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Studies on Vegetative Propagation of *Tamarindus indica* L. by Stem Cuttings in Aswan, Egypt

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Abstract: This research was conducted during 2019-2020 seasons at the tropical farm in Kom Ombo - Aswan Botanical Garden, ARC, Egypt. It aims to study the possibility of vegetative propagation of *Tamarindus indica* L. trees at 4 years old by basal, middle and terminal cuttings. The terminal ones show a success better than two others. An anatomical structure comparison of the basal & terminal (hardwood & softwood) cuttings was investigated. The cuttings treated by soaking for 24 hours in IBA at 0, 1000, 2000 and 4000 ppm. Then, are planting in 3 types of growing media: sand, loamy sand and peat moss. The effects of these treatments are studied on the response of cuttings to rooting and production of tamarind rooted cuttings. Results revealed that soaking the cuttings in IBA 4000 ppm resulted in the highest values of the survival and rooting percentages, number and length of roots, the fresh and dry weights of roots and aerial parts compared to control. The terminal cuttings of tamarind responded well to planting in the peat moss medium and give the highest rooting % and growth parameters compared to other media. In addition, the combined of high conc. of IBA gave the best results with peat moss medium and had a great impact for the success of cuttings and rooting in two seasons compared to other untreated treatments. The basic anatomical structure of two types of cuttings (basal and terminal) was similar. The specific characters of the terminal cuttings are more suitable for inducing and success of rhizogenesis.

Key words: Cutting propagation・*Tamarindus indica* L.・IBA・Peat moss・Stem anatomy

INTRODUCTION

Tamarindus indica L. belongs to the family Fabaceae, subfamily *Caesalpinoideae*, is a crucial food within the tropics. A beautiful tree that produces useful medicinal, nutritional fruits and at the same time valuable wood [1]. This tree is widespread throughout the tropics and subtropics, it originated from the tropical Africa and native to many tropical African countries including Uganda, where it naturally dominates six out of nine agroecological zones [2]. The fruit tree is naturally widespread on-farms and in the wild habitats in the tropics [3]. It grows well in a wide range of climates and conditions [4]. Also, tamarind tree is one of the ideal trees or ornamental trees that can be grown on neighboring roads in addition to protecting the environment. Tamarind has valuable medicinal and antibacterial activities from its leaves, stem, bark and fruit pulp [5]. Moreover, the tree produces high valuable wood that is used in the manufacture of furniture, various agricultural tools, hammers and others [6].

Cutting propagation offers production of true-to-type plants in a shorter period and availability of superior individuals for nursery and large-scale commercial plantation with quick productive gains. Also, Sally [7] revealed that vegetative propagation can be used to produce plants like mothers and in a shorter period compared to the growing by seed. However, studies on tamarind trees often focus on their economic importance Luo *et al*. [8]; but so far there are a few studies on the tree propagation and growth [9]. In this respect, Ferreira1 *et al.* [10] observed that soft-wood cuttings of *T. indica* had a higher rhizogenic capacity, influenced by the growing season, while winter season being the best time.

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The highest percentage of dead cuttings was observed with the semi-hardwood and hardwood cuttings for both winter and spring seasons. Moreover, the number of roots and shoots as well as percentage of rooted cuttings in soft-wood cuttings was higher with 1, 500 ppm of IBA.

Hormone treatments of stem cuttings has been used with success in the vegetative propagation of many conservation priorities (rare, endangered and threatened) and high economic value trees such as *Ginkgo biloba* [11]. Moreover, Ebeid [12] on *Chrysophyllum oliviforme* stated that using the high hormone concentrations (4000- 5000 ppm) increased the rooting percentage and growth parameters compared to the low ones (1000- 3000 ppm). Regarding the physiological conditions, the viability of cuttings has increased with plant growth regulators, which help to make the endogenous hormonal balance suitable for the process of root formation, especially between auxins, gibberellins and cytokinins, which encourages the formation of adventitious roots [13]. Therefore, it is possible to use the plant growth regulators as an exogenous treatment to balance hormones, especially indole butyric acid (IBA), considering that the ideal concentration varies according to the plant species.

