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CUTTING PROPAGATION OF *Pachira aquatica* Aubl. AS INFLUENCED BY MEDIUM TYPE AND INDOLE-3-BUTYRIC ACID CONCENTRATION

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ABSTRACT: This study was conducted at Ornamental Nursery, Faculty of Agriculture, Zagazig University, Egypt, during two consecutive seasons of 2015 and 2016. The objective of this study was to investigate two of the key factors likely to influence rooting ability *i.e.*, indole butyric acid (IBA) concentration (0.0, 1000, 2000 or 4000 ppm) and rooting media type (sand, peat moss, sand: peat moss or sand: clay, at equal volume proportions) as well as their combinations on rooting and shooting ability and quality of *Pachira aquatica* cuttings. Rooting (%), root number/cutting, root length (cm), fresh and dry weights of roots/cutting (g), No. of shoots/cutting, fresh and dry weights of shoots/ cutting (g), No. of leaves/cutting, leaf area/cutting (cm^2) as well as fresh and dry weights of leaves/cutting (g) as growth parameters were recorded. Also, total chlorophyll (SPAD unit), total carbohydrates (%), total nitrogen (%), total phosphorus (%) and potassium (%) in the leaves were determined. Moreover, anatomical study was conducted for selected treatment (peat moss and sand, 1:1 *V/V*, with different IBA concentrations). Results showed that in most cases the maximum values of the above mentioned characters were obtained by treating cuttings with IBA at 4000 ppm. Anatomical study of adventitious roots showed that the maximum root diameter with full differentiated vascular tissue was belonged to cuttings treated with IBA at 4000 ppm. The ultimate values of most of the above mentioned parameters were detected when cuttings were cultured in peat moss or its mixture with sand without significant difference between both treatments. Generally, among different combination treatments, treating cuttings with IBA at 4000 ppm before culturing them in peat moss and sand (1:1, *V/V*) proved to be the most promising treatment in this regard.

Key words: *Pachira aquatica,* propagation, cutting, rooting, IBA, medium, growth, anatomical study.

INTRODUCTION

Pachira aquatica Aubl. (American Chestnut) is belonging to family Malvaceae. It is used as hedges, live fence posts and avenue trees. It is an excellent ornamental species that flowers, even as a tree and has become popular in Europe. In Asia, the stems of young seedlings are braided to make braided bonsai money plant tree which has become highly prized and in great demand in East Asia and South East Asia. They are symbolically associated with good financial fortune and are typically seen in businesses, sometimes with red ribbons or other auspicious ornamentation attached. The trees play an important role in Taiwan's agricultural export economy. It also provides a white and soft wood which is suitable for manufacturing paper, yielding 36% cellulose paste. In ornamental nurseries, *Pachira aquatica* is usually propagated from seeds and also from cuttings (Lim, 2012).

It has been repeatedly confirmed that auxin is required for initiation of adventitious roots on

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stems, and indeed, it has been shown that divisions of the first initial cells dependent upon either applied or endogenous auxin (Hartmann *et al.*, 2011). IBA is the most commonly used for rooting in commercial operations. The other auxins used commercially are indole acetic acid (IAA) and naphthalene acetic acid (NAA). Also, many chemical analogues have been synthesized and examined for auxin-like activity, but none of them are being used on a large scale for rooting (De Klerk *et al.*, 1999).

Studies investigated the effectiveness of different auxin types (IBA, IAA and NAA) on rooting ability of some ornamental trees and shrubs cuttings stated that IBA was more effective than other auxins in this regard (Balakrishna and Bhattacharjee, 1991; Fogaca and Fett-Neto, 2005).

One of the most important prerequisites for successful rooting of cuttings is a suitable rooting medium (MacDonald, 1986). The rooting media may contribute to variation in the rooting ability of cuttings because of their physical properties and the management of the medium (Caldwell *et al.*, 1988). There is no universal or ideal rooting mix for cuttings. An appropriate propagation medium depends on the species, cutting type, season, propagation system, the cost and availability of medium components (Hartmann *et al.*, 2011). Thus, the most suitable rooting medium should be determined for each species and cultivar.

To the best of our knowledge there is no report on cutting propagation of *Pachira aquatica*. So that this study was devoted to investigate two of the key factors likely to influence rooting ability *i.e;* IBA concentration and rooting medium type as well as their combinations on rooting ability and quality of *Pachira aquatic* cuttings. The main target of this work is to improve nursery propagation and commercial multiplication of this important ornamental tree.

MATERIALS AND METHODS

The present study was conducted at Ornamental Nursery, Faculty of Agriculture, Zagazig University, Egypt, in lath house during two consecutive seasons of 2015 and 2016. This experiment included 16 treatments, which were the combinations between four media types [(sand, peat moss, sand: clay (1:1, *V/V*) and sand: peat moss (1:1, *V/V*)] and four indole butyric acid (IBA) concentrations which were; 0.0, 1000, 2000 and 4000 ppm of Indole-3-Butyric Acid Potassium Salt ($C_{12}H_{12}NO_2K$ 98%) as water soluble salt which obtained from United Agriculture Development Company (UAD), Egypt.

