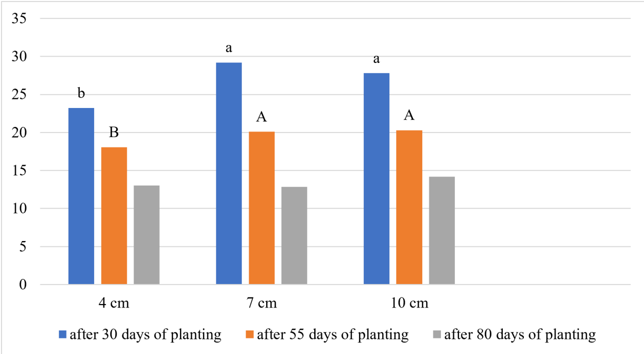

Figure 4: Effect of day of sampling and cutting size in metabolic activities of leaf tissues during rooting of Dalbergia sissoo cuttings. Each bar represents mean (a) Starch content (mg glucose/g DW) of different IBA levels

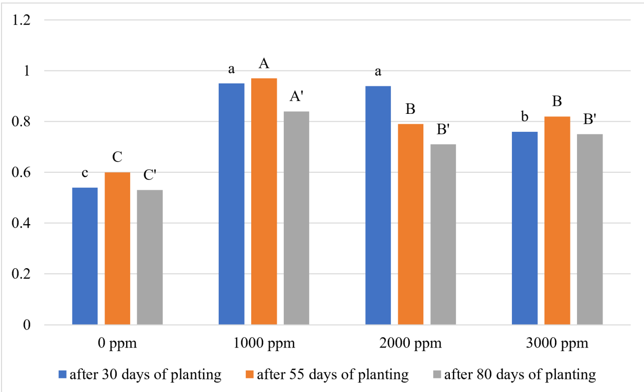

Figure 5: Effect of day of sampling and IBA level in metabolic activities of leaf tissues during rooting in the cuttings of Dalbergia sissoo. Each bar represents mean (a) Total nitrogen content (%) of different sizes of cutting

Effect of cutting size and IBA level on the physiological parameters of shisham cuttings

Total soluble sugars, starch content and total carbohydrates declined over time in all cuttings; the maximum sugar content was noted after 30 days of planting, the minimum occurred after 80 days from planting. The cuttings treated with IBA exhibited higher total soluble sugars, starch content and total carbohydrates than the cuttings planted in control. The total carbohydrate content was maximum in 7 cm cutting size (61.61 mg glucose/g DW) after 30 days from planting. Nitrogen content in cuttings that were planted in control, 1000 ppm and 3000 ppm shows similar trend viz. nitrogen content becomes maximum after 55 days of planting and then again decreases after 80 days of planting.

Effect of cutting position and IBA level on rooting and growth traits of shisham cuttings

The observations were recorded for morphological traits during the experiment. The sprouting percentage had no significant variation for cutting positions. The rooting percentage was significantly influenced by cutting positions and IBA level ($p<0.05$). Observations for rooting percentage in table 2 among different IBA levels and different cutting positions revealed that cuttings taken from middle portion had the maximum rooting (66.67 %) but cuttings taken from basal portion had the least rooting (56.67 %) after 85 days of planting. Among IBA levels, maximum rooting was observed at 2000 ppm treatment (66.67 %) which was statistically similar to 1000 ppm IBA level (64.17 %). The cuttings which were taken from the basal portion of stem had maximum shoot length (12.58 cm). The data in table 2 showed that cuttings which were prepared from the top portion have longest roots (16.58 cm) and the shortest roots were observed in basal cuttings (8.25 cm). Among IBA levels, the cuttings treated with 2000 ppm IBA (12.59 cm) had the longest roots. With regard to data in table 2, maximum number of roots were recorded in cuttings taken from middle portion of stem (18.17) and the cuttings which were prepared from basal portion of stem had minimum number of roots (12.42). Shoot and root dry biomass also varied significantly among different cutting sizes. Dry shoot biomass varied from 0.37 g to 0.74 g and dry root biomass varied from 406.3 mg to 526.3 mg.(fig 6)(fig 7)(fig 8)

Effect of cutting position and IBA level on the physiological parameters of shisham cuttings

