Arab Universities Journal of Agricultural Sciences
(2024) 32 (1) 101-110
Website: http://ajs.journals.ekb.eg

Rootability of Some Mulberry Cultivars Treated with Growth Regulators

Ayat Salah El den*, Hassan MF Elwakeel, Ahmed A Awad, Mohamed A Nasser
Horticulture Dept, Fac of Agric, Ain Shams Univ, P.O. Box 68, Hadayek Shoubra 11241, Cairo, Egypt

*Corresponding author: Ayat.salah84@gmail.com

https://doi.org/10.21608/AJS.2024.183600.1511

Received 7 January 2023; Accepted 14 June 2023

Keywords:

Hardwood,
Cutting,
Mulberry cultivars,
Growth regulators,
NAA,
IBA

Abstract: The Red and White pakestanian mulberry cultivars and Baladi mulberry trees were propagated by using medium hardwood cuttings prepared in November, December and January, and treated with the growth regulators IBA and NAA (0, 2000, 4000 and 6000 ppm) during 2020 and 2021 seasons. The hardwood cuttings treatment was planted in wooden frames inside the greenhouse in a cultivation medium consisting of peat moss and sand (1:3 v/v respectively). Data showed that Baladi mulberry cultivar gave the highest values of rooting percentage while the White Pakestanian gave the highest values for the number of roots per cutting. Concerning growth regulator treatments, IBA at 6000 gave the highest significant number of roots per cutting followed by NAA at 6000 ppm. In the interaction between the two studied factors, the highest rooting percentage was found by NAA at 6000 ppm for Baladi and White cultivars. While the highest values of root number and root length were resulted by IBA at 6000 ppm followed by NAA at 6000 ppm for Baladi and White mulberry cultivars. The C/N ratio in Baladi and White cultivars cuttings was highest in hardwood cuttings prepared in November. While the values of C/N ratio in Red mulberry cultivar cuttings were highest in hardwood cuttings prepared in January.

1 Introduction

The genus Morus has 68 species, the majority of which are found in Asia. There are more than a thousand varieties grown just in China. The White mulberry (*Morus alba*) that grows in Egyptian gardens was the main subject of the study. It also touched on the Black mulberry (*Morus nigra*) and the Red mulberry (*Morus rubra*), two other commonly grown species. Aref Hawramee et al (2019) recorded that the white mulberry, *Morus alba* L., is a fascinating tree that is widely cultivated for several purposes all over the world. In this study, an effort was undertaken to spread the cultivar that produced no fruit of *Morus alba* L. by hardwood cuttings, comparing different cuttings collection times using various concentrations of IBA (Indole-3-Butyric Acid) solution. The best survival rate of rooted seedlings was achieved by taking and planting cuttings on March 1st, according to the results, which was (20.83%) compared to February 8th (16.33%) and March 22nd (12.5%). The species *Morus alba* L. of the Mores genus, family Moraceae, is described as a subtropical tree. The three distinct species of this tree, the white, red, and black mulberry, are named for the fruit that gives it its most

well-known cultivars (*Morus alba*, *Rubra* and *Nigra* respectively). *Morus alba* L and *Morus nigra* L are the Latin names for the white and black mulberries, respectively. Morus red does not grow in Egypt; it does come in a range of colors from white to pink. White mulberry grows in Shkoder, Tirana, Durres, and other areas, while mulberry grows in hilly areas and above mountains. Solgi et al (2022) reported that landscapes often use ornamental black mulberries (*Morus nigra* L.). High-shade ornamental black mulberry trees can withstand wind and pollution. White mulberry (*Morus alba* L.) is proper for kind of soil conditions. Due to its availability, ease of conduct and low cost, the present study aims to find a method to increase the rootability of some mulberry cultivars by hardwood cuttings.

2 Materials and Methods

This work was carried out during two successive seasons (2020/ 2021 and 2021/2022) in the greenhouse at the nursery of Faculty of Agriculture Ain Shams University, Shoubra El Kheima, Cairo, Egypt. The Red and White pakestanian mulberry and Baladi mulberry cultivars were propagated by using hardwood cuttings and treated with rooting stimulants. In both seasons hardwood cuttings 15 to 20 cm in length and 1 cm in thickness were prepared in three different dates (November, December and January); the basal cut was made just below a node. The experiment was arranged in a factorial experiment with a complete randomized design with four replicates for each treatment and 8 cuttings for each replicate. The cultivation media consisted of peat moss and sand (1:3). The growth regulator treatments were as follows: control, 2000 ppm IBA, 4000 ppm IBA, 6000 ppm IBA, 2000 ppm NAA, 4000 ppm NAA and 6000 ppm NAA). The basal inch of cuttings was dipped in growth regulator treatments for 10 seconds. Control cuttings were dipped in 50% ethyl alcohol solution for 10 Sec. Cuttings were left to air dry before planting. The hardwood cuttings were taken from three-year-old mulberry trees for all cultivars. Three cutting dates preparing for all cultivars in November, December and January; they were planted in wooden frames inside the greenhouse. Irrigation was carried out continuously twice a week for 45 days.

