

## Time of Collection, Cutting Ages, Auxin Types and Concentrations Influence Rooting *Ficus religiosa* L. Stem Cuttings

Mohamadreza Salehi Salmi<sup>1,2\*</sup> and Mohsen Hesami<sup>2</sup>

1- Researcher of Etkra Organization Research and Development Center, Iran.

2- Department of Horticulture science, Ramin University of Agriculture and Natural Resources, Khoozestan, Iran.

Received: September 18, 2015

Accepted: October 20, 2015

### ABSTRACT

In many temperate and sub-tropical regions, plants exposed to seasonal changes. Changes in weather affect growth and the ability of stock plants to provide cutting material that forms adventitious roots. *Ficus religiosa* is widely cultivated in various areas of the world and can be propagated by several techniques namely, by seed or by vegetative methods. However vegetative method of *F. religiosa* still remains as an experimental procedure, more studies are required to commercialize it. In this study, Semi-hardwood and hardwood cutting were collected in beginning of each season and cuttings were treated with IBA, NAA and 2,4-D at four concentrations (0, 250, 500 and 1000 ppm) for 24 hr. For each treatment, rooting ability and percentage of surviving plants were evaluated at 12 and 24 weeks after planting, respectively. In order to gain knowledge on physiological responses of plant to seasonal changes, Soluble sugar, net CO<sub>2</sub> assimilation and transpiration rate of leaf were measured. Satisfactory rooting of *F. religiosa* cuttings was observed when collection time occurred in December 20<sup>th</sup>, whereas cuttings collected in June showed a limited capacity of rooting in both cuttings. Rooting was more successful when cuttings were soaked in 1000 ppm IBA or 500 ppm NAA. After acclimatization, maximum survival rate of plants was 94.8 %. The current findings confirm that collection times and cutting ages affect *F. religiosa* rooting. Also auxins can be a useful substance for increasing rooting ability in cuttings.

**KEY WORDS:** Cutting; Plant growth regulators; Rooting; Surviving

### 1. INTRODUCTION

*Ficus religiosa* Linn (Moraceae) is a deciduous tree native of the sub-Himalayan tract, Bengal and central India. It is widely cultivated in various areas of the world [1, 2]. As its name implies, is one of the most venerated trees in the world and since ancient times it is regarded as holy by millions of people-Buddhists as well as Hindus-in Southeast Asia [2]. Different parts of this plant have been used traditionally for the treatment of different types of diseases. The variety of biological activities that have been reported for it are antibacterial [3], anticonvulsive [4], anti-diabetic [5] and antinephropathic [6]. It is also widely planted as a street or park tree in tropical and sub-tropical countries worldwide [7]. *F. religiosa* can be propagated by several techniques namely, by seed or by vegetative methods [7]. The best propagation method is one of the uncertainties for planting on large scale. Although the direct seeding method can result in lower survival rate, the plants have the potential to be more tolerant to abiotic and biotic stresses. On the other hand, stem cutting method is recommended for quicker establishment and faster production. The disadvantage of stem cutting method is that it is required that a high volume of propagative material to be transported [2, 8, 9]. However vegetative method of *F. religiosa* still remains as an experimental procedure, more studies are required to commercialize it. In many temperate and sub-tropical regions, plants exposed to seasonal changes. Changes in temperature, humidity, wind, day length and rainfall affect growth and the ability of stock plants to provide cutting material that forms adventitious roots [10, 11, 12, 13]. In difficult-to-root tree, rooting was confined to periods of active shoot growth. In contrast, the easy-to-root tree, well during the summer regardless of the shoot growth rate. It has been reported that difficult-to-root *Backhousia citriodora* will not produce adventitious roots from cuttings during the colder months and during flowering [14]. Flowering of *B. citriodora* in southeastern Queensland is reported to occur from spring to summer [15]. The present study was undertaken with the following two primary objectives: (1) to investigate effect of collection time and cutting ages (semi-hardwood and hardwood) on root ability, and (2) to assess the effect of growth stimulating hormones.

\* **Corresponding Author:** M. R. Salehi-Salmi, Ramin University of Agriculture and Natural Resources, Department of Horticulture, Khoozestan, Iran. E.mail: m\_salehisalmi@yahoo.com

