Print : ISSN 0970-7662

Journal of Tree Sciences
online available at www.ists.in

Volume 28 No.1&2 June and December, 2009

Standardisation of the Best Season and Auxin Concentration for Rooting of the Cuttings of Wendlandia exserta Roxb. DC. - A Biofuel Species of Himalayan Region

Rajeev Dhiman* and N K Gupta

Department of Silviculture and Agroforestry
Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan, (H.P.) 173230
e-mail: rajeevforester86@gmail.com

ABSTRACT

Wendlandia exserta Roxb. DC., a member of Rubiaceae family, locally known as chila/ratela/ tikli, is well distributed throughout the sub-Himalayan tract upto 1,400 m elevation, especially on the areas that are vulnerable to landslides. It is a good fuelwood species and also provides small timber. Larger areas can be covered with this species, particularly which are sloppy and prone to soil erosion. Henceforth, an intensive research is required on its propagation. Keeping these points in view the present investigation was conducted at Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan during spring and rainy seasons. Cuttings collected and planted in spring exhibited better sprouting and rooting than those planted in rainy season. Application of 1.0% IBA + 2% captan + 2% sucrose-talc gave maximum sprouting (72.22%), rooting (5.56%) in spring. Non-apical cuttings produced better sprouting and root length but rooting in apical portion in spring. Highest rooting and root number were in apical cuttings of tree donor. The effect of donor × position was significant on root length in D_3A_2. The highest rooting (10.00%) was in $T_3A_1D_1$, $T_5A_1D_2$ and $T_5A_1D_3$.The spring season had comparatively (72.22%) higher sprouting than (52.78%) rainy season with 1.0% IBA + 2% captan + 2% sucrose-talc. In spring, maximum value was 70.00% in D_3A_1 as compare to 43.33% in D_1A_2 during rainy season. The maximum callusing (40.28%) was recorded in pole and tree donor during spring whereas it was 27.78% in tree donor during rainy season. The mean pooled value for sprouting (46.95%) and callusing (55.56%) was higher with 1.0% IBA + 2% captan + 2% sucrose-talc during spring.

Keywords:
Wendlandia exserta, donor, position, treatments, vegetative propagation.

INTRODUCTION

Wendlandia exserta Roxb. DC., a member of family Rubiaceae, is an important social forestry species which yields fuel, fodder, small timber for construction purposes and agricultural implements in the rural areas. Further, this species is good for soil conservation. Locally, it is known as chila, ratela, tikli *etc*. It is well distributed throughout the sub-Himalayan tract up to 1,400 m elevation, in outer Himalaya, Chotanagpur and parts of Indian peninsula (Troup, 1921). It is also prominent in Shivalik hills. It comes gregariously in areas where the area is vulnerable to landslides and soil is exposed due to disturbances or on abandoned agriculture. It prefers to grow in loose soils, which are exposed to direct sunlight since the species is light demander. The tree flowers in March-April and the seeds of the species are very minute and mature in May-June. Apart from this, it is silviculturaly useful in re-clothing the bare hill slopes and newly exposed (clearings) as well as geologically vulnerable areas but its regeneration is very poor due to various reasons. Therefore, for large scale success there should be adequate means of increasing its propagation potential through seeds and vegetative means.

MATERIAL AND METHODS

The present investigation was carried out in the nursery of Department of Silviculture and Agroforestry, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan, (H.P.). Cuttings of the current year growth were collected from three donor stages, which were (D_1): sapling, (D_2): pole, (D_3): tree, from two different positions which was (A_1): apical (excised tip), (A_2): sub-apical from the trees growing in Bhojnagar area of Dharampur Range under Solan Forest Division. The 10-15 cm long cuttings were selected having at least 2-3 nodes were given six different treatments *viz.*, (T_1): Control - (talc only), (T_2): 2% captan + 2% sucrose – talc, (T_3): 0.25 IBA + 2% captan + 2% sucrose – talc, (T_4): 0.5% IBA + 2% captan + 2% sucrose – talc, (T_5): 0.75% IBA + 2% captan + 2% sucrose – talc and (T_6): 1% IBA + 2% captan + 2% sucrose – talc. The spacing of 15 cm was used in the experiment and factorial randomised block design adopted for investigation. The experiment was conducted in two different seasons *viz*., July August (rainy) and January - February (spring) to standardise the best season and auxin concentration for the multiplication of the cuttings of *Wendlandia exserta.*