2.1 Rooting parameters

Rooting percentage, number of roots per cutting and root length (cm) were recorded after six weeks of planting cuttings.

2.2 Chemical determination of some internal constituent

The following chemical determinations were carried out in the basal of cuttings in the second season only for the three cutting dates (November, December and January). Total carbohydrates was determined by the phenol sulfuric method according to Nielsen (2010). Total nitrogen was determined by the Kjeldahl method according to (Rhee 2001). The C/N ratio was calculated by dividing the percent of total carbohydrates by the percent of total nitrogen.

2.3 Statistical analysis

Data were subjected to statistical analysis according to the procedures reported by Snedecor and Cochran (1980), and the means were compared by using a one-way analysis of variance test at the 0.05 level of probability in the two seasons (Bewick et al 2004). Data were statistically analyzed by the analysis of variance adopted by the SPSS package (SPSS Version 20.0).

3 Results and Discussion

3.1 Rooting percentage

The following result shows the effect of mulberry cultivar and some growth regulator treatments at different cutting dates on rooting percentage, root number per cutting and average root length of hardwood cuttings. Data in **Table 1** show the effect of some mulberry cultivars and growth regulation treatments on the rooting percentage of hardwood cuttings prepared in November 2020 and 2021 seasons.

Regarding cultivars, White Pakistanian mulberry in the first season and Baladi in the second season gave a higher significant rooting percentage than that of Red Pakistanian mulberry. Concerning growth regulator treatments, NAA at 6000 ppm gave the highest significant rooting percentage followed by IBA 600 ppm treatment in both seasons. Concerning the interaction, White mulberry cutting with NAA at 6000 ppm gave the highest significant rooting percentage in the first season but in the second season, Baladi mulberry cutting with NAA at 6000 ppm gave the high significant value.

Table 1. Effect of some mulberry cultivars and growth regulation treatments on rooting percentage of hardwood cuttings prepared in November 2020 and 2021 seasons

Treatments	Cultivars			
	Baladi	White	Red	Mean
2020 season				
IBA 2000 ppm	32 d	20 f	24 e	25 D
IBA 4000 ppm	49 bc	32 d	24 e	36 C
IBA 6000 ppm	50 b	49 bc	48 c	50 B
NAA 2000 ppm	15 g	15 g	24 e	18 E
NAA 4000 ppm	32 d	49 bc	24 e	36 C
NAA 6000 ppm	48 c	65 a	49 bc	55 A
Control	0 h	0 h	0 h	0 F
Mean	31 B`	34 A`	28 C`	
2021 season				
IBA 2000 ppm	33 g	17 ij	18 i	22 D
IBA 4000 ppm	42 d	32 g	22 h	33 C
IBA 6000 ppm	47 c	42 d	36 e	42 B
NAA 2000 ppm	16 j	17 iJ	17 ij	17 E
NAA 4000 ppm	42 d	35 f	22 h	33 C
NAA 6000 ppm	55 a	51 b	42 d	49 A
Control	0 k	0 k	0 k	0F
Mean	33 A`	26 B'	24 C'	

Means in each column row or interaction had identical letters do not differ appreciably at the 5% level

Table 2. Effect of some mulberry cultivars and growth regulation treatments on rooting percentage of hardwood cuttings prepared in December 2020 and 2021 seasons

Treatments	Cultivars			
	Baladi	White	Red	Mean
2020 season				
IBA 2000 ppm	30 g	15 i	16 i	20 E
IBA 4000 ppm	39 de	30 g	19 h	29 D
IBA 6000 ppm	44 c	39 de	33 f	39 B
NAA 2000 ppm	14 j	15 i	15 i	15 F
NAA 4000 ppm	39 de	33 f	19 h	30 C
NAA 6000 ppm	52 a	49 b	40 d	47 A
Control	0 k	0 k	0 k	0 G
Mean	31 A`	25 B`	22 C`	
2021 season				
IBA 2000 ppm	44 f	32 h	28 i	34 E
IBA 4000 ppm	56 d	51 e	32 h	46 D
IBA 6000 ppm	64 b	60 c	54 d	59 B
NAA 2000 ppm	35 g	29 i	33 h	32 F
NAA 4000 ppm	58 c	54 d	32 h	48 C
NAA 6000 ppm	74 a	63 b	60 c	66 A
Control	0 j	0 j	0 j	0 G
Mean	47 A`	41 B`	34 C`	

Means in each column row or interaction had identical letters do not differ appreciably at the 5% level

Data in **Table 2** show the effect of the mulberry cultivar and growth regulation treatments on the rooting percentage of hardwood cuttings prepared in December 2020 and 2021 seasons. Regarding the effect of cultivars, results showed that Baladi cultivar gave the highest significant rooting percentage followed by White and Red cultivars in both seasons. Concerning growth regulator treatments, the highest significant rooting percentage was recorded with NAA at 6000 ppm followed by IBA at 600 ppm. The interaction between the two studied factors showed the highest rooting percentage with cuttings of Baladi cultivar treated with NAA at 6000 ppm in both seasons of study. On the other hand, the lowest rooting percentage was found with the control followed by NAA at 2000 ppm for the three tested cultivars in both seasons.