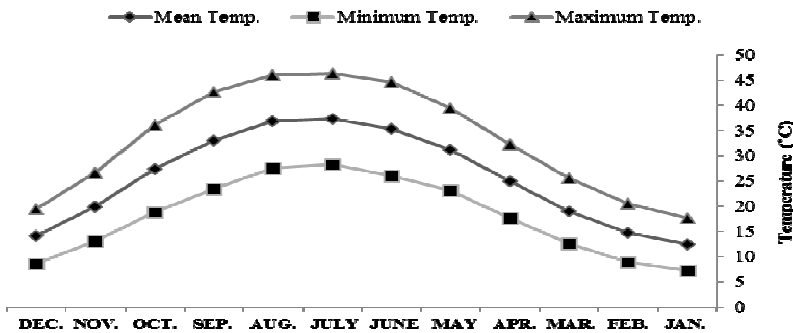
## 2. MATERIALS AND METHODS

### 2.1. Plant materials

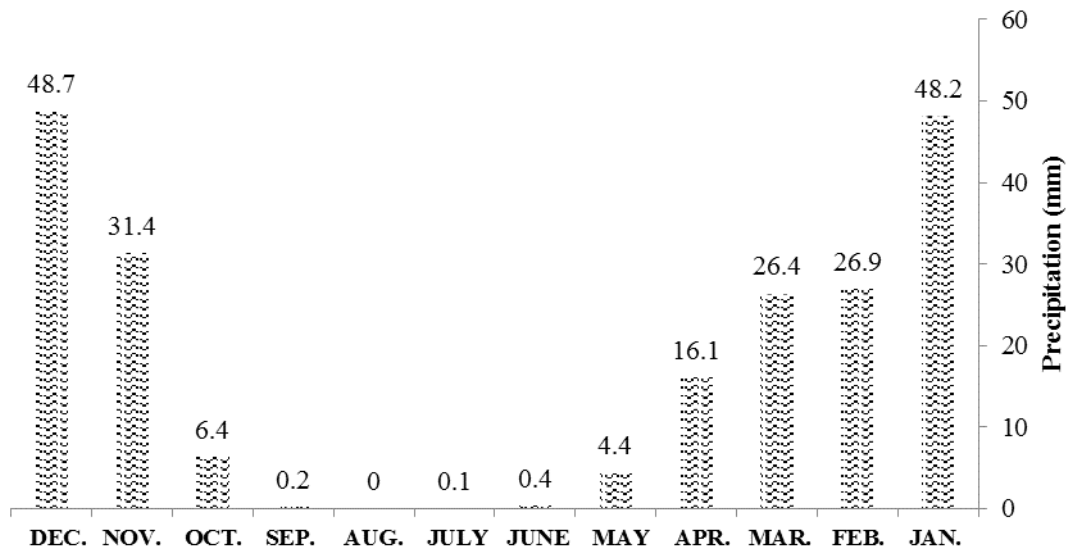
Semi-hardwood and hardwood were collected on March<sup>20<sup>th</sup></sup>, June<sup>20<sup>th</sup></sup>, September 20<sup>th</sup> and December 20<sup>th</sup> from 30 year old *F. religiosa* mother plants in a field grown at campus of Ramin Agricultural and Natural Resources University, Ahwaz, Iran (The meteorological data shown in Fig. 1 and Fig. 2).

### 2.2. Greenhouse conditions

The study was carried out in greenhouse located at the university. The propagation unit was supplemented with a fogging system, which worked automatically, based on the humidity of the greenhouse. Minimum and maximum temperatures during the experimental period were 15°C and 25°C in winter; 17.5°C and 30°C in spring; 20°C and 34°C in summer; 15°C and 28°C in fall, respectively. A shade net was placed over the greenhouse to prevent excessive heat, as necessary. In order to control fungal disease, 2% carbendazol was sprayed weekly during the rooting period.



**Figure 1.** Minimum, maximum and mean monthly temperature at campus of Ramin Agricultural and Natural Resources University, Ahwaz, Iran.



**Figure 2.** Monthly total of precipitation (mm) at campus of Ramin Agricultural and Natural Resources University, Ahwaz, Iran.

### 2.3. Treatments and measurements

In each times, two types (semi-hardwood and hardwood) of cuttings were treated with IBA, NAA and 2,4-D at four concentrations (0, 250, 500 and 1000 ppm) for 24 hr. Plant growth regulators were prepared in liquid form using absolute ethyl alcohol which was diluted to 50% with distilled water. The control was 50% ethyl alcohol. After 12 weeks cuttings were removed from the media, and rooting percentage, number of roots per rooted cutting, root lengths, number and accumulated length of stems were measured. All rooted cuttings were planted in containers

and placed in an environmentally controlled greenhouse. The percentage of surviving plants was determined after 10 weeks.

**2.4. Physiological responses of leaf plant to seasonal changes**

In order to gain knowledge on the physiological responses of plant to seasonal changes, some parameters of leaf were measured. Leaf gas exchange (net CO<sub>2</sub> assimilation rate and transpiration rate) were measured with a portable photosynthetic open-system (Li-6400) with the leaf chamber parameters light intensity (PARin) at 2000 μmol<sub>photon</sub>m<sup>-2</sup> s<sup>-1</sup> supplied by a red light diode source on the adaxial leaf surface, and CO<sub>2</sub> concentration, provided by an external CO<sub>2</sub> tank, at 360 μmol mol<sup>-1</sup>. Forty leaves were randomly selected from mother plant on March 20<sup>th</sup>, June 20<sup>th</sup>, September 20<sup>th</sup> and December 20<sup>th</sup> during 1 year and each ten leaves represented a replication during statistical analysis. Samples were analyzed using the perchloric acid/anthrone method to measure [16].

**2.5. Experimental design and statistical analysis**

The experiment was carried out as a factorial experiment based on randomized complete blocks design with four replications (20 cuttings per replication). The significant mean differences (p<0.05) were detected using LSD's pair-wise comparisons.

