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ROOTING RESPONSE OF *DESMODIUM ELEGANS* AS INFLUENCED BY AUXINS, ROOTING MEDIUM, KIND AND SOURCE OF CUTTINGS

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CHAUHAN, D. S., BHATT, B. P. & TODARIA, N. P. 2000. Rooting response of *Desmodium elegans* as influenced by auxins, rooting medium, kind and source of cuttings. A study was conducted to analyse the effect of auxins, rooting medium (soil type and soil depth), position, maturity and source (altitude) of *Desmodium elegans* stem cuttings on their rooting ability. Profuse rooting occurred when the branch cuttings were treated with indole-3-butyric acid (IBA) followed by indole-3-acetic acid (IAA). But poor rooting was noticed when cuttings were treated with naphthalene acetic acid (NAA). Control cuttings exhibited poor rooting as compared to treated ones. There was no significant impact of soil types on rooting response of branch cuttings and the data were comparable in eroded and garden soil. Planting depths, however, greatly influenced the rooting behaviour of the cuttings and those planted at 10-cm depth had a significantly high number of rooted branch cuttings compared to those inserted at 5- or 15-cm depth. Maturity influenced significantly (p=0.05) rooting capacity of stem cuttings. On average, old and mature cuttings planted at 10-cm depth into the soil had excellent rooting capacity compared to young branch cuttings. Further, branch cuttings harvested from the lower canopy of the mother tree produced rooting in a significantly (p=0.05) higher number of branch cuttings than those from the upper canopy of the same tree. Elevational range of propagation material also significantly determined (p=0.05) the root–shoot attributes of branch cuttings; those harvested from high (2000 m) altitude had better rooting than those of low (1350 m) altitude.

Key words: *Desmodium elegans* - auxins - vegetative propagation - branch cutting - rooting medium - position - maturity - soil depth - source of cutting

CHAUHAN, D. S., BHATT, B. P. & TODARIA, N. P. 2000. Tindak balas pengakaran bagi *Desmodium elegans* seperti yang dipengaruhi oleh auksin, media pengakaran, jenis dan sumber keratan. Satu kajian dijalankan untuk menganalisis kesan auksin, media keratan (jenis tanah dan kedalaman tanah), kedudukan, kematangan dan sumber (altitud) keratan batang terhadap keupayaan pengakaran *Desmodium elegans*. Pengakaran berlebihan berlaku apabila keratan ranting dirawat dengan indole 3-asid butirik (IBA) diikuti dengan indole 3-asid asetik (IAA). Tetapi pengakaran yang lemah didapati apabila keratan dirawat dengan asid asetik naftalena (NAA). Keratan yang dikawal mempamerkan pengakaran yang lemah berbanding dengan keratan yang dirawat. Jenis tanah tidak memberikan kesan bererti terhadap tindak balas pengakaran ke atas keratan dahan dan data tersebut adalah setanding dalam tanah terhakis dan tanah kebun. Kedalaman penanaman, bagaimanapun, sangat

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mempengaruhi kelakuan pengakaran keratan tersebut dan keratan yang ditanam pada kedalaman 10 cm mempunyai bilangan keratan dahan mengakar yang tinggi dengan bererti berbanding dengan keratan yang dimasukkan pada kedalaman 5 atau 15 cm. Kematangan mempengaruhi dengan bererti (p=0.05) keupayaan pengakaran bagi keratan batang. Secara purata, keratan tua dan keratan matang yang ditanam pada kedalaman 10 cm di dalam tanah mempunyai keupayaan pengakaran yang sangat baik berbanding dengan keratan dahan muda. Tambahan pula, keratan dahan yang ditebang di sudur yang rendah dari pokok induk menghasilkan pengakaran dalam bilangan yang lebih tinggi dengan bererti (p=0.05) bagi keratan dahan berbanding dengan keratan di sudur atas dari pokok yang sama. Paras ketinggian bagi bahan-bahan percambahan juga menentukan dengan bererti (p=0.05) sifat-sifat akar-pucuk bagi keratan dahan; keratan yang diambil dari altitud yang tinggi (2000 m) mempunyai pengakaran yang lebih baik berbanding dengan keratan di altitud yang rendah (1350 m).