The propagation medium is an important factor in vegetative propagation by stem cutting, as it creates a suitable environment for rooting [14]. Moreover, Weismann [15] pointed out that the growing media are critical to vegetative propagation and the rooting ability of cuttings greatly relies on media as well as micro climatic conditions. Moreover, the transition from the juvenile phase to maturity is called the meristem aging (Cyclophysis), it is the phase change as reported by Brink [16] or it is ontogenetic according to [17]. The maturation is an integral part of the life cycle of all vascular plants. However, Greenwood [18] postulated that there are 4 stages of maturity: the embryonic phase, the post embryonic juvenile vegetative phase, the adult vegetative phase and the adult reproductive phase. However, maturity in woody plants is associated with decreased in the growth rate, increased plagiotropism; changes in reproductive competence; branching properties and foliar morphology. In addition to the physiological, anatomical and biochemical changes that accompany the transition to the adult phases [19].

The aim of this work is therefore to determine the effects of IBA concentrations and different growing media on rooting success of *T. indica* softwood cuttings and to evaluate some anatomical characteristics for some types of stem cuttings of Egyptian tamarind.

MATERIALS AND METHODS

This study was carried out during February in 2019 and 2020 seasons at the Tropical Farm of Kom- Ombo, Aswan Botanical Garden, Aswan Governorate, South Egypt (N 24°05' E 32°53'); to study the effect of different growing media and concentrations of indole butyric acid (IBA) on root induction in terminal stem cuttings of *Tamarindus indica* L. trees.

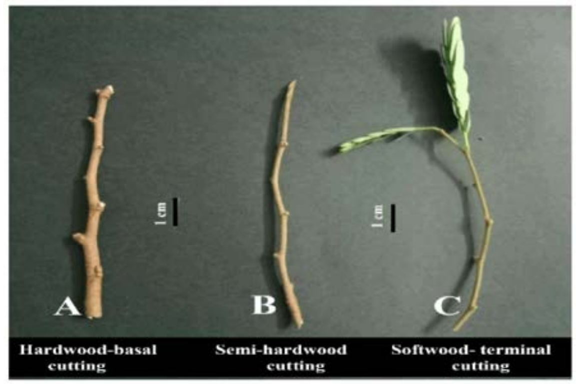

Fig. 1: Morphological shapes of different types of stem cuttings of tamarind: A. hardwood (Bs-cutting); B. semi-hardwood; C. softwood (Tr-cutting).

Table A: Some physical and chemical properties of the used sand and loamy soil as growing media

	Growing media	
Characters	Sand	Loamy sand
Sand %	85.83	71.80
Silt %	8.02	12.10
Clay %	6.15	16.10
pH	7.33	8.09
EC: ds/m	0.54	0.38
OM %	1.22	8.37
Nitrogen %	0.056	0.83
Phosphorus %	0.11	0.23
Potassium %	4.25	6.04

Table B: Physical and chemical characteristics of the peat moss

Peat moss characteristics	Value
pH	4.00
EC (ds/m^{-1})	4.23
Organic matter (%)	22.65
Total N (%)	1.10
C/N ratio	12.86
Total soluble N (ppm)	120.00
Total P (%)	0.78
Total K (%)	1.23

Preparing of Cuttings: In the first season, three types of stem cuttings were used, these are: basal, middle and terminal cuttings, but only the terminal stem cuttings highly showed success in rooting, so the other two types were excluded.

Cuttings were prepared from healthy trees with good growth characteristics, 4 years old and 10-12 cm long with 3-4 nodes (Fig. 1). Leaves were removed from the cutting, leaving two leaves at the top of the cutting to reduce water loss through transpiration. For preventing fungal infection, after preparing cuttings, they were sprayed with a fungicide solution (Tobson M 70) at a concentration of 1000 ppm before planting.

