ANSF APPLIED AND NATURAL SCIENCE FOUNDATION

Journal of Applied and Natural Science
13(1): 238 - 249 (2021)
Published online: March 8, 2021
ISSN : 0974-9411 (Print), 2231-5209 (Online)
journals.ansfoundation.org

Research Article

Responses of *Populus deltoides'* stem cuttings under treatment of different growth hormones in planting seasons

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Article Info
https://doi.org/10.31018/jans.v13i1.2530
Received: January 27, 2021
Revised: March 2, 2021
Accepted: March 6, 2021

How to Cite
Chhetri, S. *et al.* (2021). Responses of *Populus deltoides'* stem cuttings under treatment of different growth hormones in planting seasons. *Journal of Applied and Natural Science*, 13(1): 238 - 249. https://doi.org/10.31018/jans.v13i1.2530

Abstract
The farmers have widely used vegetative propagation of plants due to the low germination percentage of seeds of various plant species. So to study the asexual propagation technique of *Populus deltoides,* the present study was conducted where a number of stem cuttings of Poplar were treated with growth hormones: IBA (Indole-3-butyric acid), NAA (1-Naphthaleneacetic acid) and GA3 (Gibberellic acid) at different concentrations (100 ppm, 200 ppm and 300 ppm). Some cuttings, which were not treated with hormones, considered as control. A completely randomized design was used to conduct the experiment. The responses were recorded for the cuttings, which were collected and planted in on-season (February) and off-season (July) for 30, 60 and 90 Day after planting (DAP). The results showed that the cuttings collected and planted in February month responded with the better growth rate in shoot and root parameters. The untreated cuttings showed relatively lower values for all growth parameters than the cuttings treated with hormones. Tukey HSD test of multiple comparisons revealed that IBA, at higher concentration, had significantly ($P<0.05$) higher values for most of the growth parameters, followed by GA3. Pearson product-moment correlation showed a very strong correlation ($P>0.70$) recorded for underground biomass and other parameters. These findings can allow the farmers to select the best treatment to enhance the growth and yield of *P. deltoides.*

Keywords: Growth hormones, Planting season, Poplar, Stem cutting, Vegetative propagation

INTRODUCTION

Poplars (*Populus deltoids* Bartram ex Marshall) belong to genus *Populus* species and family Salicaceae, and were introduced in India way back in 1950 and studies have been done on their yields at various places (Fotidar, 1979, Burgess *et al.* 2005, Dillen *et al*. 2013, Truax *et al.* 2014). In India, about 225 clones of various poplars have been introduced, tested and some of them have performed very well (Chauhan *et al.,* 2008). The wood of Poplar is used for agricultural implements, cooling pads employed in room-coolers and sports goods (Rajput, 1996). The bark is used as a tonic, stimulant and blood purifier. Besides their economic importance, poplars are also preferred by farmers because of their short rotation, thus ensuring quick returns. The dependence of Indian matchwood and plywood industry on poplars is noteworthy and use of poplar leaves as fodder and fuel wood are also not rare (Singh, 1979; Singh and Singh, 2018).

P. deltoides, commonly called as Poplar, make up the backbone of agro-forestry in India (Kumar *et al*, 1999, Chavan and Dhillon, 2019). Large-scale plantation for poplar species is done for *P. deltoides* in India. The Poplar has contributed in agro-forestry land-use system appreciably to increase the tree cover outside natural forests as well as proved to be a potential resource for socio-economic development, ecological restoration and diversification of agriculture (Chauhan *et al*.2012).

P. deltoides adapts well in the Indian ecological conditions than other species and hybrids (Cortizo *et al.* 2008). Poplar generally grows well in fertile alluvial soils. Poplar trees flourish in the clayey, sand and sandy loamy soil, humid rich, fine drained and soils near to the water resources with pH of 6.5-8.0 (Singh and Singh, 2018).

Cloning or vegetative propagation of the trees has been a constructive tool in traditional tree improvement, with the promising feature of clones being important for production forestry (Libby, 1986; Henrique *et al.,* 2006). Implementation of clonal forestry has been successful in several hardwood species, particularly in eucalyptus, popular and willow (Zsuffa *et al*. 1993; Rezende *et al*. 2013) due to being a short rotation crop. Propagation of Poplar is widely increasing worldwide for the production of timber and raw materials for industrialization. Sexual propagation may be practised by farmers or the government but vegetative propagation is successful in terms of propagation and mass multiplication of Poplar. Vegetative propagation has become the preferred method of propagation to maintain individual characteristics, resulting in a genetically identical plant to the original donor plant (Araya 2005; Spriggs and Dakora 2007; Bester 2013).

The growth regulators have successfully been used by many researchers to increase the growth of stem cuttings of plant species (Soundy *et al*., 2008; Singh *et al*. 2011; Sağlam *et al*. 2014). Meanwhile, the collection and planting timing of stem cuttings has also affected the rooting of stem cutting. The present study was conducted to observe the effect of different growth hormones on various growth parameters of *P. deltoides* and find out the suitable planting season (February or July) for the same.

MATERIALS AND METHODS

The experiment was conducted to determine the effects of growth hormones on the growth parameters of cuttings *P. deltoides* L. Marsh, under nursery conditions in the forest nursery and research centre, Department of Forestry and Fisheries, Himgiri Zee University, Dehradun (Fig. 1) in the year 2018. The climate of the region was broadly humid subtropical, with cold winter and hot dry summer. The district Dehradun is micro-geographic area covering 3088 sq. km, located at between 29°55' to 30°30' N and 77°35' to 78°24' E. Geographically, the district Dehradun is surrounded by the lesser Himalaya mountain on the north, Shivalik hills on the south and the river Ganga on south-east and the river Yamuna on the north-west. Its elevation ranges from 315 to 2500 m and the gradient varies between 7 and 10 km. The area receives 137.3 cm to 188.6 cm rainfall annually, depending upon other climatic factors. In general, the temperature varies with the maximum range of 16^0 C to 36^0 C in summer (April to July) and 2^0 C to 24^0 C in winter (November to February). Most of the part of the valley is plain and riverine. The water bodies of the Doon Valley form a Bioresource-environment by maintaining a balanced ecosystem. Although the climate varies, it is up to a considerable range. Hence flora and fauna of the valley seem to be transient between the sub-montane region and the Gangetic plains.