Introduction

In Garhwal hills (Uttar Pradesh, India), *Desmodium elegans* DC. (Family Fabaceae, subfamily Papilionaceae) shows considerable promise as a multipurpose species (Chauhan 1994). The species occurs naturally in oak and spruce forests from 1300 to 2600 m above sea-level (asl) (Osmaston 1927). Its foliage is considered as an ideal fodder for stall feeding of animals and its wood is used as fuel. Due to its multifarious nature, introduction of this species under agroforestry systems would have tremendous scope for biomass allocation and enrichment of soil fertility owing to its nitrogen fixing ability. Not only would *D. elegans* help address soil fertility problems but its small size makes it suitable for planting as a hedge on field bunds to help control soil erosion (Todaria *et al.* 1993).

Vegetative propagation in forestry aims to develop fast and economic methods of raising superior planting stock (Zobel 1981). Propagation of *D. elegans* through vegetative means is required to obtain the plants of desired genetic constituent for breeding programme, to improve growth, yield, fodder and wood quality, and resistance to pests and diseases. However, the rooting ability of stem cuttings depends upon proper environmental treatments. Brix and Barker (1975) stressed the overwhelming importance of environment, particularly high humidity and rooting medium, in achieving proper rooting. Moreover, rooting capability decreases with the ontogenetic development of a plant from the juvenile to the adult phase (Bhatt & Todaria 1990). It is also known that different clones of the same species differ in their rooting capability (Hartmann & Kester 1986).

In an earlier communication, we have reported that exogenous application of IAA and IBA improved root development in stem cuttings of *D. elegans* and the species was found to be easy to root (Chauhan *et al.* 1996). A study was undertaken to examine the effect of lower concentrations of exogenously applied hormones, rooting medium, maturity of cuttings, planting depth, position of cuttings and source (altitude) of branch cuttings on rooting ability of this important nitrogen fixing tree crop of Garhwal Himalaya.

Materials and methods

Cuttings were collected from juvenile plants of *D. elegans* growing in its natural habitat (Garhwal Himalaya). After excising the apical portion, distal ends of each set of branch cuttings were dipped into 100, 200 and 500 ppm aqueous solutions of indole-3-acetic acid (IAA), indole-3-butyric acid (IBA) and naphthalene acetic acid (NAA) separately for 24 h. Similarly a control set of stem cuttings was treated with distilled water.

Treated branch cuttings were planted into nursery beds of the experimental garden of the Forestry Department (30°–31°N, 78°–78° 48' E ; 550 m asl) at Srinagar Garhwal, India, in randomised block design. Fifty subplots of 2 × 2-m size were laid down for each experiment. In each experimental unit, the branch cuttings were planted in rows 30 cm apart and in row spacing of 50 cm thereby giving a total of hundred branch cuttings per experimental unit (five replicates with twenty branch cuttings in each replicate).

A small quantity of farmyard manure was also added into the nursery beds during each study except that of the rooting medium. Rooting response was recorded only during spring (February–May) because this season is most suitable for vegetative propagation of *D. elegans* (Chauhan *et al.* 1996). The average relative humidity at the experimental site was 50.2%, mean air temperature 20.9 °C and total rainfall 110.0 mm. The planted cuttings were irrigated twice a day, avoiding water logging. Sprouting response was observed at periodic intervals of 30, 60 and 90 days of planting; however, data on root attributes were recorded only after 90 days of planting. Details of the experiments conducted were as follows.

Experiment 1

To study the effect of medium composition on rooting, branch cuttings were planted in garden soil (collected from the experimental garden itself) and eroded soil (collected from degraded land). Branches of uniform size (12 to 15 mm diameter) were planted into nursery beds filled with garden soil and eroded soil. Soil pH, organic carbon, phosphorus, potassium and nitrogen in soil samples were determined as per the standard procedures of AOAC (1980).

Experiment 2

Stem sticks of maximal height (approximately 1.5 m long and 1.8 cm diameter) were collected. From each stick, 40-cm long pieces were taken from the basal, middle and upper sections, referred herein as old, mature and young cuttings respectively. Branch cuttings of each position were planted at 5-, 10- and 15-cm depths in the soil.