Data in **Table 3** show the effect of the cultivars and growth regulation on the rooting percentage of hardwood cuttings prepared in the January 2021 and 2022 seasons. Cultivar results cleared that Baladi cultivar gave the highest significant rooting percentage followed by White and Red cultivars which recorded the lowest percentage in both seasons. Concerning growth regulator treatments, NAA at 6000 ppm gave the highest significant rooting percentage followed by IBA at 600 ppm. The interaction between the two studied factors showed that NAA at 6000 ppm recorded the highest rooting percentage with Baladi cultivar in the first season and White cultivar in the second one.

Table 3. Effect of some mulberry cultivars and growth regulation treatments on rooting percentage of hardwood cuttings prepared in January 2021 and 2022 seasons

Treatments	Cultivars			
	Baladi	**White**	**Red**	**Mean**
2021 season				
IBA 2000 ppm	40 i	28 lm	24 o	31 E
IBA 4000 ppm	53 f	47 h	28 m	43 D
IBA 6000 ppm	61 b	57 d	51 g	56 B
NAA 2000 ppm	33 j	26 n	29 kl	29 F
NAA 4000 ppm	55 e	52 g	30 k	46 C
NAA 6000 ppm	71 a	57 d	59 c	63 A
Control	0 p	0 p	0 p	0 G
Mean	45 A`	38 B`	32 C`	
2022 season				
IBA 2000 ppm	34 e	22 g	26 f	28 D
IBA 4000 ppm	52 bc	34 e	27 f	38 C
IBA 6000 ppm	53 b	51 cd	52 bcd	52 B
NAA 2000 ppm	18 h	17 h	27 f	21 E
NAA 4000 ppm	35 e	52 bcd	26 f	38 C
NAA 6000 ppm	51 d	67 a	52 bc	57 A
Control	0 i	0 i	0 i	0 F
Mean	34.1 A`	34.8 A`	30 B`	

Means in each column row or interaction had identical letters do not differ appreciably at the 5% level

Table 4. Effect of some mulberry cultivars and growth regulation treatments on number of roots per cutting for hardwood cuttings prepared in November 2020 and 2021 seasons

Treatments		Cultivars		
	Baladi	White	Red	Mean
2020 season				
IBA 2000 ppm	2 g	1 ij	2 hi	2 E
IBA 4000 ppm	3 f	2 gh	6 d	4 C
IBA 6000 ppm	10 c	14 a	11 b	12 A
NAA 2000 ppm	1 g	1 g	2 i	1 F
NAA 4000 ppm	2 gh	3 f	2 gh	2 D
NAA 6000 ppm	5 e	14 a	6 d	8 B
Control	0 k	0 k	0 k	0 G
Mean	3 C`	5 A`	4 B`	
2021 season				
IBA 2000 ppm	2.0 f	0.9 h	0.8 h	1.2 E
IBA 4000 ppm	2.8 e	1.5 g	4.8 d	3.0 C
IBA 6000 ppm	8.8 b	9.0 b	12.1 a	10.0 A
NAA 2000 ppm	0.8 h	1.1 gh	1.2 gh	1.0 E
NAA 4000 ppm	2.4 f	2.0 f	1.5 g	2.0 D
NAA 6000 ppm	4.9 d	4.9 d	6.4 c	5.4 B
Control	0 i	0 i	0 i	0 F
Mean	3.1 C`	3.2 B`	3.3 A`	

Means in each column row or interaction had identical letters do not differ appreciably at the 5% level

3.2 Number of roots per cutting

Data in **Table 4** show the effect of the examined cultivars and growth regulation on the number of roots per cutting for hardwood cuttings prepared in November 2021 and 2022 seasons. Regarding cultivar, the highest significant number of roots per cutting was detected with White cultivar in the first season and Red cultivar in the second one while the lowest values were found with Baladi cultivar in both seasons. Concerning growth regulator treatments IBA at 6000 gave the highest significant number of roots per cutting followed by NAA at 6000 ppm. The interaction between the two studied factors showed that the highest number of roots per cutting was observed with IBA at 6000 ppm for White cultivar in the first season and Red cultivar in the second one.

Data in **Table 5** show the effect of cultivar and growth regulation treatments on the number of roots per cutting for hardwood cuttings prepared in December 2020 and 2021 seasons. Regarding cultivar, the highest significant number of roots per cutting was detected with White Pakistanian mulberry throw the two seasons and Red Pakistanian mulberry in the first season. While the lowest values were found with Baladi cultivar in both seasons. Concerning growth regulator treatments IBA at 6000 gave the highest significant number of roots per cutting followed by NAA at 6000 ppm. The interaction between the two studied factors, showed that the highest number of roots per cutting was observed with IBA at 6000 ppm for Red Pakistanian mulberry in the first season and IBA at 6000 ppm for White cultivar in the second one.