**3. RESULTS**

**3.1. Rooting percentage**

Relevant data in Table 1 showed that semi-hardwood cuttings were collected on 20 December and treated with 1000 ppm IBA, had maximum rooting percentage (98%). Minimum rooting percentage related to semi-hardwood cuttings were collected on June 20<sup>th</sup> without treatments (8%). Also, the results showed that collecting on December 20<sup>th</sup> was more effective than either times of collection. Data presented in (Table 1) showed that the rooting percentage was significantly increased as a result of using of plant growth regulators, as compared to the control. The rooting percentage was more in IBA comparison with NAA and 2,4-D. Although, high concentrations of NAA and 2,4-D result in decreasing rooting percentage.

**Table 1** The effects of Time of collection, cutting ages, auxin types and concentrations on rooting percentage.

		March 20 <sup>th</sup>		June 20 <sup>th</sup>		September 20 <sup>th</sup>		December 20 <sup>th</sup>		
		ppm	semi-hard	hard	semi-hard	hard	semi-hard	hard	semi-hard	hard
IBA	0	17	17	8	12	35	27	38	34	
	250	20	21	17	17	52	49	54	49	
	500	59	54	24	25	78	66	83	76	
	1000	73	70	35	42	83	89	98	90	
NAA	0	17	18	13	9	34	27	38	35	
	250	39	37	24	19	46	40	71	65	
	500	65	64	32	27	58	58	69	67	
	1000	52	47	40	43	50	46	58	49	
2,4-D	0	16	18	14	9	33	28	41	36	
	250	60	55	35	32	49	46	64	59	
	500	57	51	20	21	34	34	52	44	
	1000	20	17	16	17	25	26	29	27	
<b>LSD (P&lt;0.05)</b>		5.15	5.28	4.03	4.45	7.07	5.85	9.62	6.12	
<b>Each value is a mean of four independent replicates.</b>										

**3.2. Number of roots per rooted cutting**

The effects of time of collection, cutting ages, auxin types and concentrations on number of roots per rooted cutting of old *F. religiosa* were detected (Table 2). The results showed that about 6.4 roots (maximum number of roots) were detected in semi-hardwood cuttings treated with 1000 ppm NAA on December 20<sup>th</sup>, while collecting semi-hardwood and hardwood cuttings on June 20<sup>th</sup> and no application of plant growth regulators cause that cuttings had minimum number of roots. The character significant increase in response to the increasing levels of plant growth regulators doses and generally, number of roots were significantly increased with increasing plant growth regulators concentrations. Also, the data showed that collecting on June 20<sup>th</sup> was less effective than either times of collection. The type of cuttings had no effect on number of roots any time.

**3.3. Root length**

Root length was affected by the time of collection, auxin types and concentrations, but not by the cutting age (Table 3). Significant variations being observed between the different types of auxin and IBA had more effective. Contrarily, high concentration of 2,4-D reduced root length compared to untreated cuttings. Root length was 12.14 cm longest in semi-hardwood cuttings treated with 1000 ppm NAA on December 20<sup>th</sup> than other treatments. The

shortest root length was observed in untreated cuttings that collected on plants propagated from stem extracted in the apex of branches.

**Table 2** The effects of Time of collection, cutting ages, auxin types and concentrations on Number of roots per rooted cutting.

	March 20 <sup>th</sup>			June 20 <sup>th</sup>		September 20 <sup>th</sup>		December 20 <sup>th</sup>	
	ppm	semi-hard	hard	semi-hard	hard	semi-hard	hard	semi-hard	hard
IBA	0	2.9	2.2	1.6	1.4	3.2	2.8	4.1	3.3
	250	3.3	2.8	2.0	1.9	3.9	3.5	4.7	3.7
	500	3.7	3.4	2.6	2.3	4.6	4.3	5.2	4.6
	1000	4.0	3.6	3.1	3.0	5.0	4.7	5.9	5.3
NAA	0	2.8	2.2	1.5	1.2	3.0	2.7	4.0	3.5
	250	3.4	2.9	2.1	1.7	4.1	3.5	4.8	4.2
	500	3.8	3.5	2.7	2.4	4.9	4.4	5.3	4.9
	1000	4.1	3.8	3.2	3.3	5.5	5.1	6.4	5.8
2,4-D	0	3.0	2.2	1.4	1.2	3.2	2.9	3.9	3.2
	250	3.5	2.8	2.0	1.8	4.6	3.8	5.6	5.4
	500	3.8	3.4	2.8	2.9	5.2	4.9	5.7	5.6
	1000	2.5	2.3	1.3	1.2	3.9	3.5	4.9	4.3
<b>LSD (P&lt;0.05)</b>		0.41	0.33	0.23	0.25	0.64	0.54	0.81	0.58

Each value is a mean of four independent replicates.

