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INFLUENCE OF ROOTING MEDIA AND INDOLE-3-BUTYRIC ACID (IBA) CONCENTRATION ON ROOTING AND GROWTH OF DIFFERENT TYPES OF *CONOCARPUS ERECTUS* L. STEM CUTTINGS

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ABSTRACT: The present study was conducted to evaluate the influence of rooting media (clay, peat moss + sand, peat moss + perlite and vermiculite), cutting types (tip, middle and basal) and different concentrations of indole-3-butyric acid (control, 50, 100 and 200 ppm IBA) on the rooting and growth of *Conocarpus erectus* L. stem cuttings. The experiment was laid out in a split-split-plot design, with three replicates. The obtained results showed that vermiculite was the best rooting medium used for improving the rooting percentage, root number, root length, stem length, branch number and leaf number per rooted cutting, followed by peat + perlite (1:1 in v/v) and peat + sand (1:1 in v/v), respectively comparing with clay soil which recorded the lowest values. The tip cutting was superior to the middle and basal ones in all rooting media used, especially in vermiculite medium. Among IBA concentrations used, cuttings treated with IBA at 100 ppm produced significantly better rooting (42.9%) than 50 ppm (36.3%), 200 ppm (36.0%) and untreated cuttings (23.1%). The greatest rooting percentage (95.0%) and the best root and growth characteristics as well as the highest endogenous contents of phenols, indole acetic acid (IAA) and the lowest abscisic acid (ABA) contents were obtained from tip cuttings treated with IBA at 100 ppm and planted in vermiculite substrate. Moreover, the combined treatment of 100 ppm IBA and vermiculite substrate significantly improved the rooting percentage, root and growth measurements of middle and basal cuttings as well as gave the highest C/N ratio in basal cutting tissues compared to the same cutting types combined with the other rooting media and IBA concentrations. Hence, it could be recommended to treat the different types of *C. erectus* stem cuttings with IBA at 100 ppm and planting in vermiculite medium for improving rooting, quality and growth of cuttings.

Key words: *Conocarpus erectus*, rooting media, IBA concentration, cutting type.

INTRODUCTION

Buttonwood (*Conocarpus erectus*, L.) belonging to Combretaceae family is an evergreen shrub or tree, which is native to Florida's mangrove forest ecosystem in North America and shores of tropical America and Africa (Dhaarani *et al*., 2017). It tolerates diseases, insects, light frosts, pests, salinity, poor drainage and drought (Little, 1983), as well as desert heat and it can also grow in very low fertility soils (Nelson, 1996). It is planted as a hedge and shade tree in yards, streets, parking lots and parks and it also protects the soil during storm and helps to fix dunes (Gilman and

Watson, 1993). Wood is most widely used for high-grade charcoal (Morton, 1981). Bark has been used for tanning leather and it contains about 16-18% tannin. Besides, the plant is used as animal food (Suleiman *et al.*, 2005) and in a number of medicinal properties including anticancer, antiviral, anti-diabetic, antioxidant, antibacterial and antifungal activities (Yasin and Al-Azawi, 2019).

Conocarpus plant is mainly propagated by stem cuttings (Mohamed *et al*., 2014). Previous researches have shown that the rooting success of semi- and hard-wood cuttings in *Conocarpus* is very low (Al-Dulaimy, 2016; Abdel-Rahman *et al*., 2020). The vegetative propagation success by stem cuttings is affected by several important factors. Among these different factors, the rooting media, cutting types, the type and concentration of auxins used, season, hormonal and physiological status of the mother plant, carbohydrates, phenols, the presence of leaves on cuttings, humidity, genetic characteristics and many other factors (Hartmann *et al*., 2014; Kumar *et al*., 2019).

Rooting medium is the most important factor which plays a main role in quality, rooting and growth of cuttings in many plants (Rajkumar *et al*., 2017; Kumar *et al*., 2019). The selection of the suitable rooting media depends on the species, cutting type, propagation season, growing conditions, propagation system used and physicochemical characteristics of the substrate as well as on its cost and availability (Sardoei, 2014; Eed *et al*., 2015). A good propagation medium would provide sufficient support to the plant, nutrients and hold plant available water, allow oxygen diffusion to the roots and permits gaseous exchange between the roots and atmosphere outside the rooting media (Manila *et al*., 2017; Dawa *et al*., 2018). Lack of one or more of these useful characteristics lead to lower rootability of cuttings (Dvin *et al*., 2011). The best rooting media must have a pH favorable to optimum nutrient availability and texture which permits unrestricted gaseous exchange and water movement for the proper root development (Larson, 1980). However, many mixtures have been used as media for plant propagation. Most propagators use a combination of organic and mineral components such as peat-perlite, peat-vermiculite-perlite, peat-sand, peat-rockwool (Sabalka, 1986). Sometimes the mineral component is used alone (e.g., vermiculite, perlite, sand, rockwool) or in combination (e.g., vermiculite-perlite, sand-polystyrene). Sufficient coarse mineral component such as perlite or coarse sand should be added to improve aeration (Hartmann *et al*., 2014). Several studies have indicated the positive effects of vermiculite, peat, perlite and sand in improving the rootability of cuttings (Ansari, 2013; Rajkumar *et al*., 2017; Jaleta and Sulaiman, 2019). Vermiculite has been found to considerably enhance the rooting and growth of cuttings in many species, especially when combined with IBA or NAA treatments compared to the other rooting media (Hosseini *et al*., 2004; Rajkumar *et al*.; 2016; Peña-Baracaldo *et al*., 2018). On the other hand, the combination of peat moss with perlite or sand is suitable for rooting and growth of cuttings in some plants compared to the other rooting media (Tsipouridis *et al*., 2005; Exadaktylou *et al*., 2009; Jaleta and Sulaiman, 2019). However, different rooting media cause variations in rooting percentage, root and vegetative growth characteristics of cuttings (Hartmann *et al*., 2014).

Exogenous auxins application, mainly IBA plays a crucial role in enhancing of rooting efficiency and also quality of stem cuttings in nurseries (Peña-Baracaldo *et al*., 2018; Kumar *et al*., 2019). However, it was observed that the type and concentration of exogenous auxins applied play an important role in rooting and growth of cuttings depending on plant species (Hartmann *et al*., 2014; Daskalakis *et al*., 2018). In this concern, Mohamed *et al*. (2014) reported that treatment of *Conocarpus erectus* cuttings with IBA at 3000 ppm remarkably enhanced the rooting percentage comparing with 2000 ppm IBA and untreated cuttings. In another study, Al-Tohaty *et al*. (2014) cleared that treatment of *Conocarpus lancifolius* cuttings with IBA at 500 and 1000 ppm significantly increased the rooting and growth of cuttings compared to untreated cuttings. The highest rooting percentage and the best root and shoot characteristics were resulted from cuttings treated with IBA at 500 ppm. Moreover, Elgalby *et al*. (2011) stated that treating cuttings of *Conocarpus lancifolius* with 500 ppm IBA improved both root length and primary root number, while 1000 ppm IBA increased the secondary root number.

