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Effect of cutting diameter and hormonal application on the propagation of *Ficus roxburghii* Wall. through branch cuttings

R. S. Rana, K. K. Sood

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Abstract. Fruit gathering from *Ficus roxburghii* Wall., a multipurpose tree, hinders its regeneration through seed. The present study was undertaken to propagate this species using branch cuttings treated with different hormones in two different seasons: rainy-July and spring-March. In both seasons (rainy and spring), large sized (1.25-2.5 cm diameter) cuttings resulted in statistically higher growth of all the studied parameters than that of small sized (< 1.25 cm diameter) cuttings, except the number of shoots in both the seasons and number of lateral roots in rainy season. The effect of hormonal treatments (Indole-acetic acid, Indole-butyric acid and Naphthyl-acetic acid) was also significant on all the studied parameters in both the study seasons except in the case of number of shoots in rainy season where the influence was not-significant. The interaction large size x IBA 100 ppm resulted in significantly better growth of the studied parameters in both seasons except for the number of lateral roots, number of shoots, shoot length and number of leaves in rainy season. This study implies that species is amenable to cloning with different hormonal treatments. In general, it was observed that growth and development of cuttings was better in spring than the rainy season. Therefore, for the successful propagation of *Ficus roxburghii*, large sized cuttings are to be treated with IBA 100 ppm and be planted in spring.
Keywords *Ficus roxburhgii* cuttings, on-farm, plant hormones, growth, regeneration.

Authors. Rakeshwar Singh Rana, Kamal Kishor Sood (kksood_2000_2000@yahoo.com) - Division of Agroforestry, Sher-e-kashmir University of Agricultural Scien-ces and Technology Main Campus-Chatha Jammu (J & K), India 180 009.
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Introduction

People in many parts of the developing world are dependent on trees to meet the day to day livelihood needs for fuelwood, timber, fodder and other non-wood forest products (Sood

2003). There has been a faster deforestation at world level at a rate of 7,317,000 ha/year between 2000-2005 (FAO 2009); in India forest land diminished drastically, covering 21% of its geographical area (FSI 2009). The policies to combat deforestation, and enhance tree cover vary from place to place depending on the type of deforestation but agroforestry appears to be a common solution in all the countries of the world (Rudel & Roper 1997, Ullsten 1998). On-farm and off-farm cultivation of trees seems to hold the potential to solve the problems of rural development by fulfilling the needs of rural people for tree as well as food products through sustainable use of the land (Nair 1989, Chundawat & Gautam 1993, Arnold & Dewees 1998). Moreover, on-farm tree cultivation has capacity to divert pressure from existing forests and increase effective tree cover at local, regional and global level (Sinclair & Walker 1998, Sood et al. 2000).

In many regions of the world, like Western Himalaya, the cultivation of various tree species in agroforestry is constrained by their poor regeneration from seed, long juvenile phase and lack of standardization of their propagation techniques. Vegetative propagation using stem cuttings is one of the techniques for faster multiplication of trees during the reproduction phase, by taking cuttings from ontogenetically mature trees (Sadhu 1996, Hartmann et al. 1997). This shortening of the juvenile phase of the tree (Hackett 1985). *Ficus roxburghii* Wall. is one of multipurpose agroforestry tree species of Western Himalaya, ascending to an elevation of about 1800 m. It belongs to Moraceae family. The ripened fruits of *Ficus roxburghii* are relished by the inhabitants in places of its occurrence for eating; jelly-like substance makes them very tasty and serves as nutrient supplement. Its leaves are used as traditional source of fodder in many areas, particularly during the dry winter season (Singh 1982). In places of occurrence of *Ficus roxburghii*, its leaves are also used as plates for food serving during feast. Tops and lops left after utilization of the fodder are used as fuelwood by the local people. Fruit collection and lopping of *Ficus roxburghii* results in its poor seed production. This, consequently, affects adversely the regeneration of this specie from seed and acts as disincentive for its plantation. Therefore, investigations on the vegetative propagation of this species have received an impetus. The cuttings of a number of plant species are either hard to root or fail completely to root when planted. The growth hormones, the substances which regulate the growth of the species, can play an important role in inducing the roots in the cuttings and influencing their growth. The plant hormones known as auxins, are the most effective rooting aids in many plant species (Sadhu 1996). Application of these hormones-Indole-acetic acid (IAA), Indole-butyric acid (IBA) and Naphthalene-acetic acid (NAA), to induce rooting in stem cuttings of several forest trees has gained importance over time (Davis & Hassing 1990, Husen 2002, Khali & Sharma 2003, Navamaniraj et al. 2008, Majeed et al. 2009, Akinyele 2010, Raju & Prasad 2010). The rooting of the cuttings in many species has also been found to be dependent of the thickness (diameter) of the cuttings (Sadhu 1996, Zhang et al. 2010).

Studies on vegetative propagation in *Ficus roxburghii* are almost non-existent. Thus present study was undertaken with a view to standardize the propagation techniques of this species through branch cuttings using growth hormones. The current study investigates the effect of different cutting thickness (diameter size) and concentrations of IAA, IBA and NAA on growth and development of *Ficus roxburghii* branch cuttings under open nursery conditions.

Materials and methods

Study area

The experiment was carried out in open conditions in the nursery of Division of Agroforestry, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu (SKUAST-J) located at Chatha, Jammu, India. The experimental site is situated at 32°39´N latitude and 74°58´ E longitude with an altitude of 332 m above mean sea level. The experimental site falls in subtropical zone. The average annual rainfall at the site is 1200 mm, 75-80% of which is received during monsoon season (July to September) and the rest 20-25% during winter months of December to February. The mean monthly weather data recorded at meteorological observatory of Sher-e-Kashmir University of Agricultural Sciences and Technology located near the experimental during study period are given in Figures 1-3.

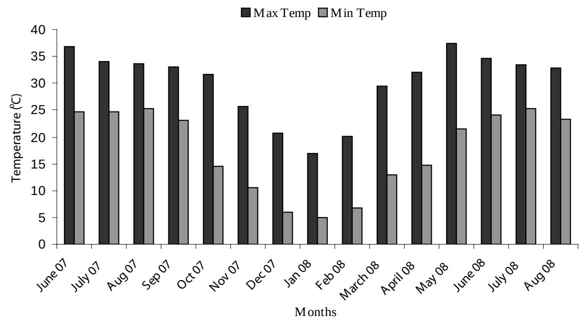

Figure 1 Daily average temperatures at experimental farm during study period.