Pachira aquatica Aubl. stem cuttings (15 cm long) were obtained from five years old trees grown at King Garden in Inshas El-Raml Region, Sharkia Governoratge. Semi-hardwood cuttings were prepared from the medium part of one year old shoots on 15th February in both seasons. The cutting bases were dipped in IBA solution with the above mentioned concentrations as well as distillated water (control) for 10 seconds then cultured in 20 cm diameter pots filled with the above mentioned media. Two cuttings were cultured in each pot. The above mentioned treatments were arranged in a split plot in randomized complete block design with three replicates, each replicate contained 16 cuttings. While medium type treatments were distributed in the main plots and IBA concentration treatments were arranged in the sub-plots.

At the end of the experiments (three months after planting), the average rooting percentage, root number, root length (cm), fresh and dry weights of roots/cutting (g), number of shoots, fresh and dry weights of shoots/cutting (g) and number of leaves were recorded. Also, leaf area (cm^2) as well as fresh and dry weights of leaves/ cutting (g) were measured. In addition, total chlorophyll (SPAD unit) by using SPAD- 502 meter (Markwell *et al.*, 1995) and total carbohydrates (Dubois *et al.*, 1956), total nitrogen (Chapman and Pratt, 1978), phosphorus (Hucker and Catroux, 1980) and potassium (Brown and Lilleland, 1946) percentages in leaves were estimated.

Anatomical Study

According to morphological and chemical measurements in the first season (2015) it was found that the best medium as recommendation was peat moss: sand (1:1, *V/V*) in this regard. Thus for anatomical studies, specimens from adventitious roots of cuttings representing IBA

concentrations which cultured in this medium were collected after 70 days of culturing during the second season (2016) and subjected to microtechniqe practices given by Willey (1971) at Agricultural Botany Dept. Laboratory, Fac. Agric., Zagazig Univ., Zagazig, Egypt. The plant specimens (1 cm long) were killed and fixed at least for 24 hr., in plant fixative which is known as FAA solution (10 ml formalin, 5 ml glacial acetic acid and 85 ml ethyl alcohol 70%). After fixation they were washed and dehydrated in ascending concentration series of ethyl alcohol then transferred to absolute alcohol before being embedded in paraffin wax (melting point 52-54ºC). Transverse sections were cut using a rotary microtome (EPMA) to a thickness of 14 microns. Paraffin ribbons were mounted on slides and sections were clarified in pure xylol for 10-20 min before transferring to absolute alcohol, stained with safranin/light green. Sections were mounted in Canada balsam. Selected sections were examined microscopically and photomicrographed using light microscope (Olympus) provided with digital camera, (Canon power shot S80) connected to a computer. The photographs were taken by Zoom Browser Ex program. Dimensions of adventitious roots were measured by using Corel Draw program ver.11.

Statistical Analysis

All collected data were subjected to analysis of variance and means of treatments were compared with the least significant difference (LSD) test at $P \leq 0.05$. The statistical calculations were performed with statistics software version 9 (Analytical software, 2008).

RESULTS AND DISCUSSION

Root System Parameters

Results in Tables 1 and 2 indicate that the highest significant values of rooting percentage, root number per cutting, root length (cm) were recorded with peat moss medium followed by mixture of peat moss and sand (1 : 1 *V/V*) compared with other investigated media. Also, both media proved to be the best media concerning fresh and dry weights of roots/ cutting. These media seem to be a convenient pots or bed for *Pachira aquatic* cuttings; as it has good drainage and good aeration. Depending on the result obtained by Agro (1998) a good medium would provide sufficient support for the plant serve as a reservoir for nutrients and water, allow oxygen diffusion to the roots and permit gaseous exchange between roots and atmosphere. These results are in harmony with those found by Santelices and Palfner (2010) on *Corylus avellana* L. cuttings, Ansari (2013) on pomegranate and Prasath *et al.* (2014) on cuttings of black pepper.

Respecting the efect of IBA,generally IBA treatments gave better rooting responses than control (distilled water) in *Pachira aquatica* cuttings (Tables 1 and 2). The highest rooting percentage, root number and length as well as fresh and dry weights of roots per cutting were recorded with 4000 ppm concentration of IBA and the lowest values in this concern were noted with control. Similar result was reported by Owen *et al*. (2003) on *Ilex glabra* and Sultana *et al.* (2016) on three bougainvillea species.

This effect may be due to that application of auxin attracts assimilates to the cutting base and stimulate meristemmatic differentiation which is probably the best-known means of promoting rooting in all kinds of cuttings (Tchoundjeu *et al*., 2002).