**Table 3** The effects of Time of collection, cutting ages, auxin types and concentrations on root length (cm).

	March 20 <sup>th</sup>			June 20 <sup>th</sup>		September 20 <sup>th</sup>		December 20 <sup>th</sup>	
	ppm	semi-hard	hard	semi-hard	hard	semi-hard	hard	semi-hard	hard
IBA	0	5.28	5.04	3.84	4.08	4.68	4.32	6.05	6.24
	250	7.08	6.60	4.92	4.68	5.52	5.04	9.12	8.41
	500	9.84	9.48	6.36	6.12	7.68	8.28	11.04	10.92
	1000	9.72	9.6	7.68	7.08	9.00	8.52	12.14	11.64
NAA	0	5.40	4.68	4.08	4.44	4.80	4.56	6.12	6.36
	250	8.76	8.40	6.00	6.24	6.84	6.48	9.63	9.12
	500	8.88	8.16	6.24	6.36	7.68	7.08	11.16	10.68
	1000	5.28	4.8	4.68	4.68	5.16	4.80	9.72	9.08
2,4-D	0	5.16	4.92	3.96	4.2	4.80	4.32	6.12	6.24
	250	7.92	7.32	4.56	4.92	5.64	5.16	10.22	10.32
	500	4.20	4.44	2.64	2.76	4.68	4.44	6.36	6.48
	1000	2.64	3.00	1.80	2.40	3.36	3.48	4.32	4.44
<b>LSD (P&lt;0.05)</b>		1.21	1.11	0.79	0.91	1.24	1.13	1.89	1.60

Each value is a mean of four independent replicates.

### 3.4. Number of stems

There were seasonally differences in number of stems of cuttings. Number of stems varies by collection date and Maximum number of stem was observed in December 20<sup>th</sup>. The results showed that there was a great deal of variation among plant growth regulators in stem formation of cuttings. 2,4-D consistently performed poorly producing stems than cuttings from the other plant growth regulators. The cutting age had not a significant effect on numbers of stem (Table 4).

**Table 4** The effects of Time of collection, cutting ages, auxin types and concentrations on number of stems.

	March 20 <sup>th</sup>			June 20 <sup>th</sup>		September 20 <sup>th</sup>		December 20 <sup>th</sup>	
	ppm	semi-hard	hard	semi-hard	hard	semi-hard	hard	semi-hard	hard
IBA	0	0.86	0.7	0.56	0.52	0.93	0.84	1.13	0.95
	250	0.95	0.84	0.65	0.63	1.09	1.05	1.27	1.04
	500	1.04	0.97	0.79	0.72	1.25	1.18	1.38	1.25
	1000	1.11	1.02	0.9	0.88	1.34	1.27	1.54	1.4
NAA	0	0.84	0.7	0.54	0.47	0.88	0.81	1.11	1.00
	250	0.97	0.86	0.68	0.59	1.13	1.00	1.29	1.15
	500	1.06	1.00	0.81	0.75	1.31	1.2	1.4	1.31
	1000	1.13	1.06	0.93	0.95	1.45	1.36	1.65	1.52
2,4-D	0	0.88	0.7	0.52	0.47	0.93	0.86	1.09	0.93
	250	1.03	0.84	0.65	0.61	1.25	1.06	1.47	1.43
	500	1.06	0.97	0.84	0.86	1.38	1.31	1.50	1.47
	1000	0.77	0.72	0.5	0.47	1.09	1.02	1.31	1.18
<b>LSD (P&lt;0.05)</b>		0.04	0.03	0.02	0.02	0.04	0.04	0.05	0.05

Each value is a mean of four independent replicates.

### 3.5. Length of stems

The results of the variation of the stem length of *F. religiosa* during the sampling date, cutting ages, auxin types and concentrations are shown in Table 5. Stem length is dependent on the cutting date, auxin types and concentrations, but not on the cutting age. The stem length was significantly ( $P < 0.05$ ) short for June 20<sup>th</sup>, while it was long on December 20<sup>th</sup> (Table 5). Current data showed that IBA and NAA increased stem length. The lower 2,4-D dose increases the stem length of *F. religiosa*, but length of stems were reduced by 500 and 1000 ppm 2,4-D when compared with 250 ppm 2,4-D.

### 3.6. Percentage of surviving plants

Table 6 shows the Percentage of surviving plants under different treatments. In semi-hard cuttings the surviving reduces compared to hard cuttings. In both cutting, surviving generally increased on December 20<sup>th</sup>. 2,4-D treatments survived less percentage of plants than the controls. However IBA, NAA treatment survived more percentage of plants than the controls.

**Table 5** The effects of Time of collection, cutting ages, auxin types and concentrations on stem length (cm).

		March 20 <sup>th</sup>		June 20 <sup>th</sup>		September 20 <sup>th</sup>		December 20 <sup>th</sup>	
	ppm	semi-hard	hard	semi-hard	hard	semi-hard	hard	semi-hard	hard
IBA	0	13.7	9.98	5.53	5.14	13.4	10.8	22.3	18.5
	250	21.0	16.6	8.86	8	19.3	15.8	38.5	28.0
	500	32.7	29.0	14.8	12.6	31.8	32.0	51.6	45.2
	1000	34.9	31.1	21.4	19.1	40.5	36.0	64.4	55.5
NAA	0	13.6	9.27	5.51	4.8	12.9	11.0	22.0	20.0
	250	26.8	21.9	11.3	9.55	25.2	20.4	41.6	34.4
	500	30.3	25.7	15.1	13.7	33.8	28.0	53.2	47.1
	1000	19.4	16.4	13.4	13.9	25.5	22.0	55.9	47.4
2,4-D	0	13.9	9.74	4.99	4.54	13.8	11.2	21.4	17.9
	250	24.9	18.4	8.21	7.97	23.3	17.6	51.5	50.1
	500	14.3	13.59	6.65	7.2	21.9	19.5	32.6	32.6
	1000	5.94	6.21	2.11	2.59	11.7	10.9	19.0	17.1
<b>LSD (P&lt;0.05)</b>		4.55	3.24	1.54	1.59	3.65	2.72	5.86	4.53

Each value is a mean of four independent replicates.