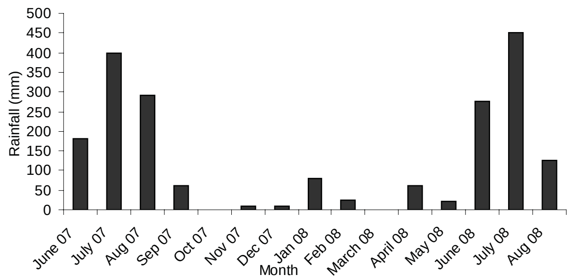

Figure 2 Total monthly rainfall at the experimental site during study period.

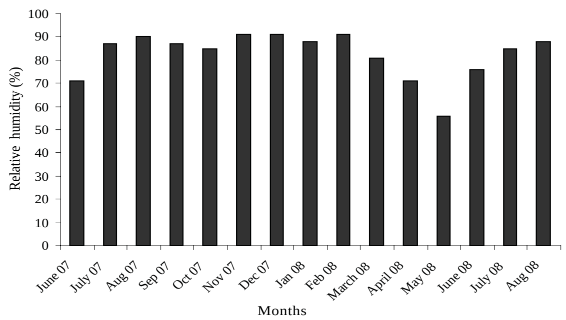

Figure 3 Daily average humidity at experimental site during study period.

The soil of the experimental site is sandy clay loam in texture (Rana 2008). The soil pH is 7.81 and the available nitrogen, phosphorus and potassium contents of the soil are 214, 13.8 and 12.8 kg/ha respectively (Rana 2008).

Experimental methodology

A fully grown fruit bearing large sized tree of this species was identified and marked for collection of branches. Only the branches free from insects and pathogens were harvested. Immediately after the removal of branches from the tree, they were wrapped in gunny bags to avoid desiccation during transportation from sampling site to the experimental area. The branches were harvested during two seasons Rainy (July 2007) and Spring (March 2008) from the same tree for planting during the respective seasons. The branches collected were given slanting cuts on both ends to obtain cuttings of 20 cm length, then the cuttings were sorted out according to two thickness (diameter) sizes (<

1.25 cm and 1.25-2.5 cm) using digital caliper. Care was taken to retain the cuttings with at least 3 buds. Paraffin wax was applied on the terminal portion of cutting to avoid the desiccation of tips of the cuttings.

The requisite concentrations of hormonal solutions were prepared. For application of hormones, the prepared cuttings were bundled into two sets of sizes < 1.25 cm and 1.25-2.5 cm, each set consisting 18 cuttings for each of 16 different treatments (3 hormones each at 5 concentration levels viz. 50, 100, 200, 500 and 1000 ppm + one control) for each diameter class and thereafter the cuttings were treated by dipping the basal 5 cm portion of each cutting in prepared concentrations of hormonal solutions for 24 hours.

The treated cuttings were planted 15 cm deep into the soil with the help of dibbler at a spacing of 30 cm x 30 cm in raised nursery beds of 1 m x 0.7 m. A light overhead watering was given immediately after planting so that cuttings get settled. Afterwards, the beds containing the planted cuttings were irrigated regularly as and when required. Weeding and hoeing was done at two weeks interval. Care was taken not to disturb the planted cuttings during these cultural operations. For rainy season, the cuttings were planted on 10th July, 2007 whereas in the spring the cuttings were planted on 1st March, 2008. The experiment was conducted in Factorial Randomized Block with 3 replications during each season. The treatments were as: (i) treatments: factor I - cutting diameter size (thickness): Small (< 1.25 cm) and Large (1.25-2.5 cm); factor II - 16 Hormonal treatments: 3 hormones each at 5 levels of concentration and one control; (ii) number of cutting planted per treatment in each diameter class = 06.

Each treatment was allocated randomly to different nursery beds for each diameter size class separately during both the study seasons. The growth and development characteristics of the cuttings were recorded after four months from their planting by uprooting the whole plants except for sprouting percentage, which was recorded after six weeks from planting. To estimate the root biomass, the roots of each uprooted plant were washed gently under tap water and these were placed on blotting paper to drain the excess water. Thereafter, data on number of roots and their biomass were recorded. All the data in the current study are reported per cutting-wise.

To know the root initiation time in different treatments and diameter size classes, a separate experiment was conducted. For each cutting diameter size, 12 cuttings per treatment were planted in beds at 30 cm x 30 cm spacing. Weekly data were recorded by uprooting two cuttings in systematic manner from each treatment for each diameter size class. The observations recorded included: survival percentage, time taken for root initiation, rooting percentage, number of lateral roots, root length, fresh and dry root biomass, number of shoots, average shoot length, number of leaves, leaf area, above ground biomass (fresh and oven dried). Leaf area was estimated using Systronics Leaf Area Meter 211 model. The dry root and above ground biomass was estimated by drying the samples (roots and above ground parts separately) in the oven at 80^{O}C for 48 hours and weighing the dried samples (Raizada & Srivastava 1989).

Data analysis

The data recorded on various parameters (survival percentage, rooting percentage, number of lateral roots, root length, fresh and dry root biomass, number of shoots, average shoot length, number of leaves, leaf area, and fresh and dry above ground biomass) were tested for normality using Kolmogorov-Smirnov test ($p < 0.05$) and were subjected to statistical analysis following the analysis of variance technique described by Gomez & Gomez (1984 at 5% level of significance using SPSS 16.0 software. The percentage data did not follow normal distribution as the observation varied considerably with 0-100% range and hence this data were transformed using the arc-sine transformation. For the data on number of lateral roots, number of shoots and leaves, square root transformations were performed as the data approximated the poisson distribution. Further, homogeneity of variances between rainy and spring season samples for each of the parameter studied was tested using F-test (Levene's test) of significance of variance between two groups, and it was found significant ($p < 0.05$). This implies that there was significant difference in variance between rainy and spring season samples for each respective parameter. Thus the analysis of season-wise pooled data was not performed, consequently, the data for each study season were statistically analyzed separately and have been presented accordingly in the results.