With respect to the interaction between medium type and IBA concentrations, data of both seasons in Tables 1 and 2 suggest that, rooting percentage, root length and number as well as fresh and dry weights of roots per cutting reached the maximum values by treating cutting with 4000 ppm IBA before culturing them in peat moss followed by the combination between 4000 ppm IBA and medium of sand: peat (1:1, *V/V*) compared to the other combinations under study. Similar result was reported by Akwatulira *et al.* (2011) on *Warburgia ugandensis* stem cuttings. This results may be due to that dipping cutting in IBA at 4000 ppm and culturing in peat moss : sand at 1 : 1 (*V/V*) gave the highest values of anatomical parameters *i.e.;* root diameter, bark thickness, secondary xylem thickness and average secondary xylem vessel diameter

Shoots and Leaves Parameters

Results presented in Tables 3, 4 and 5 reveal that in most cases number of shoots per cutting, fresh and dry weights of shoots/cutting as well as number of leaves/cutting reached the maximum values by using peat moss or its mixture

Table 1. Effect of medium type, IBA concentration and their interactions on rooting percentage, number of roots per cutting and root length (cm) of *Pachira aquatica* at 90 days after culturing during seasons of 2015 and 2016

Medium type (M)	IBA concentration ppm (I)									
	0.0	1000	2000	4000	Mean (M)	0.0	1000	2000	4000	Mean (M)
	First season					Second season				
Rooting percentage (%)										
Sand	33.33	36.67	40.67	47.33	39.50	35.67	37.33	41.67	46.67	40.33
Peat moss	52.67	53.67	61.67	63.67	57.92	51.67	54.67	60.67	64.33	57.83
Sand: peat	51.33	53.33	57.67	62.33	56.17	51.67	53.00	58.00	61.33	56.00
Sand: clay	37.33	38.00	41.33	46.33	40.75	39.67	40.67	40.33	46.67	41.83
Mean (I)	43.67	45.42	50.33	54.92		44.67	46.42	50.67	54.75	
LSD at 5%	M=0.666		I=0.521	M×I=1.118		M=0.651		I=0.288	M×I=1.163	
Number of roots / cutting										
Sand	1.40	3.41	3.49	4.67	3.24	1.22	3.00	3.56	3.77	2.89
Peat moss	3.33	3.89	7.33	11.67	6.56	3.22	3.67	6.89	11.11	6.22
Sand: peat	1.56	3.67	6.67	10.67	5.64	2.00	3.33	6.45	10.33	5.53
Sand: clay	1.33	1.20	2.30	3.67	2.12	1.44	2.33	3.44	4.41	2.91
Mean (I)	1.90	3.04	4.95	7.67		1.97	3.08	5.08	7.41	
LSD at 5%	M=0.257		I=0.365	M×I=0.681		M=0.336		I=0.519	M×I=0.958	
Root length (cm)										
Sand	3.67	5.67	6.33	6.33	5.50	3.50	4.33	7.00	7.67	5.62
Peat moss	10.00	12.33	17.67	20.67	15.17	9.33	11.67	17.33	21.67	15.00
Sand: peat	4.67	9.33	13.33	16.67	11.00	6.33	10.67	15.00	17.67	12.42
Sand: clay	3.67	5.33	8.00	8.67	6.42	4.00	5.00	7.67	9.33	6.50
Mean (I)	5.50	8.17	11.33	13.08		5.79	7.92	11.75	14.08	
LSD at 5%	M=1.043		I=0.530	M×I=1.384		M=0.590		I=0.578	M×I=1.159	

Table 2. Effect of medium type, IBA concentration and their interactions on fresh and dry weights of roots per cutting (g) of *Pachira aquatica* at 90 days after culturing during seasons of 2015 and 2016

Medium type (M)	IBA concentration ppm (I)									
	0.0	1000	2000	4000	Mean (M)	0.0	1000	2000	4000	Mean (M)
	First season					Second season				
Fresh weight of roots / cutting (g)										
Sand	0.360	0.620	1.093	1.467	0.885	0.41	0.59	1.23	1.50	0.93
Peat moss	1.71	1.947	4.830	6.083	3.642	1.74	4.24	4.79	6.19	3.65
Sand: peat	0.363	3.503	5.400	5.850	3.778	0.48	1.88	4.45	5.57	3.68
Sand: clay	0.420	1.577	1.647	2.017	1.415	0.45	0.92	1.55	1.88	1.20
Mean (I)	0.713	1.912	3.242	3.854		0.77	1.91	3.00	3.79	
LSD at 5%	M=0.104		I=0.090	M×I=0.0187		M=0.193		I=0.253	M×I=0.478	
Dry weight of roots / cutting (g)										
Sand	0.122	0.209	0.371	0.498	0.300	0.135	0.209	0.371	0.498	0.303
Peat moss	0.584	0.661	1.838	2.069	1.288	0.604	0.634	1.606	2.110	1.238
Sand: peat	0.125	1.184	1.642	1.936	1.222	0.198	1.447	1.538	1.904	1.272
Sand: clay	0.174	0.536	0.559	0.685	0.489	0.158	0.357	0.508	0.589	0.403
Mean (I)	0.251	0.648	1.103	1.297		0.274	0.662	1.006	1.275	
LSD at 5%	M=0.041		I=0.038	M×I=0.078		M=0.059		I=0.045	M×I=0.097	