For physiological parameters viz total soluble sugars, starch content and total carbohydrates declined over time in all cuttings; the maximum sugars content was observed after 30 days of planting, the minimum occurred after 80 days from planting. The cuttings treated with IBA exhibited higher total soluble sugars, starch content and total carbohydrates than the cuttings planted in control. The total carbohydrate content was maximum (65.11 mg glucose/g DW) in cuttings taken from middle portion of stem after 30 days of planting. The cutting position and days of sampling have shown significant variation in the total nitrogen content. Cuttings that were prepared from the basal position had highest nitrogen content (1.19 %) after 30 days of planting and lowest nitrogen content (0.67 %) was found in cuttings prepared from top position after 55 days of planting(fig 9)(fig 10)(fig 11)

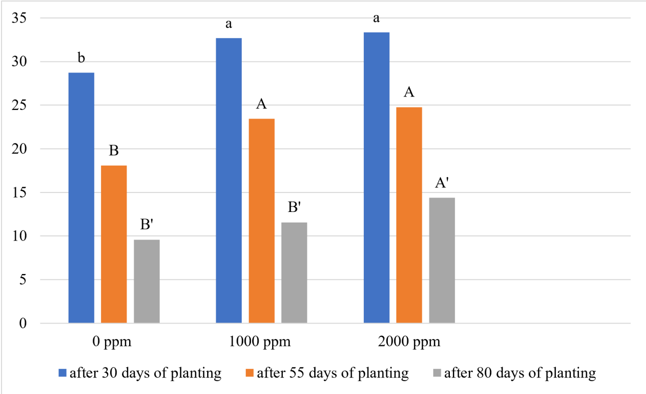

Figure 9: Effect of day of sampling and IBA level in metabolic activities of leaf tissues during rooting in the cuttings of Dalbergia sissoo. Each bar represents mean (a) Total soluble sugars (mg glucose/g DW) of different positions of cutting

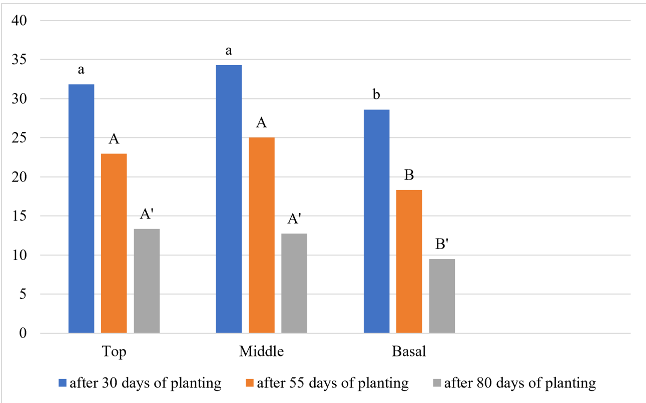

Figure 10: Effect of day of sampling and cutting position in metabolic activities of leaf tissues during rooting in the cuttings of Dalbergia sissoo. Each bar represents mean (a) Total soluble sugars (mg glucose/g DW) of different IBA levels

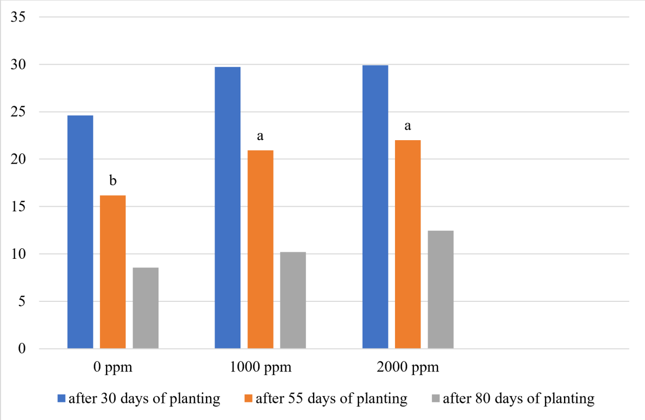

Figure 11: Effect of day of sampling and IBA level in metabolic activities of leaf tissues during rooting in the cuttings of Dalbergia sissoo. Each bar represents mean (a) Starch content (mg glucose/g DW) of different positions of cutting

DISCUSSION

Effect of cutting size and IBA level on the sprouting and rooting of shisham cuttings

The perusal of data in table 1 showed that sprouting percentage was significantly influenced by the cutting size and IBA levels. The sprouting percentage was maximum in cuttings of 7 cm size (86.67 %) which was statistically at par with 4 cm (80.83 %) and lowest value was in 10 cm cutting size (73.33 %). Rasheed *et al* (2017) while working on sprouting percentage of different sizes (5 cm, 10 cm, 15 cm) of cuttings of *Dalbergia sissoo* reported that there is a significant impact of size of cuttings on sprouting percentage and noted that the sprouting percentage was highest for 15 cm (72.10 %). It was followed by 10 cm (42.89 %) and 5 cm (18.77 %). The reason for the low sprouting percentage in treated cuttings (3000 ppm) as compared to control was the high concentration of growth hormone as compared to the cutting biomass. This finding supports the hypothesis that cuttings with low biomass are negatively impacted by high growth hormone concentrations.