Results

The data on survival percentage and rooting percentage are similar, as in all the survived cuttings root formation took place. In both seasons, large sized cuttings resulted in significantly higher survival and rooting percentage than small sized (Table 1). The maximum mean survival (9.72%) and (37.17%) respectively was recorded in large sized cuttings in rainy and spring seasons (Table 1). In rainy season, IBA 100 ppm treated cuttings resulted in maximum mean survival and rooting per cent (33.33%), which was found statistically at par with those of IBA 50 ppm, IAA 100 ppm, NAA 50 ppm each having mean 19.44% survival and rooting percentage but significantly higher than all other remaining hormonal treatments. Nine treatments-IAA 200 ppm, IAA 500 ppm, IAA 1000, IBA 500 ppm, IBA 1000 ppm, NAA 200 ppm, NAA 500 ppm, NAA 1000 ppm and the control registered no survival. In spring, the hormonal treatment of IBA 100 ppm resulted in mean highest survival (69.43%) which was statistically higher than all other hormonal treatments (Table 2). During the current study, it was noticed that none of the cuttings survived in 3 treatments i.e. NAA 500 ppm, NAA 1000 ppm and control in the spring. The interaction of Cuttings size × Hormonal concentration significantly influenced survival percentage in both seasons (Table 1). In the rainy season the interaction of large size × IBA 100 ppm exhibited maximum survival and rooting per cent (38.88%) which was statistically at par with interactions large size × IBA 50 ppm, large size × IAA 100 ppm and large size × NAA 50 ppm. The later three interactions had same survival and rooting per cent (22.22%). Of all the interactions in spring season large size × IBA 100 ppm resulted in maximum survival and rooting per cent (77.77%) which was statistically at par with small size × IBA 100 ppm interaction having survival (61.10%) but significantly higher than all the remaining interactions.

Of 16 hormonal treatments, root initiation took place only in 7 treatments in each size class in rainy season, whereas, in spring root initiation took place only in 13 treatments in each size class (Table 2). In rainy season, the minimum (5 weeks) time was taken by the large sized cuttings treated with IBA 100 ppm (Table 2). This was followed by 6 weeks root initiation time in case of large sized cuttings treated with IBA 50 ppm, IAA 50 ppm and NAA 50 ppm. In case of spring season, a minimum of 4 weeks time was taken for roots initiation by the large sized cuttings treated with IBA 100 ppm. This was followed by large sized cuttings treated with IBA 50 ppm, IBA 200 ppm and IAA 100 ppm and small sized cuttings treated with IBA 50 ppm, where the root initiation time was 5 weeks.

During the rainy season, there was no effect of cutting size on number of lateral roots (NLR) and number of shoots (NSH) but the number of leaves (NL) was significantly influenced by cutting size (Table 3). Hormonal concentration significantly influenced number of lateral roots and number of leaves but there was no signifi-

Table 1 Effect of cutting diameter and hormonal application on survival and rooting percentage of branch cuttings of *Ficus roxburghii*

Hor-mone	Concen-tration	Rainy season			Spring		
		Small Size (< 1.25 cm)	Large Size (1.25-2.5 cm)	Mean	Small Size (< 1.25 cm)	Large Size (1.25-2.5 cm)	Mean
IAA	50 ppm	11.11 (19.46)	16.66 (24.04)	13.88 (21.81)	27.77 (31.76)	38.88 (38.53)	33.32 (35.24)
	100 ppm	16.66 (24.04)	22.22 (28.11)	19.44 (26.13)	33.33 (35.24)	44.44 (41.78)	38.88 (38.53)
	200 ppm	00.00 (00.00)	00.00 (00.00)	00.00 (00.00)	22.22 (28.11)	33.33 (35.24)	27.77 (31.76)
	500 ppm	00.00 (00.00)	00.00 (00.00)	00.00 (00.00)	16.66 (24.04)	27.77 (31.76)	22.21 (28.11)
	1000 ppm	00.00 (00.00)	00.00 (00.00)	00.00 (00.00)	16.66 (24.04)	16.66 (24.04)	13.88 (21.81)
IBA	50 ppm	16.66 (24.04)	22.22 (28.11)	19.44 (26.13)	44.44 (41.78)	55.55 (48.16)	49.99 (44.94)
	100 ppm	27.77 (31.76)	38.88 (38.53)	33.33 (35.24)	61.10 (51.41)	77.77 (61.82)	69.43 (56.42)
	200 ppm	11.11 (19.46)	16.66 (24.04)	13.88 (21.81)	27.77 (31.76)	38.88 (38.53)	33.32 (35.24)
	500 ppm	00.00 (00.00)	00.00 (00.00)	00.00 (00.00)	22.22 (28.11)	33.33 (35.24)	27.77 (31.76)
	1000 ppm	00.00 (00.00)	00.00 (00.00)	00.00 (00.00)	16.66 (24.04)	22.22 (28.11)	19.44 (26.13)
NAA	50 ppm	16.66 (24.04)	22.22 (28.11)	19.44 (26.13)	27.77 (31.76)	38.88 (38.53)	33.32 (35.24)
	100 ppm	11.11 (19.46)	16.66 (24.04)	13.88 (21.81)	22.22 (28.11)	33.33 (35.24)	27.77 (31.76)
	200 ppm	00.00 (00.00)	00.00 (00.00)	00.00 (00.00)	11.10 (19.46)	22.21(28.11)	16.65 (24.04)
	500 ppm	00.00 (00.00)	00.00 (00.00)	00.00 (00.00)	00.00 (00.00)	00.00 (00.00)	00.00 (00.00)
	1000 ppm	00.00 (00.00)	00.00 (00.00)	00.00 (00.00)	00.00 (00.00)	00.00 (00.00)	00.00 (00.00)
Control	No treatment	00.00 (00.00)	00.00 (00.00)	00.00 (00.00)	00.00 (00.00)	00.00 (00.00)	00.00 (00.00)
	Mean	06.94 (15.23)	09.72 (18.15)	08.33 (16.74)	26.91 (31.24)	37.17 (37.52)	31.82 (34.33)

Effect	CD (p = 0.05)*	
	Rainy season	Spring
Size (Diameter)	2.90	3.41
Hormonal concentration	9.13	8.71
Size x Hormonal concentration	12.92	12.32