Table 3. Effect of medium type, IBA concentration and their interactions on number of shoots per cutting and fresh and dry weights of shoots per cutting (g) of *Pachira aquatica* at 90 days after culturing during seasons of 2015 and 2016

Medium type (M)	IBA concentration ppm (I)									
	0.0	1000	2000	4000	Mean (M)	0.0	1000	2000	4000	Mean (M)
	First season					Second season				
Number of shoots / cutting										
Sand	1.00	1.00	1.00	1.33	1.08	1.00	1.00	1.33	1.33	1.17
Peat moss	1.33	1.33	2.00	2.33	1.75	1.00	1.33	1.67	2.33	1.58
Sand: peat	1.33	1.67	1.67	1.67	1.58	1.00	1.67	1.33	2.00	1.50
Sand: clay	1.00	1.33	1.00	1.33	1.17	1.00	1.00	1.33	1.33	1.17
Mean (I)	1.17	1.33	1.42	1.67		1.00	1.25	1.42	1.75	
LSD at 5%	M=0.570		I= 0.351		M × I=0.831	M=0.492		I=0.438		M × I=0.903
Fresh weight of shoots / cutting (g)										
Sand	0.42	0.90	1.02	1.56	0.97	0.45	0.93	1.05	1.52	0.99
Peat moss	1.12	1.18	2.55	3.38	2.06	1.11	1.16	2.45	3.21	1.98
Sand: peat	1.02	1.98	2.14	2.92	2.02	1.08	1.88	1.96	2.42	1.83
Sand: clay	0.76	0.78	1.08	2.08	1.18	0.76	0.71	1.04	1.92	1.11
Mean (I)	0.83	1.21	1.70	2.49		0.85	1.17	1.62	2.27	
LSD at 5%	M=0.119		I=0.128		M×I=0.251	M=0.113		I=0.078		M×I=0.176
Dry weight of shoots / cutting (g)										
Sand	0.10	0.21	0.23	0.38	0.23	0.11	0.22	0.24	0.35	0.23
Peat moss	0.27	0.27	0.59	0.77	0.48	0.26	0.27	0.56	0.75	0.46
Sand: peat	0.24	0.45	0.47	0.68	0.46	0.25	0.43	0.46	0.56	0.42
Sand: clay	0.18	0.16	0.25	0.48	0.27	0.17	0.18	0.23	0.44	0.25
Mean (I)	0.19	0.27	0.39	0.58		0.19	0.27	0.37	0.52	
LSD at 5%	M=0.030		I= 0.028		M×I= 0.057	M=0.026		I=0.019		M×I=0.041

Table 4. Effect of medium type, IBA concentration and their interactions on number of leaves and leaf area (cm^2) per cutting of *Pachira aquatica* at 90 days after culturing during seasons of 2015 and 2016

Medium type (M)	IBA concentration ppm (I)									
	0.0	1000	2000	4000	Mean (M)	0.0	1000	2000	4000	Mean (M)
	First season					Second season				
Number of leaves/cutting										
Sand	1.00	1.67	2.00	2.00	1.67	1.00	1.33	1.67	2.00	1.50
Peat moss	1.00	2.00	2.33	3.00	2.08	1.33	2.33	2.33	2.67	2.17
Sand: peat	1.33	1.33	2.00	2.67	1.83	1.67	2.33	2.33	2.00	2.08
Sand: clay	1.00	1.33	1.67	2.33	1.58	1.00	1.67	1.67	2.00	1.58
Mean (I)	1.08	1.58	2.00	2.50		1.25	1.92	2.00	2.17	
LSD at 5%	M=0.433		I=0.427		M × I=0.855	M=0.399		I=0.415		M × I=0.821
Leaf area/cutting (cm^2)										
Sand	33.46	43.51	78.49	135.52	72.74	28.86	54.80	97.87	129.96	77.87
Peat moss	194.03	205.32	244.55	297.16	235.26	132.08	181.91	204.74	266.14	196.22
Sand: peat	61.55	70.55	115.64	278.28	131.51	67.43	81.90	110.44	255.19	128.74
Sand: clay	26.61	102.23	121.23	144.17	98.57	34.45	65.58	120.61	134.97	88.90
Mean (I)	78.91	105.40	139.98	213.78		65.71	96.05	133.41	196.57	
LSD at 5%	M=7.615		I=6.854		M × I=14.065	M=12.466		I=7.890		M × I=18.433

Table 5. Effect of medium type, IBA concentration and their interactions on fresh and dry weights of leaves per cutting (g) of *Pachira aquatica* at 90 days after culturing during seasons of 2015 and 2016