Experiment 3

Branch cuttings were obtained from two different positions of a mother plant, i.e. lower and upper canopy. Branches of uniform size (12 to 15 mm diameters) were cut into 25-cm long pieces. After excising the apical portion and leaves, the top cut ends of cuttings from each position were sealed with moist cotton to minimise water losses. Branch cuttings were treated with auxins and planted into nursery beds.

Experiment 4

To assess the effect of elevational range of propagation material on rooting response, branch cuttings were collected from low (1350 m asl) and high (2000 m asl) altitudes and treated with aqueous concentrations of auxins. Treated branch cuttings were planted into nursery beds.

Test of significance, *t*-test, was computed to record the significant (p=0.05) differences in root–shoot attributes between concentrations of a particular auxin. Each value was also compared with the control at 1 and 5% levels of significance. Correlation coefficient (*r*) was assessed to record the effect of planting depths on root–shoot growth, irrespective of treatments.

Results

Effect of rooting medium on rooting response of branch cuttings

There were no significant differences in rooting response of branch cuttings of *D. elegans* planted in either eroded or garden soil, irrespective of hormonal treatments. However, a comparatively higher number of cuttings rooted in garden soil. The average root length was also comparatively higher in garden soil but shoot length was higher in eroded soil (Table 1).

As regards hormonal effect on rooting response, IBA induced rooting in the maximum number of cuttings, followed by IAA. NAA was least effective in inducing rooting. IBA induced rooting in a significantly higher number of branch cuttings in garden soil than in eroded soil. IAA and NAA treated cuttings did not exhibit any significant differences in rooting behaviour planted in either garden soil or eroded soil. The control branch cuttings had moderate rooting response both in garden soil as well as degraded soil. Thus the effect of rooting medium on rooting response of branch cuttings of *D. elegans* is ruled out.

Effect of maturity stage and planting depth on root–shoot attributes

Young branch cuttings exhibited poor rooting response. But rooting response changed with the planting depths which gave on average 11.0, 17.0 and 18.0% rooting, when cuttings were planted at 5-, 10- and 15- cm depths respectively, irrespective of treatments. Exogenous application of IBA induced rooting in the maximum number of cuttings, followed by IAA, and NAA produced poor rooting at any depth. The average shoot length also increased with increasing planting depth of the branch cuttings, irrespective of hormonal application. Except in the IAA treatment, the average root length was also lowest at 5-cm depth (Table 2).

Table 1. Effect of rooting medium (E=eroded soil and G=garden soil) on root and shoot attributes of branch cuttings of *Desmodium elegans*

Treatment (ppm)	Percentage of rooted cuttings		Shoot length (cm)		Root length (cm)	
	E	G	E	G	E	G
IAA 100	20.0	10.0*	15.3	23.3**(a)	7.9 (a)	9.8 (a)
IAA 200	10.0*	30.0*	30.4**(a)	19.7*(ab)	10.8 (ab)	11.1 (a)
IAA 500	30.0	20.0	31.2**(a)	17.7*(b)	13.4 (b)	9.3 (a)
IBA 100	20.0(a)	50.0**	38.0**	19.6*(a)	8.8 (a)	11.3 (a)
IBA 200	20.0(a)	40.0**	19.3*(a)	18.6*(a)	7.6 (a)	8.4 (ab)
IBA 500	40.0**	30.0*	15.6(a)	8.3	10.0 (a)	5.2*(b)
NAA 100	10.0*	10.0*(a)	23.6**	6.6*	12.2	7.5 (a)
NAA 200	30.0*	10.0*(a)	11.0	20.3*	7.3	9.4 (a)
NAA 500	0.0	20.0	0.0	30.5**	0.0	11.5 (a)
Control	20.0	20.0	13.0	11.7	10.8	10.9
Mean	20.0 ± 10.9	24.0 ± 12.8	20.1 ± 11.1	17.6 ± 6.8	8.9 ± 3.5	9.4 ± 1.9

Individual values for each treatment were compared with control (*significant at $p = 0.05$; **significant at $p = 0.01$). Between concentrations of each hormone, means followed by the same letter are not significantly ($p = 0.05$) different. ± indicates standard deviation.