Note: Figures in parentheses are transformed (arcsine) values.

cant effect in case of number of shoots. There was no effect of interaction on number of lateral roots, number of shoots and number of leaves during rainy season (Table 3). In spring the effect of cutting size, hormonal concentration and interaction was significant the on number of lateral roots, number of shoots and number of leaves except the effect of cutting size on the number of shoots where the effect was non-significant (Table 3). For the rainy season, the IBA 100 ppm treatment showed maximum (17.30) mean number of lateral roots which was statistically at par with IAA 50 ppm, IAA 100 ppm, IBA 50 ppm, IBA 200 ppm and NAA 50 ppm treatments (Table 3). In spring planted cuttings, IBA 100 ppm treatment showed highest (20.74) mean number of lateral roots which was statistically at par with IBA 50 ppm but significantly higher than all other remaining hormonal treatments (Table 3). In spring season, the interaction large size × IBA 100 ppm resulted in maximum (23.17)

Table 2 Effect of cutting diameter and hormonal application on survival and rooting percentage of branch cuttings of *Ficus roxburghii*

Hormone	Concentration	Rainy season		Spring	
		Small Size (< 1.25 cm)	Large Size (1.25-2.5 cm)	Small Size (< 1.25 cm)	Large Size (1.25-2.5 cm)
IAA	50 ppm	7	6	7	6
	100 ppm	9	7	6	5
	200 ppm	-	-	8	7
	500 ppm	-	-	9	8
	1000 ppm	-	-	9	9
IBA	50 ppm	9	6	6	5
	100 ppm	7	5	5	4
	200 ppm	9	7	8	5
	500 ppm	-	-	7	6
	1000 ppm	-	-	8	7
NAA	50 ppm	7	6	7	6
	100 ppm	9	7	8	7
	200 ppm	-	-	9	8
	500 ppm	-	-	-	-
	1000 ppm	-	-	-	-
Control	No treatment	-	-	-	-

number of lateral roots which was statistically at par with interaction small size × IBA 100 ppm and large size x IBA 50 ppm but had statistically significantly higher number of lateral roots than all the remaining interactions (Table 3).

In spring season, IBA 100 ppm treatment resulted in maximum mean number of shoots (2.41) which was statistically at par with IAA 100 ppm treatment (1.91) but significantly different from all other treatments. Large size x IBA 100 ppm interaction possessed highest (2.66) number of shoots in spring. This was statistically at par with interactions large size x IBA 50 ppm, large size x IAA 50 ppm, large size x IAA 100 ppm, large size x NAA 50 ppm, small size x IBA 100 ppm and small size x IAA 100 ppm but significantly different from remaining interactions (Table 3).

In rainy season, the maximum mean number of leaves was obtained (13.16) with IBA 100 ppm concentration which was statistically at par with that of IAA 100 ppm, IBA 50 ppm and NAA 50 ppm treatments. In spring season, IBA 100 ppm resulted in maximum mean number of leaves (19.42) which was significantly greater than all other hormonal treatments. In spring, the interaction large size × IBA 100 ppm had maximum number of leaves (22.34) which was statistically at par with small size × IBA 100 ppm (16.50) leaves but significantly different from all other remaining interactions (Table 3).

In rainy as well as spring season, cutting size, hormonal treatment and interaction of cutting size x hormonal significantly influenced root length (RL), fresh root biomass (FRB) and dry root biomass (DRB) (Table 4). Both the rainy and spring season planted large sized cuttings produced significantly higher root length (8.89 cm and 8.99 cm respectively) than that of small size (6.80 cm and 7.39 cm respectively). In both the rainy season and spring IBA 100 ppm treatment resulted in maximum mean root length (11.50 cm and 13.05 cm respectively) which was statistically higher than all other treatments in the respective season (Table 4). In the rainy season, interaction large size ×

Table 3 Effect of cutting diameter and hormonal application on survival and rooting percentage of branch cuttings of *Ficus roxburghii*