Medium type (M)	IBA concentration ppm (I)									
	0.0	1000	2000	4000	Mean (M)	0.0	1000	2000	4000	Mean (M)
	First season					Second season				
Fresh weight of leaves / cutting (g)										
Sand	0.92	1.51	2.74	5.14	2.57	0.97	1.89	2.79	5.44	2.77
Peat moss	6.69	7.70	9.57	12.59	9.14	5.04	7.17	8.97	12.77	8.49
Sand: peat	1.99	2.62	4.34	11.84	5.20	3.16	3.29	4.34	11.22	5.50
Sand: clay	1.04	3.57	4.50	5.59	3.67	1.02	3.28	4.17	5.94	3.60
Mean (I)	2.66	3.85	5.29	8.79		2.55	3.91	5.07	8.84	
LSD at 5%	M=0.254		I=0.170	M × I=0.387		M=0.626		I=0.349	M × I=0.867	
Dry weight of leaves / cutting (g)										
Sand	0.13	0.22	0.40	0.76	0.38	0.15	0.20	0.39	0.80	0.39
Peat moss	0.99	1.14	1.42	1.87	1.36	0.83	1.06	1.15	1.80	1.21
Sand: peat	0.29	0.39	0.64	1.76	0.77	0.59	0.49	0.64	1.70	0.86
Sand: clay	0.15	0.53	0.67	0.83	0.54	0.15	0.47	0.63	0.85	0.52
Mean (I)	0.39	0.57	0.78	1.30		0.43	0.56	0.70	1.29	
LSD at 5%	M=0.038		I=0.026	M × I=0.058		M=0.086		I=0.066	M × I=0.143	

with sand (1:1, *V/V*) without difference significant between both treatments compared to the other media types under study. However, the highest significant leaf area per cutting was achieved by using peat moss medium compared with the other tested medium.

These results are in accordance with those found by Adams *et al.* (2003) on *Dieffenbachia maculate*, Ogbu *et al.* (2008) on *Mussaenda* spp and Ibironke and Victor (2016) on *Mussaenda philippica*.

Differences in performance between various rooting medium can be attributed to a direct effect of the substrate on the basal portion of the cutting, rather than to indirect or earlier physiological changes Khayyat *et al.* (2007). The superiority of media contained peat moss (peat moss alone or combined with sand) in this study compared with other tested media may be attributed to its high water holding capacity which associated with higher rates of water uptake in the cutting. Addition of sand to peat moss gave the medium further advantages since it improved aeration and drainage conditions of the mixture.

It is quite clear from the results in Tables 3, 4 and 5 that only the highest concentration of IBA (4000 ppm) could significantly surpassed control treatment concerning number of shoots/ cutting. On the other side, using of any IBA applied concentrations significantly enhanced fresh and dry weights of shoots/ cutting, number of leaves/ cutting, leaf area per cutting as well as fresh and dry weights of leaves/cutting. Generally, all abovementioned characters were gradually improved by increasing IBA concentration and reached to the ultimate values with the highest concentration (4000 ppm).

According to Fukaki *et al.* (2007) auxin is a key plant hormone that promotes lateral root formation which reflected in shoots and leaves growth. Similar results were reported by Shirzad *et al.* (2012) on *Ficus benjamina* cuttings, Khajehpour *et al.* (2014) on cuttings of olive and Nayagam (2016) on *Bombax ceiba* tree. The increase in the abovementioned parameters may

be due to more rooting percentage and number of roots which reflected in increasing shoots and leaves measurements (Jamal *et al.*, 2016).

Concerning the effect of interaction between medium type and IBA concentration generally, the maximum values of all abovementioned parameters were achieved by treating cuttings with 4000 ppm followed by culturing them in peat moss alone or mixed with sand. While the former treatment was significantly higher than all applied treatments, there was no significant difference between both treatments concerning number of shoots/cutting, number of leaves/ cutting, leaf area/cutting and leaves area/ cutting especially during the second season.

Ismail and Asghar (2007) reported that *Ficus hawaii* cuttings treated with increasing concentrations of IBA produced more roots which increased aerial growth of the plants resulted in the highest leaf area.

Chemical Determinations

Total chlorophyll (SPAD unit), phosphorus (%) and potassium (%) in leaves were significantly magnified by culturing the cuttings in peat moss alone or mixed with sand compared with other applied media without significant differences between both media in this regard (Tables 6 and 7). However, the highest total carbohydrates and nitrogen percentages in leaves were detected by using peat moss medium followed by its mixture with sand.

These results are in line with those found by Akakpo *et al.* (2014) concern soluble, insoluble and total sugars contents of sheanut tree (*Vitellaria paradoxa* C. F. Gaertn) stem cuttings.

Results in Tables 6 and 7 clearly show that there was a linear relationship between IBA concentration and total chlorophyll, total carbohydrates, total nitrogen, phosphorus and potassium percentages in leaves in most cases.

In this regard, Sivaci and Yalcin (2006) reported that total leaf chlorophyll content of three apple kinds (Golden Delicious', 'Starkrimson Delicious' and 'Misket Delicious') were significantly increased by the treatment of IBA. Also, Deb *et al.* (2009) revealed that the maximum leaf chlorophyll content in semi hardwood cuttings of lemon (*Citrus limon*) was recorded when cuttings were treated with IBA.