RESULTS AND DISSCUSSION

The observation on sprouting and its progress was initiated one week after planting and were recorded up to two months. The observations on callusing and rooting were recorded after 120 days of planting of the cuttings by removing from planting beds during rainy and spring season. During rainy season, the cuttings of pole donor (D_2) and non-apical position (A_2) resulted in higher sprouting (39.44%) and (38.89%) respectively. Significantly highest sprouting of 52.78 per cent was registered in T_6 (1.0% IBA + 2% captan + 2% sucrose- talc). During spring season, the sprouting was recorded 66.94% and 60.93 per cent in cuttings collected from tree donor (D_3) and non-apical (A_2) position of cuttings. Maximum callusing of 27.78%, 26.67 % and 43.33 % was observed in tree donor (D_3), apical position (A_1) and T_6 (1.0% IBA + 2% captan + 2% sucrose- talc) formulation respectively during rainy season. Higher callusing per cent of 40.28% and 42.04 % was observed in tree donor D_3 and non-apical position (A_2) and significantly maximum callusing of 55.56 per cent was recorded in T_6 (1.0% IBA + 2% captan + 2% sucrose- talc) formulation during spring season. In spring season rooting parameters were studied because the cuttings in rainy season could not survive. So, during spring season, Rooting per cent was affected significantly by donor stage, position and auxin concentration with the highest rooting of 3.06 per cent which was observed in the cuttings collected from tree donor (D_3) compared to 1.67 per cent and 1.39% in sapling (D_1) and pole donor (D_2) and a highest rooting of 5.56 per cent was observed in cuttings treated with T_6 (1.0% IBA+2% captan+2% sucrose- talc) concentration. Significantly the root number varied from 2.08 roots was recorded when cuttings were taken from tree (D_3) respectively. Similarly, the apical cuttings exhibited significantly higher root number *i.e.* 1.43 and significantly maximum root number of 3.89 roots was recorded when cuttings were treated with 1.0% IBA+2% captan + 2% sucrose- talc (T_6) formulation. The maximum root length (2.56 cm) was observed in tree donor (D_3) and the non-apical cuttings (A_2) exhibited significant root length of 2.16 cm and maximum root length of 6.01 cm was recorded in T_5 (0.75% IBA + 2% captan+2% sucrose- talc) respectively, (Table-1). It had been widely reported that the ability of cutting to root decreases with age of cutting donors (Black, 1973; Hartmann *et.al.*, 2009 and Nautiyal *et. al.*1991), but the results obtained were in contradiction in the present findings where the best results were obtained in tree donors than those of sapling and pole donors. The observations are in contrast to the widely held view that rooting propensity of cuttings decreased with increasing age /stage of the donor plants. However, these results are in agreement with the findings of Shamet and Naveen (2005) who reported that tree donor cuttings performed remarkably better than pole and sapling donors in spring season in *Celtis australis*. This work is also corroborated by Ivory (1971) who had indicated that age of the tree did not noticeably affect rooting in *Pinus radiata* cuttings. Similarly, Addullah *et al.* (1988) while working with Sycamore (*Platanus orientalis*) had achieved better results in 8-year than 4-year old donor plants. The callusing and root length were found with maximum values in non-apical position, but rooting and root number was found more in apical portion during spring season. The results are in contradiction for rooting per cent and root number but for other parameters these are in favour with the superiority of basal/ lower portions in rooting as reported by many researchers. Similarly, Kanwar *et al.* (1996) got higher rooting in *Ulmus laevigata* (63.3 per cent in winter and 50.00 per cent in rainy season) cuttings prepared from basal portion. The results of present investigation are also in line with the findings of Hamooh (2004) who reported that basal cuttings of *Ficus carica* resulted in highest rooting and root number when treated with 1500 ppm IBA. Similarly, Akoumianaki *et al.* (2004) reported highest rooting when *Bauhinia variegata* cuttings from basal region of shoots, treated with 2000 ppm IBA. Nautiyal *et al.* (2007) and Madhwal *et al.* (2008) reported 4000 ppm to be the best rooting hormone for juvenile shoot cuttings of *Podocarpus neriifolius and Terminalia chebula*. Similarly, Tiwari *et al.* (2004) reported cent per cent rooting and maximum length of roots (30.5cm) in *Vitex negundu* when cuttings were treated with 500 and 1000 ppm NAA.