On the other hand, stem cutting types have been reported strongly influence the rooting success (Caldwell *et al*., 1988). This was may be correlated with anatomical structure of the stem or difference in chemical composition of the plant along the stem (Hartmann *et al*., 2014). Some investigators revealed that the tip cuttings of *Conocarpus spp*. rooted better than middle or basal ones (Al-Dulaimy, 2016; Abdel-Rahman *et al*., 2020).

There is no available information in the literature with respect to vegetative propagation by use of rooting media, cutting types and auxin concentrations for induction of rooting of *C. erectus* cuttings. Therefore, the current study aimed to evaluate the rooting and growth of different types of *C. erectus* stem cuttings in response to rooting media and the concentration of IBA that will enhance successful establishment of the plant in the nursery.

MATERIALS AND METHODS

The current investigation was conducted at the Experimental Farm of Floriculture, Faculty of Agriculture, Assiut University, Egypt, during the two successive seasons of 2016 and 2017 to evaluate the influence of rooting media and to optimize the concentration of indole-3-butyric acid (IBA) on rooting and growth of different types of *C. erectus* stem cuttings.

Healthy 6-year-old mother plants of *C. erectus* were used as source of cuttings. On March 1st of both seasons, three cutting types (tip, middle and basal) were taken from one-year-old branches of *C. erectus*. These cuttings had a uniform length (15 cm long) and the mean thicknesses were 0.5, 0.8 and 1.2 cm for the terminal, middle and basal cuttings, respectively in both seasons. The different cutting bases were soaked in aqueous solutions of 50, 100 and 200 ppm IBA for 20 hours, while the control group was soaked in distilled water. After treating cuttings with IBA, they were inserted in plastic pots of 20 cm diameter filled with four different rooting media i.e. clay, peat moss + sand (1:1 in v/v), peat moss + perlite (1:1 in v/v) or vermiculite. The sand was washed well before use. The constituents and properties of the rooting media used were estimated according to the methods described by Jackson (1973) as shown in Table (1). The experiment was conducted under saran house and covered by tightly

Table 1. Some physical and chemical analysis of the rooting media used at the beginning of the experiment (average of 2016 and 2017 seasons) *.

Rooting media (v/v ratio)	Soluble ions (meq/100 g substrate) * Cations			Anions			K^+ (mg/100 g substrate)	pH**	EC*** (dS m^{-1})	Organic matter (%)
	Ca^{2+}	Mg^{2+}	Na^+	HCO_3^-	Cl^-	$SO_4^=$				
Clay	3.11	2.54	3.64	3.19	3.56	2.54	0.24	8.21	1.52	1.71
Peat + sand (1:1)	1.38	0.85	1.82	1.42	1.61	1.02	0.17	6.61	0.92	34.15
Peat + perlite (1:1)	0.89	1.26	0.98	0.85	1.25	1.03	0.39	5.86	0.61	50.34
Vermiculite	0.92	1.34	0.34	0.75	0.80	1.05	0.42	7.76	0.28	1.12

*** Each value represents the means of 3 replicates**
**** Soil-water suspension (1:5)**
***** Soil-water extract (1:5).**

polyethylene film to maintain high relative humidity.

The experiment was arranged in a split-split-plot design, with three replicates. Rooting media (clay, peat + sand, peat + perlite and vermiculite) represented in the main plots, meanwhile cutting types (tip, middle and basal) and IBA concentrations (control, 50, 100 and 200 ppm) represented the sub-plots and sub-subplots, respectively. Each experimental unit contained 10 cuttings.

The cuttings in present investigation were held in rooting substrates almost three months after IBA treatments. Data were recorded on the rooting percentage, root number, root length, stem length**,** branch number and leaf number per rooted cutting. Then, one centimeter sample of the basal end representing each treatment were taken and dried for determination of total carbohydrates, nitrogen and total phenols contents. Total carbohydrates percentage was estimated colorimeterically using anthrone sulphuric acid method described by Hansen and Moller (1975). Total nitrogen content was determined by semi-micro Kjeldahl method according to Bzlack *et al*. (1982). Then, carbohydrates/nitrogen ratio (C/N ratio) was calculated. The total phenols content was estimated colorimeterically by Folin ciocalteau reagent (FCR) method (Vasco *et al*., 2008).

Endogenous hormones of IAA and ABA in tissues of fresh cutting bases were isolated by extraction with volatile organic solvents, and quantified according to Zhang *et al*. (1998) using C_{18} reversed-phase high performance liquid chromatography (RP-HPLC) column. It was isocratically eluted at 2 ml min^{-1} with methanol, 2% acetic acid and H_2O (40:20:20) as mobile phases, detection was with an absorbance monitor operating at 254 nm.

Data obtained during the two seasons were subjected to the statistical analysis using Statistix 8.1 analytical software. Means were compared using the least significant differences (L.S.D.) test at 5% level of probability according to Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Rooting percentage:

The obtained results in Tables (2 and 3) clearly show that rooting percentage of *C. erectus* cuttings was significantly affected by the different rooting media, cutting types, IBA concentrations and their interactions during both seasons. Among all the substrates used, vermiculite treatment showed the highest rooting percentage (50.7% as average of both seasons), followed by peat + perlite (34.3%) and peat + sand (30.6%), while the lowest rooting percentage (22.7%) was recorded in clay medium. The increase was 123.3% in vermiculite, 51.1% in peat moss + perlite and 34.8% in peat moss + sand substrates over clay medium (Table 2).

These results are in accordance with those obtained by Rajkumar *et al*. (2016), Manila *et al.* (2017) and Peña-Baracaldo *et al*. (2018), who observed that vermiculite substrate was the best rooting medium in increasing the rooting percentage of many species cuttings than the other substrates. The main reasons in increasing the rooting percentage of *C. erectus* cuttings under vermiculite medium may be due to better aeration, excellent drainage, more water holding capacity and release of nutrients gradually from vermiculite medium resulting in better rooting percentages (Ansari, 2013; Manila *et al.*, 2017). According to Wild and Jones (1992), vermiculite can adsorb phosphate forms available to the plant, which is a beneficial factor because phosphates are constituents of nucleic acids and phospholipids as well as being essential for cell division and development of meristematic tissues. In addition, the present study clears also that the addition of perlite or sand as a mineral component into peat moss substrate in proportions 1:1 by volume considerably improved the rootability of different types of *C. erectus* cuttings

Table 2. Effect of rooting media, cutting types and indole-3-butyric acid (IBA) concentrations on rooting percentage, root number and root length (cm) of *Conocarpus erectus* cuttings during the 2016 and 2017 seasons.