Hor-mone	Concen-tration	Para-meter	Rainy season			Spring		
			Small Size (< 1.25 cm)	Large Size (1.25-2.5 cm)	Mean	Small Size (< 1.25 cm)	Large Size (1.25-2.5 cm)	Mean
	50 ppm	NLR	7.52 (2.74)	13.52 (3.67)	10.52 (3.24)	15.46 (3.93)	16.64 (4.07)	16.05 (4.00)
		NSH	1.00 (1.00)	1.50 (1.22)	1.25 (1.11)	1.50 (1.22)	1.83 (1.34)	1.66 (1.28)
		NL	6.13 (2.47)	9.32 (3.05)	7.72 (2.53)	9.25 (3.04)	11.15 (3.33)	10.20 (3.19)
	100 ppm	NLR	13.32 (3.64)	14.15 (3.76)	13.73 (3.70)	16.24 (4.03)	17.70 (4.13)	16.65 (4.08)
		NSH	1.16 (1.07)	1.33 (1.15)	1.24 (1.11)	1.83 (1.35)	2.00 (1.41)	1.91 (1.37)
		NL	8.30 (2.89)	10.42 (3.23)	9.36 (3.05)	13.38 (3.65)	15.32 (3.91)	14.35 (3.78)
	200 ppm	NLR	-	-	-	11.15 (3.34)	12.52 (3.53)	11.83 (3.43)
IAA		NSH	-	-	-	1.33 (1.15)	1.50 (1.22)	1.41 (1.18)
		NL	-	-	-	8.72 (2.95)	9.54 (3.08)	9.13 (3.02)
	500 ppm	NLR	-	-	-	7.83 (2.79)	9.12 (3.05)	8.47 (2.90)
		NSH	-	-	-	1.16 (1.07)	1.33 (1.15)	1.24 (1.11)
		NL	-	-	-	8.52 (2.91)	9.25 (3.04)	8.88 (2.97)
	1000 ppm	NLR	-	-	-	3.19 (1.78)	6.19 (2.48)	4.69 (2.16)
		NSH	-	-	-	1.00 (1.00)	1.16 (1.07)	1.08 (1.03)
		NL	-	-	-	4.77 (2.18)	7.71 (2.78)	6.24 (2.49)
	50 ppm	NLR	12.18 (3.48)	14.26 (3.77)	13.22 (3.63)	15.42 (3.92)	18.12 (4.25)	16.77 (4.09)
		NSH	1.16 (1.07)	1.66 (1.28)	1.41 (1.18)	1.50 (1.22)	1.83 (1.35)	1.66 (1.28)
		NL	9.68 (3.11)	10.87 (3.30)	10.27 (3.20)	12.34 (3.51)	14.56 (3.81)	13.45 (3.66)
	100 ppm	NLR	16.14 (4.01)	18.47 (4.29)	17.30 (4.15)	18.32 (4.27)	23.17 (4.81)	20.74 (4.54)
		NSH	1.33 (1.15)	2.16 (1.46)	1.74 (1.30)	2.16 (1.47)	2.66 (1.63)	2.41 (1.55)
		NL	11.12 (3.33)	15.21 (3.90)	13.16 (3.61)	16.50 (4.06)	22.34 (4.72)	19.42 (4.40)
	200 ppm	NLR	7.41 (2.72)	12.48 (3.53)	9.94 (3.15)	12.17 (3.48)	13.36 (3.65)	12.76 (3.57)
IBA		NSH	1.00 (1.00)	1.50 (1.22)	1.25 (1.11)	1.33 (1.15)	1.50 (1.22)	1.41 (1.18)
		NL	6.24 (2.49)	10.15 (3.18)	8.19 (2.61)	10.62 (3.25)	13.18 (3.63)	11.90 (3.44)
	500 ppm	NLR	-	-	-	8.42 (2.90)	9.27 (3.04)	8.84 (2.97)
		NSH	-	-	-	1.16 (1.07)	1.33 (1.15)	1.24 (1.11)
		NL	-	-	-	8.45 (2.90)	9.36 (3.06)	8.90 (2.98)
	1000 ppm	NLR	-	-	-	5.18 (2.27)	6.25 (2.49)	5.71 (2.38)
		NSH	-	-	-	1.00 (1.00)	1.16 (1.07)	1.08 (1.03)
		NL	-	-	-	6.58 (2.56)	7.54 (2.74)	7.06 (2.65)
	50 ppm	NLR	10.36 (3.21)	12.39 (3.51)	11.37 (3.37)	11.14 (3.33)	15.74 (3.96)	13.44 (3.65)
		NSH	1.16 (1.07)	1.33 (1.15)	1.24 (1.11)	1.50 (1.22)	1.66 (1.28)	1.58 (1.25)
		NL	7.64 (2.76)	9.16 (3.03)	8.40 (2.89)	9.27 (3.04)	11.31 (3.36)	10.29 (3.20)
	100 ppm	NLR	6.10 (2.46)	10.17 (3.18)	8.13 (2.85)	9.69 (3.10)	13.86 (3.72)	11.77 (3.41)
NAA		NSH	1.00 (1.00)	1.16 (1.07)	1.08 (1.03)	1.33 (1.15)	1.50 (1.22)	1.41 (1.18)
		NL	5.10 (2.25)	8.46 (2.90)	6.78 (2.37)	8.82 (2.96)	12.16 (3.48)	10.49 (3.23)
	200 ppm	NLR	-	-	-	4.18 (2.04)	7.16 (2.67)	5.67 (2.38)
		NSH	-	-	-	1.00 (1.00)	1.16 (1.07)	1.08 (1.03)
		NL	-	-	-	4.08 (2.01)	7.24 (2.69)	5.66 (2.37)
	Mean	NLR	10.43 (3.22)	13.63 (3.69)	11.89 (3.44)	10.64 (3.26)	12.95 (3.54)	11.79 (3.43)
		NSH	1.11 (1.05)	1.52 (1.23)	1.31 (1.14)	1.36 (1.16)	1.58 (1.25)	1.47 (1.21)
		NL	7.74 (2.78)	10.51 (3.24)	9.12 (3.01)	9.33 (3.05)	11.58 (3.40)	10.45 (3.23)

Table 3 (continuation)

Effect	Parameter	CD (p = 0.05)*	
		Rainy season	Spring
Size (Diameter)	NLS	NS	0.17
	NSH	NS	NS
	NL	0.45	0.18
Hormonal concentration	NLS	1.06	0.45
	NSH	NS	0.26
	NL	0.97	0.48
Size x Hormonal concentration	NLS	NS	0.63
	NSH	NS	0.38
	NL	NS	0.68

Note: NLS - Number of lateral shoots, NSH - Number of shoots, NL - Number of leaves. Figures in parentheses are transformed (square root) values.

IBA 100 ppm showed maximum root length (12.24 cm) which was statistically at par with the interactions small size cuttings × IBA 100 ppm and large size cuttings × IAA 100 ppm but was significantly longer than all other interactions. Among all the interactions in spring season, the longest root length (14.76 cm) was also recorded with large size × IBA 100 ppm interaction which was significantly longer than all other interactions (Table 4).

The fresh and dry root biomass has also been reported per cutting-wise (Table 4). In both the seasons, large sized cuttings resulted in significantly higher fresh and dry root biomass (0.92 g and 1.54 g respectively) than that of small sized (0.55 g and 1.13 g respectively). In rainy season as well spring season, IBA 100 ppm treatment resulted in maximum mean fresh root biomass (1.47 g and 3.07 g respectively) which was found to be statistically higher than all the other hormonal treatments. Large size × IBA 100 ppm concentration produced maximum fresh root biomass (1.80 g and 3.67 g) in rainy and spring respectively which was significantly higher than all other remaining interactions in the respective seasons (Table 4). The rainy as well spring season planted cuttings produced significantly more dry root biomass (0.31 g and 0.46 g respectively) with large size than that of small size (0.19 g and 0.34 g respectively). In rainy as well as spring season, maximum mean dry root biomass (0.50 g and 0.88 g respectively) was obtained with IBA 100 ppm treatment which was significantly higher than all other hormonal treatments. In rainy and spring seasons, the interactions of large size x IBA 100 ppm resulted in highest dry root biomass (0.62 g and 1.02 g) which was significantly higher than other interactions in the respective season

In both the seasons, large sized cuttings produced significantly longer shoots than small sized cuttings (Table 5). In both the study seasons, shoot length (SL) was also significantly influenced by the hormonal treatments (Table 5). In rainy season, IBA 100 ppm showed maximum mean shoot length (10.45 cm) which was statistically at par with IBA 50 ppm, IAA 100 ppm and NAA 50 ppm treatments. In spring season, IBA 100 ppm treatment resulted in a mean shoot length of 13.94 cm which was statistically longer than all other treatments (Table 5). In the rainy season the interaction effect was non-significant whereas in spring the interaction of large size × IBA 100 ppm resulted in longest shoot (15.34 cm) which was statistically longer than all other interactions (Table 5).