Table 5. Effect of some mulberry cultivars and growth regulation treatments on number of roots per cutting for hardwood cuttings prepared in December 2020 and 2021 seasons

Treatments	Cultivars			
	Baladi	White	Red	Mean
2020 season				
IBA 2000 ppm	2.0 gh	1.0 j	1.0 j	1.3 E
IBA 4000 ppm	2.8 f	1.7 hi	4.8 e	3.1 C
IBA 6000 ppm	8.9 b	9.0 b	12.2 a	10 A
NAA 2000 ppm	1.0 j	1.1 j	1.0 j	1.0 F
NAA 4000 ppm	2.7 f	2.1 g	1.5 i	2.0 D
NAA 6000 ppm	4.9 de	5.1 d	6.6 c	5.5 B
Control	0 k	0 k	0 k	0 G
Mean	3.1 B`	3.3 A`	3.4 A`	
2021 season				
IBA 2000 ppm	4 g	2 i	2 i	3 E
IBA 4000 ppm	5 ef	4 g	7 d	5 C
IBA 6000 ppm	11 c	15 a	13 b	13 A
NAA 2000 ppm	2 i	3 hi	2 i	2 F
NAA 4000 ppm	4 fg	3 gh	3 gh	4 D
NAA 6000 ppm	5 e	14 a	11 c	10 B
Control	0 g	0 g	0 g	0 G
Mean	4 C`	6 A`	5 B`	

Means in each column row or interaction had identical letters do not differ appreciably at the 5% level

Table 6. Effect of some mulberry cultivars and growth regulation treatments on number of roots per cutting for hardwood cuttings prepared in January 2021 and 2022 seasons

Treatments		Cultivars		
	Baladi	White	Red	Mean
2021 season				
IBA 2000 ppm	3.3 h	1.8 j	1.6 j	2.2 E
IBA 4000 ppm	3.9 g	2.7 i	6.0 e	4.2 C
IBA 6000 ppm	10.8 c	14.2 a	12.3 b	12.4 A
NAA 2000 ppm	2.0 j	1.5 j	1.5 j	1.7 F
NAA 4000 ppm	3.5 gh	3.0 hi	2.7 i	3.0 D
NAA 6000 ppm	4.7 f	14.0 a	10.0 d	9.5 B
Control	0 k	0 k	0 k	0 G
Mean	4.0 C`	5.3 A`	4.8 B`	
2022 season				
IBA 2000 ppm	2 g	1 hi	1 h	2 E
IBA 4000 ppm	3 f	2 g	6 d	4 C
IBA 6000 ppm	10 c	14 a	11 b	12 A
NAA 2000 ppm	0.8 i	1.01 i	1.5 h	1 F
NAA 4000 ppm	2 g	3 f	2 g	2 D
NAA 6000 ppm	5 e	13 a	6 d	8 B
Control	0 j	0 j	0 j	0 G
Mean	3 C`	5 A`	4 B`	

Means in each column row or interaction had identical letters do not differ appreciably at the 5% level

Data in **Table 6** present the effect of cultivar and growth regulation treatments on the number of roots for hardwood cuttings prepared in January 2021 and 2022. Regarding the cultivar, the highest significant number of roots per cutting was detected with White Pakistanian mulberry throw the two seasons. While the lowest values were found with Baladi cultivar in both seasons. Concerning growth regulator treatments, IBA at 6000 gave the highest significant values of root length followed by NAA at 6000 ppm. The interaction between the two studied factors showed that the highest number of roots per cutting was observed with IBA at 6000 ppm for white Pakistanian mulberry and NAA at 6000 ppm for white Pakistanian mulberry in the two seasons.

3.3 Root length

Table 7 presents the effect of some cultivar and growth regulation treatments on the root length of hardwood cuttings prepared in November 2020 and 2021 seasons. Regarding cultivar, the highest significant root length was detected with White cultivar in the first season and Baladi cultivar in the second one while the lowest values were found with Red cultivar in both seasons. Concerning growth regulator treatments, IBA at 6000 gave the highest significant values of root length followed by NAA at 6000 ppm. The interaction between the two studied factors showed that the highest root length was observed with IBA at 6000 ppm for White cultivar in both seasons.

Table 7. Effect of some mulberry cultivars and growth regulation treatments on root length (cm) of hardwood cuttings prepared in November 2020 and 2021 seasons

Treatments	Cultivars			
	Baladi	White	Red	Mean
2020 season				
IBA 2000 ppm	1.0 g	0.5 i	1.0 g	0.8 D
IBA 4000 ppm	1.2 f	1.0 g	0.5 h	1.0 C
IBA 6000 ppm	2.2 b	2.4 a	2.0 c	2.2 A
NAA 2000 ppm	0.5 i	0.8 h	1.0 g	0.7 E
NAA 4000 ppm	1.0 g	1.6 de	0.7 i	1.0 C
NAA 6000 ppm	1.6 e	1.7 d	1.3 f	1.5 B
Control	0 j	0 j	0 j	0 F
Mean	1.0 B`	1.1 A`	0.9 C`	
2021 season				
IBA 2000 ppm	1.0 fg	0.6 j	0.8 h	0.8 E
IBA 4000 ppm	1.2 ef	1.0 fg	0.8 h	1.0 D
IBA 6000 ppm	2.2 a	2.1 a	1.7 bc	2.0 A
NAA 2000 ppm	0.6 ij	0.9 gh	0.8 hi	0.8 E
NAA 4000 ppm	1.5 cd	1.2 e	0.6 j	1.1 C
NAA 6000 ppm	1.8 b	1.6 bc	1.4 d	1.6 B
Control	0 k	0 k	0 k	0 F
Mean	1.5 A`	1.2 B`	0.9 C`	