The perusal of data in table 1 showed that 2000 ppm had the highest rooting percentage (74.45 %) which was statistically similar to 1000 ppm IBA level and the lowest rooting percentage was observed in 3000 ppm IBA level (58.89 %) after 85 days of planting. The results are in support with the findings of Afzal *et al* (2005) who observed that the auxin treatment improved and enhanced rooting. A higher concentration of auxins, however, actually prevented cuttings from rooting. Auxins, whether naturally occurring or synthetically applied have been found by several researchers to induce adventitious roots on stem cuttings (Nanda 1975, Verma *et al* 1992, Puri and Shamet 1988). The application of IAA was shown to be even more successful in encouraging cuttings to root (Cooper, 1935). The 7 cm cutting size showed maximum rooting (70.50 %) which was statistically at par with 4 cm cutting size (70 %) after 85 days of planting. When it comes to rooting plant cuttings, the size of the cutting can indeed make a difference. Generally, smaller cuttings, like 4 cm size, may have a harder time establishing roots because they have less stored energy. On the other hand, larger cuttings, like the 10 cm size, may take longer to root because they require more energy to support their growth and 90 cc hycotrays were used for planting the cuttings, higher the cutting size, less space available for cuttings to root. The 7 cm cutting size seems to strike a balance between having enough stored energy and being able to establish roots more efficiently. The highest rooting was observed in 7 cm cutting size from which it can be concluded that instead of using cuttings of larger size, cuttings with small size can also be used for successful vegetative propagation of *Dalbergia sissoo* so that larger number of cuttings can be prepared from hedge orchard of desirable clone.

The results for various growth and rooting traits (root length, roots per cutting, shoot biomass, root biomass) showed that when compared to the cuttings planted in control, IBA greatly increased all growth parameters; the chemical and physical characteristics of plant may be responsible for this effect. The results agree with findings of Khan *et al* 2006 and Pandey *et al* 2011. Auxins control all aspects of plant development, including cellular, organ, and ultimately whole plant growth. Auxin may encourage lateral expansion (as in root swelling) or axial elongation (as in shoots), depending on the particular tissue. With regard to size, 7 cm cutting size exhibits more number of roots per cutting and had longer roots as compared to 10 cm cutting size. This may be due to the fact that smaller cuttings like 7 cm have a higher concentration of growth hormones and nutrients. This helps them to establish roots more quickly. It might be due to the increase auxin content which might have stimulated the growth process of plants and the action of auxin activity might have accelerated cell elongation and cell division along with suitable environment which might have helped in increasing the growth process. Husen (2008) also reported that IBA 2000 ppm showed good results.(fig 12)(fig 13)(fig 14)

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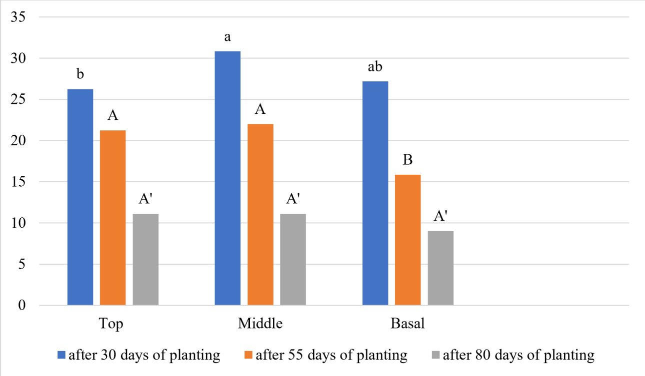

Figure 12: Effect of day of sampling and cutting position in metabolic activities of leaf tissues during rooting in the cuttings of Dalbergia sissoo. Each bar represents mean (a) Total starch content (mg glucose/g DW) of different IBA levels