In rainy and spring seasons the leaf area (LA) per cutting was significantly higher (441.55 cm^2 and 909.71 cm^2 respectively) with large sized cuttings than that of small sized cuttings (300.76 cm^2 and 784.41 cm^2 respectively). The leaf area was also significantly influenced by the hormonal treatments in both the study seasons (Table 5). In rainy as well as

Table 4 Effect of diameter and hormonal application on root length, and fresh and dry root biomass of *Ficus roxburghii* branch cuttings.

Hormone	Concentration	Parameter	Rainy season Small Size (< 1.25 cm)	Rainy season Large Size (1.25-2.5 cm)	Rainy season Mean	Spring Small Size (< 1.25 cm)	Spring Large Size (1.25-2.5 cm)	Spring Mean
IAA	50 ppm	RL	4.94	8.47	6.70	8.12	9.61	8.86
		FRB	0.30	0.72	0.51	1.22	1.63	1.42
		DR	0.11	0.24	0.17	0.36	0.42	0.39
	100 ppm	RL	8.12	9.34	8.73	8.82	10.17	9.49
		FRB	0.74	1.15	0.94	1.78	2.32	2.05
		DRB	0.25	0.37	0.31	0.57	0.68	0.62
	200 ppm	RL	-	-	-	7.34	8.82	8.08
		FRB	-	-	-	1.14	1.32	1.23
		DRB	-	-	-	0.30	0.39	0.34
	500 ppm	RL	-	-	-	6.75	7.94	7.34
		FRB	-	-	-	0.78	1.09	0.93
		DRB	-	-	-	0.25	0.32	0.28
	1000 ppm	RL	-	-	-	4.08	6.72	5.40
		FRB	-	-	-	0.44	0.65	0.54
		DRB	-	-	-	0.13	0.21	0.17
IBA	50 ppm	RL	7.42	8.38	7.90	8.47	9.31	8.89
		FRB	0.76	1.20	0.98	1.83	2.17	2.00
		DRB	0.26	0.41	0.33	0.52	0.66	0.59
	100 ppm	RL	10.76	12.24	11.50	11.34	14.76	13.05
		FRB	1.14	1.80	1.47	2.47	3.67	3.07
		DRB	0.39	0.62	0.50	0.75	1.02	0.88
	200 ppm	RL	4.84	8.15	6.49	8.12	9.15	8.63
		FRB	0.28	0.61	0.44	1.42	1.81	1.62
		DRB	0.10	0.21	0.15	0.44	0.61	0.52
	500 ppm	RL	-	-	-	7.47	8.35	7.91
		FRB	-	-	-	0.94	1.21	1.07
		DRB	-	-	-	0.32	0.42	0.37
	1000 ppm	RL	-	-	-	6.25	7.79	7.02
		FRB	-	-	-	0.54	0.78	0.66
		DRB	-	-	-	0.18	0.25	0.21
NAA	50 ppm	RL	7.42	8.37	7.89	7.86	8.78	8.32
		FRB	0.46	0.62	0.54	1.14	1.58	1.36
		DRB	0.16	0.22	0.19	0.32	0.52	0.42
	100 ppm	RL	4.56	7.31	5.93	7.31	8.15	7.73
		FRB	0.18	0.38	0.28	0.76	1.15	0.95
		DRB	0.08	0.15	0.11	0.26	0.37	0.31
	200 ppm	RL	-	-	-	4.26	7.43	5.84
		FRB	-	-	-	0.31	0.63	0.47
		DRB	-	-	-	0.10	0.21	0.15
	Mean	RL	6.80	8.89	7.84	7.39	8.99	8.19
		FRB	0.55	0.92	0.73	1.13	1.54	1.33
		DRB	0.19	0.31	0.25	0.34	0.46	0.40

Table 4 (continuation)

Effect	Parameter	CD (p = 0.05) Rainy season	Spring
Size (Diameter)	RL	1.20	0.49
	FRB	0.08	0.09
	DRB	0.01	0.01
Hormonal concentration	RL	2.25	1.25
	FRB	0.15	0.21
	DRB	0.03	0.04
Size x Hormonal concentration	RL	3.18	1.78
	FRB	0.21	0.29
	DRB	0.05	0.06

Note: RL - Root length, FRB - Fresh root biomass, DRB - Dry root biomass.

spring season, IBA 100 ppm treatment resulted in maximum mean leaf area (1347.92 cm^2 and 1659.68 cm^2 respectively) which was significantly higher than all other hormonal treatments in the respective seasons (Table 5). The effect of interaction Cutting size x Hormonal treatment was also significant with respect to leaf area in both the study seasons (Table 5). In rainy season, the interaction large size x IBA 100 ppm resulted in highest leaf area (1457.28 cm^2) which was statistically at par with interaction small size x IBA 100 ppm having leaf area of 1238.70 cm^2 but was significantly higher than all other interactions (Table 5). In spring season, the same interaction resulted in maximum leaf area (1794.12 cm^2), however, in this case it was significantly different than all other interactions.

In both the rainy and spring season fresh above ground biomass (FAGB) (35.04 g and 31.61 g respectively) was significantly higher in large sized cuttings compared to small sized (24.20 g and 26.67 g) (Table 5). IBA 100 ppm resulted in statistically significanty higher FAGB than all other hormonal treatments in both the study seasons (Table 5). In both the seasons, the interaction large size x IBA 100 ppm resulted in highest fresh above ground biomass (53.28 g and 71.16 g in rainy and spring respectively) which was significantly higher than all other interactions (Table 5).