Although, significant ($p=0.05$) differences were recorded in root–shoot growth of branch cuttings when treated with different concentrations of auxins, irrespective of hormonal treatments, there were no significant impact of planting depths on root–shoot attributes of young branch cuttings. Correlation coefficient r exhibited positive correlation (non-significant) between planting depths and root–shoot attributes of cuttings (Table 2).

Mature branch cuttings gave better rooting than young branch sections. Planting depth significantly influenced ($p=0.05$) rooting response of branch cuttings and those planted at 10-cm depth had the highest (42.0%) rooting percentage, followed by those planted at 15-cm depth (28.0%), irrespective of hormonal concentration. Branch cuttings planted at 5-cm depth exhibited the minimum number of rooted cuttings. The average shoot and root lengths were highest in the branch cuttings planted at 10-cm depth as compared to those planted either at 5- or 15-cm depth (Table 3).

Table 2. Rooting response of young branch cutting of *D. elegans* at different planting depths

Treatment (ppm)	Percentage of rooted cuttings			Shoot length (cm)			Root length (cm)		
	5 cm	10 cm	15 cm	5 cm	10 cm	15 cm	5 cm	10 cm	15 cm
IAA 100	0.0	20.0	40.0	0.0	17.5	14.2	0.0	6.8(a)	7.8(a)
IAA 200	30.0	30.0*	0.0	15.1(a)	11.9*	0.0	6.6(a)	5.7(a)	0.0
IAA 500	20.0	0.0	20.0	17.6(a)	0.0	26.6	8.9(a)	0.0	9.8(a)
IBA 100	20.0(a)	30.0*	20.0	14.0(a)	21.5	15.0(a)	7.5(a)	11.5*(a)	11.8(a)
IBA 200	20.0(a)	20.0(a)	30.0	14.3(a)	12.3*(a)	10.7(ab)	7.5(a)	10.0*(ab)	9.3(ab)
IBA 500	20.0(a)	20.0(a)	40.0	13.6(a)	7.9**(a)	8.7(b)	10.2(a)	6.0(b)	5.2(b)
NAA 100	0.0	20.0	20.0	0.0	8.9**(a)	16.9	0.0	8.0(a)	9.5(a)
NAA 200	0.0	0.0	10.0	0.0	0.0	23.3	0.0	0.0	7.3(a)
NAA 500	0.0	10.0*	0.0	0.0	11.0*(a)	0.0	0.0	8.9(a)	0.0
Control	0.0	20.0	0.0	0.0	17.3	0.0	0.0	5.2	0.0
Mean	11.0 ± 11.4	17.0 ± 10.1	18.0 ± 14.7	7.5 ± 7.5	10.8 ± 6.7	11.5 ± 9.1	4.1 ± 4.0	6.2 ± 3.6	6.1 ± 4.3
r		0.284			0.302			0.278	

Individual values for each treatment were compared with control (*significant at p = 0.05; **significant at p = 0.01). Between concentrations of each hormone, means followed by the same letter are not significantly (p = 0.05) different. ± indicates standard deviation. *r* represents correlation coefficient computed between planting depths and growth attributes of branch cuttings.

Table 3. Rooting response of mature branch cutting of *D. elegans* at different planting depths

Treatment (ppm)	Percentage of rooted cuttings			Shoot length (cm)			Root length (cm)		
	5 cm	10 cm	15 cm	5 cm	10 cm	15 cm	5 cm	10 cm	15 cm
IAA 100	40.0**	40.0*	0.0	21.2(a)	19.9*(a)	0.0	6.7(a)	7.3(a)	0.0
IAA 200	30.0*(a)	60.0*	40.0*	12.1*	20.6*(a)	13.4	8.4(a)	9.2(a)	8.1(a)
IAA 500	30.0*(a)	50.0	50.0**	20.6(a)	19.8(a)	21.4*	8.5(a)	10.8(a)	11.6(a)
IBA 100	30.0*(a)	50.0(a)	40.0*(a)	17.6(a)	18.2(ab)	20.8*(a)	8.2(a)	10.5(a)	10.0(a)
IBA 200	30.0*(a)	60.0*	50.0**	14.6(a)	16.4(a)	18.1(a)	7.8(a)	11.7*(a)	10.8(a)
IBA 500	30.0*(a)	50.0(a)	40.0*(a)	16.0(a)	21.5*(b)	20.2*(a)	10.8(a)	12.1*(a)	13.5(a)
NAA 100	0.0	20.0**(a)	20.0*	0.0	8.9*(a)	16.9	0.0	8.0(a)	9.5(a)
NAA 200	0.0	20.0**(a)	0.0	0.0	21.6*	0.0	0.0	9.9(a)	0.0
NAA 500	0.0	20.0**(a)	10.0**	0.0	9.0*(a)	10.2*	0.0	4.5(a)	6.3(a)
Control	20.00	50.0	30.0	17.5	15.3	15.5	7.8	6.8	9.8
Mean	21.0 ± 14.5	42.0 ± 15.4	28.0 ± 18.3	12.0 ± 8.2	17.1 ± 4.5	13.7 ± 7.6	5.8 ± 3.9	9.1 ± 2.3	8.0 ± 4.4
r		0.364*			0.405*			0.662**	