Table1: Mean effect of donor stage, position and auxin concentration on sprouting, callusing and rooting during rainy and spring season

Treatments	Rainy season		Spring season				
	Sprouting (%)	Callusing (%)	Sprouting (%)	Callusing (%)	Rooting (%)	Root number	Root length (cm)
Donor (D)							
D_1	36.67 (36.44)	21.39 (24.14)	44.44 (41.85)	31.67 (33.29)	1.67 (1.39)	0.97 (1.26)	1.77 (1.39)
D_2	39.44 (38.46)	26.94 (29.53)	61.39 (52.11)	40.28 (39.24)	1.39 (1.38)	0.86 (1.23)	1.24 (1.29)
D_3	33.06 (32.12)	27.78 (29.99)	66.94 (55.81)	40.28 (39.19)	3.06 (1.71)	2.08 (1.54)	2.56 (1.63)
CD $^{((0.05)}$	NS	NS	6.29	4.94	0.26	0.2	0.26
Position (A)							
A_1	33.89 (34.03)	26.67 (28.07)	54.26 (47.78)	32.78 (34.33)	2.22 (1.52)	1.43 (1.37)	1.55 (1.38)
A_2	38.89 (37.32)	24.07 (27.70)	60.93 (52.07)	42.04 (40.15)	1.85 (1.43)	1.19 (1.31)	2.16 (1.49)
CD $^{((0.05)}$	NS	NS	NS	4.03	0.21	0.16	0.22
Auxin concentration (T)							
T_1	17.78 (22.26)	9.44 (13.81)	45.00 (42.07)	28.33 (31.62)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
T_2	29.44 (30.88)	16.11 (21.44)	50.00 (44.88)	33.33 (34.79)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
T_3	35.56 (36.35)	22.22 (25.31)	55.56 (49.10)	32.22 (34.10)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
T_4	40.56 (38.52)	27.22 (31.08)	58.89 (50.69)	39.44 (38.38)	1.67 (1.38)	0.89 (1.25)	1.63 (1.37)
T_5	42.22 (39.33)	33.89 (34.57)	63.89 (53.55)	40.50 (39.17)	5.00 (2.16)	3.06 (1.82)	6.01 (2.38)
T_6	52.78 (46.72)	43.33 (41.10)	72.22 (59.24)	55.56 (45.37)	5.56 (2.29)	3.89 (2.00)	3.49 (1.87)
CD $^{((0.05)}$	8.57	7.6	8.89	6.98	0.37	0.28	0.38

Figures in parentheses indicate the *arc sine* transformed values

Effect of auxin concentration, position and donor stage (T× A×D) on sprouting, callusing and rooting characteristics during rainy and spring season

The data reveals that auxin, position and donor stage interaction had non-significant effect on per cent sprouting in both the seasons. Maximum per cent sprouting (66.67%) was observed when non-apical (A_2) cuttings of sapling donor (D_1) were treated with T_6 (1.0% IBA + 2% captan + 2% sucrose- talc) formulation ($T_6A_2D_1$) (Table- 2) and the effect of auxin × position × donor stage (T×A×D) interaction on callusing was found to be non-significant, a maximum success rate of 50.00 per cent in $T_6A_2D_3$ interaction was observed during rainy season. However, during spring season, the maximum sprouting of 86.67% was observed when apical cuttings from tree donor were treated with 1.0% IBA + 2% captan + 2% sucrose- talc (T_6 A_1D_3) and the maximum callusing (63.33%) was however, observed in $T_6A_2D_1$ combination, However, the significant highest rooting (10.00%) was seen $T_3A_1D_1$, $T_5A_1D_2$ and $T_5A_1D_3$. Most of the interactions were not able to initiate roots in cuttings. The effect of auxin × position × donor stage (T × A × D) interaction on primary number of roots, primary root length and survival was found to be significant. The maximum number of roots (8.00) was however, observed in $T_6A_1D_3$combination. Similarly in case of root length maximum value of 11.50 cm was observed in $T_5A_2D_3$. The better performance of apical type cuttings of *Wendlandia exserta* may be attributed to the better status of growth regulators (auxins) in comparison to those of lower /non-apical ones. It has also been suggested that the endogenous auxin levels decrease as the distance from the apices of branches within the same plant increases (Jacobs, 1979). Bonga (1982), on the other hand, was of the view that such variations in the performance of cutting types is due to the presence of some juvenile cells/ tissues even in mature tissue. In case of tree species, the degree of juvenility is inversely proportional to the distance along the trunk and branches between the root shoot junction and branches (Razdan, 1993). The enhancement of bud sprouting in IBA treated cuttings might be due to the stimulation of hydrolysis of nutrient reserves and their mobilization. The high rooting success can be attributed to the complimentary interaction of the applied auxin with endogenous counterpart (Sparks and Chapman, 1970). Nanda (1970); Hassig and Davis (1994) also reported that auxins induce hydrolysis and mobilization of nutritional factors to the site of application, thereby promoting root initiation in the cuttings. Limbasiya *et al.* (2007) suggested that accumulation of certain substances at the base of cuttings enhanced the interaction between applied hormone and rhizocaline thus stimulating the meristem to divide quickly and form roots. Van Overbeek *et al.* (1946) demonstrated that the rooting of *Hibiscus rosa-sinensis* was dependent upon rooting factors produced in the leaves and the effect of these factors could be replaced by 2% sucrose solution and nitrogenous substances. Captan also increases the per cent rooting and the survival of cuttings as increase in rooting was related to the fungicide concentration used, however high levels inhibit rooting (Grigsby, 1965; Hansen and Hartmann, 1967). The increased rooting effect obtained with fungicides is probably due to the control of disease and/or a synergistic hormonal effect on rooting by the fungicide (Couvillon, 1988).