Means in each column row or interaction had identical letters do not differ appreciably at the 5% level

Table 8. Effect of some mulberry cultivars and growth regulation treatments on root length (cm) of hardwood cuttings prepared in December 2020 and 2021 seasons

Treatments	Cultivars			
	Baladi	White	Red	Mean
2020 season				
IBA 2000 ppm	1.0 fg	0.5 i	0.7 h	0.7 E
IBA 4000 ppm	1.1 ef	1.0 fg	0.7 h	0.9 D
IBA 6000 ppm	2.1 a	1.8 b	1.6 bc	1.9 A
NAA 2000 ppm	0.5 i	0.9 g	0.7 h	0.7 E
NAA 4000 ppm	1.5 cd	1.2 e	0.5 i	1.0 C
NAA 6000 ppm	1.7 b	1.5 bc	1.3 d	1.5 B
Control	0 j	0 j	0 j	0 F
Mean	1.1 A`	1.0 B`	0.9 C`	
2021 season				
IBA 2000 ppm	1.6 d	1.0 e	1.0 e	1.2 D
IBA 4000 ppm	1.6 d	1.1 e	1.0 e	1.2 D
IBA 6000 ppm	3.0 a	2.6 b	2.3 ab	2.8 A
NAA 2000 ppm	1.0 e	1.0 e	1.0 e	1.0 E
NAA 4000 ppm	2.0 c	1.6 d	1.5 d	1.7 C
NAA 6000 ppm	3.0 a	2.0 c	1.6 d	2.2 B
Control	0 f	0 f	0 f	0 F
Mean	1.7 A`	1.4 B`	1.3 B`	

Means in each column row or interaction had identical letters do not differ appreciably at the 5% level

Data in **Table 8** show the effect of the used cultivars and growth regulators on the root length of hardwood cuttings prepared in December 2020 and 2021 seasons. Regarding cultivar, Baladi cv. gave the highest significant values of root length in both seasons. Concerning growth regulator treatments, IBA at 6000 ppm gave the highest significant values of root length followed by NAA at 6000 ppm. The interaction between the two studied factors, data showed that IBA at 6000 ppm for Baladi mulberry gave the highest significant value of root length in the two seasons.

Data in **Table 9** show the effect of mulberry cultivars and growth regulation on the root length of hardwood cuttings prepared in January 2021 and 2022. Regarding cultivar, the highest significant values of root length were detected with Baladi cultivar in the first season and Red cultivar in the second one while the lowest values were found with Red cultivar in the second season. Concerning growth regulator treatments, gave the highest significant values of root length followed by NAA at 6000 ppm. The interaction between the two studied factors, NAA at 6000 ppm for Baladi mulberry had the highest significant value of root length in the first season and IBA at 600 ppm for Whit Pakistanian mulberry in the second season.

Table 9. Effect of some mulberry cultivars and growth regulation treatments on root length (cm) of hardwood cuttings prepared in January 2021 and 2022 seasons

Treatments	Cultivars			
	Baladi	White	Red	Mean
2021 season				
IBA 2000 ppm	1.5 df	1.0 f	1.0 f	1.1 D
IBA 4000 ppm	1.6 df	1.0 f	1.0 f	1.2 D
IBA 6000 ppm	3.0 a	2.8 ab	2.6 b	2.8 A
NAA 2000 ppm	1.0 f	1.0 f	1.0 f	1.0 E
NAA 4000 ppm	2.0 c	1.7 df	1.5 e	1.7 C
NAA 6000 ppm	3.0 a	2.0 c	1.7 d	2.2 B
Control	0 g	0 g	0 g	0 F
Mean	1.6 A`	1.3 B`	1.2 B`	
2022 season				
IBA 2000 ppm	1.0 f	0.6 i	1.0 f	0.9 D
IBA 4000 ppm	1.3 e	1.0 fg	0.8 h	1.0 C
IBA 6000 ppm	2.2 a	2.4 a	2.0 b	2.2 A
NAA 2000 ppm	0.5 i	0.8 gh	1.0 f	0.8 D
NAA 4000 ppm	1.0 f	1.7 cd	0.5 i	1.1 C
NAA 6000 ppm	1.6 d	1.8 c	1.4 e	1.6 B
Control	0 j	0 j	0 j	0 E
Mean	1.1 B`	1.2 A`	0.9 C`	

Means in each column row or interaction had identical letters do not differ appreciably at the 5% level

3.4 Total carbohydrates

The result in **Fig 1** shows the total carbohydrates in hardwood cutting of some mulberry cultivars at different preparing cutting dates in the second season. Data indicated that the total carbohydrates in Baladi and White mulberry cultivars cuttings were highest in hardwood cuttings prepared in November, followed closely by hardwood cuttings prepared in December, while the lowest values were found in hardwood cuttings prepared in January. On the other hand, the total carbohydrates in Red mulberry cultivar cuttings were highest in hardwood cuttings prepared in December and the lowest in hardwood cuttings prepared in November.