Individual values for each treatment were compared with control (*significant at p = 0.05; **significant at p = 0.01). Between concentrations of each hormone, means followed by the same letter are not significantly (p = 0.05) different. ± indicates standard deviation. *r* represents correlation coefficient computed between planting depths and growth attributes of branch cuttings.

Different concentrations of auxins had significant (p=0.05) impact on rooting response of branch cuttings. On average, IBA and IAA treated cuttings significantly enhanced (p=0.05) growth attributes of cuttings as compared to NAA treated cuttings, irrespective of planting depth. Significant (p=0.05) differences were also observed for shoot and root growth of cuttings when treated with various concentrations of auxins. The control also produced rooting in a large number of cuttings with the highest (50.0%) at 10-cm depth. There was significant positive correlation between root–shoot attributes of cuttings and depths, irrespective of hormonal concentration (Table 3).

The rooting response of old branch cuttings planted at different depths is shown in Table 4. Branch cuttings planted at 10-cm depth exhibited the maximum rooting. Shoot and root lengths of branch sections also remained high when planted either at 10- or 15-cm depth as compared to 5-cm depth, irrespective of hormonal concentration (Table 4).

The concentration of auxin had significant (p=0.05) impact on rooting response of old branch cuttings. Rooting response of the control cuttings was also significantly different from the treated cuttings. There were significant (p=0.05) differences in rooting percentage of cuttings between planting depths and those planted at 10-cm depth responded in a significantly higher number of rooted branch cuttings. Similarly shoot and root lengths of branch cuttings planted at 10- or 15-cm depth were significantly higher than those planted at 5-cm depth. IBA treated cuttings not only induced rooting in the highest number of branch cuttings but also enhanced shoot and root lengths to a greater extent, followed by IAA treated cuttings. Poor rooting was recorded when cuttings were treated with NAA, irrespective of planting depth (Table 4).

It is therefore clear from Tables 2–4 that, besides auxin concentration, planting depth and maturity of the cuttings significantly determine the rooting potential of this promising species. At each depth, mature and old cuttings, which generally showed no significant differences in rooting response, produced better rooting than young cuttings. On average, mature and old cuttings treated with different concentrations of IBA and planted at 10-cm depth in the soil had excellent rooting capacity. Moreover, control mature and old cuttings also had good rooting response when planted at 10-cm depth.

Effect of position of branch cuttings on their rooting response

Branch cuttings obtained from the lower canopy of mother trees exhibited rooting in a significantly (p = 0.01) higher number of branch cuttings, irrespective of hormonal concentration. On average, there was 36% rooting in basal cuttings as compared to only 19% in upper canopy cuttings, irrespective of treatment. The average shoot length was also significantly higher in the lower canopy cuttings. Root length was not significantly affected by the position of branch cuttings although it was also higher in the lower canopy cuttings (Table 5).