The interaction between different rooting media and IBA concentrations showed that, in most cases the all chemical constituents parameters reached to the highest significant values as cuttings bases dipped in 4000 ppm IBA and cultured in peat moss or its mixture with sand without significant differences between both treatments in this connection (Tables 6 and 7).

Anatomical Study

Transverse sections in adventitious root as affected by various IBA concentrations are presented in Table 8 and illustrated in Fig. 1. It could be observed that untreated cuttings initiated small root diameter with undifferentiated vascular tissues and unarranged cortical cells compared to the other tested IBA treatments. However, the lowest IBA concentration (1000 ppm) resulted in increasing root diameter with developed and differentiated vascular system as well as organized cortical cells concomitant with increased in both epidermis and cortex thickness compared to control (untreated cutting). Cuttings treated by medium (2000 ppm) and high (4000 ppm) concentrations of IBA showed wide differences between them and the lowest concentration (1000 ppm) or control. Since, it was observed the appearance of secondary growth in adventitious roots which was absence in the lowest concentration and control. In addition, the highest concentration (4000 ppm) gave the highest values of anatomical parameters *i.e.;* root diameter, bark thickness, secondary xylem thickness and average secondary xylem vessel diameter which reached to 1682.06, 132.29, 364.06 and 54.97, respectively, compared to the moderate concentration (2000 ppm) which reached to 1355.49, 96.63, 260.00 and 43.31, respectively. This result is in agreement with those reported by San Jose *et al.* (2012).

Conclusion

This study provides preliminary results concerning vegetative propagation of *Pachira aquatica* by cutting for the first time. Obtained results clearly demonstrate that cuttings of this plant had low root ability, since only about 43.67% of cuttings could rooted without auxin treatment. Increasing of IBA concentration was concomitant with improving in cutting root

Table 6. Effect of medium type, IBA concentration and their interactions on total chlorophyll (SPAD unit) and total carbohydrates percentage in leaves of *Pachira aquatica* at 90 days after culturing during seasons of 2015 and 2016

Medium type (M)	IBA concentration ppm (I)									
	0.0	1000	2000	4000	Mean (M)	0.0	1000	2000	4000	Mean (M)
	First season					Second season				
Total chlorophyll (SPAD unit)										
Sand	40.33	42.67	43.67	45.33	43.00	40.33	42.33	44.33	45.00	43.00
Peat moss	45.00	46.67	47.67	51.33	47.67	43.67	45.67	47.67	52.67	47.42
Sand: peat	44.67	46.67	48.33	50.00	47.42	43.67	45.33	47.33	51.00	46.83
Sand: clay	43.00	44.33	46.00	46.67	45.00	42.33	44.67	45.33	45.67	44.50
Mean (I)	43.25	45.08	46.42	48.33		42.50	44.50	46.17	48.58	
LSD at 5%	M=0.440		I=0.587		M×I=1.107	M=1.036		I=00.769		M×I=1.682
Total carbohydrates percentage										
Sand	11.67	12.59	13.11	13.41	12.69	11.86	12.03	12.78	13.51	12.55
Peat moss	12.82	13.28	13.58	13.90	13.40	12.78	13.33	13.78	13.97	13.47
Sand: peat	12.35	12.74	13.06	13.24	12.85	12.67	13.00	13.18	13.59	13.11
Sand: clay	11.85	12.80	13.36	13.48	12.87	11.70	12.63	13.43	13.58	12.84
Mean (I)	12.17	12.85	13.28	13.51		12.25	12.75	13.29	13.66	
LSD at 5%	M=0.219		I=0.226		M × I=0.447	M=0.252		I=0.251		M×I=0.502

Table 7. Effect of medium type, IBA concentration and their interactions on nitrogen, phosphorus and potassium percentages in leaves of *Pachira aquatica* at 90 days after culturing during seasons of 2015 and 2016