The stem cuttings of *P. deltoides* were selected for the study to check the effect of different growth regulators viz: IBA, NAA, and GA_3 (purchased from the certified company) on its different growth parameters. Each growth regulator was prepared in three different concentrations: 100 ppm, 200 ppm and 300 ppm (Ullah *et al.,* 2013). One experiment was also conducted in a control condition with no treatment applied. The treatments were distributed as T1: No Treatment; T2: IBA 100ppm; T3: IBA 200 ppm; T4: IBA 300 ppm; T5: NAA 100ppm; T6: NAA 200 ppm; T7: NAA 300 ppm; T8: GA3 100ppm; T9: GA3 200 ppm; T10: GA3 300 ppm

Stem cutting of plant species (*P. deltoides*) of about 15 cm long and having at least 3 internodes were used as the planting material. The basal portion of the cutting was cut off and dipped into the distilled water for 24 hour (Haider *et al.,* 2015). The cuttings were treated with the treatments for at least 10 minutes (Chauhan *et al.,* 2015) and planted using a completely randomized design (CRD) with 3 replications. Each replication was having 3 numbers of cuttings. The experiment was conducted in the on-season (February) and off-season (July) of planting. Thus, a total 180 cuttings were utilized by the experiment in both seasons of planting. The cuttings were planted in an open condition in the nursery raised beds at 15cm x 15 cm spacing. The data for various growth parameters were recorded in 30, 60 and 90 DAP.

Determination of growth parameters

The following parameters were taken into consideration for the assessment of cuttings of the different stem as a result of the growth regulator. Shoot length (cm) was measured from the root collar to the terminal bud base using measuring rod/metallic tape. The cuttings were removed from the ground without any damage and the number of roots per cutting was counted along with the length of the root. The leaves were removed from the cutting without any damage to the plant and the number of leaf/ cutting was counted. The Shoot diameter was measured using a digital Calliper. The fresh shoot and root weight for each cuttings was taken separately by using an electronic tap pan balance; fresh root and shoot were dried at 60^{O}C in an oven over 24 hours as per treatment and replication wise till constant weight was attained. Dry root and shoot weight (gm) were recorded using Electronic top pan balance.

Statistical analysis

The experiment was laid out in Completely Random-

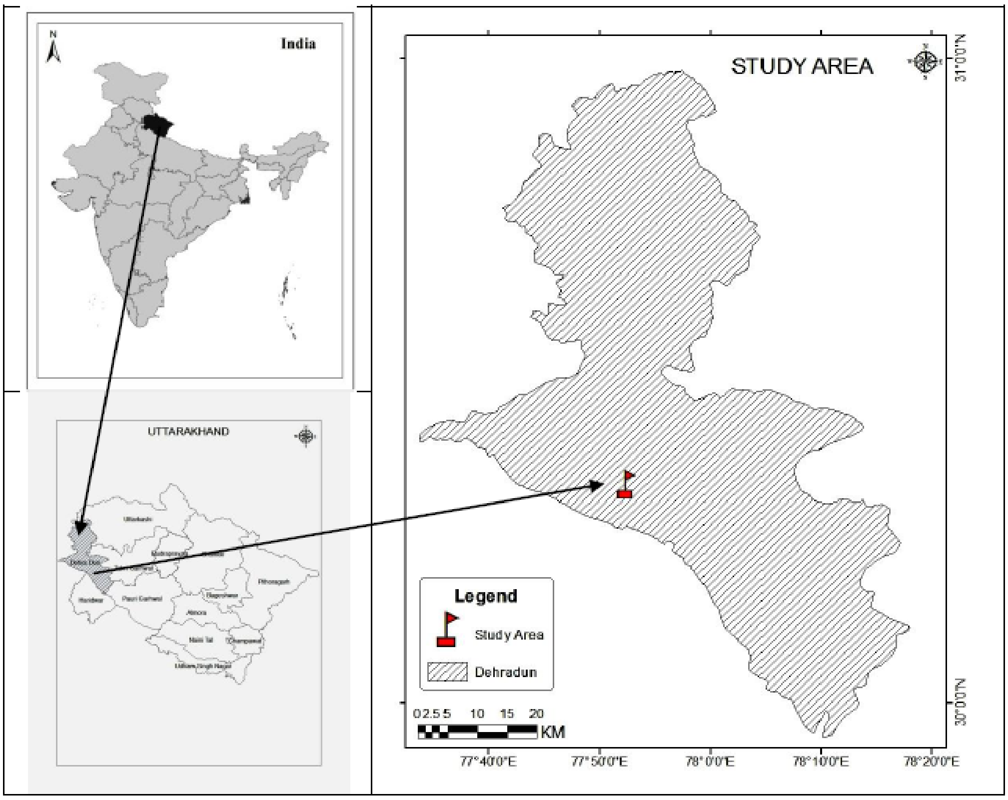

Fig. 1. *Map of experimental site and study area at the nursery of Department of Forestry and Fisheries, Himgiri Zee university, Dehradun, Uttarakhand, India*

ized Design having 10 treatments (including one control) with each replicated thrice. A multivariate ANOVA (Analysis of Variance) was used to test the significance at 5 % level as well as 1 % among different treatments and seasons of planting. For multiple comparisons, the Tukey HSD Post Hoc Test was used to test the difference between different treatments. Pearson product-moment correlation coefficient was calculated to analyse the relationship among different growth parameters. IBM SPSS V 21 was used for statistical analysis and Minitab Version 19 (Trial Version) was used for graphical representations.