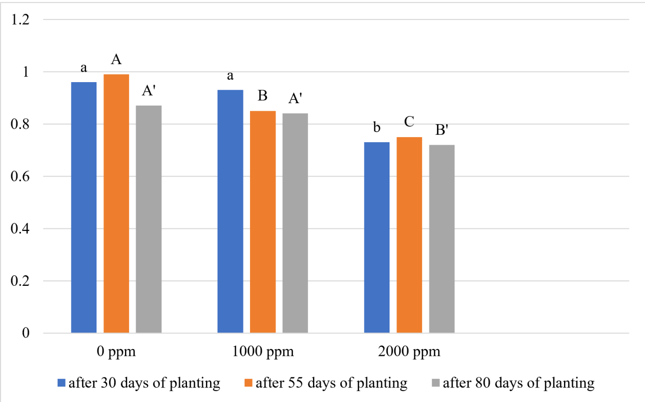

Figure 13: Effect of day of sampling and IBA level in metabolic activities of leaf tissues during rooting in the cuttings of Dalbergia sissoo. Each bar represents mean (a) Total nitrogen content (%) of different positions of cutting

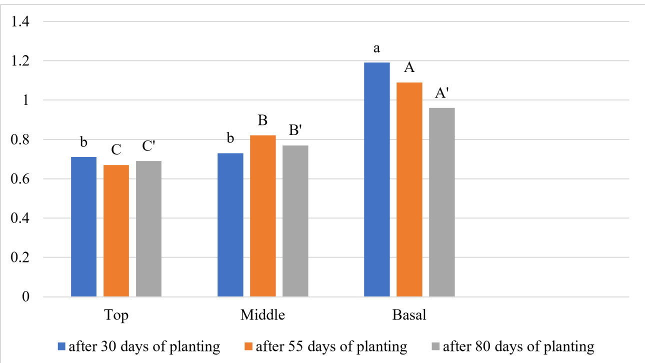

Figure 14: Effect of day of sampling and cutting position in metabolic activities of leaf tissues during rooting in the cuttings of Dalbergia sissoo. Each bar represents mean (a) Total nitrogen content (%) of different IBA levels

Effect of cutting size and IBA level on the physiological parameters of shisham cuttings

The content of total soluble sugars (mg glucose/g DW), starch content (mg glucose/g DW), total carbohydrates (mg glucose/g DW) was found maximum in the shoot cuttings treated with IBA. The results are in conformity with the study conducted by Husen (2008). Auxin induction increases sugar content in cuttings may be related to an increase in starch hydrolysis (Nanda 1975, Haissig 1974, Husen and Pal 2007). Regardless of the day of sample, the total soluble sugar and starch levels dropped over time. As roots proceeded, the amount of total soluble sugars as well as starch content decreased. For such decrease it has been suggested (Nanda 1975; Husen and Pal 2001) that hydrolytic enzymes release into the rooting zone of cuttings stored carbohydrates, primarily starch and sugars, where they are used to supply the energy required for cellular differentiation and division. The current research also revealed that stored carbohydrates were used in shoot cuttings during adventitious root development. For size, smaller cuttings tend to have less sugars and starch content because they have smaller storage capacity. The larger cuttings have more tissue to store carbohydrates. Cuttings treated with IBA have more nitrogen content as compared to control because IBA promotes root development in the cuttings and when the roots develop, they can absorb more nutrients from soil, including nitrogen. The nitrogen concentration of shoot cuttings varied significantly during the initiation of adventitious root primordium and growth. In most of cases, there was rise in nitrogen content with the passage of time from the day of planting upto the day 55, with decrease in the nitrogen content of cuttings at the day 80 irrespective of the treatment of cuttings with IBA. It has been found that cuttings of several other species exhibit comparable patterns in protein during adventitious root regeneration. (Rout *et al* 1996, Nanda 1975). The peak nitrogen content values have often been noted during the induction of root primordia and have been linked to increased enzymatic protein synthesis throughout the process of root regeneration (Nanda 1975). Generally, larger cuttings (10 cm) have more developed shoots which can store more nitrogen. Additionally, the longer shoot length in larger cuttings provides more space for nitrogen to be stored within the plant.

Effect of cutting position and IBA level on the rooting and growth traits of shisham cuttings

The perusal of data depicted that sprouting percentage was significantly influenced by IBA level. Maximum sprouting was noted in cuttings planted at 1000ppm IBA level (79.17 %) which was statistically at par with

2000 ppm IBA level (77.50 %). IBA stimulates cell division and growth, leading to an increased sprouting percentage as compared to cuttings planted in control. Many studies have found the possible role of auxins for sprouting in *Dalbergia sissoo* (Husen 2004, 2008).