In rainy season, the impact of donor stage and position was non-significant on sprouting but in spring season, the donor and the treatment effect was significant but the position effect was non-significant for sprouting. The maximum sprouting of 62.50 was in T_6 (1.0% IBA + 2% captan + 2% sucrose-talc) and minimum 31.39% inT_1. When the impact of seasons was compared the spring season (S_2) had comparatively higher level of sprouting then rainy season and it was having maximum value of 72.22% in T_6 (1.0% IBA + 2% captan + 2% sucrose-talc) in contrast to maximum sprouting of 52.78% during rainy season in the same treatment. In case of minimum value in rainy season it was 17.78% in contrast to 45.00% during spring season in control being quite higher. The apical and non-apical impact was significant on sprouting when compared for two seasons. The sprouting was more (60.93%) in spring season for non-apical than (54.26%) apical cuttings whereas in rainy season the value of 38.89% and 33.89% was obtained in non-apical and apical cuttings respectively. The effect of donor was non-significant in rainy season as compared to spring season, but the interaction effect was found to be significant when seasons were compared and the values for sprouting were quite maximum in spring season in tree donor (66.94%) whereas it was maximum in pole donor (39.44%) during rainy season. The impact of portion and donor stage was higher in spring season with maximum value of 70.00% in D_3A_1 as compare to 43.33% in D_1A_2 during rainy season. It was apparent from the given pooled data that donor stage, season and auxin concentration brought about significant impact on callusing of the cuttings. The maximum value (40.28%) was recorded in pole donor (D_2) and tree donor (D_3) during spring whereas it was 27.78% in tree donor (D_3) but the minimum value (21.39%) was observed in sapling donor (D_1) during rainy season. The mean pooled value was found higher (46.95%) in T_6 (1.0% IBA + 2% captan + 2% sucrose-talc) while the minimum value (18.89%) was found in T_1.the maximum callusing was 55.56% in T_6 (1.0% IBA + 2% captan + 2% sucrose-talc) treatment during spring respectively. The cuttings planted in spring (March-April) resulted in better sprouting and rooting behavior as compared to those struck in monsoon season. Highest per cent sprouting (72.22%), callusing (55.56%) and rooting (5.56%) were recorded when the cuttings were subjected to 1.0% IBA + 2% captan + 2% sucrose- talc and planted in spring (March-April). These results are in agreement with the findings of Todaria (1993) who concluded spring and summer seasons as favourable for root initiation in *Kydia calycina.* Bhardwaj and Mishra (2005) concluded that leafless cutting collected during February before bud burst, rooted significantly better than leafy cuttings of *Ulmus villosa* taken in July. Induction of adventitious roots in cuttings is invariably dependent on the season when cuttings are collected and planted. This is true even for the species which root throughout the year, as these also show variation in their rooting capacity. Further, the optimum season for taking cuttings varies not only with respect to species to species but also within the species (Anand and Heberlein, 1975). Shamet and Naveen (2005) reported significantly higher rooting (73.33%) in *Celtis australis* cuttings during rainy season (July-August) as compared to only 34.17 per cent success in spring (February- March) when both were treated with 0.4% IBA-talc. This work also found contradictiory results to the work done by Husen and Pal (2007) who observed best rooting response of *Tectona grandis* in rainy season (July-August). *Murraya koenigii* cuttings planted in spring (March-April) resulted in better sprouting and rooting behaviour as compared to those struck in monsoon season (Munde, 2009) are in line with the present study.