Treatments	First season (2016)			Second season (2017)		
	Rooting%	Root No.	Root length	Rooting%	Root No.	Root length
Rooting media:						
Clay	23.1	6.0	5.2	22.2	6.1	5.6
Peat + sand	31.7	7.9	8.4	29.4	8.2	9.0
Peat + perlite	36.4	9.4	9.3	32.2	9.7	9.8
Vermiculite	50.6	13.1	11.8	50.8	13.4	12.7
L.S.D. at 5%	4.3	0.3	0.2	1.2	0.5	0.3
Cutting types:						
Tip	67.9	14.0	13.4	62.1	14.6	14.2
Middle	26.3	8.1	7.6	24.8	7.9	8.3
Basal	12.1	5.2	5.0	14.2	5.6	5.2
L.S.D. at 5%	1.7	0.3	0.2	1.8	0.3	0.3
IBA concentrations (ppm):						
Control	23.1	4.9	6.6	23.1	4.6	6.9
50	38.1	9.8	8.7	34.4	10.3	9.5
100	43.3	12.3	10.8	42.5	12.4	11.3
200	37.2	9.3	8.6	34.7	10.2	9.1
L.S.D. at 5%	1.9	0.1	0.2	2.0	0.3	0.3

comparing with clay medium. Similar results were obtained by Tsipouridis *et al*. (2005), Exadaktylou *et al*. (2009) and Jaleta and Sulaiman (2019), who reported that combination of peat with perlite or peat with sand is suitable for rooting cuttings of some plants. The increment of rooting percentage of *C. erectus* cuttings as a result of peat + perlite and peat + sand treatments may be associated to better soil aeration and appropriate moisture holding of these media resulting in better rooting percentages (Ercişli *et al*., 2002). Sand is a natural and mostly used rooting medium for the most of the vegetative propagated plants. Possessing different physical and chemical properties it is when mixed with other media effectively improves the rooting (Wei *et al.,* 2017). On the other hand, the reduction in rooting percentage with clay medium may be due to high water holding capacity leading to low aeration in the soil (Landis, 1995). Stem cuttings are sensitive to oxygen deficiency and go to rotting immediately. If the propagation media is highly humid, rooting process is delayed as a result of oxygen deficiency (Erstad and Gislerod, 1994). According to Yeboah and Amoah (2009), high aeration in propagation media is responsible for promoting metabolic activities and improving adventitious root formation.

Concerning the effect of cutting type (Table 2), it was obvious that the tip cutting recorded significantly maximum rooting percentage (65.0%), followed by middle cutting (25.6%), while the minimum rooting percentage was recorded in basal cuttings (13.2%). The increments were 153.9% and 392.4% in tip cuttings over middle and basal ones, respectively. Similar results were obtained by Mohamed *et al*. (2014), Al-Dulaimy (2016) and Abdel-Rahman *et al*. (2020) on *Conocarpus spp*., who revealed that rooting percentage of the tip cuttings was better than those taken from the middle and basal portion of the branch. The difference in rooting percentage of tip, middle and basal cuttings may be attributed to higher concentration of endogenous root promoting substances in the tip cutting

Table 3. Combined effect of rooting media, cutting types and indole-3-butyric acid (IBA) concentrations on rooting percentage, root number and root length (cm) of *Conocarpus erectus* cuttings during the 2016 and 2017 seasons.

Rooting media	Cutting types	IBA Con. "ppm"	First season (2016)			Second season (2017)		
			Rooting%	Root No.	Root length	Rooting%	Root No.	Root length
Clay	Tip	Control	36.7	2.8	6.2	33.3	3.0	7.9
		50	50.0	11.5	10.0	46.7	12.2	11.3
		100	63.3	15.3	13.0	60.0	14.7	12.8
		200	56.7	10.4	10.3	50.0	10.0	10.1
	Middle	Control	6.7	1.7	1.7	6.7	1.5	1.7
		50	16.7	4.9	3.2	20.0	4.5	3.2
		100	16.7	7.2	5.7	20.0	7.5	7.2
		200	13.3	4.5	2.9	6.7	6.3	3.0
	Basal	Control	3.3	1.3	1.3	3.3	1.1	1.4
		50	6.7	3.3	2.5	6.7	3.7	2.5
		100	3.3	4.5	3.3	6.7	5.0	3.5
		200	3.3	3.9	2.2	6.7	4.1	2.4
Peat + sand	Tip	Control	50.0	5.8	10.2	40.0	6.3	11.4
		50	70.0	14.3	12.8	60.0	14.3	14.2
		100	80.0	16.7	15.3	70.0	17.3	16.0
		200	66.7	13.5	12.2	63.3	14.6	13.8
	Middle	Control	6.7	2.6	3.3	10.0	1.9	3.3
		50	26.7	7.9	9.3	20.0	7.8	10.7
		100	30.0	10.1	10.3	26.7	9.4	10.7
		200	23.3	8.5	8.3	23.3	8.7	7.7
	Basal	Control	3.3	1.7	2.7	6.7	1.7	3.3
		50	10.0	4.7	4.2	10.0	5.3	4.5
		100	6.7	5.2	6.7	13.3	6.0	6.3
		200	6.7	4.3	5.2	10.0	5.0	6.0
Peat + Perlite	Tip	Control	56.7	8.4	14.0	50.0	7.8	14.8
		50	80.0	15.5	15.0	70.0	16.9	15.3
		100	80.0	19.0	16.9	73.3	19.3	16.7
		200	70.0	15.4	13.5	63.3	15.9	14.8
	Middle	Control	10.0	5.6	5.1	13.3	5.3	5.3
		50	26.7	9.3	6.8	20.0	9.1	6.3
		100	40.0	11.7	10.0	33.3	11.4	12.1
		200	30.0	8.3	9.3	23.3	8.7	11.2
	Basal	Control	6.7	3.9	3.8	6.7	4.0	4.5
		50	10.0	5.0	5.3	6.7	5.5	5.7
		100	16.7	5.7	6.2	16.7	6.6	5.8
		200	10.0	5.1	5.6	10.0	6.0	5.0
Vermiculite	Tip	Control	63.3	12.4	14.7	60.0	11.0	13.4
		50	80.0	20.3	16.3	80.0	22.2	17.7
		100	96.7	24.7	19.2	93.3	26.1	20.3
		200	86.7	17.2	15.3	80.0	21.3	17.1
	Middle	Control	20.0	7.3	11.3	26.7	6.0	11.7
		50	46.7	12.1	10.2	40.0	11.3	12.3
		100	56.7	16.7	12.2	56.7	14.8	14.0
		200	50.0	11.8	11.5	50.0	12.4	12.3
	Basal	Control	13.3	5.7	4.7	20.0	5.4	4.7
		50	33.3	8.5	9.0	33.3	10.8	10.9
		100	30.0	11.4	10.6	40.0	10.8	10.7
		200	30.0	8.6	7.1	30.0	9.3	6.7
L.S.D. at 5%			6.7	0.8	0.8	6.8	1.0	1.0

tissues and also more cell which are capable of becoming meristematic (Hartmann *et al*., 2014; Abdel-Rahman *et al*., 2020). On the other hand, the low rooting percentage of basal cuttings may be due to higher lignification rate of the basal cutting tissues which can represent a mechanical barrier for root emergence (Trobec *et al*., 2005).