The perusal of data in table 2 showed that rooting percentage was significantly influenced by cutting position and IBA level. The cuttings taken from middle portion had the maximum rooting (66.67 %) but cuttings taken from basal portion had the least rooting (56.67 %). For IBA levels, highest rooting was observed at 2000 ppm treatment (66.67 %) which was statistically similar to 1000 ppm IBA level (64.17 %). Auxins play important role in inducing rooting or enhancing rooting response in many tree species viz *E. globulus, E. saligna* (Fett-Neto *et al* 2001), *Aesculus indica* (Majeed *et al* 2009) and *Triplochiton scelroxylon* (Leakey *et al* 1982). Cuttings prepared from the middle portion of stem have higher rooting percentage because middle portion of stem tends to have more auxin thats where it naturally accumulates, which helps stimulate root development. The results are in support with the findings of Husen (2004) who observed that middle part of shoots have more rooting percentage. The physiological status of shoot tissues may vary depending on where branch is located on the parent plant, which could lead to gradients in cellular activity, growth regulator and assimilate levels, lignification levels, and other factors along the stem axis. These variations could be the cause of the position effect on rooting.

The results are in agreement with that of Mohana *et al* (2014).IBA promotes cell elongation and shoot growth. Hence cuttings treated with IBA had longer shoots. The findings are in support with the study conducted by Khudhur and Omer (2015). Cuttings taken from basal portion of the stem often have more shoot length (12.58 cm) because the basal portion contains more dormant buds. These buds have the potential to grow into new shoots when the conditions are favourable. Cuttings prepared from top portion of the stem often have longer roots because that's where the apical meristem is located. The apical meristem is a region of actively dividing cells that promote root growth. So when cuttings are taken from the top portion, more growth potential lies in cuttings giving them better chance to develop longer roots. The treatment of cuttings with IBA also promoted the initiation of roots. In teak, Nautiyal *et al* (1992) reported that maximum root length was obtained by IBA treatment.(fig 15)

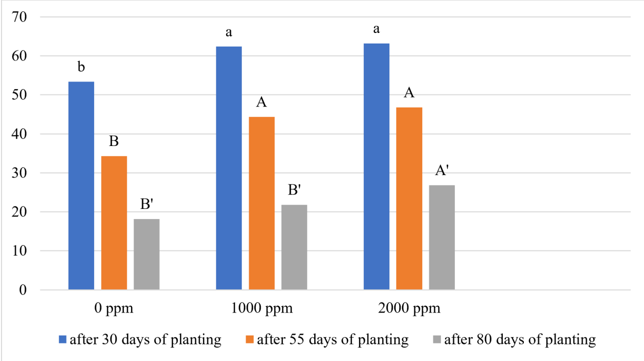

Figure 15: Effect of day of sampling and IBA level in metabolic activities of leaf tissues during rooting in the cuttings of Dalbergia sissoo. Each bar represents mean (a) Total carbohydrates (mg glucose/g DW) of different positions of cutting

Cuttings taken from middle portion of the stem often have more roots because that region contains a higher concentration of auxin. Auxin is a plant hormone that promotes root development. Haissig (1972) showed that the division of first root initial cell is dependent upon either exogenous or endogenous auxins. Pain and Roy (1981) and Shamet and Kumar (1988) noticed a differential increase in number of roots per cutting in *Dalbergia sissoo* as a result of IBA application. Basal cuttings have more shoot biomass because basal region contains a higher concentration of dormant buds. These buds lead to the growth and development of new shoots. IBA at 2000 ppm level gave higher shoot biomass. The findings are in agreement with earlier studies (Husen 2004, 2008), where IBA applied at 2000 ppm gave the best results. Cuttings taken from the middle portion of stem have more root biomass. The middle portion of stem contains a higher concentration of nutrients and growth factors, which promote root development. Husen (2004) also noted the similar results while studying the effect of position of cuttings in *Dalbergia sissoo.*

Effect of cutting position and IBA level on the physiological parameters of shisham cuttings