Medium type (M)	IBA concentration ppm (I)									
	0.0	1000	2000	4000	Mean (M)	0.0	1000	2000	4000	Mean (M)
	First season					Second season				
Total nitrogen percentage										
Sand	2.61	2.63	2.63	2.62	2.62	2.59	2.61	2.65	2.61	2.61
Peat moss	2.62	2.67	2.77	2.81	2.71	2.61	2.66	2.73	2.74	2.68
Sand: peat	2.58	2.62	2.72	2.79	2.68	2.56	2.61	2.68	2.77	2.65
Sand: clay	2.61	2.55	3.63	2.66	2.61	2.54	2.57	2.62	2.69	2.60
Mean (I)	2.60	2.62	2.69	2.72		2.57	2.61	2.67	2.70	
LSD at 5%	M=0.025		I=0.030		M × I=0.057	M=0.025		I=0.028		M × I=0.055
Phosphorus percentage										
Sand	0.425	0.422	0.459	0.459	0.441	0.422	0.422	0.440	0.448	0.475
Peat moss	0.434	0.469	0.496	0.539	0.485	0.431	0.466	0.484	0.518	0.482
Sand: peat	0.470	0.450	0.512	0.525	0.489	0.442	0.448	0.503	0.535	0.433
Sand: clay	0.422	0.429	0.429	0.445	0.431	0.430	0.443	0.443	0.450	0.441
Mean (I)	0.438	0.443	0.474	0.492		0.431	0.445	0.467	0.488	
LSD at 5%	M=0.015		I=0.011		M×I=0.024	M=0.011		I=0.009		M×I=0.019
Potassium percentage										
Sand	2.13	2.17	2.18	2.22	2.17	2.11	2.16	2.17	2.22	2.16
Peat moss	2.20	2.24	2.28	2.43	2.29	2.22	2.24	2.29	2.38	2.28
Sand: pat	2.21	2.24	2.18	2.22	2.30	2.21	2.24	2.34	2.40	2.30
Sand: cay	2.14	2.16	2.22	2.22	2.18	2.12	2.18	2.21	2.22	2.18
Mean (I)	2.17	2.20	2.24	2.33		2.16	2.20	2.25	2.30	
LSD at 5%	M=0.032		I=0.027		M×I=0.056	M=0.017		I=0.016		M×I=0.0333

Table 8. Effect of selected media (peat moss : sand at 1 : 1 *V/V*) and IBA concentration on measurements of certain histological features in transverse sections of adventitious roots formed on *Pachira aquatica* stem cutting at 70 days after culturing during second season (2016)

Treatment	Character						
	Root diameter (µ)	Epidermis thickness (µ)	Cortex thickness (µ)	vascular cylinder thickness (µ)	Bark thickness (µ)	Secondary xylem thickness (µ)	Average secondary xylem vessel diameter (µ)
0.0 IBA	1191.09	15.26	778.00	397.83	**	**	**
1000 ppm IBA	1437.89	20.46	1012.69	404.74	**	**	**
2000 ppm IBA	1355.49	*	*	*	96.63	260.00	43.31
4000 ppm IBA	1682.06	*	*	*	132.29	364.06	54.97

* Not observed due to absence secondary growth. ** Not observed due to secondary growth.