Table 2: Effect of donor stage, position and auxin concentration (interaction) on sprouting, callusing and rooting of *Wendlandia exserta* cuttings during spring season

Treatment (T×A×D)	Rainy season		Spring season				
	Sprouting (%)	Callusing (%)	Sprouting (%)	Callusing (%)	Rooting (%)	Root number	Root length (cm)
$T_1A_1D_1$	20.00 (26.07)	6.67 (8.85)	23.33 (28.08)	16.67 (23.86)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
$T_1A_1D_2$	20.00 (26.07)	13.33 (17.22)	43.33 (41.16)	30.00 (33.21)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
$T_1A_1D_3$	16.67 (19.22)	6.67 (8.85)	56.67 (49.22)	30.00(33.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
$T_1A_2D_1$	16.67 (19.93)	6.67 (12.29)	30.00 (33.00)	20.00 (26.57)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
$T_1A_2D_2$	23.33 (27.29)	6.67 (12.29)	56.67 (49.14)	33.33 (34.22)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
T_1A_2D3	10.00 (15.00)	16.67 (23.36)	60.00 (51.85)	40.00 (38.86)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
$T_2A_1D_1$	23.33 (28.08)	13.33 (17.71)	23.33 (28.29)	16.67 (23.36)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
$T_2A_1D_2$	30.00 (33.21)	20.00 (26.07)	53.33 (47.01)	33.33 (35.22)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
$T_2A_1D_3$	23.33 (24.15)	16.67 (19.93)	56.67 (49.14)	33.33 (35.22)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
$T_2A_2D_1$	36.67 (36.93)	10 (15.00)	46.67 (43.08)	30.00 (33.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
$T_2A_2D_2$	33.33 (34.93)	16.67 (23.86)	56.67 (48.93)	46.67 (43.08)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
$T_2A_2D_3$	30.00 (27.99)	20.00 (26.07)	63.33 (52.86)	40.00 (38.86)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
$T_3A_1D_1$	26.67 (31.00)	20.00 (21.93)	26.67 (30.00)	16.67 (23.36)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
$T_3A_1D_2$	36.67 (36.93)	26.67 (26.16)	56.67 (49.22)	33.33 (35.22)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
$T_3A_1D_3$	30.00 (32.71)	30.00 (32.22)	66.67 (55.08)	36.67 (36.93)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
$T_3A_2D_1$	46.67 (43.08)	13.33 (17.22)	63.33 (57.99)	33.33 (35.01)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
$T_3A_2D_2$	40.00 (39.15)	20.00 (26.07)	56.67 (48.93)	40.00 (38.86)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
$T_3A_2D_3$	33.33 (35.22)	23.33 (28.29)	63.33 (53.36)	33.33 (35.22)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
$T_4A_1D_1$	30.00 (33.00)	20.00 (26.57)	26.67 (31.00)	23.33 (28.08)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
$T_4A_1D_2$	43.33 (40.78)	36.67 (36.93)	70.00 (57.70)	36.67 (36.93)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
$T_4A_1D_3$	36.67 (32.01)	33.33 (34.93)	73.33 (59.01)	43.33 (41.07)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
$T_4A_2D_1$	43.33 (41.16)	23.33 (28.78)	60.00 (51.93)	36.67 (36.15)	6.67 (2.54)	2.67 (1.82)	5.88 (2.38)
$T_4A_2D_2$	46.67 (43.08)	26.67 (31.00)	60.00 (51.15)	46.67 (43.08)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
$T_4A_2D_3$	43.33 (41.07)	23.33 (28.29)	63.33 (53.36)	50.00 (45.00)	3.33 (1.77)	2.67 (1.67)	3.91 (1.85)
$T_5A_1D_1$	40.00 (39.15)	33.33 (30.00)	16.67 (36.15)	26.67 (30.29)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
$T_5A_1D_2$	46.67 (42.99)	36.67 (37.23)	70.00 (57.29)	30.67 (37.23)	10.00 (3.32)	6.67 (2.76)	9.16 (3.17)
$T_5A_1D_3$	30.00 (28.08)	43.33 (41.16)	80.00 (63.93)	43.33 (40.86)	10.00 (3.32)	5.33 (2.48)	7.83 (2.92)
$T_5A_2D_1$	50.00 (44.71)	30.oo (33.00)	70.00(57.290	50.00 (45.00)	6.67 (2.54)	4.67 (2.21)	7.59 (2.68)
$T_5A_2D_2$	46.67 (42.99)	36.67 (37.23)	63.33 (53.86)	50.00 (44.71)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
$T_5A_2D_3$	40.00 (38.07)	23.33 (28.78)	63.33 (52.78)	36.67 (36.93)	3.33 (1.77)	1.67 (1.48)	11.50 (3.52)
$T_6A_1D_1$	40.00 (39.15)	33.33 (35.22)	53.33 (46.22)	46.67 (42.00)	3.33 (1.77)	2.00 (1.55)	3.05 (1.73)
$T_6A_1D_2$	56.67 (49.14)	43.33 (41.16)	73.33 (59.21)	40.00 (39.15)	6.67 (2.54)	3.67 (2.03)	5.77 (2.36)
$T_6A_1D_3$	60.00 (50.85)	46.67 (43.08)	86.67 (72.29)	46.67 (42.99)	10.00 (3.32)	8.00 (2.95)	2.04 (1.67)
$T_6A_2D_1$	66.67 (55.08)	46.67 (43.08)	73.33 (59.21)	63.33 (52.86)	3.33 (1.77)	2.33 (1.61)	4.72 (1.96)
$T_6A_2D_2$	50.00 (45.00)	40.00 (39.15)	76.67 (61.72)	56.67 (48.93)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
$T_6A_2D_3$	43.33 (41.07)	50.00 (44.92)	70.00 (56.79)	50.00 (45.29)	10.00 (3.32)	7.33 (2.87)	5.39 (2.52)
$CD^{0.05}$	NS	NS	NS	NS	0.90	0.70	.0.66