3.5 Total nitrogen

The result in **Fig 2** shows the total nitrogen in hardwood cutting of some mulberry cultivars at different preparing cutting dates in the second season. Data indicated that the total nitrogen% in Baladi and White mulberry cultivars cuttings were highest in hardwood cuttings prepared in January, followed closely by hardwood cuttings prepared in December, while the lowest values were found in hardwood cuttings prepared in November. On the other hand, the total nitrogen% in Red mulberry cultivar cuttings was highest in hardwood cuttings prepared in December and the lowest in hardwood cuttings prepared in November and January.

3.6 C/N ratio

The result in **Fig 3** shows the C/N ratio in hardwood cutting of some mulberry cultivars at different prepared cutting dates in the second season. Data indicated that C/N ratio in Baladi and White mulberry cultivars cuttings was highest in hardwood cuttings prepared in November, while the lowest values were found in hardwood cuttings prepared in January. On the other hand, the values of C/N ratio in Red mulberry cultivar cuttings were highest in hardwood cuttings prepared in January and the lowest in hardwood cuttings prepared in November and December.

The seasonal timing of cuttings can play an important role in rooting (Harrison-Murray 1991) where different external factors can have an impact on rooting parameters; for example, auxin and naphthylacetic acid treatments can increase the cutting ability for rooting (Marks and Simpson 2000, Kaul 2008). Rooting percentage, root number and length of roots for mulberry cuttings differed according to cultivars, type of auxin and auxin concentration. The treatment with IBA at a concentration of 6000 ppm gave the highest values for the number of roots and their length, while the highest percentage of rooting resulted when the treatment with NAA was at a concentration of 6000 ppm**.** The results are consistent with those from the studies that have been mentioned below regarding the impact of the auxin group of hormones on roots and plant development. IAA and IBA were found to be effective in *Malus pumila, Chukrasia velutina, Pisum sativum* (De Klerk et al 1997, Tchoundjeu et al 2002). IAA, IBA, and NAA were also found to be effective in Malus (Tchoundjeu et al 2002). Total carbohydrates, total nitrogen and C/N ratio in the basal of cutting were affected by the timing of taken cuttings. The ratio of carbohydrate to nitrogen was higher in November and December, which was reflected in the rooting percentage, where the highest percentage of rooting was for the cuttings taken during November. These results are in harmony with those found by Souza et al (2019**)** on fig cutting where reducing

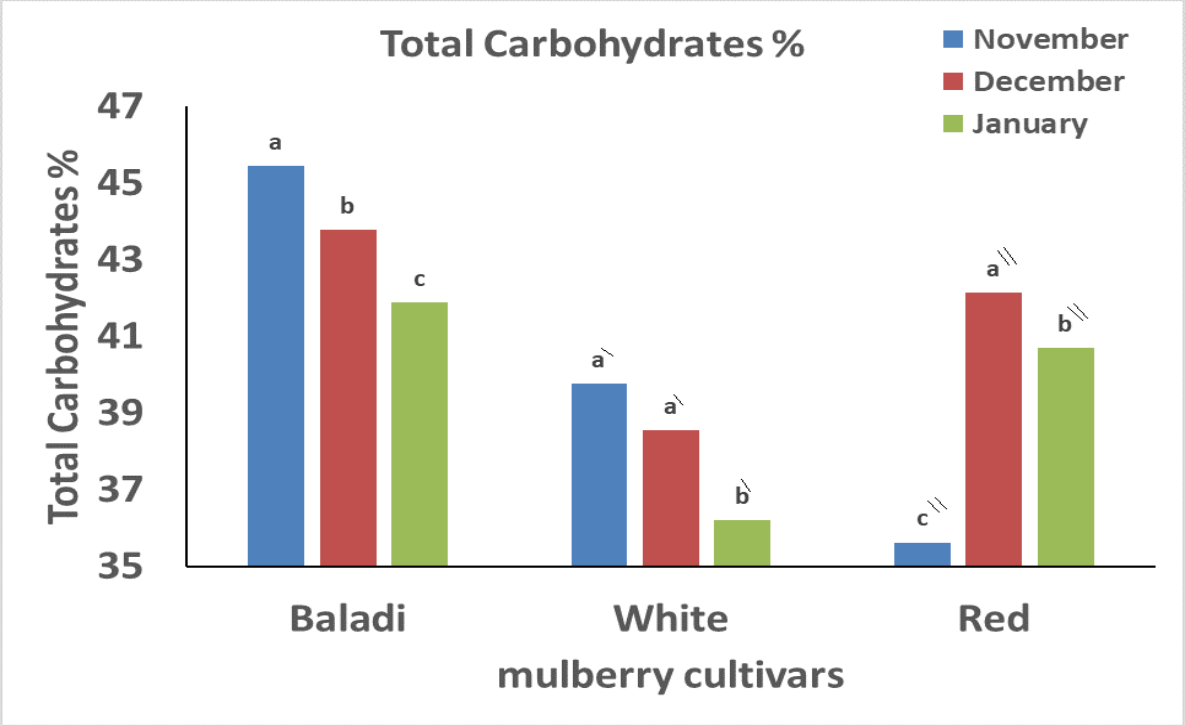

Fig 1. Total carbohydrates % in hardwood cutting of some mulberry cultivars at different preparing cutting dates in the second season