**Table 6** The effects of Time of collection, cutting ages, auxin types and concentrations on Percentage of surviving plants.

		March 20 <sup>th</sup>		June 20 <sup>th</sup>		September 20 <sup>th</sup>		December 20 <sup>th</sup>	
	ppm	semi-hard	hard	semi-hard	hard	semi-hard	hard	semi-hard	hard
IBA	0	64.7	64.7	50.0	58.3	62.9	66.7	71.1	70.6
	250	70.0	66.7	64.7	64.7	80.8	79.6	83.3	85.7
	500	79.7	79.6	79.2	76.0	84.6	84.8	92.8	94.7
	1000	84.9	84.3	80.0	81.0	84.3	86.5	94.9	95.6
NAA	0	58.8	61.1	53.8	55.6	64.7	63.0	71.1	71.4
	250	79.5	81.1	66.7	68.4	82.6	82.5	88.7	87.7
	500	86.2	85.9	78.1	77.8	86.2	84.5	94.2	95.5
	1000	84.6	85.1	80.0	81.4	88.0	89.1	94.8	93.9
2,4-D	0	62.5	61.1	57.1	55.6	63.6	64.3	70.7	69.4
	250	63.3	65.5	57.1	56.3	69.4	71.7	81.3	83.1
	500	50.9	49.0	45.0	42.9	58.8	61.8	65.4	65.9
	1000	40.0	47.1	43.8	41.2	48.0	46.2	51.7	51.9
<b>LSD (P&lt;0.05)</b>		12.8	15.0	11.1	16.0	17.3	15.6	12.5	13.29

Each value is a mean of four independent replicates.

### 3.7. Physiological responses of leaf plant to seasonal changes

Measuring of carbohydrate revealed significant differences during the 1-year period (Fig. 3, a). In leaf of *F. religiosa*, concentrations (mg/g) of sugar ranged from 16.7(for September 20<sup>th</sup>) to 28.3 (for December 20<sup>th</sup>). In figure 3 b and c, the changes in leaf gas exchange parameters, net CO<sub>2</sub> assimilation rate and transpiration rate, of *F. religiosa* are compared. The value of this parameters were significantly different during seasons. Net CO<sub>2</sub> assimilation rate were measured at 10.9  $\mu\text{mol m}^{-2} \text{s}^{-1}$  on December 20<sup>th</sup> higher than other seasons. Also transpiration rate was highest on June 20<sup>th</sup> and lowest on December 20<sup>th</sup>.

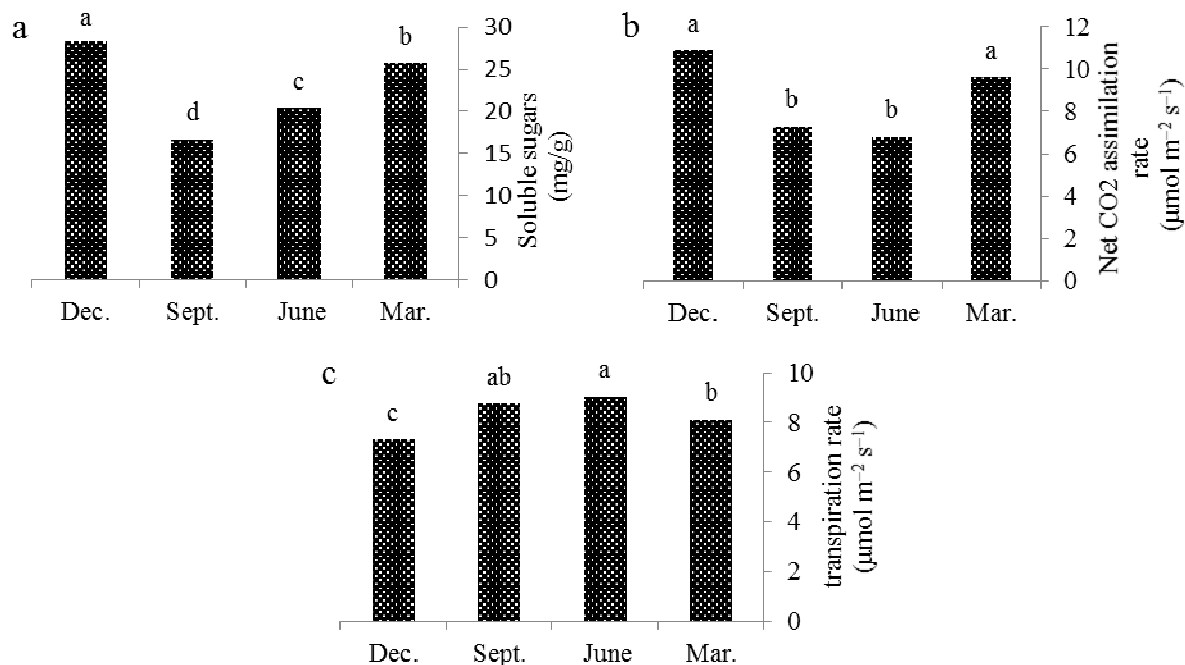


Figure 3. Effect of seasonal changes on: Soluble sugar (a), leaf net assimilation (b) and Transpiration rate (c) of *F. religiosa*.