Table 4. Rooting response of old branch cuttings of *D. elegans* at different planting depths

Treatment (ppm)	Percentage of rooted cuttings			Shoot length (cm)			Root length (cm)		
	5 cm	10 cm	15 cm	5 cm	10 cm	15 cm	5 cm	10 cm	15 cm
IAA 100	0.0	50.0*(a)	40.0*(a)	0.0	22.8(a)	21.7*(a)	0.0	6.8(a)	7.2(a)
IAA 200	30.0(a)	60.0**	40.0*(a)	11.2	21.1(ab)	23.1*(a)	7.5(a)	12.3*(b)	10.9(a)
IAA 500	20.0(a)	50.0*(a)	20.0*	18.8*	16.5(b)	23.5*(a)	8.9(a)	10.4(ab)	9.9(a)
IBA 100	20.0*	70.0**	50.0**	17.8(a)	19.3(a)	12.3**	8.0(a)	11.6(a)	6.7(a)
IBA 200	30.0(a)	60.0**	40.0*(a)	19.8*(a)	21.2(a)	17.1**	9.2(a)	11.9*(a)	9.5(a)
IBA 500	30.0(a)	50.0*	40.0*(a)	21.3*(a)	20.5(a)	24.2*	11.8*(a)	12.5*(a)	11.1(a)
NAA 100	0.0	30.0*	20.0*(a)	0.0	25.6*(a)	29.3	0.0	11.2(a)	12.5*(a)
NAA 200	0.0	20.0**(a)	20.0*(a)	0.0	22.3(a)	22.5*	0.0	12.8*(a)	10.3(a)
NAA 500	0.0	20.0**(a)	10.0**	0.0	11.2*	4.9**	0.0	3.5	2.6*
Control	30.0	40.0	30.0	13.3	19.9	29.2	6.5	7.3	7.3
Mean	17.0 ± 14.2	45.0 ± 16.3	31.0 ± 12.2	10.2 ± 8.8	20.0 ± 3.7	20.8 ± 7.1	5.2 ± 4.4	10.0 ± 2.9	8.8 ± 2.7
r		0.271			0.666**			0.441*	

Individual values for each treatment were compared with control (*significant at p = 0.05; **significant at p = 0.01). Between concentrations of each hormone, means followed by the same letter are not significantly (p = 0.05) different. ± indicates standard deviation. *r* represents correlation coefficient computed between planting depths and growth attributes of branch cuttings.

Table 5. Effect of position (U=harvested from upper canopy and L=lower canopy of mother tree) of branch cuttings of *D. elegans* on their rooting response

Treatment (ppm)	Percentage of rooted cuttings		Shoot length (cm)		Root length (cm)	
	U	L	U	L	U	L
IAA 100	30.0**(a)	40.0**	12.5*(a)	24.8*(a)	9.1 (a)	10.2 (a)
IAA 200	30.0**(a)	50.0**	13.6*(a)	32.9**	7.9 (a)	13.6 (a)
IAA 500	30.0**(a)	30.0*	18.6**	27.6*(a)	9.6 (a)	11.2 (a)
IBA 100	20.0*(a)	60.0**	20.6**(b)	31.2**	11.9* (a)	14.8 (a)
IBA 200	20.0*(a)	40.0**	11.4*(a)	20.1	7.9 (a)	9.7
IBA 500	20.0*(a)	50.0**	15.5**(ab)	25.9*	10.5 (a)	15.1(a)
NAA 100	20.0*	30.0*	11.8*	16.7(ab)	7.3(a)	8.4 (a)
NAA 200	10.0	20.0(a)	6.2	18.7(b)	8.9(a)	7.2 (a)
NAA 500	0.0	20.0(a)	0.0	14.1(a)	0.0	8.2 (a)
Control	10.0	20.0	5.2	18.2	7.0	10.9
Mean	19.0 ± 9.4	36.0 ± 13.6	11.5 ± 6.0	23.0 ± 6.1	8.0 ± 3.0	10.9±2.6

Individual values for each treatment were compared with control (*significant at p = 0.05; **significant at p = 0.01). Between concentrations of each hormone, means followed by the same letter are not significantly (p = 0.05) different. ± indicates standard deviation.

Among the treatments, IBA gave the best rooting followed by IAA and NAA. However, there were no significant differences in rooting response of IAA and IBA treated cuttings, irrespective of position of branch cuttings. But NAA treated basal or upper cuttings showed the poorest rooting response.