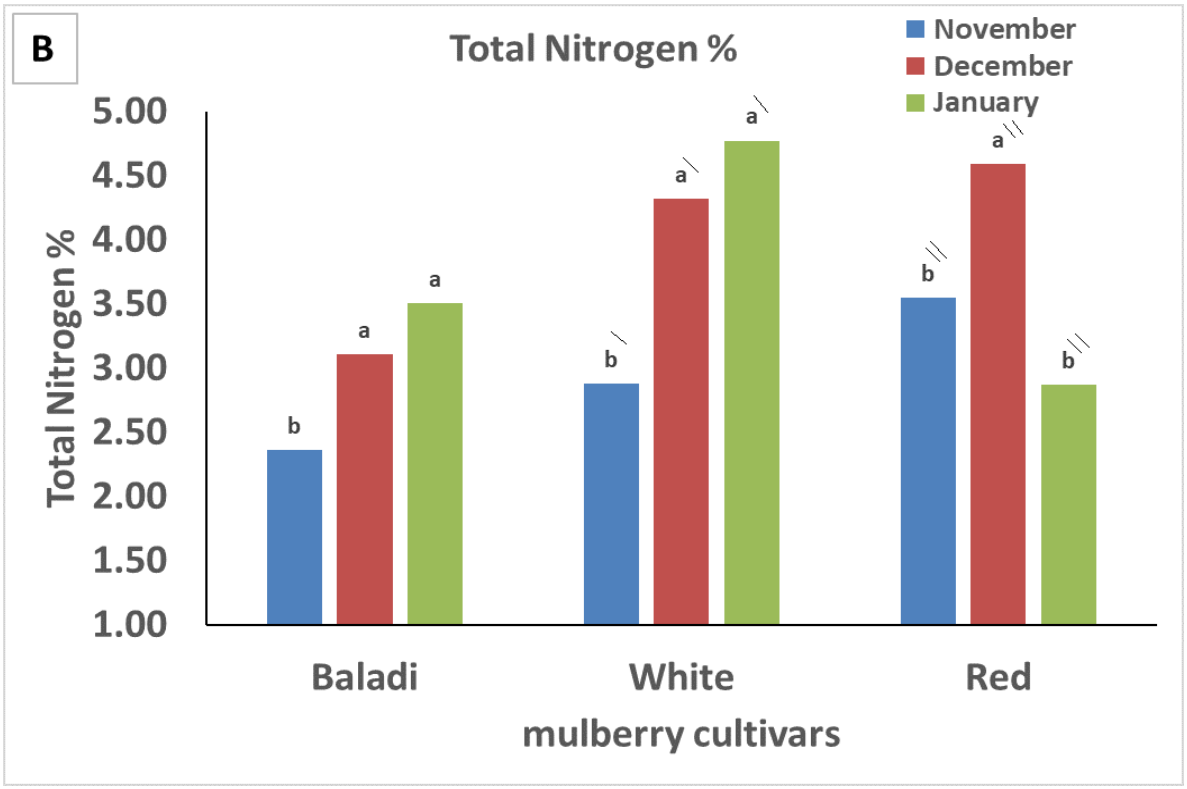

Fig 2. Total nitrogen% in hardwood cutting of some mulberry cultivars at different preparing cutting dates in the second season