RESULTS

Effect of various growth regulators on different growth parameters of *P. deltoides* in 30 DAP in two different seasons of planting

In the present study, on-season planting, the analysis showed a significant effect (P<0.001) on all the growth parameters (Table 1). The analysis of the multiple comparisons of various treatments, Tukey HSD test showed that there were statistically same values of number of sprouting and sprouting length in all treatments except in the control conditions, which showed relatively lower value as compared to others.

IBA, with 300ppm, showed consistently higher values after 30 days of planting for the number of leaves, the number of roots/cutting, root length/cutting, fresh weight of shoot, dry weight of root and shoot diameter (at par with GA3 100 ppm). The values of all the parameters were recorded significantly lower in control conditions. The highest fresh root weight (0.821 gm) was recorded for the cuttings treated with GA3 300 ppm, which was significantly (P<0.05) higher than the values observed in other treatments.

In off-season planting, the treatments were overall having a significant effect (P<0.001) on all the parameters. For most of the parameters (No. of sprouting, No. of leaves, sprouting length, no. of the root, root length and fresh weight of shoot), IBA 300 ppm showed the maximum values which was also at par with the values under other treatments. GA3 300 ppm had relatively higher values for fresh weight of root (0.704 gm). The cuttings which were not treated with any growing media showed the least values of all the parameters.

When comparing the growth response of Poplar in two different seasons, the results showed significantly higher (P<0.01) values for all the parameters except for dry weight of root, which did not differe significantly in two different seasons (Table 2).

Effect of various growth regulators on different growth parameters of *P. deltoides* in 60 DAP in two different seasons of planting

Data for different parameters recorded after 60 days of

Table 1. Effect of various growth regulators on different growth parameters of *P. deltoides* in 30 DAP.

Treatments	No. of sprouting	No. of leaves	Sprouting length (cm)	No. of roots per cutting	Root length per cutting (cm)	Fresh weight of shoot (gm)	Fresh weight of root (gm)	Dry weight of shoot (gm)	Dry weight of root (gm)	Shoot diameter (cm)
ON SEASON PLANTING (FEBRUARY)										
Control (No Treatment)	0.398 b	1.750 e	1.721 b	1.444 d	1.213 d	0.180 e	0.126 d	0.083 d	0.029 g	0.016 d
IBA 100ppm	2.444 a	2.234 cde	2.776 a	2.111 c	1.947 cd	0.853 b	0.492 bc	0.512 a	0.100 f	0.043 b
IBA 200ppm	2.111 a	2.298 cd	2.781 a	2.111 c	2.501 bc	0.634 cd	0.515 bc	0.369 b	0.111 e	0.031 bcd
IBA 300ppm	3.000 a	3.187 a	3.376 a	2.889 a	3.403 a	1.579 a	0.594 b	0.091 cd	0.213 a	0.063 a
NAA100ppm	2.444 a	3.107 ab	3.287 a	2.341 abc	2.748 abc	0.542 cd	0.178 d	0.323 b	0.109 ef	0.033 bc
NAA200ppm	2.333 a	2.629 bc	3.205 a	2.778 ab	2.889 ab	0.619 cd	0.448 c	0.116 cd	0.213 a	0.029 bcd
NAA300ppm	2.778 a	2.351 cd	3.177 a	2.333 abc	2.962 ab	0.703 bc	0.168 d	0.157 cd	0.151 d	0.026 cd
GA3 100ppm	2.667 a	2.359 cd	3.296 a	2.222 bc	2.891 ab	0.470 d	0.410 c	0.183 c	0.163 c	0.070 a
GA3 200ppm	2.889 a	2.027 de	3.200 a	2.222 bc	2.774 ab	0.489 d	0.479 bc	0.170 cd	0.183 b	0.034 bc
GA3 300ppm	2.667 a	2.171 cde	3.219 a	2.222 bc	3.324 a	0.551 cd	0.821 a	0.150 cd	0.193 b	0.074 a
p-value	*P<0.001*	*P<0.001*	*P<0.001*	*P<0.001*	*P<0.001*	*P<0.001*	*P<0.001*	*P<0.001*	*P<0.001*	*P<0.001*
OFF-SEASON PLANTING (JULY)										
Control (No Treatment)	.669 c	1.336 c	1.319 b	1.000 b	1.040 d	0.134 e	0.101 d	0.063 f	0.090 f	0.020 c
IBA 100ppm	2.014 ab	2.222 ab	2.563 a	1.889 a	1.737 cd	0.721 b	0.395 bc	0.200 d	0.170 a	0.050 ab
IBA 200ppm	2.111 ab	2.111 ab	2.436 a	1.778 a	2.314 bc	0.520 cd	0.406 bc	0.120 e	0.136 cd	0.053 a
IBA 300ppm	2.333 ab	2.667 a	3.167 a	2.222 a	3.204 a	1.360 a	0.500 b	0.300 b	0.150 bc	0.037 b
NAA100ppm	1.889 b	2.222 ab	2.903 a	2.222 a	2.521 abc	0.416 cd	0.143 d	0.260 bc	0.106 e	0.037 b
NAA200ppm	2.000 ab	2.333 ab	2.848 a	2.222 a	2.656 ab	0.491 cd	0.354 c	0.260 bc	0.156 ab	0.040 ab
NAA300ppm	2.111 ab	2.222 ab	2.925 a	2.111 a	2.683 ab	0.568 bc	0.137 d	0.370 a	0.103 ef	0.037 b
GA3 100ppm	2.111 ab	2.000 abc	2.954 a	1.889 a	2.608 ab	0.367 d	0.340 c	0.220 cd	0.130 d	0.043 ab
GA3 200ppm	2.667 a	1.778 bc	2.807 a	1.778 a	2.515 abc	0.412 cd	0.393 bc	0.230 cd	0.122 d	0.040 ab
GA3 300ppm	2.000 ab	1.778 bc	2.873 a	1.889 a	3.040 ab	0.462 cd	0.704 a	0.190 d	0.130 d	0.037 b
p-value	*P<0.001*	*P<0.001*	*P<0.001*	*P<0.001*	*P<0.001*	*P<0.001*	*P<0.001*	*P<0.001*	*P<0.001*	*P<0.001*