Effect of elevational range of propagation material on their rooting response

There was significant (p= 0.01) impact of propagation source (altitude) on root–shoot attributes of branch cuttings of *D. elegans* and those obtained from low (1350 m asl) altitude showed only 23.0% rooting as compared to 44.0% rooting in high (2000 m asl) altitude cuttings, irrespective of treatment.

Significant differences were observed in rooting response of branch cuttings with auxin treatments. On average, high elevational IAA, IBA and NAA treated cuttings exhibited rooting in a significantly higher number of branch cuttings than low altitude cuttings, treated with the same auxins. Among the hormonal treatments, NAA treated low altitude cuttings had the lowest rooting response. Moreover, rooting response of NAA (100 and 200 ppm) treated low altitude cuttings was even significantly (p= 0.05) lower than that of the control cuttings (Table 6).

Table 6. Effect of elevational range of propagation source on rooting response of branch cuttings of *D. elegans*

Treatment (ppm)	Percentage of rooted cuttings		Shoot length (cm)		Root length (cm)	
	1350 m	2000 m	1350 m	2000 m	1350 m	2000 m
IAA 100	50.0**	40.0**	11.3(a)	22.7(a)	7.4 (a)	10.3* (a)
IAA 200	30.0*(a)	50.0**	11.3(a)	24.1(a)	6.7 (a)	12.8* (a)
IAA 500	30.0*(a)	60.0**	20.3*	23.0(a)	15.3*	10.6* (a)
IBA 100	40.0**	70.0**	6.6*(a)	29.2*(a)	14.3*(a)	13.4* (a)
IBA 200	20.0(a)	60.0**	12.9(b)	28.5(a)	11.3(ab)	14.8(a)
IBA 500	20.0(a)	50.0**	9.7(ab)	25.7(a)	7.2(b)	13.9(a)
NAA 100	10.0*(a)	40.0**	8.8*(a)	23.6	7.0(a)	10.4* (a)
NAA 200	10.0*(a)	30.0*	6.7*(a)	15.3*(a)	5.0(a)	9.2* (a)
NAA 500	0.0	20.0	0.0	17.3*(a)	0.0	8.9* (a)
Control	20.0	20.0	12.3	24.6	8.6	18.2
Mean	23.0 ± 14.2	44.0 ± 16.2	10.0 ± 5.0	23.4 ± 4.1	8.3 ± 4.2	12.3±2.8

Individual values for each treatment were compared with control (*significant at p = 0.05; **significant at p = 0.01). Between concentrations of each hormone, means followed by the same letter are not significantly (p = 0.05) different. ± indicates standard deviation.

Discussion

The rooting response of branch cuttings of *D. elegans* is significantly determined by auxin, maturity of cuttings, planting depth, position and source of cuttings. In the present study no general conclusion can be made about the effect of a particular concentration of a particular auxin. However, IBA treated cuttings gave excellent rooting, followed by IAA treated cuttings, and NAA induced poor rooting in almost all the experiments. Several workers have reported that auxins, natural or artificial, trigger adventitious roots in stem cuttings (Bhatt 1991, Verma *et al.* 1992, Puri & Verma 1995).

Rooting medium did not markedly influence rooting behaviour of cuttings. This indicates that there is no significant contribution of rooting medium either in inducing rooting or growth attributes of cuttings of *D. elegans*. However, growth was comparatively better in garden soil. Although soil pH was slightly alkaline in both soil types, organic carbon, available phosphorus, and nitrogen percentage were significantly (p= 0.01) higher in garden soil than in eroded soil. Therefore, these differences in rooting medium may have some influence on root growth and probably due to this fact, root length was high in garden soil planted cuttings. Although, there is no such other study for comparison, an ideal rooting medium is that which provides sufficient porosity allowing good aeration, has high water holding capacity, and is well drained. It can also affect the type of roots arising from the cuttings (Pal 1995). Hartmann and Kester (1986) also reported that propagation structure, media, fertilisers, sanitation and container greatly influence the rooting attributes of cuttings.

It is well known that rooting capability decreases with the ontogenetic development of a plant from the juvenile to the adult phase (Hartmann & Kester 1986). In this investigation it was found that the lower (considered here as old stem segments) and middle (mature branch cuttings) portions of the branch cuttings had better rooting capability than those of the upper (young) branch sections.