#### 4. DISCUSSION

Because the physiological status of mother plant is an important prerequisite in achieving a homogeneous rooting of cutting [17], we reported in Fig.1 and Fig 2 the meteorological conditions in the month's preceding sampling of cuttings. As observed, seasonal changes strongly affected the physiological status of mother plant that is an important prerequisite in achieving a rooting of cutting [18]. Temperature and precipitation changes during a year affect photosynthesis, carbohydrate content [19, 20, 21, 22, 23], flowering and the ability of stock plants to provide cutting material that forms adventitious roots [10, 11]. Temperature affects all biochemical reactions of photosynthesis [24]. A wide variation in temperature between winter and summer was found in the areas studied (Fig. 1). When temperatures exceed and rainfall is reduced (on June and September), photosynthetic rates decrease. Respiration rates also increase as a function of temperature, and interaction between photorespiration and photosynthesis becomes apparent in temperature responses [24]. Thus, these changes in photosynthetic properties and carbohydrate production in response to temperature and water play an important role in capacity of rooting and survival rate of plants. Rooting ability of cuttings has often been affected by the temperature of the stock plant environment prior to taking cuttings [25, 26, 27]. Warmer seasons often coincide with increased bud activity and flowering [11, 12, 27]. Reproductive stage of *F. religiosa* accrue in warm season could increase competition for metabolites or growth regulators, including auxins [13, 28] and reduce the ability of mother plants to provide material for cuttings that can form roots [29]. These results were further supported in studies that indicate time of collection as one of the major factors affecting macro-propagation in plant species [30, 31, 32, 33]. However, The effect of flowering on rooting differs between species. McComb and Wroth (1986) reported that cuttings of the summer flowering *Eucalyptus resinifera* do not form roots readily during flowering [14]. Anecdotal evidence suggests that *Backhousia citriodora* will not produce adventitious roots from cuttings during the colder months and during flowering. Flowering of *B. citriodora* in southeastern Queensland is reported to occur from spring to summer [15].

A significant effect of cutting ages (semi-hard and hard) on rooting, length and number of roots per cutting; length and number of stems; Percentage of surviving plants was observed. Some studies indicate larger diameter or older cuttings resulting in root development, growth stem and better survival [34, 35, 36]. Rossi (1999) showed that cutting lengths of 30cm affected both aboveground biomass production and survival rate of *Salix 'Aquatika'* positively [35]. Longer cuttings can contain larger carbohydrate reserves, which is likely related to the greater growth attained by the 40 cm-long cuttings.

This study also showed that the use of auxin containing IBA, NAA and 2,4-D can positively influence the formation and quantity of roots in this specie, however, over a range of applied NAA (1000 ppm) and 2,4-D (500 and 1000 ppm) concentrations did not show corresponding increases in capacity of rooting. Hartmann and Kester (1983) stated that IBA could be used in a wide range of concentrations without giving toxic effect to the cuttings [37]. This may arise as a result of IBA-induced basipetal transport of assimilates, with sink strength successively enhanced by increases in IBA concentration [17]. This process may account for the increase in number of roots per rooted cutting with increasing IBA concentration recorded here, which is consistent with the response of other tropical tree species such as *Triplochiton scleroxylon* [38], *Nauclea diderrichii* [39], *Cordia alliodora* and *Albizia guachepele* [40]. The increased leaf abscission and associated cutting mortality with increasing IBA may also be attributed to this process, reflecting a depletion in foliar nutrient contents and the consequent onset of leaf senescence. In addition, a significant number of 2,4-D-treated, rooted plants do not survive in the greenhouse during the process of hardening. The inhibitory effect caused by high exogenous auxin also occurred in other plants [41]. IBA and NAA are commercially widely used to induce adventitious root in cuttings of many plant species and they were found to be more stable and effective in most cases [42, 43, 44]. One hypothesis is that IBA slowly releases free IAA for root initiation [45]. Whereas other evidence suggests IBA itself might serve as an auxin [42]. The exact mechanism of IBA action still remains elusive [44]. This result corroborates with several studies that indicate high auxin application can produce toxicity, 2,4-D and NAA are more toxic than IBA [46], so lower 2,4-D and NAA concentrations than IBA concentrations should be selected. Practically, speeding up the process of adventitious root formation is considered an advantage, as the earlier the cuttings were able to form roots, the greater the chances for them to survive.