As shown in Table (2), it was noticed that all IBA concentrations used significantly increased rooting percentage of *C. erectus* cuttings compared to untreated cuttings. Treating cuttings with IBA at 100 ppm recorded significantly higher rooting percentage (42.9%), followed by 50 ppm IBA (36.3%) which was not significantly different from 200 ppm IBA (36.0%). However, the lowest percentage of rooting (23.1%) was recorded with untreated-IBA cuttings. The increments in rooting percentage were 85.7, 57.1 and 55.8% with 100, 50 and 200 ppm IBA over the untreated-IBA treatment. These results are in agreement with the findings of Elgalby *et al*. (2011), AL-Tohaty *et al*. (2014) and Mohamed *et al.* (2014), who indicated that IBA concentration plays a crucial role in rooting, quality and growth of *Conocarpus spp*. cuttings. The increment in rooting percentage of *C. erectus* stem cuttings treated with different concentrations of IBA, especially at 100 ppm could be due to the effect of auxins in enhancing the root ability of stem cuttings through their ability to promote the initiation of root primordia and to enhance the translocation of carbohydrates, rooting co-factors and nitrogenous substances from leaves to the base of cuttings for enhancing adventitious root formation (Rajkumar *et al*., 2016). Besides, auxins help in elongation of meristematic cells and differentiation of cambial initial into root primordial (Nanda, 1975). It also accelerates the translocation of nutrients from upper part of the cuttings to their basal ends by increasing the activity of enzymes. This increases hydrolysis of carbohydrates for providing enough energy for rooting response of the cells (Arya *et al*., 1994). As reported by Rolston *et al.* (1996), treating cuttings with auxin increased number of root primordia which led to increase the rooting percentage. Loach (1996) also stated that IBA treatment stimulates cell division and increased uniformity of rooting. The promoting effect of IBA on rooting is because of its conversion to IAA in plant tissue (Kumar *et al*., 2019). Besides, IBA may synergistically modify the action of IAA or the endogenous synthesis of IAA; IBA can enhance tissue sensitivity for IAA and increase rooting (Babaie *et al*., 2014). The exogenous auxins application lower the IAA oxidation and this might reduce the consumption of phenolic antioxidants, which play a very important role as protectors of the IAA against oxidation (de Klerk *et al*., 1999). Although IBA is one of the most effective compounds stimulating rooting in many species (Hartmann *et al*., 2014), its effect can vary depends on the cutting types and the concentration used (Mohamed *et al.*, 2014). According to Leakey *et al*. (1982), auxins application at suitable concentration is very crucial for successful rooting of cuttings. High concentrations of auxin can cause degradation of the basal tissues of cuttings, interference in hormonal balance in plant, damage to the cells, reduction of rooting and inhibition of buds growth and even shoot development (Blythe *et al*., 2004). The reduction in rooting percentage at higher IBA concentrations is also a clear indication that some auxin concentrations are inhibitory to root initiation in a number of other plant species (Leakey *et al*., 1990). Akwatulira *et al*. (2011) stated that IBA at 8000 ppm was optimum in *Warburgia ugandensis* cuttings, while the same concentration was inhibitory in *Ulmus panifolia* cuttings (Griffin and Schroeder, 2004).

The interaction effect among different rooting media, cutting types and IBA concentrations on rooting percentage of *C. erectus* cuttings was significant in both seasons (Table 3). The highest rooting percentage (95.0%) was achieved by tip cuttings treated with 100 ppm IBA and planted in vermiculite substrate, followed by peat + perlite (76.7%), peat + sand (75.0%) and clay medium (61.7%), with the same cutting type and IBA concentration. Meanwhile, the minimum rooting percentages (6.7 and 3.3%) were obtained from untreated-IBA middle and basal cuttings with clay medium, respectively.

The combined treatment of 100 ppm IBA with vermiculite substrate significantly improved the rooting percentage of middle (56.7%) and basal cuttings (35.0%) compared to the same cutting types combined with the other rooting media and IBA concentrations. Similar results were reported by Hosseini *et al*. (2004), Rajkumar *et al*. (2017) and Shiri *et al*. (2019), they revealed that vermiculite was the best substrate for rooting cuttings, especially when combined with a suitable concentration of IBA. Padekar *et al*. (2018) revealed that the days required for sprouting, rooting and survival percentages of *Momordica dioica* cuttings were found to be significantly influenced by the rooting media, cutting types and different IBA concentrations. The combined treatment of tip cuttings treated with 1000 ppm IBA combined with soil + sand + FYM medium recorded significantly minimum number of days required for sprouting, the highest rooting and survival percentages as compared with the remaining treatment combinations.

Root and vegetative characteristics:

The obtained results in Tables (2, 3, 4 and 5) indicate that rooting media and IBA concentrations considerably affected root and vegetative measurements in all cutting types of *C. erectus* in both seasons. It is evident from data that vermiculite substrate significantly improved the root number, root length, stem length, branch number and leaf number per rooted cutting compared to the other rooting media (Tables 2 and 4). However, the lowest root and vegetative characteristics were recorded with clay medium. Several investigations have shown that the use of vermiculite as rooting media resulted in a considerable increase in root and vegetative characteristics of cuttings

Table 4. Effect of rooting media, cutting types and indole-3-butyric acid (IBA) concentrations on stem length (cm), branch number and leaf number of *Conocarpus erectus* during the 2016 and 2017 seasons.

Treatments	First season (2016)			Second season (2017)		
	Stem length	Branch No.	Leaf No.	Stem length	Branch No.	Leaf No.
Rooting media:						
Clay	21.10	1.10	7.10	21.20	1.11	7.30
Peat + sand	21.30	1.13	10.10	22.00	1.18	10.90
Peat + Perlite	23.50	1.53	11.00	23.20	1.50	11.80
Vermiculite	25.50	1.80	13.50	25.80	1.86	14.10
L.S.D. at 5%	0.30	0.02	0.30	0.30	0.09	0.30
Cutting types:						
Tip	25.30	1.59	12.80	25.60	1.61	13.40
Middle	22.20	1.34	10.10	22.50	1.35	10.80
Basal	20.90	1.24	8.30	21.00	1.27	8.90
L.S.D. at 5%	0.20	0.02	0.30	0.40	0.03	0.30
IBA concentrations (ppm):						
Control	20.60	1.14	8.40	20.80	1.18	9.00
50	23.10	1.36	10.60	23.30	1.37	11.20
100	25.00	1.70	12.90	25.20	1.74	13.70
200	22.60	1.37	9.90	22.90	1.35	10.30
L.S.D. at 5%	0.30	0.02	0.20	0.30	0.04	0.30

Table 5. Combined effect of rooting media, cutting types and indole-3-butyric acid (IBA) concentrations on stem length (cm), branch number and leaf number of *Conocarpus erectus* during the 2016 and 2017 seasons.