IBA Treatment: The cuttings were treated with the different concentrations of IBA (0, 1000, 2000 and 4000 ppm) were used. IBA solutions were prepared individually by dissolving the auxin in ethanol 95%, followed by distilled water as 1:1, then the cuttings were treated by soaking the cutting base in the aqueous solution of IBA for 24 hours or in distilled water (for control). Cuttings treated with auxin at different concentrations were immediately inserted in the different types of growing media in 24 x 24 cm perforated polyethylene bags, filling only by 75% with one of the different media. The cuttings were set in the growing media at approximately 7 cm deep with gentle spray irrigation applied when needed and the bags were placed on shelves in the saran house. However, the cuttings were covered with plastic sheet until the end of the experiment.

The Experiment Design: This experiment was carried out in factorial experimental design with three media types (sand, loamy sand and peat moss) (A) and 4 IBA concentrations (B) with three replicates, containing 8 cuttings per experimental unit, for a total of 288 cuttings of the experiment. Three months after treatments, observations were recorded for, survival and rooting percentages, roots number per cutting and length, root fresh and dry weights per cutting as well as shoots fresh and dry weights per cutting. However, root length was measured as the length of the tallest three roots while, the roots and shoots dry weights/ cutting were recorded after drying the plant parts for 72 h at 70°C.

The Anatomical Investigation: The anatomical study was applied at the day 0 for 5 cuttings of hardwood (Basal- abbreviated: Bs.) and softwood (Terminal- abbreviated: Tr.). These were collected from *T. indic*a saplings and processed for sectioning. The fresh cutting was soaked at least 48 hours in the formalin acetic acid alcohol (FAA) solution; preserved in 70% alcohol and dehydrated in series of ethyl alcohol. Sectors were taken by a rotary microtome and stained in safranin and fast green and then mounted in Canada balsam [20]. Sectors were examined using a light microscope on magnifications x= 4 & x= 10 to adjust a fine resolution. Photos were captured using the ToupTek- ToupView digital camera installed to a Labomed- Labo. America light microscope eyepiece. Some anatomical characters were investigated. These are: cortex thickness (µm), cortex layers number, pith diameter (µm), pith rays' number in each vascular cylinder, xylem region thickness (µm), these characters are presented by viewing [minimum maximum (average)] values in Table 1.

Statistical Analysis: The recorded data were tabulated and statistically analyzed by the method of Snedecor [21] and L.S.D as mentioned by Little and Hills [22].

RESULTS AND DISCUSSION

The present study revealed a significant effect of the rooting media (sand, loamy sand and peat moss) and IBA concentrations (0, 1000, 2000 and 4000 ppm) on adventitious root formation in terminal stem cuttings of *Tamarindus indica* L. In addition to relevant the anatomical structure and characters for softwood cuttings comparing to those of hardwood (basal) ones. Indicating some anatomical interpretations for inducing the rooting.

The Anatomical Observations: The hardwood (Basal) and softwood (Terminal) stem cuttings from juvenile *Tamarindus indica* L. trees at 4 years old showed similar basic anatomical structures (Fig. 2: A & B). The stems covered by periderm, followed by the cortical tissue. This is composed of parenchymatous cell, arranged in rows ranges from 2-6 layers in both types of investigated stem cuttings (Fig. 2: C & D). These cells are outwardly peripheral to the vascular cylinder. The pericycle is next to the cortex. It is differentiated from sclerenchyma cells. Some solitary crystals are observed within both cortical and pericycle regions. The vascular cylinder in Tr-cutting is of a continuous vascular xylem tissue surrounded by an external phloem. The xylem region is larger in the hardwood cuttings (300-450 µm thickness), in addition to containing thicker vessels intermixed with high number of fibers (Fig. 2: E & F). High number of pith rays are penetrating the vascular xylem and phloem. These rays are more in Tr-cuttings (24-37 rays) than those in the Bs-cuttings (17-26 ones) (Fig. 2: E & F). The rays in the

Table 1: Comparison of some anatomical cross- sections of terminal and basal stem cuttings in *T. indica* L.