In both the study seasons the large sized cuttings produced significantly higher dry above ground biomass (DAGB) than that of small sized cuttings (Table 5). In both the seasons, IBA 100 ppm treatment resulted in highest dry above ground biomass which was statistically superior to other hormonal treatments (Table 5). The interaction large size x IBA 100 ppm had the maximum dry above ground biomass (11.23 g and 16.28 g respectively) in rainy and spring seasons. In rainy season this interaction was statistically at par with small size x IBA 100 ppm and large size x IBA 50 ppm interactions. However, in spring it had statistically significantly higher dry above ground biomass than all the remaining interactions (Table 5).

In both the seasons large size cuttings resulted in significantly higher root: shoot ratio (dry weight basis) than that of small cuttings (Table 6). The maximum root: shoot ratio (0.035) was obtained in large size compared to small size (0.031) in rainy season. Similarly, it was 0.049 in large sized cuttings compared to 0.043 in small sized cuttings in spring season (Table 6). Root: shoot ration was also influenced significantly by the hormonal treatments in rainy and spring seasons (Table 6). In the rainy season IBA 100 ppm treatment resulted in maximum root: shoot ratio (0.048) on dry weight basis which was significantly higher than all other treatments. In spring season also, IBA 100 ppm treatment resulted in maximum root: shoot ratio (0.060) which was at par with IBA 50 ppm, IBA 200 ppm and IAA 100 ppm treatments. In rainy season, interaction large size x IBA

Table 5 Effect of diameter and hormonal application on shoot length, leaf area and fresh and dry above ground biomass in *Ficus roxburghii* branch cuttings

Hormone	Concentration	Parameter	Rainy season			Spring		
			Small Size (< 1.25 cm)	Large Size (1.25-2.5 cm)	Mean	Small Size (< 1.25 cm)	Large Size (1.25-2.5 cm)	Mean
IAA	50 ppm	SL	4.61	7.63	3.06	7.85	8.12	7.98
		LA	389.00	986.43	687.79	1054.67	1158.76	1106.71
		FAGB	15.96	31.64	23.80	34.51	41.82	38.16
		DAGB	3.87	7.64	5.75	7.21	8.69	7.95
	100 ppm	SL	8.12	8.56	8.34	8.18	8.65	8.41
		LA	786.00	878.96	832.69	1146.21	1254.46	1200.33
		FAGB	27.36	36.87	32.11	49.33	56.31	52.82
		DAGB	6.54	8.78	7.66	10.43	11.94	11.18
	200 ppm	SL	-	-	-	7.36	7.40	7.38
		LA	-	-	-	924.82	1082.28	1003.55
		FAGB	-	-	-	32.48	35.22	33.85
		DAGB	-	-	-	6.80	7.44	7.12
	500 ppm	SL	-	-	-	6.85	7.28	7.06
		LA	-	-	-	892.31	987.24	939.77
		FAGB	-	-	-	26.12	29.62	27.87
		DAGB	-	-	-	6.64	7.21	6.92
	1000 ppm	SL	-	-	-	6.40	6.95	6.67
		LA	-	-	-	552.81	887.57	720.19
		FAGB	-	-	-	15.46	21.18	18.32
		DAGB	-	-	-	3.86	6.01	4.84
IBA	50 ppm	SL	8.34	9.16	8.75	9.01	10.24	9.62
		LA	948.64	168.59	1008.60	1136.37	1325.86	1231.11
		FAGB	32.15	38.14	35.14	47.12	53.59	50.35
		DAGB	7.72	9.15	8.43	9.62	11.35	10.48
	100 ppm	SL	9.38	11.52	10.45	12.55	15.34	13.94
		LA	1238.70	1457.28	1347.90	1525.24	1794.12	1659.68
		FAGB	39.17	53.28	46.22	63.49	71.16	67.32
		DAGB	9.36	11.23	10.29	12.87	16.28	14.57
	200 ppm	SL	5.01	8.17	6.59	8.51	9.12	8.81
		LA	388.32	976.43	682.37	1121.18	1224.81	1172.99
		FAGB	15.52	33.78	24.65	39.36	48.82	44.09
		DAGB	3.72	8.07	5.89	8.28	10.28	9.28
	500 ppm	SL	-	-	-	7.98	8.72	8.35
		LA	-	-	-	928.47	964.22	946.34
		F AGB	-	-	-	31.29	34.69	32.99
		DAGB	-	-	-	6.59	7.30	6.94
	1000 ppm	SL	-	-	-	6.80	7.68	7.24
		LA	-	-	-	742.62	897.36	819.99
		FAGB	-	-	-	20.44	23.82	22.13
		DAGB	-	-	-	5.13	5.88	5.50
NAA	50 ppm	SL	7.15	7.86	7.50	7.82	8.15	7.98
		LA	742.94	884.63	813.78	1089.41	1124.36	1106.88
		FAGB	26.67	30.12	28.39	32.61	38.62	35.61
		DAGB	6.28	7.21	6.74	7.23	9.84	8.53
	100 ppm	SL	4.60	7.23	5.91	7.24	7.86	7.55
		LA	317.91	812.52	565.21	914.82	972.41	490.77
		FAGB	12.58	21.49	17.03	24.17	32.81	28.49
		DAGB	3.06	6.74	4.90	6.87	8.82	7.84

Table 5 (continuation)

Hormone	Concentration	Parameter	Rainy season Small Size (< 1.25 cm)	Rainy season Large Size (1.25-2.5 cm)	Rainy season Mean	Spring Small Size (< 1.25 cm)	Spring Large Size (1.25-2.5 cm)	Spring Mean
NAA	200 ppm	SL	-	-	-	3.74	6.72	5.23
		LA	-	-	-	521.70	882.36	702.30
		FAGB	-	-	-	10.48	18.24	14.36
		DAGB	-	-	-	3.12	5.64	4.38
	Mean	SL	6.74	8.59	7.66	7.71	8.63	8.17
		LA	300.76	441.55	371.14	784.41	909.71	818.77
		FAGB	24.20	35.04	29.62	26.67	31.61	29.14
		DAGB	2.53	3.67	3.10	5.90	7.29	6.59

Effect	Parameter	CD (p = 0.05) Rainy season	CD (p = 0.05) Spring
Size (Diameter)	SL	1.67	0.50
	LA	92.32	60.30
	FAGB	3.91	1.68
	DAGB	0.90	0.43
Hormonal concentration	SL	3.14	1.28
	LA	172.72	153.74
	FAGB	7.32	4.30
	DAGB	1.69	1.11
Size x Hormonal concentration	SL	NS	1.81
	LA	244.27	217.42
	FAGB	10.36	6.08
	DAGB	2.39	1.58

Note: SL - Shoot length, LA - Leaf area, FAGB - Fresh above ground biomass, DAGB - Dry above ground biomass.