Rooting media	Cutting types	IBA Con. "ppm"	First season (2016)			Second season (2017)		
			Stem length	Branch No.	Leaf No.	Stem length	Branch No.	Leaf No.
Clay	Tip	Control	19.30	1.03	6.40	20.20	1.07	6.70
		50	24.10	1.13	9.70	23.50	1.20	8.70
		100	26.60	1.28	11.10	26.40	1.29	11.50
		200	23.70	1.10	9.10	23.70	1.13	9.80
	Middle	Control	18.60	1.07	4.20	18.80	1.03	4.30
		50	20.30	1.10	7.00	20.30	1.03	6.90
		100	22.70	1.20	9.00	21.30	1.22	9.60
		200	21.50	1.07	7.00	21.80	1.07	7.60
	Basal	Control	17.40	1.00	3.30	17.70	1.00	3.50
		50	18.20	1.00	5.80	18.90	1.03	5.80
		100	20.50	1.13	7.20	21.00	1.16	7.50
		200	20.00	1.03	5.40	20.70	1.07	5.60
Peat + sand	Tip	Control	21.20	1.19	10.70	21.90	1.66	12.00
		50	23.30	1.18	12.50	25.00	1.19	13.30
		100	26.90	1.27	15.50	27.30	1.29	16.00
		200	22.60	1.17	12.10	23.60	1.18	12.90
	Middle	Control	18.30	1.08	8.40	18.90	1.03	9.10
		50	20.30	1.09	9.00	21.60	1.10	10.70
		100	22.60	1.20	11.50	24.00	1.23	12.40
		200	21.60	1.11	10.00	22.70	1.15	9.80
	Basal	Control	17.70	1.00	6.90	17.70	1.00	7.10
		50	20.10	1.06	7.40	19.90	1.06	9.10
		100	21.00	1.13	9.70	21.20	1.18	10.60
		200	20.00	1.04	7.00	19.80	1.07	7.60
Peat + perlite	Tip	Control	23.30	1.22	11.80	23.70	1.23	12.60
		50	25.70	1.55	13.60	24.90	1.50	14.00
		100	28.40	2.70	16.20	27.90	2.62	17.00
		200	25.00	1.77	12.00	24.60	1.53	12.90
	Middle	Control	21.70	1.10	8.90	22.00	1.15	11.10
		50	23.30	1.30	11.00	23.10	1.37	11.90
		100	24.00	1.90	12.60	23.30	1.85	14.30
		200	22.50	1.50	10.00	22.10	1.33	10.30
	Basal	Control	21.00	1.02	7.70	21.20	1.02	8.10
		50	22.50	1.30	9.40	22.50	1.28	9.70
		100	23.30	1.70	10.30	22.30	1.70	10.70
		200	21.00	1.33	8.60	21.00	1.36	9.10
Vermiculite	Tip	Control	24.60	1.40	12.80	24.30	1.37	12.80
		50	29.20	2.40	16.60	29.70	2.47	17.30
		100	33.50	2.90	21.00	36.20	2.86	22.10
		200	27.60	2.20	14.10	27.10	2.10	15.00
	Middle	Control	22.30	1.30	10.20	22.60	1.37	11.00
		50	26.10	1.70	13.70	26.00	1.70	14.30
		100	26.50	2.10	17.00	26.50	2.37	18.50
		200	23.50	1.60	12.10	24.50	1.67	11.50
	Basal	Control	21.40	1.23	9.10	20.70	1.20	9.60
		50	23.60	1.47	11.10	23.90	1.50	12.30
		100	24.70	1.93	13.30	24.60	2.17	14.10
		200	22.50	1.47	10.90	23.50	1.50	11.30
L.S.D. at 5%			1.20	0.08	0.80	1.10	0.15	0.90

comparing with the other substrates (Ansari, 2013; Manila *et al*., 2017; Peña-Baracaldo *et al*., 2018). The positive effect of vermiculite substrate in increasing the root and shoot characteristics of cuttings may be attributed to its role on improving the soil aeration resulting in high water retention capacity and more availability of nutrients to roots (Rajkumar *et al*., 2017; Kumar *et al*., 2019). Besides, the highest stem length, branch number and leaf number recorded from vermiculite substrate may be attributed to easy translocation of water and nutrients to the above ground parts of the cuttings, leading to their rapid growth and multiplication (Akwatulira *et al*., 2011; Dawa *et al*., 2018). According to Grange and Loach (1983), water uptake by cuttings is indirectly proportional to the water content of the medium, as determined by its water retention and aeration properties (Kumar *et al*., 2019). The increase in water uptake could be attributed to increase auxin uptake (Ercişli *et al*., 2002). On the other hand, the present results revealed that the cuttings planted in peat + perlite or peat + sand substrates showed better root and shoot performance than clay soil. These results may be attributed to that these substrates allow air to reach the newly forming roots and also holds enough water to prevent the lower end of the cuttings from drying (Dawa *et al*., 2018). The combination of peat and perlite in a rooting substrate is synergistic; peat often improves the fertilizing capacity of a substrate and perlite enhances aeration and drainage within the container because of its uniformity and lightness (Al-Makhmari, 2016). Sand is a natural and mostly used rooting medium for the most of the vegetative propagation in plants. Possessing different physical and chemical properties it is when mixed with other media effectively improves the vegetative growth parameters of carnation plant (Wei *et al.,* 2017). The reduction in root and shoot parameters of *C. erectus* cuttings in clay medium could be due to very low aeration and porosity which can lead to rotting of the cuttings (Amri *et al*., 2009).

Concerning the effect of cutting types, it is evident from the obtained data in Tables (2 and 4) that the tip recorded the highest root number and root length per rooted cutting, which reflected in improving the vegetative growth characteristics in terms of stem length, branch number and leaf number compared to the middle and basal ones during both seasons. Similar results were also obtained by Mohamed *et al*. (2014), Al-Dulaimy (2016) and Abdel-Rahman *et al*. (2020), who indicated that propagation of *Conocarpus spp.* by tip cuttings significantly improved the root and shoot parameters comparing with middle and basal ones. Besides, Padekar *et al*. (2018) revealed also that using the tip cutting in propagation of *Momordica dioica* resulted in the best root and shoot characteristics of rooted cuttings compared to middle and basal ones. The increment in root and vegetative characteristics of *C. erectus* tip cuttings may be due to high content of endogenous root-promoting substances in the tip cutting tissues and the anatomical structure of the stem (Hansen, 1986).