(Different letters, mentioned with the values, between treatments represent significant differences (P<0.05) based on Tukey Post Hoc) lanting showed a significant effect (P<0.01) of various treatments in all growth parameters. The multiple comparisons showed many statistical at par values with the maximum value of different parameters. The number of sprouting (3.150), dry weight of root (0.350 gm) and shoot diameter (0.071cm) were relatively higher in the cuttings which were treated by IBA 300 PPM, which was statistically at par with other treatments (Table 3). The cuttings, which were planted in control conditions, showed relatively lower values for all parameters compared to the cuttings treated with the growth hormones.

In off season planting, all treatments were overall having a significant effect (P<0.01) on various parameters excluding shoot diameter, which showed a non-significant response (P>0.05) after 60 days of planting. The no-treatment (control) cuttings showed consistently lower values for all parameters. Other than that, most parameters were having statistically (P>0.05) same values under different treatments (based on post hoc test). Fresh weight of root and dry weight of shoot showed the same responses as showed in 30 DAP. Root length (3.862 cm) and fresh weight of shoot (1.774 gm) showed relatively higher values under IBA 300 PPM. The planting season was also having a significant effect (P<0.01) on different parameters (Table 4), which showed that the cuttings planted in on-season were having relatively higher values for all the parameters after 90 days of planting.

Effect of various growth regulators on different growth parameters of *P. deltoides* in 90 DAP in two different seasons of planting

In on-season planting, all the parameter showed a significant difference (P<0.05) under various treatments after 90 days of planting (Table 5). The cuttings planted with no-treatment showed relatively lower values for all parameters. Other than that, based on the Tukey HSD test, the values of most of the parameters did not differ significantly (P>0.05) under different treatments. Dry weight of shoot (1.009 gm) was recorded significantly higher (P<0.05) in the cuttings treated with IBA 100 ppm.

In off-season planting, the growth response of poplar cuttings was also same under different treatment as in on-season planting for some parameters (Table 5). IBA 300 ppm for fresh weight of shoot (2.276 gm); GA3 300 ppm for fresh weight of root (1.059 gm) and IBA 200 for shoot diameter (0.120 cm) showed relatively higher values as compared to other treatments.

Comparison between two seasons of planting showed a significant difference (P<0.01) for all parameters, excluding the number of roots, under different treatments (Table 6).

Trends of various parameters during 3 months of planting

In on-season, most of the parameters showed a rapid increase for the first sixty days. However, this increment slowed down when observed after 90 DAP (Fig. 2). This type of trend was the most common with the cuttings which were given no treatment. Under other treatments, some parameters (fresh weight of root, dry weight of root and shoot) showed an increasing trend of values after 60 DAP (Fig. 2).

In the off-season of planting, most of the parameters showed a contrasting pattern from the on-season planting. The increase in the trend of different parameters is more constant for 3 months. The cutting planted with no-treatment showed a relatively lower trend for all parameters as compared to the cutting under different treatments (Fig. 3).

Correlation among various growth parameters

The pooled data of all three months to analyze the correlation among various growth parameters showed that all the growth parameters were significantly and positively correlated (P<0.01) with each other (Table 7). This positive and significant correlation among all the parameters indicated that improving one variable's performance can trigger the performance of other parameters. The result showed a very strong relationship (r > 0.70) of underground biomass with most of the parameters. Aboveground biomass was having a relatively lower correlation (r < 0.60) with other variables. The number of sprouts was having a strong relationship with the number of roots (r = 0731) and shoot diameter (r = 0.750). Length of sprouts and number of leaves were also having a very strong correlation with all the variables, excluding the dry weight of shoot (r < 0.60) and shoot diameter (r < 0.40). Root length and shoot diameter showed a relatively weaker correlation with each other (r = 0.350).

Table 2. Effect of two different planting seasons (February and July) on various growth parameters in 30 DAP.

Parameters	F-Statistic	p-value
No of Sprouting	27.389	.000
No of leaves	42.278	.000
Sprouting length	14.588	.000
No of Roots / cutting	41.853	.000
Root length / cutting	10.090	.003
Fresh weight of shoot	50.435	.000
Fresh weight of root	54.450	.000
Dry Weight of shoot	0.783	.382
Dry weight of root	208.413	.000
Shoot Diameter	4.189	.047