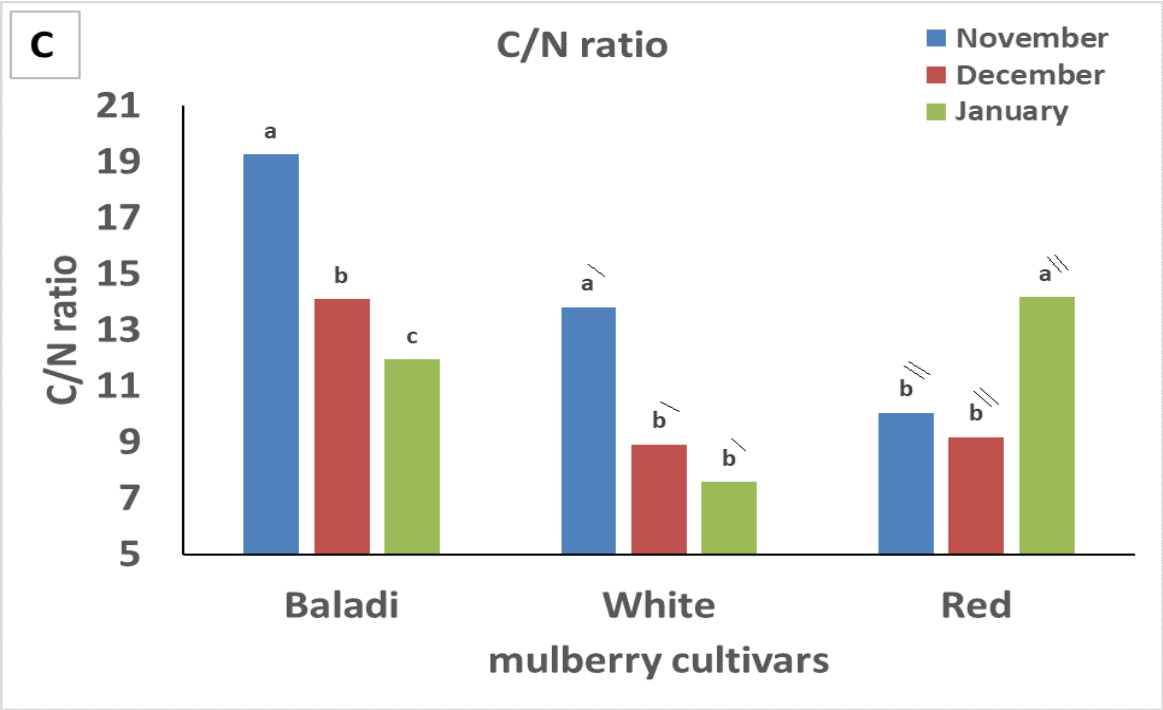

Fig 3. C/N ratio in hardwood cutting of some mulberry cultivars at different preparing cutting dates in the second season

sugar was the most crucial component in the growth of the cutting; although carbohydrate content also significantly influences root development. Because the basal of the cutting contains a higher ratio of C/N, the cutting done in November had the best results. Štefančič et al (2005) reported that the process of adventitious root formation is influenced by a few internal factors such as the ratio of carbohydrates to nitrogen contents.

4 Conclusion

Using NAA at 6000 ppm enhanced rooting percentage, while IBA at 6000 ppm was the best treatment in increasing the number and length of roots per cutting for the three mulberry cultivars under study.

References

Aref Hawramee OK, Aziz RR, Hassan DA (2019) Propagation of white mulberry *Morus alba* L. fruitless cultivar using different cutting times and IBA. *IOP* Conference Series*: Earth and Environmental Science* 388, 012069. https://doi.org/10.1088/1755-1315/388/1/012069

Bewick V, Cheek L, Ball J (2004) Statistics review 9: One-way analysis of variance. *Critical Care* 8, 130. https://doi.org/10.1186%2Fcc2836

De Klerk GJ, Brugge JT, Marinova S (1997) Effectiveness of indoleacetic acid, indolebutyric acid and naphthaleneacetic acid during adventitious root formation *in vitro* in *Malus* 'Jork 9' *Plant Cell, Tissue and Organ Culture* 49, 39–44. https://doi.org/10.1023/A:1005850222973

Harrison-Murray RS (1991) A leaf-model evaporimeter for estimating potential transpiration in propagation environments *Journal of Horticulture Science* 66, 131-139. https://doi.org/10.1080/00221589.1991.11516135

Kaul K (2008) Variation in rooting behavior of stem cuttings in relation to their origin in *Taxus wallichiana* Zucc. *New Forests* 36, 217-224. http://dx.doi.org/10.1007/s11056-008-9094-7

Marks TR, Simpson SE (2000) Interaction of explants type and indole-3-butyric acid during rooting *in vitro* in a range of difficult and easy-to-root woody plants. *Plant Cell, Tissue and Organ Culture* 62, 65-74. https://doi.org/10.1023/A:1006443124007

Nielsen SS (2010) Phenol-Sulfuric Acid Method for Total Carbohydrates. In: Nielsen SS (Ed), Food Analysis Laboratory Manual. Food Science Texts Series. Springer, Boston, MA. 47–53. https://doi.org/10.1007/978-1-4419-1463-7_6

Rhee KC (2001) Determination of Total Nitrogen. *Current Protocols in Food Analytical Chemistry* 1, B1.2.1–B1.2.9. https://doi.org/10.1002/0471142913.fab0102s00

Snedecor GW, Cochran WG (1980) Statistical Methods. 6th (ed), Iowa State University Press, Ames, USA.

Solgi M, Taghizadeh M, Bagheri H (2022) Response of black mulberry onto white mulberry rootstock to stenting (cutting- grafting) techniques and IBA concentrations. *Ornamental Horticulture* 28, 78-84. http://dx.doi.org/10.1590/2447-536x.v28i1.2413

Souza JMA, Leonel S, de Souza SM et al (2019) Use of plant growth regulators in fig tree seedlings 'Roxo de Valinhos'. *Bioscience Journal* 35, 441-449. https://doi.org/10.14393/BJ-v35n2a20198-41758

Štefančič M, Štampar F, Osterc G (2005) Influence of IAA and IBA on root development and quality of *Prunus* "GiSelA5" leafy cuttings. *HortScience* 40, 2052–2055. https://doi.org/10.21273/HORTSCI.40.7.2052

Tchoundjeu Z, Avana ML, Leakey RRB, et al (2002) Vegetative propagation of *Prunus africana*: Effects of rooting medium, auxin concentrations and leaf area. *Agroforestry Systems* 54. 183–192. http://dx.doi.org/10.1023/A:1016049004139