As illustrated in Tables (2 and 4), it is clearly shown that the root and vegetative growth characteristics of *C. erectus* rooted cuttings were found to be markedly influenced by the different IBA concentrations in both seasons. All IBA concentrations used significantly enhanced all root and vegetative parameters when compared to untreated cuttings. Application of IBA at 100 ppm gave strong effects on root number and root length, stem length, branch number and leaf number per rooted cutting of *C. erectus* compared to the other concentrations used. The concentration of 50 ppm IBA was close to 200 ppm IBA in increasing both root and vegetative parameters compared to untreated control. These results indicated that IBA concentration of 50 ppm was low and 200 ppm was high for enhancing the root and growth characteristics of *C. erectus* cuttings. Similar results were also reported by Al-Dulaimy (2016) and Abdel-Rahman *et al*. (2020) on *Conocarpus erectus*, they indicated that the exogenous IBA application significantly improved root and vegetative parameters of rooted cuttings compared to untreated cuttings. They also added that IBA concentrations may be important for the root and growth performance of cuttings in many plants. Exogenous application of auxin may have caused hydrolysis and translocation of carbohydrate and nitrogenous substances present at the base of cuttings, which resulted in an increase in the root characteristics (Singh *et al.,* 2003). Application of IBA at optimum concentration increases the rate of amyloplast disappearance, amyloplast levels decrease naturally during rooting process (Singh *et al*., 2014). Gilani *et al*. (2019) showed that at optimum IBA, the reduction of amyloplast can be increased and cambium activities are stimulated, that will mobilize stored food material to the root initiation zones, hence promoting adventitious root formation. This trend is in line with the findings of Mohamed (2005) on *Vitis vinifera*, who reported that the lower concentration of IBA (5000 ppm IBA) gave the highest number and length of roots compared with the higher concentration (6000 ppm IBA) used on middle cuttings. Induction of more roots in treated cuttings with IBA may be due to the fact that cambial activity involved in root initiation is stimulated by exogenous IBA application in many species (Hartmann *et al*., 2014). On the other hand, the increment in root length as a result of IBA application may be attributed to the fact that proteins from IBA break hydrogen bonds between cellulose micro fibrils promoting cell wall loosening and cells will eventually elongate (Kumar *et al*., 2015). At suitable concentration of IBA, the rate of cambium dedifferentiation is increased, accelerated hydrolytic activity leading to produce better root length (Gilani *et al*., 2019). Besides, IBA promotes root length by influencing the synthesis of enzymes which stimulate cell enlargement (Rajkumar *et al*., 2017). Moreover, the increase in root parameters of *C. erectus* rooted cuttings may be due to higher accumulation of photosynthetic, metabolites and nutrients with IBA application (Rajkumar *et al*., 2016). Besides, Padekar *et al*. (2018) postulated also that the increment in root and growth measurements in cuttings treated with IBA might be due to its effect on cell wall elasticity, which accelerates cell division and stimulates root growth. On the other hand, the increment in vegetative growth characteristics might be associated with the increased number and length of roots in treated cuttings that enhances uptake of water and nutrients from the rooting media and hence more vegetative growth (Dawa *et al*., 2018). Roots system is significantly involved in plant growth due to their role in water and nutrient uptake, therefore maintaining an active roots growth is essential for plant development (Hartmann *et al.*, 2014).

Statistical analysis of the obtained results in this study (Tables 3 and 5) revealed that the root and vegetative characteristics of *C. erectus* cuttings were significantly influenced by the interaction among rooting media, cutting type and IBA concentrations during both seasons. Generally, treating tip cuttings with IBA at 100 ppm gave better root and growth parameters of cuttings than untreated-IBA cuttings in all rooting media used. The best combined treatment of tip cuttings treated with 100 ppm IBA and planted in vermiculite substrate which recorded the highest rooting percentage produced the highest root number and root length which positively reflected on better vegetative characteristics in terms of stem length, shoot number and leaf number per rooted cutting, followed by peat + perlite and peat + sand, respectively with the same cutting type and IBA concentration. Meanwhile the lowest root and vegetative characteristics were recorded with untreated-IBA middle and basal cuttings and planted in clay medium. In addition, the combined treatment of 100 ppm IBA and vermiculite substrate could significantly improve all root and vegetative growth characteristics studied of middle and basal cuttings compared to the same cutting types combined with the other rooting media and IBA concentrations. These results are in close conformity with the findings of Rajkumar *et al*. (2017) and Padekar *et al*. (2018), who observed that the root and vegetative parameters of rooted cuttings were greatly influenced by the rooting media, cutting type and IBA concentration. Rajkumar *et al*. (2016) stated that the maximum root and vegetative growth characteristics of *Punica granatum* cuttings were recorded with cuttings treated with 2500 ppm IBA with vermiculite substrate.

Some studies have shown that treatment of tip cuttings of *Conocarpus spp*. with IBA led to increase the root, shoot characteristics as compared to the untreated-IBA middle and basal cuttings (Al-Dulaimy, 2016; Abdel-Ramann *et al*., 2020). The reason in increasing the root and vegetative growth characteristics of *C. erectus* tip cuttings treated with IBA compared to untreated-IBA middle and basal cuttings may be attributed to higher endogenous IAA content in tip cutting tissues (Wróblewska, 2015). This stimulated cell division which resulted in the root primordia formation to absorb water and nutrients from the medium for early root growth and subsequent vegetative growth (Hartmann *et al*., 2014). Besides, the high water holding capacity and good aeration of the vermiculite media, peat + perlite and peat + sand were efficiently utilized by the stem cuttings in combination with available nutrients from the rooting media for shoot growth (Kumar *et al*., 2019). Sand with coir dust (1:1) medium with 150 ppm NAA was best for root growth performances in soft wood cuttings of *Chirita moonii* (Rubasinghe *et al.*, 2009).

C/N ratio and total phenols content:

As shown in Tables (6 and 7), C/N ratio and total phenols content in basal part of *C. erectus* cuttings were significantly influenced by different rooting media, cutting types and IBA concentrations in both seasons. Among the rooting media, the highest C/N ratio and total phenols content in cutting tissues were recorded under vermiculite medium which led to best rooting and growth of cuttings, followed by peat + perlite and peat + sand, respectively while the lowest values were recorded with

Table 6. Effect of rooting media, cutting types and indole-3-butyric acid (IBA) concentrations on C/N ratio and total phenols content (mg GAE/g dry weight) in cutting tissues of *Conocarpus erectus* during the 2016 and 2017 seasons.