## 5. CONCLUSION

Based on the results of this study, it could be concluded that rooting of cuttings is a complex phenomenon which involves very different events and Successful rooting is determined by the number of roots formed, root elongation and shoot growth. All auxin types at optimum concentration used in this study have improved the rooting of *F. religiosa* cuttings compared to control. However, the present study indicates that 1000 ppm IBA treatments had improved rooting ability by increasing rooting percentage, number of roots per rooted cutting, root lengths, number and accumulated length of stems. It also can be concluded that rooting ability of cuttings is strongly influenced by collection time. In particular, the highest rooting ability occurred in cuttings collected in late autumn (December 20<sup>th</sup>), whereas the lowest rooting ability was found in cuttings collected in late spring (June 20<sup>th</sup>). In late spring, the rapid growth followed by the development of fruits could increase competition for resources and reduce the ability of stock plants to provide material for cuttings that can form roots.

## REFERENCES

1. McFarland, G. B., 1944. Thai-English Dictionary. Stanford University press, pp: 431-456.
2. Galil, J., 1984. *Ficus religiosa* L. – the tree-splitter. Bot. J. Linn. Soc., 88: 185–203.
3. Pawar, P. L. and B. M. Nabar, 2010. Effect of plant extracts formulated in different ointment bases on MDR strains. Indian J. Pharmacol. Sci., 72: 397–401.
4. Patil, M. S., C. R. Patil, S. W. Patil and R. B. Jadhav, 2011. Anticonvulsant activity of aqueous root extract of *Ficus religiosa*. J. Ethnopharmacol., 133: 92–96.
5. Kirana, H., S. S. Agrawal and B. P. Srinivasan, 2009. Aqueous extract of *Ficus religiosa* linn. reduces oxidative stress in experimentally induced type 2 diabetic rats. Indian J. Exp. Biol., 47: 822–826.
6. Ballabh, B., O. P. Chaurasia, Z. Ahmed and S. B. Singh, 2008. Traditional medicinal plants of cold desert Ladakh-used against kidney and urinary disorders. J. Ethnopharmacol., 118: 331–339.
7. Singh, D., B. Singh and R. K. Goela, 2011. Traditional uses, phytochemistry and pharmacology of *Ficus religiosa*: A review. J. Ethnopharmacol., 134: 565–583.
8. Williamson, E. M. and P. M. Hooper, 2002. Major Herbs of Ayurveda. Churchill Livingstone London Publishers, pp: 145–149.
9. Pullaiah, T., 2006. Encyclopedia of World Medicinal Plants. Regency India Publishers, pp: 958–959.
10. Moe, R. and A. S. Anderson, 1988. Stock plant environment and subsequent adventitious rooting. In: Adventitious Root Formation in Cuttings (eds. Davis, T. D., B. E. Haissig and N. Sankhla) pp: 115-121. Dioscorides Press, Portland, OR.

11. Day, J. S. and B. R. Loveys, 1998. Propagation from cuttings of two woody ornamental Australian shrubs, *Boronia megastigma* Nees. (brown boronia) and *Hypocalymma angustifolium* Endl. (white myrtle). *Aust. J. Exp. Agric.*, 38: 201–206.
12. Kibbler, H., M. E. Johnston and R. R. Williams, 2004. Adventitious root formation in cuttings of *Backhousia citriodora* F. Muell. 1. Plant genotype, juvenility and characteristics of cuttings. *Sci. Hort.*, 102: 133–143.
13. Cristofori, V., Y. Roupheal and E. Rugini, 2010. Collection time, cutting age, IBA and putrescine effects on root formation in *Corylus avellana* L. cuttings. *Sci. Hort.*, 124: 189–194.
14. McComb, J. A. and M. Wroth, 1986. Vegetative propagation of *Eucalyptus resinifera* and *E. maculata* using coppice cuttings and micropropagation. *Aust. J. For. Res.*, 16: 231–242.
15. Stanley, T. D. and E. M. Ross, 1986. *Flora of South Eastern Queensland*. Queensland Department of Primary Industries, Brisbane, pp: 54–61.
16. McCready, M. R., J. Guggolz, V. Silveira and S. H. Owens, 1950. Determination of starch and amylose in vegetables. *Anal. Chem.*, 22: 1156–1158.
17. Hartmann, H. P., D. E. Kester and J. T. Davies, 1990. *Plant Propagation: Principle and Practices*. Prentice-Hall, New Jersey, pp: 632–649.
18. Hartmann, H. T., D. E. Kester, F. T. Davies, and R. L. Geneve, 2002. *Plant propagation: principles and practices*. Upper Saddle River, NJ: Prentice Hall, pp: 253–257.
19. Kitajima, K., S. S. Mulkey and S. J. Wright, 1997. Seasonal leaf phenotypes in the canopy of a tropical dry forest: photosynthetic characteristics and associated traits. *Oecologia*, 109: 490–498.
20. Stewart, C. R. and P. Bannister, 1973. Seasonal changes in carbohydrate content of three *Vaccinium* sp. with particular reference to *V. uliginosum* and its distribution in the British Isles. *Flora*, 162: 134–155.
21. Pakonen, T., E. Saari, K. Laine, P. Havas and P. Lahdesmaki, 1991. How do seasonal changes in carbohydrate concentrations in tissues of the bilberry (*Vaccinium myrtillus* L.) reflect carbon resource allocation patterns? *Acta Oecol.*, 12: 249–259.
22. Ogren, E., 1996. Premature dehardening in *Vaccinium myrtillus* during mild winter: a cause for winter dieback. *Funct. Ecol.*, 10: 724–732.
23. Taulavuori, K., K. Laine, E. Taulavuori, T. Pakonen and E. Saari, 1997. Accelerated dehardening in bilberry (*Vaccinium myrtillus* L.) induced by a small elevation in air temperature. *Environ. Pollut.*, 98: 91–95.
24. Taiz, L. and E. Zeiger, 2010. *Plant Physiology*. Benjamin Cummings. Redwood City, CA, pp: 90–93.
25. Dykeman, B., 1976. Temperature relations in root initiation and development of cuttings. *Int. Plant Prop. Soc.*, 26: 201–207.
26. Worrall, R. J., 1976. Effects of time of collection, growing-conditions of mother plants and growth regulators on rooting of cuttings of *Telopea speciosissima* (Proteaceae). *Sci. Hort.*, 5: 153–160.
27. Hansen, J., 1990. Influence of cutting position and temperature during rooting on adventitious root formation and axillary bud break of *Stephanotis floribunda*. *Sci. Hort.*, 40: 345–354.
28. Kevers, C., J. Hausman, O. Faivre-Rampant, D. Evers, and T. Gaspar, 1997. Hormonal control of adventitious rooting: progress and questions. *J. Appl. Bot.*, 71: 71–79.
29. Kibbler, H., M. E. Johnston and R. R. Williams, 2004. Adventitious root formation in cuttings of *Backhousia citriodora* F. Muell. 2. Seasonal influences of temperature, rainfall, flowering and auxins on the stock plant. *Sci. Hort.*, 102: 343–358.
30. Klein, J. D., S. Cohen and Y. Hebbe, 2000. Seasonal variation in rooting ability of myrtle (*Myrtus communis* L.) cuttings. *Sci. Hort.*, 83: 71–76.
31. Swamy, S. L., S. Puri and A. K. Singh, 2002. Effect of auxins (IBA and NAA) and season on rooting of juvenile and mature hardwood cuttings of *Robinia pseudoacacia* and *Grewia optiva*. *New Forests*, 23: 143–157.
32. Bhardwaj, D. R. and V. K. Mishra, 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.
33. Haile, G., K. Gebrehiwot, M. Lemenih, and F. Bongers, 2011. Time of collection and cutting sizes affect vegetative propagation of *Boswellia papyrifera* (Del.) Hochst through leafless branch cuttings. *J. Arid. Environ.*, 75: 873–877.
34. Dickmann, D., H. Phipps and D. Netzer, 1980. Cutting diameter influences early survival and growth of several *Populus* clones. St. Paul, MN, USA: USDA Forest Service, pp: 4–5.