IBA treated shoot cuttings exhibit higher content of total soluble sugars (mg glucose/g DW), starch content (mg glucose/g DW), total carbohydrates (mg glucose/g DW) because IBA promotes the accumulation and storage of these nutrients. Similar results have been found in the previous studies conducted by Husen (2008). Rooting is also reported to be dependent on auxin-carbohydrate interactions (Anderson *et al* 1975). Cuttings made from middle portion of stem often have higher amount of total soluble sugars and starch content because that region contains a higher concentration of stored carbohydrates. The total soluble sugars and starch content also decrease with the passage of time as suggested by Husen (2008). The nitrogen content in basal cuttings decreases with passage of time. Similar results have been found which shows that total nitrogen concentration did not increase in basal stems during root formation of chrysanthemum (Good and Tukey, 1967). Basal cuttings are taken from the lower portion of plant, closer to the root system. The roots of plant are responsible for absorbing nitrogen, so basal cuttings have higher concentration of nitrogen. It was observed that cuttings planted in control can sometimes have more nitrogen because IBA treatment can enhance root growth, it may divert some of the plants' resources away from nitrogen uptake and allocation.

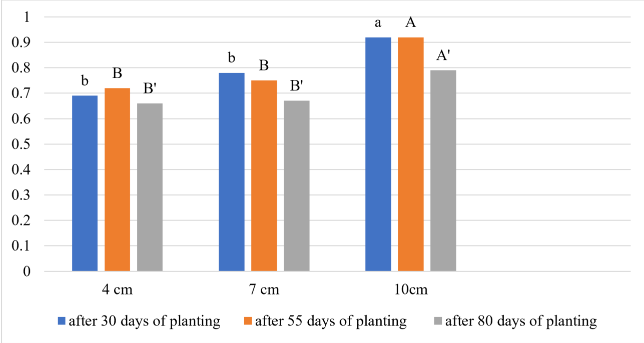

Figure 6: Effect of day of sampling and cutting size in metabolic activities of leaf tissues during rooting in the cuttings of Dalbergia sissoo. Each bar represents mean (a) Total nitrogen content (%) of different IBA levels

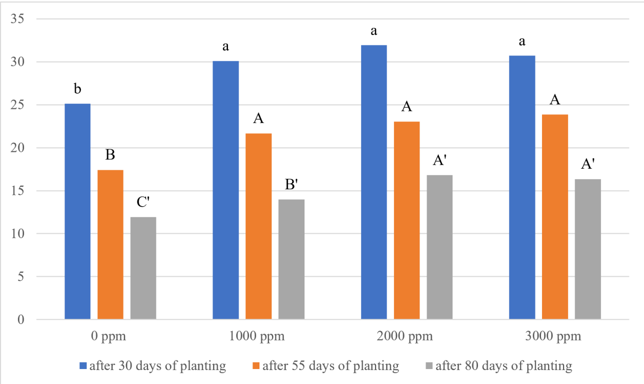

Figure 1: Effect of day of sampling and IBA level in metabolic activities of leaf tissues during rooting of Dalbergia sissoo cuttings. Each bar represents mean (a) Total soluble sugars (mg glucose/g DW) of different sizes of cutting

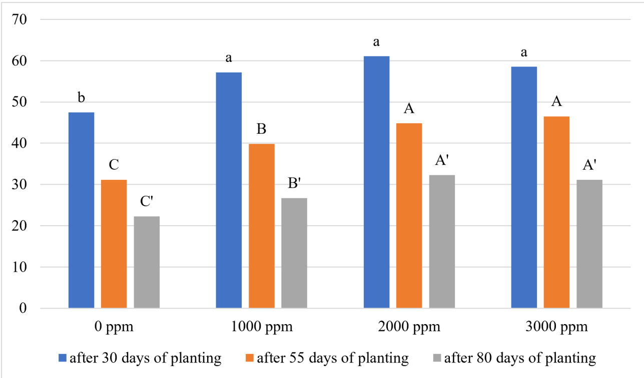

Figure 7: Effect of day of sampling and IBA level in metabolic activities of leaf tissues during rooting in the cuttings of Dalbergia sissoo. Each bar represents mean (a) Total carbohydrates (mg glucose/g DW) of different sizes of cutting