Treatments	First season (2016)		Second season (2017)	
	C/N ratio	Total phenols	C/N ratio	Total phenols
Rooting media:				
Clay	10.2	33.3	10.4	35.0
Peat + sand	12.4	41.4	11.7	43.3
Peat + Perlite	14.8	44.7	13.5	46.3
Vermiculite	16.6	46.9	15.4	47.9
L.S.D. at 5%	0.3	1.0	0.2	0.7
Cutting types:				
Tip	11.7	51.0	10.5	52.4
Middle	13.6	40.5	12.7	41.8
Basal	15.3	33.2	15.0	35.2
L.S.D. at 5%	0.2	0.9	0.3	0.7
IBA concentrations (ppm):				
Control	11.4	33.4	10.5	34.9
50	13.4	43.8	13.0	45.7
100	16.1	48.3	15.0	49.6
200	13.2	40.7	12.5	42.4
L.S.D. at 5%	0.2	0.7	0.1	0.7

Table 7. Combined effect of rooting media, cutting types and indole-3-butyric acid (IBA) concentrations on C/N ratio and total phenols content (mg GAE/g dry weight) in cutting tissues of *Conocarpus erectus* during the 2016 and 2017 seasons.

Rooting media	Cutting types	IBA Con. "ppm"	First season (2016) C/N ratio	First season (2016) Total phenols	Second season (2017) C/N ratio	Second season (2017) Total phenols
Clay	Tip	Control	6.7	37.9	6.5	39.4
		50	8.6	48.9	8.6	51.9
		100	10.6	54.9	10.4	54.8
		200	8.3	46.6	8.1	48.5
	Middle	Control	8.9	19.0	9.1	20.5
		50	9.8	31.6	11.0	33.7
		100	11.4	39.0	12.7	40.4
		200	10.1	31.0	10.6	31.7
	Basal	Control	10.9	14.2	10.2	15.8
		50	12.2	24.5	12.5	26.7
		100	14.2	28.3	14.0	32.1
		200	11.1	24.0	11.4	24.2
Peat + sand	Tip	Control	8.6	43.6	8.0	42.1
		50	10.7	51.7	10.0	54.1
		100	13.3	58.1	11.2	57.1
		200	9.6	48.6	9.1	49.7
	Middle	Control	9.8	32.9	9.8	34.3
		50	12.9	44.4	12.5	46.6
		100	14.4	46.9	13.5	50.4
		200	12.2	40.0	12.7	42.9
	Basal	Control	12.0	23.0	11.8	29.5
		50	14.3	37.2	13.4	38.2
		100	15.6	37.8	15.4	42.4
		200	14.9	31.9	13.4	33.0
Peat + Perlite	Tip	Control	10.2	41.2	9.1	42.9
		50	13.7	54.1	11.5	56.7
		100	15.5	62.6	14.6	62.8
		200	13.5	48.3	11.0	53.6
	Middle	Control	12.4	37.2	11.0	36.9
		50	14.9	46.1	13.2	48.0
		100	17.1	49.9	15.2	50.9
		200	15.1	43.6	12.7	43.9
	Basal	Control	13.6	31.8	12.3	33.7
		50	16.1	39.2	16.3	41.2
		100	19.5	46.1	18.8	45.1
		200	16.3	36.3	16.1	39.7
Vermiculite	Tip	Control	12.4	44.9	11.3	46.5
		50	14.2	57.4	12.7	59.1
		100	17.1	63.9	14.2	65.7
		200	13.5	53.1	12.3	53.9
	Middle	Control	14.8	40.0	12.5	40.7
		50	15.7	49.7	15.3	49.7
		100	21.2	50.8	17.2	50.0
		200	16.1	46.2	14.7	47.7
	Basal	Control	16.2	35.0	14.8	36.1
		50	17.8	41.3	19.0	42.7
		100	23.0	41.5	22.8	43.1
		200	17.1	38.4	18.0	40.0
L.S.D. at 5%			0.7	2.5	0.7	2.4

clay medium with significant differences between them (Table 6). This could be due to the fact that vermiculite medium has better aeration potential and drainage which provided with good root system led to more water and nutrients uptake from rooting media resulting in better vegetative growth, higher C/N ratio and total phenols content.

Concerning the effect of cutting types, basal cuttings contained higher C/N ratio and lower total phenols content than tip and middle ones, while tip cuttings contained higher total phenols content and lower C/N ratio (Table 6). It is evident from the current findings that the root ability of basal cuttings was not related to their content of C/N ratio, while there was a positive correlation between root ability of tip cuttings and higher C/N ratio. Similar trends were reported by Denaxa *et al*. (2012) and Abdel-Rahman *et al*. (2020). Abdel-Rahman and El-Naggar (2014) postulated that basal cuttings of *Bougainvillea* contained higher C/N ratio than tip and middle ones. For phenols, Haissig (1974) and Abdel-Rahman *et al*. (2020) revealed that phenols in juvenile tissues of certain plants tend to be higher than their mature forms. More lignified tissues have additionally a higher IAA-oxidase activity (Liu *et al*., 1998); therefore conditions were less favorable for rooting of basal cuttings, which clearly could not keep the endogenous IAA concentration on the level of satisfying rooting.

On the other hand, the obtained data in Table (6) indicate that the exogenous IBA application significantly increased C/N ratio and total phenols content compared to untreated-IBA cuttings. The highest C/N ratio and total phenols content were recorded with IBA at 100 ppm, followed by 50 and 200 ppm IBA, respectively with significant differences between them. Generally, the basal cuttings treated with 100 ppm IBA under vermiculite medium contained the highest C/N ratio, while tip cuttings contained the highest total phenols content with same IBA concentration under vermiculite medium compared to the other combinations (Table 7). These results are in agreement with the findings of Mahrose (2000) and Abdel-Rahman *et al*. (2020), who revealed that the high rootability of cuttings was associated with high C/N ratio and total phenols content in cutting tissues. According to Attia and Moftah (1992), treatment of *Euphorbia pulcherrima* cuttings with IBA considerably increased C/N ratio and consequently enhanced the rootability of cuttings. Exogenous IBA application could have an indirect influence on rooting by increasing the speed of transformation and movement of sugars and other assimilates to the base of cuttings thereby stimulating root formation (Davies, 2004).

Several investigations have reported that treatment of cuttings with IBA resulted in an increase in total phenols content (Amin *et al*., 2006; Abdel-Rahman *et al*., 2020). Phenols act as auxin-cofactor in promotion of adventitious root formation and reduction in rootability of cuttings can be due to the reduction of phenolic compounds (Khandan-Mirkohi *et al*., 2015). The role of phenolic compounds in adventitious root formation is in protecting the rooting-inducer endogenous auxin IAA from being destructed by peroxidase, which can act as an IAA oxidase (De Klerk *et al*., 2011). According to Scagel and Linderman (1998), the increment in total phenols content in cutting tissues as a result of treatment of cuttings with IBA has a direct role in inhibiting auxin oxidation so more auxin is available to induce roots and enhance the root and vegetative growth characteristics of cuttings.