35. Rossi, P., 1999. Length of cuttings in establishment and production of short-rotation plantations of *Salix* 'Aquatika'. *New Forests*, 18: 161–177.
36. Camp, J. C., R. J. Rousseau and E. S. Gardiner, 2011. Longer black willow cuttings result in better initial height and diameter growth in biomass plantations. In the 16<sup>th</sup> biennial southern silvicultural research conference, pp: 163-180.
37. Hartmann, H. T. and D.E. Kester, 1983. *Plant Propagation-principle and Practices*. Eaglewood Cliffs, New Jersey, pp: 572- 596.
38. Leakey, R. R. B., V. R. Chapman and K. A. Longman, 1982. Physiological studies for tropical tree improvement and conservation. Some factors affecting root initiation in cuttings of *Triplochiron scleroxylon* K. Schum. *For. Ecol. Manage.*, 4: 53-66.
39. Leakey, R. R. B., 1990. *Nauclea diderrichii*: rooting of stem cuttings, clonal variation in shoot dominance, and branch plagiotropism. *Trees*, 4: 164 169.
40. Mesen, J. F., 1993. *Vegetative propagation of Central American hardwoods*, Ph.D. Thesis, University of Edinburgh.
41. Tworowski, T. and F. Takeda, 2013. Rooting response of shoot cuttings from three peach growth habits. *Sci. Hort.*, 115: 98–100.
42. Ludwig-Müller, J., A. Vertocnik and C. D. Town, 2005. Analysis of indole-3-butyric acid induced adventitious root formation on *Arabidopsis* stem segments. *J. Exp. Bot.*, 56: 2095–2105.
43. Rout, G. R., 2006. Effect of auxins on adventitious root development from single node cuttings of *Camellia sinensis* (L.) Kuntze and associated biochemical changes. *Plant Growth Regul.*, 48: 111–117.
44. Wei, K., L. Wang, H. Cheng, C. Zhang, C. Ma, L. Zhang, W. Gong and L. Wu, 2013. Identification of genes involved in indole-3-butyric acid-induced adventitious root formation in nodal cuttings of *Camellia sinensis* (L.) by suppression subtractive hybridization. *Gene*, 514: 91–98.
45. Zolman, B. K., N. Martinez, A. Millius, A. R. Adham and B. Bartel, 2008. Identification and characterization of *Arabidopsis* indole-3-butyric acid response mutants defective in novel peroxisomal enzymes. *Genetics*, 180: 237–251.
46. Zeng, X. and Q. N. Lu, 1988. *Application of Plant Growth Regulators in Fruit Trees*. Agricultural Publishing House, Beijing, p. 23.