Figures in parentheses indicate the *arc sine* and *square root* transformed values

Table 3: Effect of season on sprouting of cuttings of *Wendlandia exserta*

Treatments	Seasons (S)																				
	Rainy season (S_1)									Mean	Spring season (S_2)									Mean	Mean
	D_1		Mean	D_2		Mean	D_3		Mean		D_1		Mean	D_2		Mean	D_3		Mean		
Auxin (T)	A_1	A_2		A_1	A_2		A_1	A_2			A_1	A_2		A_1	A_2		A_1	A_2			
T_1	20.00	16.67	18.34	20.00	23.33	21.67	16.67	10.00	13.34	17.78	23.33	30.00	26.67	43.33	56.67	50.00	56.67	60.00	58.34	45.00	31.39
	(26.07)	(19.93)	(23.00)	(26.07)	(27.29)	(26.68)	(19.22)	(15.00)	(17.11)	(22.26)	(28.08)	(33.00)	(30.54)	(41.16)	(49.14)	(45.15)	(49.22)	(51.85)	(50.54)	(42.08)	(32.17)
T_2	23.33	36.67	30.00	30.00	33.33	31.67	23.33	30.00	26.67	29.44	23.33	46.67	35.00	53.33	56.67	55.00	56.67	63.33	60.00	50.00	39.72
	(28.08)	(36.93)	(32.51)	(33.21)	(34.93)	(34.07)	(24.15)	(27.99)	(26.07)	(30.88)	(28.29)	(43.08)	(35.69)	(47.01)	(48.93)	(47.97)	(49.14)	(52.86)	(51.00)	(44.89)	(38.88)
T_3	26.67	46.67	36.67	26.67	40.00	33.34	30.00	33.33	31.67	33.89	36.67	63.33	50.00	56.67	56.67	56.67	66.67	63.33	65.00	57.22	45.56
	(31.00)	(43.08)	(37.04)	(36.93)	(40.78)	(38.04)	(32.71)	(35.22)	(33.97)	(36.35)	(30.00)	(57.99)	(44.00)	(49.22)	(48.93)	(49.08)	(55.08)	(53.36)	(54.22)	(49.10)	(42.72)
T_4	30.00	43.33	36.67	43.33	46.67	45.00	36.67	43.33	40.00	40.56	26.67	60.00	43.34	70.00	60.00	65.00	73.33	63.33	68.33	58.89	49.72
	(33.00)	(41.16)	(37.08)	(40.78)	(43.08)	(41.93)	(32.01)	(41.07)	(36.54)	(38.52)	(31.00)	(51.93)	(41.47)	(57.70)	(51.15)	(54.43)	(59.01)	(53.36)	(56.19)	(50.69)	(44.60)
T_5	40.00	50.00	45.00	46.67	46.67	46.67	30.00	40.00	35.00	42.22	36.67	70.00	53.34	70.00	63.33	66.67	80.00	63.33	71.67	63.89	53.06
	(39.15)	(44.71)	(41.93)	(42.99)	(42.99)	(42.99)	(28.08)	(38.07)	(33.08)	(39.33)	(36.15)	(57.29)	(46.72)	(57.29)	(53.86)	(55.58)	(63.93)	(52.78)	(58.36)	(53.55)	(46.44)
T_6	40.00	66.67	53.34	56.67	50.00	53.34	60.00	43.33	51.67	52.78	53.33	73.33	63.33	73.33	76.67	75.00	86.67	70.00	78.34	72.22	62.50
	(39.15)	(55.08)	(47.12)	(49.14)	(45.00)	(47.07)	(50.85)	(41.07)	(45.96)	(46.72)	(46.22)	(59.21)	(52.72)	(59.21)	(61.72)	(60.47)	(72.29)	(56.79)	(64.54)	(59.24)	(52.98)
Mean	30.00	43.33		37.22	40.00		32.77	33.33			33.33	57.22		61.11	61.66		70.00	63.88			
	(32.74)	(40.15)		(38.18)	(39.01)		(31.17)	(33.07)			(33.29)	(50.41)		(51.93)	(44.13)		(58.11)	(53.50)			