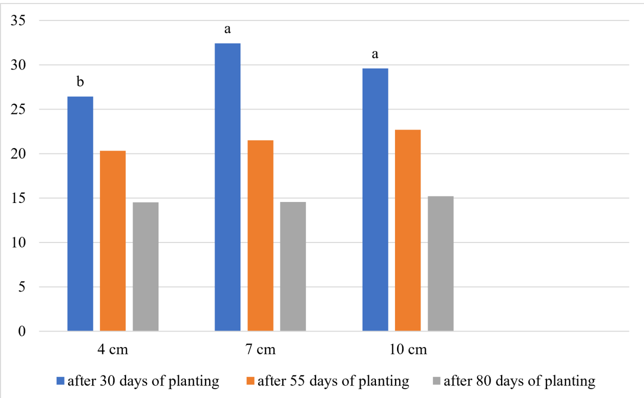

Figure 2: Effect of day of sampling and cutting size in metabolic activities of leaf tissues during rooting of Dalbergia sissoo cuttings. Each bar represents mean (a) Total soluble sugars (mg glucose/g DW) of different IBA levels

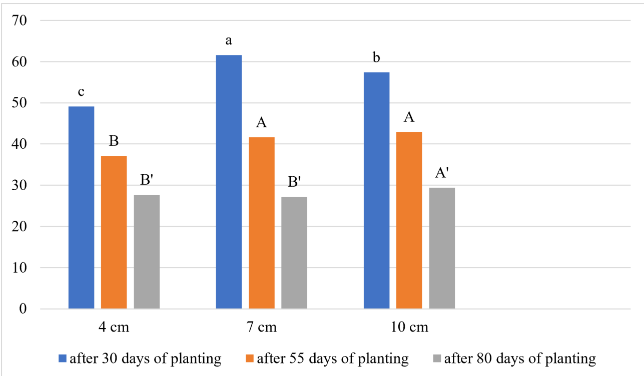

Figure 8: Effect of day of sampling and cutting size in metabolic activities of leaf tissues during rooting in the cuttings of Dalbergia sissoo. Each bar represents mean (a) Total carbohydrates (mg glucose/g DW) of different IBA levels

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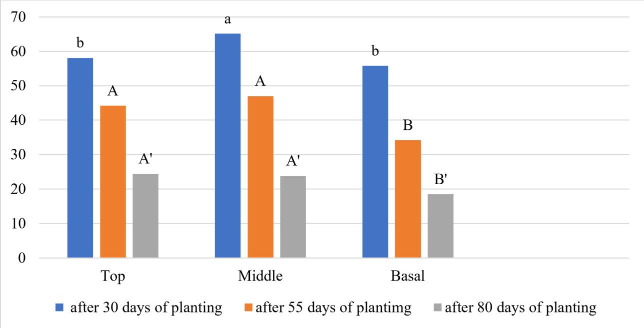

Figure 16: Effect of day of sampling and cutting position in metabolic activities of leaf tissues during rooting in the cuttings of Dalbergia sissoo. Each bar represents mean (a) Total carbohydrates (mg glucose/g DW) of different IBA levels

CONCLUSION

From the observations recorded and displayed in the form of tables and graphs, it is hereby concluded that the smaller cutting sizes (4 cm) can be used for vegetative propagation of *Dalbergia sissoo* irrespective of larger cutting sizes as smaller cuttings showed higher values for sprouting percentage (80.83 %), rooting percentage (70.00 %) and other growth traits which were statistically at par with with those of 7 cm length. It will enhance the cutting productivity per stock plant. With regard to position, cuttings taken from middle portion of stem showed best performance for rooting percentage (66.67 %) and other rooting traits. For IBA levels, 1000 ppm showed better results for various morphological and physiological traits which were statistically at par with 2000 ppm IBA level.

Table 1: Rooting and growth traits of shoot cuttings of three different sizes of *Dalbergia sissoo* in relation to IBA levels and at different intervals from planting