Anatomical characters [min-max (average)]	Tr-cutting	Bs-cutting
Cortex thickness (µm)	70-92.5 (84.64)	37.5-75 (60)
Cortex layers no.	4-6 (5)	2-5 (3.5)
Pith diameter (µm)	510-600 x 330-400 (534 x 362)	430-450 x 270-400 (440 x 317.5)
Pith rays no. in vascular cylinder	24-37 (31)	17-26 (22.6)
Xylem thickness (µm)	100-150 (129)	300-450 (413.75)

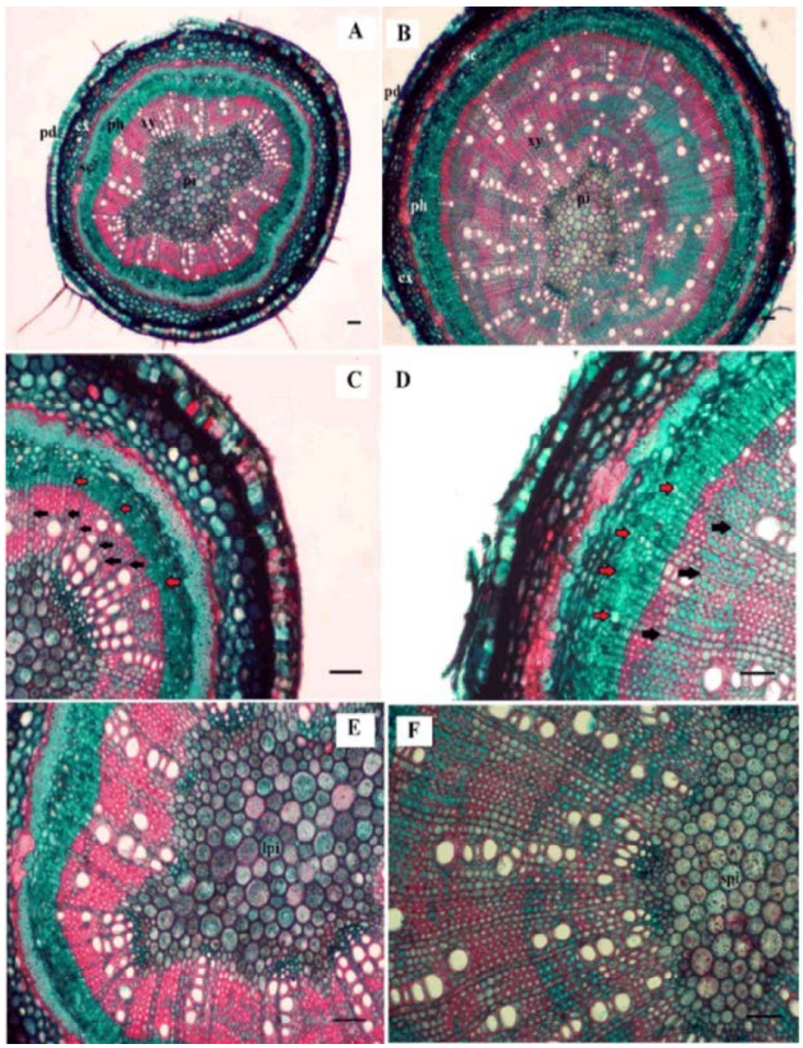

Fig. 2: Transverse sections of terminal (Tr) and basal (Bs) parts of micro-cuttings in *Tamarindus indica* L. (Tamarind) at Day 0; the whole sector showing the difference in area of the pith and the quantity of xylem tissue in (A) Tr- cutting with large pith and small quantity of xylem & (B) Bs-cutting with small pith and large quantity of xylem [magnification x= 4, bar 100 µm]. (C) magnification x= 10 showing well-initiated parenchyma cells in cortex, continuous vascular vessels and phloem and large no. of pith rays penetrating vascular cylinder; black arrows indicate large no. of radiated rays within the vascular vessels, red arrows indicate penetrated rays within phloem; bar 100 µm. (E) no. of pith rays and the large pith region at magnification x= 10, bar 100 µm. (D & F) magnifications x= 10, bar 100 µm showing the Bs-cutting; in (D) slightly compressed cortex parenchymatous cells and semi-continuous vascular cylinder; black arrows indicate separating rays among xy-tissue, red arrows indicate the separated bulks of phloem within semi-continuous bundles. In (E) less no. of pith rays and large xylem region; abb.: pd.: Periderm, cx.: Cortex, sc.: Sclerenchyma cells, ph.: Phloem, xy.: Xylem, pi.: Pith, spi.: Small pith & lpi.: Large pith