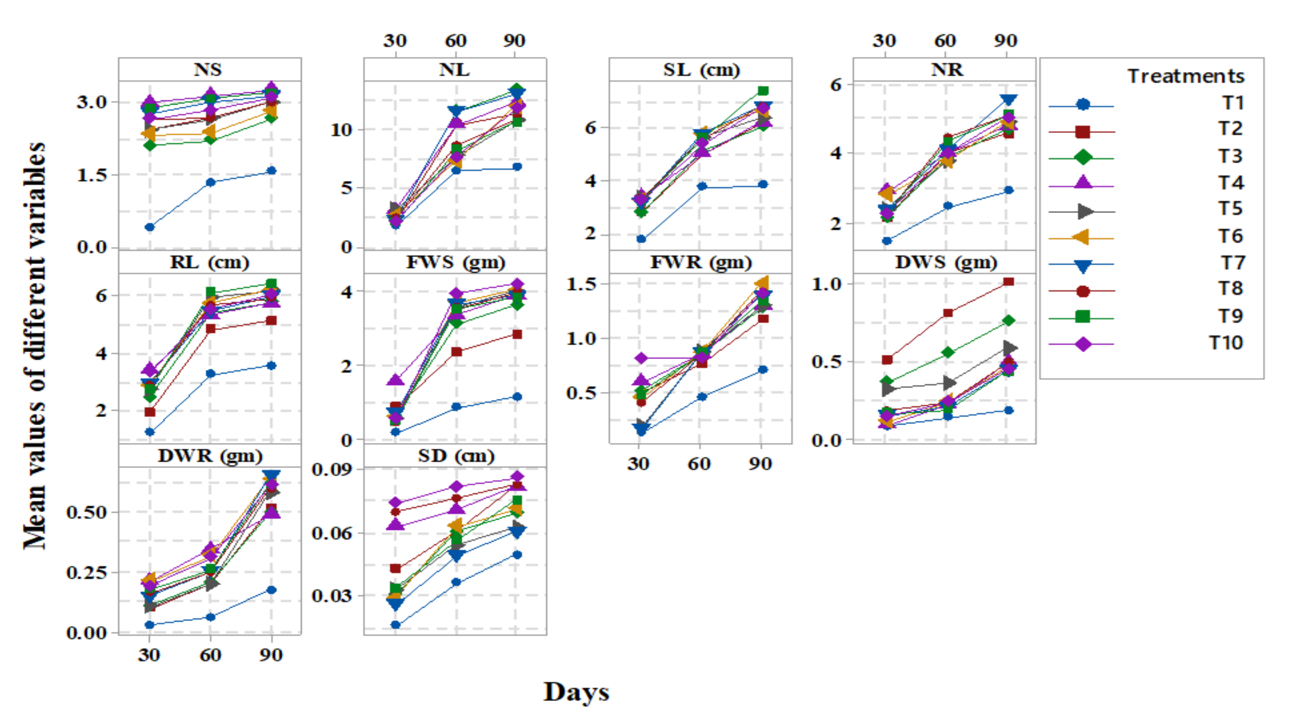

Fig. 2. *Trends of various growth parameters in on-season planted cuttings during 3 months of planting. (T1: No Treatment; T2: IBA 100ppm; T3: IBA 200 ppm; T4: IBA 300 ppm; T5: NAA 100ppm; T6: NAA 200 ppm; T7: NAA 300 ppm; T8: GA3 100ppm; T9: GA3 200 ppm; T10: GA3 300 ppm) (NS: Number of Sprouts; NL: Number of Leaves; SL: Sprout Length; NR: Number of Roots; RL: Root Length; FWS: Fresh Weight of Shoot; FWR; Fresh Weight of Root; DWS: Dry Weight of Shoot; DWR: Dry Weight of Root; SD: Shoot Diameter).*

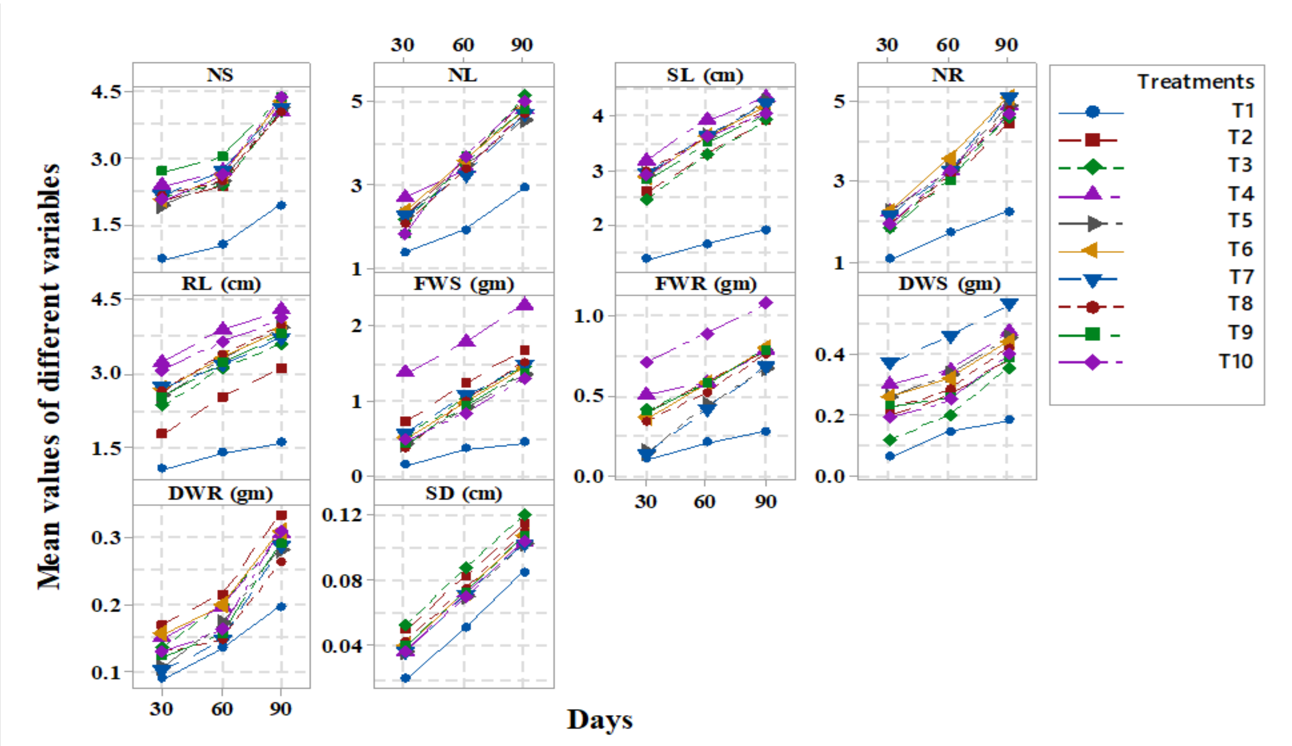

Fig. 3. *Trends of various growth parameters in off-season planted cuttings during 3 months of planting. (T1: No Treatment; T2: IBA 100ppm; T3: IBA 200 ppm; T4: IBA 300 ppm; T5: NAA 100ppm; T6: NAA 200 ppm; T7: NAA 300 ppm; T8: GA3 100ppm; T9: GA3 200 ppm; T10: GA3 300 ppm) (NS: Number of Sprouts; NL: Number of Leaves; SL: Sprout Length; NR: Number of Roots; RL: Root Length; FWS: Fresh Weight of Shoot; FWR; Fresh Weight of Root; DWS: Dry Weight of Shoot; DWR: Dry Weight of Root; SD: Shoot Diameter).*

Table 3. Effect of various growth regulators on different growth parameters of *P. deltoides* in 60 DAP.