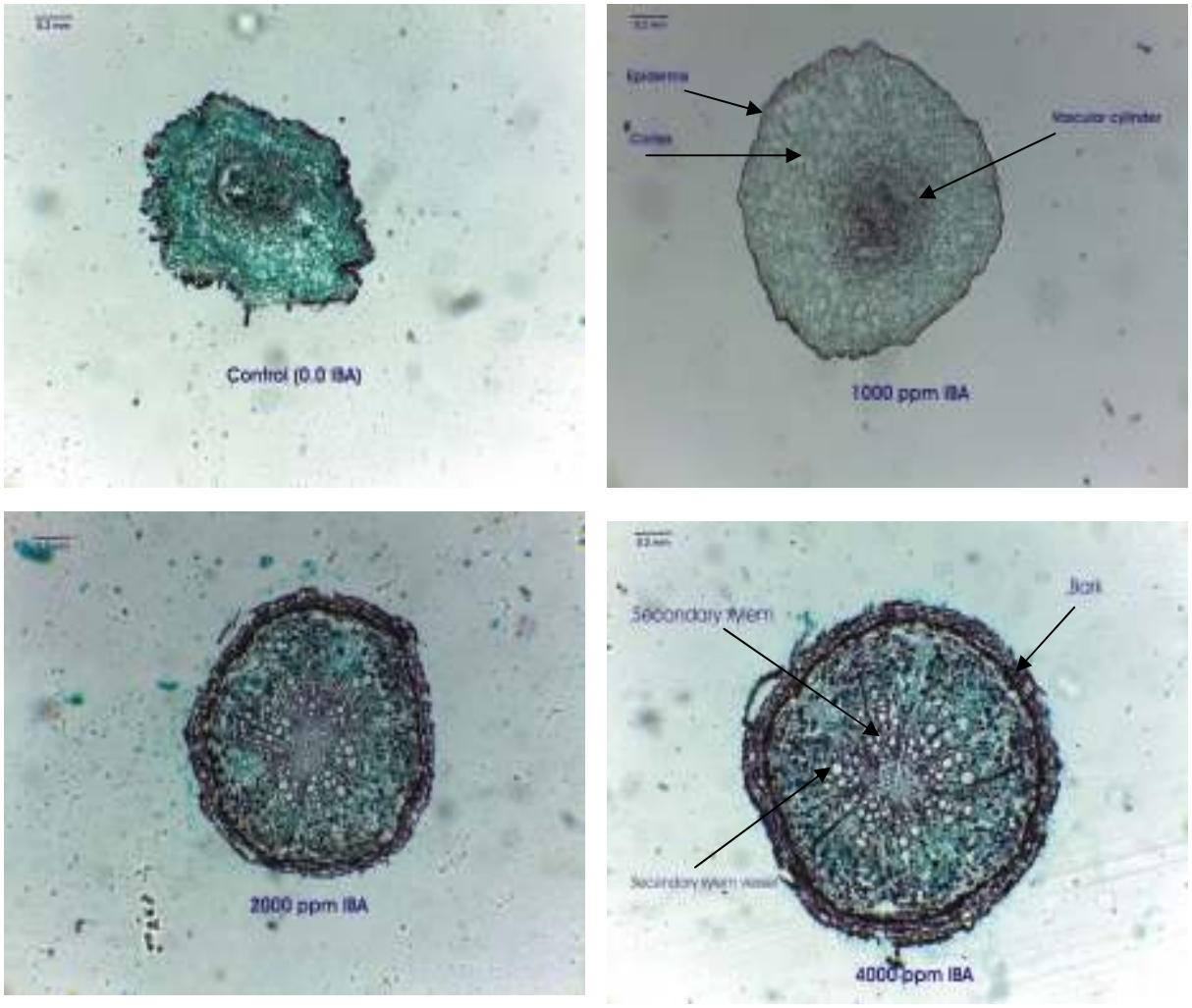

Fig.1. Transverse sections of adventitious roots initiated on *Pachira aquatic*a cuttings treated with different concentrations of IBA and cultured in sand: peat moss (1:1, *V/V*) during second season (2016)

ability, so that the highest concentration (4000 ppm) was the best treatment in this regard. Peat moss alone or combined with sand (1:1, *V/V*) proved to be the best rooting medium among different tested medium, but from an economic point of view, it is better to use the mixture of peat moss and sand. Our recommendation to propagate this plant by cuttings is to treat the cuttings with IBA (4000 ppm) before culturing them in mixture of peat moss and sand (1:1, *V/V*). Further studies will be needed to improve cutting root ability of this important ornamental tree.

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تأثيـــر نـــوع البيئة وتركيـــز إندول حمـــض البيوتريك علـــى إكثـــار نبـــات البشـــيرة بالعقـــل

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أجريت هذه الدراسة بمشتل الزينة بكلية الزراعة - جامعة الزقازيق- مصر، خلال موسمين متتالين (٢٠١٥ و ٢٠١٦)، وتهدف هذه الدراسة لإختبار عاملين من المحتمل أن يؤثرا على القدرة التجذيرية للعقل وهما تركيز إندول حمض البيوتريك (صفر، ١٠٠٠ ، ٢٠٠٠ أو ٤٠٠٠ جزء/مليون) ونوع بيئة التجذير (الرمل، البيت موس، الرمل: البيت موس أو الرمل: الطمي بنسب حجمية متساوية) بالإضافة إلى تأثير تداخل الفعل بينهما على قابلية وجودة تكوين الجذور والأفرع على عقل نبات البشيرة. حيث تم تسجيل كلاً من صفات النسبة المئوية للتجذير وعدد الجذور/عقلة وطول الجذر (سم) والوزن الطازج والجاف للجذور/عقلة (جم)، وعدد الأفرع/عقلة، والوزن الطازج والجاف للأفرع/عقلة (جم)، وعدد الأوراق/عقلة، ومساحة الأوراق (سم^{٢})، والوزن الطازج والجاف للأوراق/عقلة (جم) كصفات نمو، أيضاً، تم تقدير كل من الكلوروفيل الكلي (كوحدات SPAD) والنسب المئوية لكل من الكربوهيدرات الكلية والنيتروجين الكلي والفسفور والبوتاسيوم في الأوراق، كذلك، أجريت دراسة تشريحية لبعض المعاملات المختارة (المعاملة بتركيزات مختلفة من إندول حمض البيوتريك والزراعة في بيئة مكونة من الرمل و البيت موس بنسب حجمية متساوية)، وقد أظهرت النتائج أنه في معظم الحالات قد أمكن الحصول على أعلى القيم للصفات سالفة الذكر بمعاملة العقل بتركيز ٤٠٠٠ جزء/مليون من إندول حمض البيوتريك، كما أظهرت الدراسة التشريحية للجذور العرضية أن أكبر قطر للجذور مع تكشف كامل للنسيج الوعائي قد حدث في جذور العقل التي عوملت بتركيز ٤٠٠٠ جزء/مليون من إندول حمض البيوتريك، كما تم تسجيل أعلى القيم لمعظم الصفات سابقة الذكر عند زراعة العقل في بيئة البيت موس أو مخلوطة مع الرمل مع عدم وجود فرق معنوي بين كلتا المعاملتين، وبصفة عامة، فمن بين مختلف معاملات التداخل المختبرة يمكن التوصية بمعاملة العقل بإندول حمض البيوتريك بتركيز ٤٠٠٠ جزء فى المليون قبل زراعتها في بيئة تحتوي على مخلوط من البيت موس و الرمل بنسب حجمية متساوية.

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