Table 2: Effect of growing media and different concentrations of IBA on the survival and rooting percentage of the softwood cuttings for *Tamarindus indica* during 2019 and 2020 seasons

	2019 season					2020 season					
	IBA ppm (B)					IBA ppm (B)					
Growing media (A)	0	1000	2000	4000	Mean	0	1000	2000	4000	Mean	Means of seasons
Survival (%)											
Sand	12.57	24.10	27.30	29.07	23.26	14.87	23.90	30.33	33.00	25.53	24.40
Loamy sand	20.03	34.40	37.07	38.57	32.52	22.67	28.20	35.87	38.70	31.36	31.94
Peat moss	35.27	42.53	46.47	52.90	44.29	31.93	39.63	41.70	56.47	42.43	43.36
Mean	22.62	33.68	36.95	40.18		23.16	30.58	35.97	42.72		
LSD at 5 %		A= 0.93; B= 1.07; A x B= 1.86					A =0.99; B= 1.15; A x B =1.98				
Rooting (%)											
Sand	1.83	15.47	24.13	28.50	17.48	1.97	14.33	26.20	28.73	17.81	17.65
Loamy sand	2.87	26.23	31.07	37.90	24.52	2.93	24.17	29.73	39.43	24.07	24.30
Peat moss	5.00	35.60	45.27	53.57	34.86	5.17	38.77	46.07	52.37	35.59	35.23
Mean	3.23	25.77	33.49	39.99		3.36	25.76	34.00	40.18		
LSD at 5 %		A = 0.95; B = 1.09; A x B = 1.90					A = 0.87; B = 1.00; A x B = 1.74				

Bs-cuttings tend to separate the vascular tissues into distinct bundles. The later cuttings have semi-continuous vascular cylinder (Fig. 2: C & D). The central part of cuttings sectors is of somewhat regular shape of pith region. The pith is composed of the storage parenchyma cells. The central pith region is larger in sections of Tr-cuttings (534 x 362 µm size); while more regular and smaller in the sections of the hardwood (Bs-cuttings) (Fig. 2: A & B).

Effect of IBA and Growing Media on the Survival and Rooting Percentage: Obtained data in Table (2) showed that there were significant differences in the percentage values of survival and rooting due to the use of different rooting media. Moreover, the results showed that planting the cuttings in peat moss alone as a growing media give significantly better results in terms of survival % of rooting (43.4%) and rooting percentage (35.2%) in the mean seasons, followed by planting cuttings in loamy sand soil for survival % (31.9%) and rooting percentage (24.3 %) in the mean of two seasons. On the other hand, inserted cuttings in sand soil resulted in the lowest of survival and rooting percentages in both seasons. Through the current results, among the used concentrations of rooting hormone (IBA), the highest one (4000 ppm) showed better results compared to the rest of the concentrations, also by increasing the concentration used up to 4000 ppm, with which the measurements of both survival rate and percentage of rooting were significantly increased.

Regarding the interaction between types of the used growth media and different concentrations of indole butyric acid, there was a significant effect on both survival and rooting percentages in both seasons as shown in Table (2). Nevertheless, the highest values of these two characters (54.7% and 52.5% for survival and rooting percentages, respectively) were due to treating *T. indica* cuttings with the higher concentration of IBA (4000 ppm) and planting in peat moss in the two seasons. On the other hand, planting cuttings without IBA treatment and the planting in sand soil resulted in the lowest values of these two characters.