100 ppm resulted in maximum root: shoot ratio (0.055). This interaction had statistically higher root: shoot ratio than all the remaining interactions. Similarly, in spring season the same interaction resulted in maximum root: shoot ratio (0.062) which was found to be at par with interactions large size x IBA 50 ppm, small size x IBA 100 ppm, large size x IAA 100 ppm, small size x IAA 100 ppm, small size x IBA 50 ppm, large size x IBA 200 ppm and large size x IBA 500 ppm (Table 6).

Discussion

The rooting percentage was significantly higher in large sized cuttings than that of small sized. Similar results were noticed by Navjot & Kahlon (2007) in pomegranate (*Punica granatum*). In vegetative propagation, the sprouting depends on food reserves available within the cuttings (Wright 1975). These larged sized cuttings usually have higher sprouting owing to more food reserve available in these. For the same reason the rooting percent in large sized cuttings was also higher. The early root formation in the large sized cuttings could also be attributed to early sprouting which might have resulted in formation of rooting hormones in the sprouts. Similar observations of early rooting were recorded in IBA treated *Thymus vulgaris* cuttings by Chandregowda et al. (2006). Early root initiation enables the plant to absorb sufficient water and nutrients from soil, thereby resulting in more survival of the cuttings, but the cuttings in which the root formation is delayed or does not take place, those get wilted and ultimately die causing poor survival rate (Sadhu 1996). Thus, the survival was higher in large sized cuttings owing to early root initiation in the current study. Also, the large sized cuttings are less liable to desiccation in comparison to small sized consequently, the former resulted in higher survival. The increased sur-

Table 6 Effect of diameter and hormonal application on root: shoot ratio of *Ficus roxburghii* branch cuttings

Hormone	Concentration	Rainy season			Spring		
		Small Size (< 1.25 cm)	Large Size (1.25-2.5 cm)	Mean	Small Size (< 1.25 cm)	Large Size (1.25-2.5 cm)	Mean
IAA	50 ppm	0.028	0.031	0.029	0.049	0.048	0.048
	100 ppm	0.038	0.042	0.040	0.054	0.056	0.055
	200 ppm	-	-	-	0.044	0.052	0.048
	500 ppm	-	-	-	0.037	0.044	0.040
	1000 ppm	-	-	-	0.016	0.034	0.025
IBA	50 ppm	0.033	0.044	0.038	0.054	0.058	0.056
	100 ppm	0.041	0.055	0.048	0.058	0.062	0.060
	200 ppm	0.026	0.026	0.026	0.053	0.059	0.056
	500 ppm	-	-	-	0.048	0.057	0.052
	1000 ppm	-	-	-	0.035	0.042	0.038
NAA	50 ppm	0.025	0.030	0.027	0.044	0.052	0.048
	100 ppm	0.026	0.022	0.024	0.037	0.041	0.039
	200 ppm	-	-	-	0.032	0.037	0.034
	Mean	0.031	0.035	0.033	0.043	0.049	0.046

Effect	CD (p = 0.05) Rainy season	Spring
Size (Diameter)	0.002	0.002
Hormonal concentration	0.005	0.006
Size x Hormonal concentration	0.007	0.008

vival percentage with the use of IBA in apple stem cuttings was also reported by Lone & Sofi (2007).

The number of roots per cutting, root length, root biomass (fresh and dry) shoot length, number of leaves, above ground biomass were also higher in large sized cuttings in the current study. Zhang et al. (2010) also reported a significant increase in root length, root biomass and shoot length of cuttings with increase in diameter of cuttings in *Feijoa sellowiana*. This was possibly because of early root initiation in large sized cuttings which provided longer time for their growth and development. The higher food reserve in large sized cuttings could be another reason for their better growth and development of the cuttings.

All the studied growth and development parameters (survival and rooting percents, number of roots, root length, number of shoots, shoot length, leaf area, fresh and dry root biomass, fresh and dry above ground biomass and root: shoot ratio) showed an increasing trend from 50 ppm to 100 ppm concentration in case IAA and IBA in spring as well as rainy season. Then a decreasing trend in these parameters was noticed with increase in concentration of these hormones up to 1000 ppm in both the study seasons. This implies that 100 ppm is optimum concentration of IAA and IBA to induce rooting in this species. In case of NAA there was a consistent decline in the studied growth and development characteristics with increase in concentration from 50 ppm onwards in rainy as well spring season. However, the overall growth and development of cuttings was better with IBA 100 ppm than that of IAA 100 ppm and NAA 50 ppm. Thus IBA 100 ppm is superior amongst all the hormonal treatments in terms and growth and development of planted cuttings in both the study seasons. The overall better growth and development with IBA treatment could be because of its greater stability, transportability, ability to produce roots and consequently results in lower morality in plants (Shagoo et al. 2007). Further, this could also be attributed to the fact that growth hormones determine cell elongation and cell division thereby promoting roots length (Abidin & Baker 1984) and consequently resulting better overall growth of the cuttings.

Conclusion

It is implicit from the study that *Ficus roxburghii* is amenable to cloning to varying extent by hormonal treatment in spring as well as rainy season, and higher success and growth rate can be obtained by using branch cuttings treated with IBA 100 ppm. Large sized cuttings resulted in better success and growth of the cuttings than small sized cuttings in both the seasons. The root and shoot parameters had higher values in rooted cuttings in spring season than in the rainy in respective hormonal treatments. This implies that spring season is better for inducing growth and development in cuttings of *Ficus roxburghii*. Thus IBA 100 ppm treatment of large sized cuttings in spring is the most superior treatment combination to obtain better growth and development of the cuttings. This method of propagation has potential to lower the fruit bearing period and would also act as incentive to farmers to plant this species in agroforestry systems in areas of its occurrence. Studies need to be undertaken to investigate the effect of this method on the reduction of the fruit bearing period, and growth and development of tree under field planting conditions.

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