Figures in parentheses indicate the *arc sine* transformed values

CD$^{(0.05)}$

T = 6.09 T*A = NS A*S = NS A*D*S = NS A = 3.52, T*D = NS

D*S = 6.10 T*A*D*S = NS D = 4.31 T*S = NS T*A*D = NS **S** = 3.52

A*D = 6.10 T*D*S=NS

CONCLUSION

Wendlandia exserta seems to be a difficult- to- root species based on its rooting behaviour. However, it can be made to root under nursery (shaded) conditions by applying the best auxin- formulation (1.0% IBA + 2% captan + 2% sucrose- talc) to the apical cuttings in spring season. Maximum sprouting per cent was recorded in tree donor, but it was non-significant in case of position and 1.0% IBA + 2% captan + 2% sucrose- talc treatment was found maximum in spring season while in rainy season maximum sprouting per cent was recorded in tree donor in non- apical position and among the treatments 1.0% IBA + 2% captan + 2% sucrose- talc was found maximum. The callusing per cent was higher in pole donor with 1.0% IBA + 2% captan + 2% sucrose- talctreatment and non-apical position of rainy season whereas in spring maximum mean value for callusing percent was obtained in tree donor in apical position. In spring season, non-significantly maximum mean value for rooting was seen in tree donor of apical position with maximum mean value of 1.0% IBA + 2% captan + 2% sucrose- talc treatments while maximum primary root number was obtained in tree donor apical position with maximum mean value for 1.0% IBA + 2% captan + 2% sucrose- talc treatment. The root length was higher in tree donor with 0.75% IBA + 2% captan + 2% sucrose- talc treatment and non-apical position. In spring season, non-significantly maximum mean value for rooting was seen in tree donor of apical position with maximum value for cuttings treated with 1.0% IBA + 2% captan + 2% sucrose- talc. The spring season gave the best results with reference for rooting behaviour in the species.

REFERENCES

Abdullah YS, Abdullah MO and Al- Asnoo J 1988 Effect of tree age,cutting length and their distance from the base of shoots on the propagation of *Platanus occidentalis* L.seedlings. *Mesopotamia Journal of Agriculture* **20** (3): 221-236.

Akoumianaki Loannidou A, Fragkouli R and Gedeon M 2004 Propagation of *Bauhinia variegata* L. by cuttings and seed. *Advances in Horticultural Science* **18** (1):26-28.

Anand VK and Heberlein GT 1975 Seasonal changes in the effects of auxin on rooting in stem cuttings of *Ficus Infectoria*.

Physiology plantarum **34**: 330-334.

Black DK 1973 Influence of shoot origin and certain pre- and post severance treatment on the rooting and growth characteristics of Douglos fir (*Pseudotsuga menziessi*) stem cuttings. *Desertation Abstracts International* **33**(8): 3399.

Bonga JM 1982 Vegetative propagation in relation to juvenility, maturity and rejuvenation. In: Tissue culture in forestry. J M Bonga and D J Durzan (eds).

Couvillon Gary A 1988 Rooting response to different treatments. *Acta Horticulture* **111**: 187- 196.

Grigsby HC 1965 Captan aids rooting of loblolly pine cuttings. *Proc. Int Plant Prop. Soc.* **15**: 147-150.