Effect of IBA and Growing Media on the Root Length and Number: The results of used different growth media and indole butyric acid (IBA) concentrations after 3 months on length and number of roots/ cutting of terminal stem cuttings for *T. indica* trees are given in Table (3). Planting cutting in peat moss as growing media demonstrated higher roots length and number than from the other media during the two seasons. On the other hand, IBA treatment was found very effective and the differences among the used concentrations were significant for root length and number in *T. indica* cuttings. A maximum root length and number were achieved in cuttings treated with the application of 4000 ppm IBA. The effect of interaction between media and IBA concentrations was significant for the root length and number in both seasons. The highest values of roots number and length were achieved with planting terminal cuttings in peatmoss with 4000 ppm IBA treatment for both seasons.

Table 3: Effect of growing media and different concentrations of IBA on the root length (cm) and root number/ cutting of the softwood cuttings for *Tamarindus indica* during 2019 and 2020 seasons

	2019 season					2020 season					
	IBA ppm (B)					IBA ppm (B)					
Growing media (A)	0	1000	2000	4000	Mean	0	1000	2000	4000	Mean	Means of seasons
Root length (cm)											
Sand	1.77	2.83	2.47	3.40	2.62	2.07	2.53	2.73	3.43	2.69	2.66
Loamy sand	2.70	3.37	4.13	4.60	3.70	2.37	3.33	3.67	4.20	3.39	3.55
Peat moss	3.67	4.47	4.80	5.63	4.64	3.77	4.53	5.03	5.17	4.63	4.65
Mean	2.71	3.56	3.80	4.54		2.73	3.47	3.81	4.27		
LSD at 5 %		A= 0.13; B= 0.15; A x B= 0.25					A= 0.11; B= 0.13; A x B=0.23				
Root number/cutting											
Sand	3.27	3.97	4.17	4.67	4.02	3.30	3.83	4.27	4.53	3.98	4.00
Loamy sand	3.63	4.10	4.47	5.10	4.33	3.60	4.47	4.27	5.47	4.45	4.39
Peat moss	4.33	4.90	5.30	6.17	5.17	4.80	5.43	5.57	5.93	5.43	5.30
Mean	3.74	4.32	4.64	5.31		3.90	4.58	4.70	5.31		
LSD at 5 %		A= 0.15; B= 0.17; A x B= 0.25					A= 0.15; B= 0.17; A x B= 0.29				

Table 4: Effect of growing media and different concentrations of IBA on the root fresh and dry weights (gm) of the terminal cuttings for *Tamarindus indica* during 2019 and 2020 seasons

	2019 season					2020 season					
	IBA ppm (B)					IBA ppm (B)					
Growing media (A)	0	1000	2000	4000	Mean	0	1000	2000	4000	Mean	Means of seasons
Root fresh weight (g)											
Sand	2.60	3.73	4.03	4.53	3.72	2.53	3.53	4.00	4.70	3.69	3.71
Loamy sand	3.17	4.17	4.87	5.13	4.34	3.47	4.23	5.03	5.37	4.53	4.44
Peatmoss	4.17	4.57	6.20	6.60	5.39	4.03	4.33	6.13	6.30	5.20	5.30
Mean	3.31	4.16	5.03	5.42		3.34	4.03	5.05	5.46		
LSD at 5 %		A= 0.13 B= 0.15 A x B=0.27					A= 0.11 B= 0.13 A x B=0.22				
Root dry weight (g)											
Sand	0.297	0.360	0.450	0.523	0.41	0.263	0.360	0.440	0.567	0.41	0.41
Loamy sand	0.343	0.537	0.570	0.600	0.51	0.283	0.447	0.540	0.630	0.48	0.50
Peatmoss	0.413	0.553	0.660	0.800	0.61	0.403	0.560	0.660	0.770	0.60	0.61
Mean	0.351	0.483	0.560	0.641		0.317	0.456	0.547	0.656		
LSD at 5 %		A= 0.03; B= 0.03; A x B=0.05					A= 0.02; B= 0.02; A x B=0.04				