Treaments	No. of Sprouting	No. of leaves	Sprouting length (cm)	No. of roots per cutting	Root length per cutting (cm)	Fresh weight of shoot (gm)	Fresh weight of root (gm)	Dry weight of shoot (gm)	Dry weight of root (gm)	Shoot diameter (cm)
ON SEASON PLANTING (FEBRUARY)										
Control (No Treatment)	1.333 d	6.444 c	3.713 b	2.444 b	3.266 b	0.860 c	0.459 b	0.140 e	0.065 e	0.037 e
IBA 100ppm	2.698 abc	10.445 ab	5.004 ab	4.000 a	4.830 ab	2.370 b	0.768 a	0.814 a	0.204 d	0.061 bc
IBA 200ppm	2.222 c	11.556 a	5.110 ab	3.889 a	5.449 a	3.150 ab	0.855 a	0.559 b	0.209 cd	0.061 bc
IBA 300ppm	3.150 a	10.371 ab	4.998 ab	4.000 a	5.358 a	3.380 ab	0.860 a	0.226 de	0.350 a	0.071 ab
NAA100ppm	2.667 abc	7.778 bc	5.605 a	3.778 ab	5.955 a	3.591 ab	0.873 a	0.365 c	0.202 d	0.055 cd
NAA200ppm	2.378 bc	7.333 bc	5.772 a	3.778 ab	5.776 a	3.720 a	0.878 a	0.243 d	0.319 a	0.063 bc
NAA300ppm	3.038 ab	11.556 a	5.761 a	4.111 a	5.499 a	3.669 ab	0.876 a	0.211 de	0.254 bc	0.049 d
GA3 100ppm	2.692 abc	8.667 abc	5.582 a	4.444 a	5.702 a	3.557 ab	0.862 a	0.240 d	0.251 bcd	0.077 a
GA3 200ppm	3.088 ab	8.222 bc	5.564 a	4.333 a	6.132 a	3.552 ab	0.861 a	0.193 de	0.263 b	0.057 cd
GA3 300ppm	2.848 abc	7.667 bc	5.364 a	4.000 a	5.564 a	3.970 a	0.818 a	0.245 d	0.313 a	0.082 a
p-value	*P<0.001*	*P<0.001*	*P<0.001*	*P<0.01*	*P<0.01*	*P<0.001*	*P<0.001*	*P<0.001*	*P<0.001*	*P<0.001*
OFF SEASON PLANTING (JULY)										
Control (No Treatment)	0.997 b	1.889 b	1.599 b	1.667 b	1.379 d	0.359 d	0.203 d	0.144 f	0.136 a	0.051 d
IBA 100ppm	2.321 a	3.556 a	3.269 a	3.000 a	2.517 c	1.221 b	0.578 b	0.261 d	0.215 a	0.082 a
IBA 200ppm	2.358 a	3.444 a	3.254 a	3.222 a	3.068 bc	1.022 bc	0.569 b	0.199 e	0.199 a	0.087 a
IBA 300ppm	2.667 a	3.333 a	3.910 a	3.222 a	3.862 a	1.774 a	0.574 b	0.347 b	0.197 a	0.072 bc
NAA100ppm	2.444 a	3.444 a	3.591 a	3.222 a	3.252 ab	0.902 bc	0.433 bc	0.331 bc	0.171 a	0.070 c
NAA200ppm	2.556 a	3.556 a	3.592 a	3.556 a	3.282 ab	0.973 bc	0.570 b	0.319 bc	0.199 a	0.073 bc
NAA300ppm	2.667 a	3.222 a	3.606 a	3.222 a	3.138 bc	1.062 bc	0.411 c	0.459 a	0.147 a	0.071 bc
GA3 100ppm	2.444 a	3.333 a	3.578 a	3.111 a	3.355 ab	0.995 bc	0.515 bc	0.282 cd	0.148 a	0.075 b
GA3 200ppm	3.000 a	3.667 a	3.474 a	3.000 a	3.189 b	0.932 bc	0.570 b	0.254 d	0.158 a	0.073 bc
GA3 300ppm	2.556 a	3.667 a	3.596 a	3.222 a	3.618 ab	0.839 c	0.879 a	0.248 de	0.163 a	0.070 bc
p-value	*P<0.001*	*P<0.001*	*P<0.001*	*P<0.001*	*P<0.001*	*P<0.001*	*P<0.001*	*P<0.001*	*P>0.05*	*P<0.001*

Different letters, mentioned with the values, between treatments represent significant differences (P<0.05) based on Tukey Post Hoc)

Table 4. Effect of two different planting seasons (February and July) on various growth parameters in 60 DAP.