Haissig BE and Davis TD 1994 A historical evaluation of adventitious rooting research to 1993. In: Biology of adventitious root formation. T D Davis and B E Haissig (eds.). Plenum Press, New York. 275- 331.

Hamooh BT 2004 Cuttings types and IBA concentration in relation to rooting of stem hardwood cuttings of fig tree (*Ficus carica* L.). *Annals of agricultural Science* **49**(2)**:** 661-669.

Hansen CJ and Hartmann HT 1967 The use of indolebutyric acid and captan in the propagation of clonal peach and peach-almond hybrid rootstocks by hardwood cuttings. *Proc. Amer. Soc. Hort. Sci.* **92**: 135-140.

Hartmann HT, Kester DE, Davies FT and Geneve RL 2009 Plant propagation: principles and practices. PHI Learning Pvt. Ltd., New-Delhi. p. 880.

Husen A and Pal M 2007 Seasonal changes in rooting response of hardwood cuttings of teak *(Tectona grandis* Linn. F.) in relation to drift of total soluble sugar, starch and total nitrogen. *Annals of Forestry* **15**(**1**): 11-31.

Ivory MH 1971 Techniques for rooting cuttings of *Pinus radiate* in Kenya. *Afr. Agric. For. J.* **36(4)**:356-160.

Jacobs W P. 1979 Plant hormones and plant development Cambridge University Press, Cambridge, U. K.

Kanwar BS, Bhardwaj SD and Shamet GS 1996 Vegetative propagation of *Ulmus laevigata* by stem cuttings. *Journal of Tropical Forest Science* **8**(3): 333-338.

Limbasiya RT, Patel RM, Kolambe BN, Patil NS, Vashi BG and Jadeja DB 2007 IB A induced rooting and growth response of *Jatropha curcas* L cuttings undef normal and salt stress conditions. *Indian Forester* **133(6)**: 785-793.

Madhwal Kavita, Kumar Pankaj, Nautiyal S**,** Rayal SP and Nautiyal DP 2008 Rooting response of juvenile shoot cuttings of *Terminalia chebula* Retz. under different hormonal treatments, *Indian Forester* **134**(2): 270-274.

Mishra VK and Bhardwaj DR 2005 Vegetative propagation of *Ulmus villosa:* effects of plant growth regulators, collection time, type of donor and position of shoot on adventitious root formation in stem cuttings. *New Forests* **29:** 105-116.

Munde Arvind 2009 Vegetative propagation studies of soapnut (*Sapindus mukorossi* Gaertn. and Curry patta (*Murraya koenigii* Linn. Streng) through cuttings. M.Sc. Thesis. Dr. Y. S. Parmar UHF. Solan. India: 107pp.

Nanda KK 1970 Investigations on the use of auxins in vegetative reproduction of forest plants. *Final Report PL 480. Research Project.* Botany Department. Punjab University. Chandigarh. 215p.

Nautiyal S, Nautiyal DP, Bhandari HCS, Kumar Pankaj and Prakash Rakesh 2007 Mass propagation protocol for *Podocarpus nerifolius* D. Don. through juvenile shoot cuttings. *Indian Forester* **133(2)**: 262-265.

Nautiyal S, Singh U and Gurumurti K 1991 Rooting response of branch cuttings of teak *(Tectona grandis)* as influenced by growth hormones and position of the cutting in the crown. *Indian Forester* **117(2)**: 112-121.

Razdan MK 1993 An introduction to plant tissue culture. Oxford and JBH Publishers, New Delhi.

Shamet GS and Naveen CR. 2005. Study of rooting in stem cuttings of khirk (*Celtis australis* Linn.). *Indian Journal of Forestry* **28(4)**: 363-369.

Sparks D and Chapman JW 1970 Effect of indole-3- butyric add on rooting and survival of air layered branches of pecan *(Carya illinoensis* cv. Stuart). Hort *Sci.* **5**: 445-446.

Tewari DK, Vassudevan P and Santosh 2004 Effect of plant growth regulators on vegetative propagation of *Vitex negundu*. L. *Indian Forester* **130(1)**: 45-52.

Todaria NP 1993 Propagation studies on social and agroforestry species of mountains. *Final Technical Report.* Department of Forestry, H. N. 8. Garhwal University, U. P. 35p.

Troup RS 1921 The Silviculture of Indian Trees. Vol.11. Clarendon Press. Oxford, pp. 538-539.

Van Overbeek J, Gordon Solon A and Gregory Luis E (1946) An analysis of the function of the leaf in the process of root formation in cuttings. *Amer. J. Botany* **33**: 100- 107