Table 5: Effect of growing media and different concentrations of IBA on the shoot fresh and dry weights (gm) of the softwood cuttings for *Tamarindus indica* during 2019 and 2020 seasons

	2019 season					2020 season					
	IBA ppm (B)					IBA ppm (B)					
Growing media (A)	0	1000	2000	4000	Mean	0	1000	2000	4000	Mean	Means of seasons
Shoot fresh weight (g)											
Sand	2.60	3.40	4.13	4.97	3.77	3.07	3.50	3.87	5.43	3.97	3.87
Loamy sand	3.50	3.87	5.07	5.50	4.48	3.47	4.13	5.03	5.97	4.65	4.57
Peatmoss	4.40	5.67	6.53	8.47	6.27	4.43	5.50	6.37	8.53	6.21	6.24
Mean	3.50	4.31	5.24	6.31		3.66	4.38	5.09	6.64		
LSD at 5 %		A= 0.16; B= 0.19; A x B=0.32					A= 0.17; B= 0.19; A x B=0.34				
Shoot dry weight (g)											
Sand	0.350	0.427	0.480	0.570	0.46	0.313	0.423	0.420	0.593	0.44	0.45
Loamy sand	0.377	0.460	0.600	0.693	0.53	0.347	0.520	0.623	0.770	0.57	0.55
Peatmoss	0.507	0.670	0.697	0.857	0.68	0.497	0.620	0.747	0.853	0.68	0.68
Mean	0.41	0.52	0.59	0.71		0.39	0.52	0.60	0.74		
LSD at 5 %		A= 0.05; B= 0.05; A x B=0.07					A= 0.04; B= 0.05; A x B=0.07				

Effect of IBA and Growing Media on the Root Fresh and Dry Weights: The results of roots fresh and dry weights per terminal cuttings of *T. indica*, in response to growth media and concentrations of IBA and during 2019 and 2020 seasons are tabulated in Table (4). There was a significant difference in the two characters measured for different treatments. However, using peat moss as a growing media for cuttings gave the best results for the two characters, while the lowest values of weights were recorded with sand soil. Also, IBA at 4000 ppm gave the highest roots fresh and dry weights, while the lowest weight values of the fresh and dry roots were recorded with the control as mean of the two seasons. Concerning the effects of interaction between the used media and IBA concentrations on the roots fresh and dry weights per cutting, the highest value of roots fresh and dry weights was noticed when cuttings were planted in peat moss medium and treated with IBA at 4000 ppm. On the other hand, the untreated cuttings grown in sand soil produced the lowest values for the roots fresh and dry weights in the two seasons.

Effect of IBA and Growing Media on the Shoot Fresh and Dry Weights: The results from the study as reported in Table (5) indicated that there were significant differences among treatments and their interactions for shoot fresh and dry weights during the two seasons. However, planting cuttings in the peat moss medium resulted in the highest values of the two characters during the two studied seasons, while the lowest values was resulted from sand medium. Dipping the bases of terminal stem cuttings for 24 hours in IBA solution at a concentration of 4000 ppm resulted in the highest measurements of both fresh and dry weights of shoots compared to the rest of the concentrations for both seasons. Also, the interaction between the used treatments was significant for those two parameters for both seasons, although the treating cuttings with the highest concentration of IBA in peat moss resulted in the highest values. On the contrary, the lowest values of the shoot weights were recorded in the case of planting cuttings without IBA treatment in sand soil.

Obtained results in this research indicate that the survival and the rooting percentages, root length, number of roots/ cutting, roots fresh and dry weights as well as shoot fresh and dry weights were significantly affected by the rooting media and IBA treatment in both seasons. Also, control cuttings rooted poorly and rooting percentage increased with IBA doses up to 4000 ppm, suggesting that IBA concentrations may be important for the rooting performance of *T. indica* L. cuttings. However, the stimulation of adventitious root formation in stem cuttings with auxins and commercial rooting mixtures is well known in many species those are difficult-to-root [12].