Parameters	F-Statistic	p-value
No of Sprouting	9.445	.004
No of leaves	711.174	.000
Sprouting length	258.551	.000
No of Roots / cutting	57.988	.000
Root length / cutting	326.908	.000
Fresh weight of shoot	643.908	.000
Fresh weight of root	280.155	.000
Dry Weight of shoot	30.082	.000
Dry weight of root	101.231	.000
Shoot Diameter	194.348	.000

DISCUSSION

Growth regulator is one of the most important factors in affecting the growth performance of stem cuttings. The current study provides evidence of the positive effect of the application of growing media on stem cuttings of *P. deltoides.* Auxins are responsible for the development in plants as they play an important role in cell division expansion (Majda and Robert, 2018). During root formation, the level of auxins in the plants affects the initial cell division (Ludwig, 2000; Kochhar *et al*., 2005, Perrot-Rechenmann, 2010, Velasquez, 2016). The cuttings, which were not treated with any media, showed comparatively lower values for all growth parameters in both seasons. These responses may have occurred due to the accretion of metabolites at the auxins application position, enlargement of cells, hydrolysis enhancement of carbohydrates, proteins synthesis, and cell division (Strydem and Hartman, 1960). However, IBA was found to be more effective media than NAA and GA3 for most of the parameters in both growing seasons. Phuyal *et al.* (2018) recorded IBA to be more effective than NAA. They also found an increment in shoot and root parameters of *Zanthoxylum armatum* with the increase in the concentration of growth hormones. The present study also showed relatively higher values in the higher concentration of IBA and GA3. Meanwhile, in case of NAA treatment, the values for most of the parameters showed no difference or the values of some parameters (No of leaves, sprouting length, No. of roots per cutting, fresh weight of root, dry weight of root & shoot and shoot diameter) were higher in a lower concentration. Although, these types of responses were mainly observed in initial days of planting (30 DAP).

Several experiments showed the importance of growing media in inducing the roots on stem cuttings (Tchoundjeu *et al*., 2004, Jacygrad *et al*., 2012; Usman and Akinyele, 2015, Majeed *et al*. 2009, Ibironke and Victor, 2016 and Phuyal *et al*. 2018). These growing media are well known to have a positive impact on the number of roots per cutting of *Azadirachta indica, Aloysia citrodora Cyclopia subternata* and *Toona ciliate* (Gehlot *et al*., 2014; Ibrahim *et al*., 2015, Mabizela *et al*. 2016, Thakur *et al*. 2018).

IBA was found to be more effective than NAA in increasing root formation. The application of IBA might have caused the vascular differentiation of cells and the production of more number of roots. The high concentration of growth hormones enhanced the length of roots and shoots due to the timely formation of roots and more utilization of the nutrients (Banjara, 2017).

Several researchers have recorded the better rooting ability of IBA at higher concentrations. Majeed *et al*. (2009) provided IBA at 4000 ppm is the most favourable plant growth regulator for rooting of *Aesculus indica*. *Dalbergia sisso* and *D. latifolia* also responded with relatively higher rooting rate with the application of IBA at 5000 ppm (Sharma and Pandey, 1999). High rooting rate was also obtained for *Celtis australis* cuttings treated with 3000 ppm IBA (Shameet *et al*. 1989). Thakur *et al.* (2018) also observed a positive rooting response in the cuttings of *Toona ciliate* treated with the higher concentration (8000 ppm) of IBA.

In both planting seasons, GA3 was showing a relatively higher value for fresh weight of root in the highest concentration as compare to the other treatments, mainly in initial days of planting. GA3 treatment is mostly used to enhance the growth and vigor of the plants. However, it helps in plant growth and length of internodes by boosting the division and enlargement of plant cells (Dayan *et al*., 2012; Miceli *et al.,* 2019). Auxins play a key role in the productions of adventitious roots in plants (Davis and Hassig, 1990, Steffens and Rasmussen, 2016; Guan *et al.,* 2019) and also determine the rooting capacity of plants.

NAA is mostly used to induce the longer root system, which may result in less fibrous root system. In the current study, the values for the root parameters under NAA treatments were mostly at par with the maximum values, which provide the evidence of the positive effect of NAA on rooting growth. The studies have also revealed an increment in the rooting of various plant species viz. *Taxus wallichiana, Andrographis paniculata, D. sissoo, Hemarthria compressa,* with the application of NAA (Kaul, 2008; Yan, 2014; Khudur and Omer, 2015; Hossain, 2016).

Seasonal effect

The previous studies have shown that the time of collection and planting is an important factor in vegetative propagation of *Lippia javanca* and *Boswellia papyrifera* (Soundy *et al.,* 2008; Haile *et al.*, 2011). In the present study, the higher values for most of the root and shoot

Table 5. Effect of various growth regulators on different growth parameters of *P. deltoides* in 90 DAP