Indole acetic acid (IAA) and Abscisic acid (ABA) contents:

Table (8) shows HPLC analysis of samples extracted from the tip, middle and basal cuttings of *C. erectus* for the control and treated with 100 ppm IBA in clay and vermiculite medium. It is clear that IAA content in cutting tissues planted in vermiculite was higher (33.04 µg/g f.w.) than in clay medium (22.64 µg/g f.w.). Treating cuttings with IBA at 100 ppm showed the highest content of IAA (35.12

Table 8. Content of indole acetic acid (IAA) and abscisic acid (ABA) at root zone of three cutting types of *Conocarpus erectus* L. treated with 100 ppm IBA and the control under vermiculite and clay medium.

Rooting media	Cutting type	IBA concentration (ppm)		
		Control	100	Mean
		IAA (µg/g f.w.)		
Clay	Tip	31.120	45.240	38.180
	Middle	8.520	29.400	18.960
	Basal	5.030	16.510	10.770
	Mean	14.890	30.380	22.640
Vermiculite	Tip	48.240	61.250	54.750
	Middle	19.240	37.150	28.200
	Basal	11.210	21.170	16.190
	Mean	26.230	39.860	33.040
General mean		20.560	35.120	27.840
		ABA (µg/g f.w.)		
Clay	Tip	0.124	0.052	0.088
	Middle	0.182	0.124	0.153
	Basal	0.412	0.306	0.359
	Mean	0.239	0.161	0.200
Vermiculite	Tip	0.091	0.028	0.060
	Middle	0.150	0.103	0.127
	Basal	0.321	0.264	0.293
	Mean	0.187	0.132	0.160
General mean		0.213	0.146	0.180

µg/g f.w.) compared to control (20.56 µg/g f.w.). The highest IAA content (61.25 µg/g f.w.) was obtained from tip cuttings treated with IBA at 100 ppm under vermiculite medium. However, the lowest IAA content (5.03 µg/g f.w.) was recorded with untreated-IBA basal cuttings under clay medium. The current study indicates a positive correlation between the higher endogenous IAA content and rootability of cuttings. These results are in accordance with those reported by Weigel *et al*. (1984) and El Botaty and Saleh (2018), who cleared that treatment of cuttings with IBA increased the endogenous IAA content led to improve the rooting and growth of cuttings comparing with untreated cuttings. Better rooting and growth of tip cuttings comparing with the middle and basal ones can be due to the presence of higher IAA and phenols levels as well as lower ABA content in tip cutting tissues, so it is possible that IAA and phenols levels decrease with increased distance from shoot tip leading to low rooting percentage (Palanisamy and Kumar, 1997).

As for ABA content, the obtained results (Table 8) show that clay medium exhibited the highest ABA content (0.200 µg/g f.w.), while the lowest content (0.160 µg/g f.w.) was recorded in vermiculite medium. Treatment of *C. erectus* cuttings with 100 ppm IBA caused a reduction in endogenous ABA content (0.146 µg/g f.w.) compared to the control (0.213 µg/g f.w.). The lowest endogenous ABA content (0.028 µg/g f.w.) was obtained from tip cuttings treated with 100 ppm IBA under vermiculite medium, while the highest value (0.412 µg/g f.w.) was recoded with untreated-IBA basal cuttings under clay medium. These results are in agreement with those reported by Tilahun *et al*. (2019) and Abdel-Rahman *et al*. (2020), who stated that a low IAA and high ABA contents is correlated with low rootability of cuttings, whereas the opposite was found in high rooting rate cuttings.

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تأثير بيئة التجذير وتركيز إندول حمض البيوتيريك على تجذير ونمو الأنواع المختلفة من العقل الساقية لنبات الكونوكاربس

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أجريت الدراسة الحالية بهدف تقييم تأثير بيئة التجذير (طين، بيت موس + رمل، بيت موس + بيرليت، فيرمكيوليت)، أنواع العقلة الساقية (طرفية، وسطية، قاعدية)، التركيزات المختلفة لإندول حمض البيوتيريك (صفر، ٥٠، ١٠٠، ٢٠٠ جزء فى المليون) على تجذير ونمو العقل الساقية لنبات الكونوكاربس. صممت التجربة بنظام القطع المنشقة مرتين، مع ثلاث مكررات. أظهرت النتائج المتحصل عليها أن بيئة الفيرمكيوليت كانت أفضل بيئات التجذير المستخدمة لتحسين نسبة التجذير، عدد الجذور، طول الجذر، طول الساق، عدد الفروع، عدد الأوراق لكل عقلة مجذرة، يليها بيئة البيت موس + البيرليت (١:١ بالحجم)، البيت موس + الرمل (١:١ بالحجم) على الترتيب مقارنة ببيئة الطين والتى سجلت أقل القيم للصفات المدروسة. تفوقت العقلة الطرفية على العقل الوسطية والقاعدية فى جميع بيئات التجذير المستخدمة وبصفة خاصة فى بيئة الفيرمكيوليت. من بين تركيزات إندول حمض البيوتيريك المستخدمة، فإن معاملة العقل بإندول حمض البيوتيريك بتركيز ١٠٠ جزء فى المليون حسن نسبة التجذير معنويا (٤٢,٩٪) مقارنة بتركيز ٥٠ جزء فى المليون (٣٦,٣٪) و ٢٠٠ جزء فى المليون (٣٦,٠٪) والعقل غير المعاملة (٢٣,١٪). أعلى نسبة تجذير (٩٥,٠٪) وأفضل صفات جذرية، خضرية وأيضا أعلى محتوى للفينولات الكلية، إندول حمض الخليك وأقل محتوى لحمض الأبسيسيك تم الحصول عليه من العقلة الطرفية المعاملة بإندول حمض البيوتيريك بتركيز ١٠٠ جزء فى المليون والمنزرعة فى بيئة الفيرمكيوليت. علاوة على ذلك، فإن المعاملة المشتركة لإندول حمض البيوتيريك بتركيز ١٠٠ جزء فى المليون وبيئة الفيرمكيوليت حسنت معنويا نسبة التجذير، الصفات الجذرية والخضرية للعقل الوسطية والقاعدية، كما أعطت أعلى نسبة من الكربوهيدرات و النيتروجين فى أنسجة العقلة القاعدية مقارنة بنفس أنواع العقل مشتركة مع بيئات التجذير وتركيزات إندول حمض البيوتيريك الأخرى. بناءا على ذلك، يمكن التوصية بمعاملة جميع أنواع العقل الساقية لنبات الكونوكاربس بإندول حمض البيوتيريك بتركيز ١٠٠ جزء فى المليون والزراعة فى بيئة الفيرمكيوليت بهدف تحسين التجذير وجودة ونمو العقل.