Here, our results meet other studies on some difficult rooting species. Rana *et al.* [23] studied the hardwood cuttings of *Actinidia deliciosa* and recommended the IBA concentrations between 4000-8000 ppm. Meanwhile, Ercisli *et al.* [24] pointed out that 6000 ppm IBA application seems to be the best one for *A. deliciosa* trees' rooting. Akwatulira *et al*. [25] also, pointed out that the high rooting percentage of the *Warburgia ugandensis* stem cuttings treated with 0.8% IBA concentration was concordant with Aminah *et al*. [26] who stated that application of 0.8% IBA resulted in the highest rooting percentage of *Shorea parvifolia* and *S. macroptera* stem cuttings. This could be because of the effect of auxins that have been reported to enhance rooting of cuttings through the translocation of carbohydrates and other nutrients to the rooting zone [27].

Davis and Hassig [28] revealed that the production of adventitious roots in plants through cells division. Moreover, the multiplication and specialization of cells are also controlled by plant growth substances as auxins. The treatment of stem cuttings with auxins can increase the percentage of rooting, root initiation and number of roots on stem cutting. In this respect, application of optimal IBA concentration is very important for successful rooting of cuttings [29]. On the other hand, one of the most important criteria for the best rooting of cuttings is suitable growing media [30].

In our study variable results were observed between the cuttings of *T. indica* trees in the applied media. The growth indicators were the highest in peatmoss medium, while the lowest values were recorded in the sand medium. These results may imply that peatmoss has better water retention properties. In this respect, Grange and Loach [31] revealed that water uptake of the stem cuttings is indirectly proportional to the water content of the growing media or its water retention and aeration properties [30]. Meanwhile, the interaction between the growing media and the IBA concentrations could affect rooting response, since increasing water uptake could be expected to increase the uptake of hormone [32].

Ofori *et al.* [33] reported higher rates of survival in cuttings of *Milicia excelsa* taken from juvenile donors may be due to their superior regenerative capacity, in terms of root/shoot growth potentials, leading to their faster establishment and better performance after out planting. The decrease in rooting potential of stem cuttings due to aging and maturity of donor plants has been reported for different plant species [34-36].

The rooting characteristics and vigor in many woody species those are difficult-to-root are related to their stem anatomy Ballester *et al*. [37] and [12]. Our observations revealed that the stem cuttings of *T. indica* trees shows some specific anatomical differences. The differences among basal and terminal cuttings are apparent in the development of the vascular tissues in both their structure and behavior.

In this respect, the stem basal hardwood cuttings, which is failed in rooting are more lignified than the softwood ones. These also have wide band of secondary xylem with thicker vessels. In this study, an anatomical comparison between the structure of the Tr-softwood and the Bs-hardwood cuttings is introduced. The softwood cuttings have larger cortical tissue. That is conducted to the hypothesis stated by [38]. They revealed that young stems have good root initiation throughout the peripheral regions of vascular tissues. That is due to that the root primordia may occur in these peripheral parenchymatous cells. In addition to, the high auxin levels are reported to be favorable for beginning the rhizogenesis [39, 40].

The Tr-cuttings have high number of pith rays compared to Bs-cuttings. In our observations, the rays of the Tr-cuttings are radiating and penetrating the vascular xylem and phloem. Here, we conduct to Buraczyk and Zakrzewski [41] who stated that the end of vascular rays near the periderm induces the root growing. In comparison to the Bs-cuttings with compressed less cortical tissue, large amount of xylem and fiber tissues, a smaller number of pith rays and non-continuous rays near the periderm. Hence, this anatomical behavior ensures the success of the terminal cuttings of *T. indica* in rooting.

In conclusion, the application of IBA (4000 ppm) is the best concentration for rooting of cuttings of *Tamarindus indica* L. trees. There is a valuable variation among the different media in terms of rooting and growth characteristics. The use of peat moss as a growing medium for terminal cuttings is more suitable for tamarind trees' rooting. Moreover, apart from IBA-treatment and rooting medium, other factors such as the cutting type should be carefully taken in consideration.

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