Treatments	No. of sprouting	No. of leaves	Sprouting length (cm)	No. of roots per cutting	Root length per cutting (cm)	Fresh weight of shoot (gm)	Fresh weight of root (gm)	Dry weight of shoot (gm)	Dry weight of root (gm)	Shoot diameter (cm)
ON SEASON PLANTING (FEBRUARY)										
Control	1.556 b	6.736 b	3.823 b	2.889 b	3.574 b	1.158 b	0.708 b	0.185 d	0.177 b	0.050 f
IBA 100ppm	3.000 a	11.334 ab	6.121 ab	4.555 ab	5.148 ab	2.864 ab	1.172 a	1.009 a	0.515 a	0.082 ab
IBA 200ppm	2.667 a	13.437 a	6.034 ab	4.667 a	5.792 a	3.658 a	1.276 a	.756 b	0.500 a	0.070 cd
IBA 300ppm	3.278 a	12.297 a	6.227 ab	4.778 a	5.762 a	3.928 a	1.294 a	.493 c	0.491 a	0.082 ab
NAA100ppm	3.000 a	10.778 ab	6.349 ab	4.889 a	6.192 a	4.023 a	1.300 a	.589 bc	0.583 a	0.063 de
NAA200ppm	2.833 a	12.000 a	6.657 a	4.889 a	6.237 a	4.075 a	1.508 a	.465 c	0.640 a	0.071 cd
NAA300ppm	3.143 a	13.064 a	6.818 a	5.556 a	6.007 a	3.925 a	1.400 a	.445 c	0.652 a	0.061 e
GA3 100ppm	3.000 a	10.889 ab	6.821 a	5.111 a	5.942 a	4.001 a	1.430 a	.493 c	0.600 a	0.083 ab
GA3 200ppm	3.203 a	10.667 ab	7.414 a	5.111 a	6.457 a	3.857 a	1.340 a	.436 c	0.619 a	0.076 bc
GA3 300ppm	3.120 a	11.778 a	6.731 a	5.000 a	6.057 a	4.246 a	1.411 a	.451 c	0.613 a	0.087 a
p-value	*P<0.001*	*P<0.01*	*P<0.05*	*P<0.01*	*P<0.01*	*P<0.01*	*P<0.001*	*P<0.001*	*P<0.001*	*P<0.001*
OFF SEASON PLANTING (JULY)										
Control	1.889 b	2.889 b	1.877 b	2.222 b	1.584 d	0.435 c	0.276 c	.182 f	.198 c	.086 e
IBA 100ppm	4.000 a	5.000 a	3.892 a	4.444 a	3.085 c	1.672 b	0.768 b	.385 de	.333 a	.115 b
IBA 200ppm	4.000 a	5.111 a	3.891 a	4.555 a	3.586 bc	1.464 b	0.771 b	.353 e	.302 ab	.120 a
IBA 300ppm	4.000 a	4.778 a	4.340 a	4.889 a	4.252 a	2.276 a	0.774 b	.468 b	.304 ab	.103 d
NAA100ppm	4.111 a	4.555 a	4.253 a	4.889 a	3.890 ab	1.355 b	0.662 b	.453 b	.282 ab	.103 d
NAA200ppm	4.222 a	4.778 a	4.143 a	5.111 a	3.842 ab	1.428 b	0.784 b	.440 bc	.309 ab	.107 cd
NAA300ppm	4.111 a	4.667 a	4.214 a	5.111 a	3.712 ab	1.482 b	0.674 b	.561 a	.286 ab	.103 d
GA3 100ppm	4.000 a	4.667 a	4.071 a	4.778 a	3.942 ab	1.515 b	0.751 b	.420 bcd	.262 bc	.110 bc
GA3 200ppm	4.333 a	4.778 a	4.015 a	4.667 a	3.777 ab	1.375 b	0.781 b	.382 de	.290 ab	.107 cd
GA3 300ppm	4.333 a	5.000 a	4.033 a	4.667 a	4.087 ab	1.300 b	1.059 a	.397 cde	.309 ab	.104 d
p-value	*P<0.001*	*P<0.001*	*P<0.001*	*P<0.001*	*P<0.001*	*P<0.001*	*P<0.001*	*P<0.001*	*P<0.001*	*P<0.001*

Different letters, mentioned with the values, between treatments represent significant differences (P<0.05) based on Tukey Post Hoc)

Table 6. Effect of two different planting seasons (February and July) on various growth parameters in 60 DAP.

Parameters	F-Statistic	p-value
No of Sprouting	128.216	.000
No of leaves	462.349	.000
Sprouting length	191.280	.000
No of Roots / cutting	2.300	.137
Root length / cutting	269.904	.000
Fresh weight of shoot	318.240	.000
Fresh weight of root	314.584	.000
Dry Weight of shoot	92.843	.000
Dry weight of root	195.931	.000
Shoot Diameter	2816.901	.000

parameters of *P. deltoides* were attained from the cuttings collected and planted in February as compared to cuttings collected and planted in July month. These higher values may have occurred because the accretion of carbohydrates is comparatively higher in the cutting collected during the dry periods due to lower physical activity of donor plants than in the cuttings collected after leaf flushing. Therefore, the mobilization of carbohydrates and other metabolites in very high amounts results in the easier rooting of the cutting collected in February (Haile *et al*. 2011)

Correlation among growth parameters

All growth parameters were observed to be significantly (P<0.01) and positively correlated with each other in the cutting planted in both seasons. There was a very strong correlation (r > 0.70) recorded for underground biomass and other parameters. This significant and positive correlation among the root and shoot parameters indicated that a possible simultaneous improvement could be obtained while selecting one particular trait or another (Dhillon and Singh, 2010). The correlations between these parameters provide a huge benefit to scientists for improving these traits. Many researchers (Tewari *et al.* 1994; Rawat *et al.,* 2001; Verma and Bangarwa, 2005; Kumar *et al.,* 2017) also established a positive correlation among various growth parameters of *P. deltoides*.

Conclusion

As sexual propagation is not so much effective in *P. deltoides*, vegetative propagation using stem cutting is thought to be more successful method for mass production of plant material. The study revealed a significant effect of growth hormones on various growth parameters. The highest concentration of IBA and GA3 showed maximum values for most of the growth parameters. These significant effects were observed mainly in 30 DAP, which proved that the growth hormones affected the plant growth mainly in the initial days of the plant's life. On the other hand, collection and planting of the planting material are recommended in February month, as plants showed relatively higher values when planted in dry periods than the plants in the monsoons. The present findings could be of great significance for producing quality plant material of P. deltoides commercially and benefit the Agroforestry systems.

Conflict of interest

The authors declare that they have no conflict of interest.

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Table 7: Significant correlations (r -values) among 6 months growth variables (significant at the 1% level).

Parameters (n = 180)	No. of Sprouting	No of leaves	Sprouting length	No of roots per cutting	Root length per cutting	Fresh weight of shoot	Fresh weight of root	Dry weight of shoot	Dry weight of root
No. of leaves	.287**								
Sprouting length	.465**	.850**							
No. of Roots per cutting	.731**	.722**	.797**						
Root length per cutting	.448**	.853**	.922**	.778**					
Fresh weight of shoot	.361**	.874**	.917**	.746**	.923**				
Fresh weight of root	.490**	.826**	.866**	.797**	.839**	.831**			
Dry Weight of shoot	.426**	.585**	.538**	.595**	.479**	.453**	.545**		
Dry weight of root	.475**	.767**	.832**	.765**	.758**	.795**	.871**	.523**	
Shoot Diameter	.750**	.283**	.361**	.702**	.350**	.315**	.482**	.399**	.458**

**. Correlation is significant at the 0.01 level (2-tailed).

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