IBA level (ppm)	Cutting size (cm)			Mean
	4	7	10	
Sprouting percentage after 55 days of planting				
0 (Control)	86.67	93.33	70.00	83.33
1000	93.33	86.67	83.33	87.77
2000	83.33	86.67	76.67	82.22
3000	60.00	80.00	63.33	67.78
Mean	80.83	86.67	73.33	
CD (0.05)	**Cutting size=9.115**	**IBA level=10.571**	**Interaction=NS**	
Rooting percentage after 85 days of planting				
0 (Control)	66.67	70.00	56.67	64.45
1000	83.33	76.67	63.33	74.44
2000	80.00	76.67	70.00	75.56
3000	56.67	70.00	50.00	58.89
Mean	71.66	73.34	60.00	
CD (0.05)	**Cutting size=10.57**	**IBA level=12.21**	**Interaction=NS**	
Shoot length (cm)				
0 (Control)	9.93	12.09	12.88	11.63
1000	10.28	11.69	11.91	11.29
2000	10.43	12.18	12.40	11.67
3000	10.38	10.81	11.65	10.95
Mean	10.26	11.69	12.21	
CD (0.05)	**Cutting size=1.08**	**IBA level=NS**	**Interaction=NS**	
Root length (cm)				
0 (Control)	7.58	8.33	6.43	7.45
1000	9.06	10.13	7.54	8.91
2000	11.00	12.25	8.37	10.54
3000	8.62	9.83	7.56	8.67
Mean	9.07	10.14	7.48	
CD (0.05)	**Cutting size=1.08**	**IBA level=NS**	**Interaction=NS**	
Roots per cutting				
0 (Control)	12.75	16.67	11.75	13.72
1000	11.92	17.33	11.58	13.61
2000	22.67	27.08	16.08	21.94
3000	19.42	21.5	15	18.64
Mean	16.69	20.65	13.60	
CD (0.05)	**Cutting size=1.60**	**IBA level=1.85**	**Interaction=3.20**	
Dry shoot biomass (g)				
0 (Control)	0.31	0.68	0.92	0.64
1000	0.36	0.72	0.88	0.65
2000	0.42	0.77	0.97	0.72
3000	0.38	0.89	0.94	0.74
Mean	0.37	0.77	0.93	
CD (0.05)	**Cutting size=0.03**	**IBA level=0.03**	**Interaction=NS**	
Dry root biomass (mg)				
0 (Control)	331.5	366.0	190.6	296.0
1000	442.8	405.2	239.4	362.5
2000	457.5	521.8	366.3	448.5
3000	386.4	427.5	223.1	345.7
Mean	404.5	430.1	254.9	
CD (0.05)	**Cutting size=15.2**	**IBA level=13.2**	**Interaction=26.3**	

Table 2: Rooting and growth traits of shoot cuttings of three different positions of *Dalbergia sissoo* in relation to IBA levels and at different intervals from planting

IBA level (ppm)	**Cutting position**			**Mean**
	Top	Middle	Basal	
Sprouting percentage after 55 days of planting				
0 (Control)	70.00	72.50	55.00	64.17
1000	70.00	82.50	85.00	79.17
2000	77.50	77.50	77.50	77.50
Mean	72.50	77.50	72.50	
CD (0.05)	**Cutting position=NS**	**IBA level=9.13**	**Interaction=NS**	
Rooting percentage after 85 days of planting				
0 (Control)	45.00	57.50	47.50	50.00
1000	60.00	70.00	62.50	64.17
2000	67.50	75.00	60.00	67.50
Mean	57.50	67.50	56.67	
CD (0.05)	**Cutting position=7.34**	**IBA level=7.34**	**Interaction=NS**	
Shoot length (cm)				
0 (Control)	10.59	11.66	11.66	11.30
1000	11.09	12.48	13.20	12.25
2000	11.56	12.95	12.88	12.46
Mean	11.08	12.36	12.58	
CD (0.05)	**Cutting position=0.72**	**IBA level=0.72**	**Interaction=NS**	
Root length (cm)				
0 (Control)	17.21	12.19	7.96	12.45
1000	15.63	10.81	7.96	11.47
2000	16.91	12.02	8.84	12.59
Mean	16.58	11.67	8.25	
CD (0.05)	**Cutting position=0.81**	**IBA level=0.81**	**Interaction=NS**	
Roots per cutting				
0 (Control)	9.94	16.06	10.38	12.13
1000	12.06	18.56	10.75	13.79
2000	15.94	19.88	16.13	17.31
Mean	121.65	18.17	12.42	
CD (0.05)	**Cutting position=1.14**	**IBA level=1.14**	**Interaction=NS**	
Dry shoot biomass (g)				
0 (Control)	0.39	0.59	0.71	0.56
1000	0.31	0.52	0.70	0.51
2000	0.40	0.63	0.79	0.61
Mean	0.37	0.58	0.74	
CD (0.05)	**Cutting position=0.04**	**IBA level=0.04**	**Interaction=NS**	
Dry root biomass (mg)				
0 (Control)	366.9	510.0	248.0	375.0
1000	417.9	505.8	312.2	412.0
2000	469.2	563.0	186.6	406.3
Mean	418.0	526.3	406.3	
CD (0.05)	**Cutting position=28.3**	**IBA level=28.3**	**Interaction=49.0**	

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