Reuveni *et al.* (1990) found the highest rooting in cuttings obtained from the basal portion of the shoot compared to the upper ones. Hartmann and Kester (1986) also suggested that stem cuttings obtained from the same branch of the tree differ in rooting behaviour and those from the lower section of the branch exhibit more profuse rooting than those of the middle and upper branch sections. Lek (1930) reported that root initials in woody dicots distinctly decrease from the base to the tip of the shoots. Therefore, the rooting ability of basal portions of such shoots (considered here as mature and old cuttings) would be greater than that of the uppermost branch sections. The higher carbohydrate reserve might be an added advantage in such cuttings as early growth of branch cuttings depends on reserved food material present within the branch section and early shoot growth is followed by root formation (Wright 1975). This investigation indirectly supports the fact that there is direct relationship between thickness of stem cuttings and root–shoot attributes of branch cuttings as branch thickness decreases from the base upwards (Morsink & Smith 1974, Reuveni *et al.* 1990, Rossi 1993).

Planting depths of stem cuttings also influence their rooting capacity. In general, stem cuttings planted at 10- and 15- cm depths had significantly better growth attributes than those planted at 5-cm depth in the soil, irrespective of treatment. A strong correlation is shown between planting depths and root–shoot attributes of mature and old cuttings, irrespective of hormonal concentration. In an earlier study, Duguma (1988) reported that deeper planted mature and old stem segments of *Gliricidia sepium* and *Leucaena leucocephala* had a higher survival percentage than young branch sections. Thus these findings are in agreement with our observations.

The position of the branch on the mother tree affects significantly the rooting attributes of cuttings both qualitatively and quantitatively. Test of significance t computed for various growth parameters showed that a significantly ($p = 0.01$) higher number of lower canopy stem cuttings rooted than upper canopy branch cuttings, irrespective of hormonal concentration. The differential rooting ability of different parts of the tree might be attributed to the amount of food material and chemical composition present (Hartmann & Kester 1986). Komissorov (1969) also pointed out that good regenerative capacity of cuttings from the lower part is mainly due to the higher content of nutrients. Being near to the collar it could also be due to the presence of more active or dormant root primordia in the basal part. The overall performance of lower canopy branch cuttings was far better than that of the upper ones. Bloomberg (1963) suggested that the large number of roots on such cuttings would give rise to a better growth of the cuttings. The effects of position of branch cuttings on their rooting behaviour have also been reported in many species (Tang & Srivastava 1985, Srivastava *et al.* 1986, Rossi 1993). The high rooting capacity of the basal cuttings of *D. elegans* may also be attributed to the fact that juvenility tends to persist in the lower part of the plant.

Hartmann and Kester (1986) suggested that different clones of the same species may differ in rooting capability, thus the distribution of mother plant is bound to affect the rooting capacity of stem cuttings. As *D. elegans* has a wide range of natural distribution, the stem cuttings were therefore collected from 1350 and 2000 m asl. The experiment demonstrated the overall superiority of high altitude cuttings in terms of rooting response and root–shoot parameters. Bhatt and Todaria (1993) also observed that high altitude cuttings of *Boehmeria rugulosa* and *Debregeasia salicifolia* had better root–shoot attributes than low altitude cuttings. Various other workers have suggested the possibility of decreased sexual multiplication with increasing altitude (Ledig & Korbobo 1983) and, therefore, there are better chances of asexual multiplication in high altitude species/clones. Nautiyal and Purohit (1986) reported that only high altitude species of *Berberis* showed rooting compared to the middle and low altitudinal species. The higher rooting capability of high altitude stem cuttings of *D. elegans* may probably be due to their greater carbohydrate reserve which is utilised during the course of root initiation (Crawford & Huxter 1977). Further, it may be due to the comparatively higher levels of phenolics in high altitude races (Khanduri & Purohit 1981) as phenolics have been found to act as auxin cofactors or synergists in root initiation (Hartmann & Kester 1986).

On the basis of these findings it may be concluded that mass multiplication of *D. elegans* through branch cuttings is possible if high altitude mature and old branch cuttings are harvested from the lower canopy of mother plants and treated with a low concentration (100 ppm) of IBA.

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