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Effects of Indole-Butyric Acid Doses, Different Rooting Media and Cutting Thicknesses on Rooting Ratios and Root Qualities of 41B, 5 BB and 420A American Grapevine Rootstocks

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Abstract

The present study was conducted to investigate the effects of different rooting media [perlite, perlite+sand (1:1), perlite+sand+soil (1:1:1)], different indole butyric acid (IBA) doses (control, 1000, 2000, 3000 and 4000 ppm) and different cutting thicknesses [thin (4-7 mm), medium (8-10 mm) and thick (10-12 mm)] on rooting and root qualities of 41B, 5BB and 420A American grapevine rootstocks adapted to Van region of Turkey. Within the scope of the study, rooting ratios (%), number of roots, root lengths (cm) and root weights (g) were determined.

The differences in rooting ratios, number of roots, root lengths and root weights of rootstocks were found to be significant ($P<0.05$). Rooting ratios and root quality parameters of cuttings significantly varied with rootstocks, IBA doses, rooting media and cutting thicknesses. With regard to rooting ratios, number of roots and root weights, 5BB rootstock yielded better outcomes than 420A and 41B rootstocks. Compared to control treatment, IBA treatments increased rooting ratio, number of roots, root length and root weight of all three rootstocks. Among the rooting media, the best outcomes for rooting ratio, root length and root weight were obtained from perlite medium and the best results for number of roots were obtained from perlite+sand+soil medium. With regard to cutting thickness, thick cuttings were prominent and they were closely followed by medium ones.

Keywords: Grapevine rootstock, rooting, root quality, hormone, rooting medium, cutting thickness

INTRODUCTION

Viticulture has been practiced in Anatolia for more than 5500 years. Grape is cultivated almost all over Turkey except for high altitudes of Eastern Anatolia and along the Black Sea costs [1]. According to 2014 data, Turkey had 4.175.356 tons fresh grape production from 4.670.929 da vineyard area. Of this production, 53% was used as table grape, 36% was used as raisin and 11% was used for vine production [2].

Phylloxera got into Europe from the United States in 1863 [3]. Phylloxera pest entered into Turkey in 1881 and since then, local cultivars have started to be grafted on American rootstocks [4,5]. The most effective measure against phylloxera is to use American rootstocks. The use of American rootstocks has brought together several problems in viticulture. The greatest one of these problems is the low yield and quality levels in grafted and ungrafted grapevine sapling production under nursery conditions [6]. Rooting ratios in American rootstocks may greatly vary based on rootstocks. Such a case then greatly influence the ratio of grafted and ungrafted sapling obtained from these rootstocks [7]. Total number of grapevine sapling production in Turkey significantly varies form years to years. The amount was realized as 7.129.690 in 2013 and 5.465.230 in 2014 [8].

The success in ungrafted sapling production mostly depend on possible control exerted on several factors with great influences over the processes from nutrition and care of grapevines from which cuttings were taken for regeneration to removal and classification of rooted saplings. There are several studies carried out about the control of these factors. Grapevine sapling production is performed in consecutive stages. Each step passed through in grapevine sapling production may influence sapling yield. The factors effecting sapling yield may be given as: cutting preservation conditions [9]; grafting technique [10]; quality of the paraffin used in grafting [11]; temperature and humidity of folding ambient and disease development [12]; different folding environments [13], keeping cuttings at hot ambient before grafting [14]; grafting combining state [15, 16]; adaptation to outer environment, planting date of grafted cuttings [17]; climate and soil conditions [18]; use of different cover materials [19]; use of different shading ratios [20, 21]; use of different mulching materials [22, 23]; cultural practices and sapling removal [24].

American rootstocks exhibit different responses against hormone treatments. Ehrlinger and Howel [25] reported that 3000 ppm IBA treatment increased number of roots in 6 out of 9 grapevine cultivar. Villa et al. [26] indicated that IBA and NAA hormone doses of between 1000 - 4000 ppm did not have significant improvements in rooting of Riparia de Traviu grape cultivar. Kelen and Demirtaş [27] reported that 1000 and 2000 ppm IBA treatments in perlite+sand medium yielded higher rooting ratio, number of roots, root lengths and fresh root weights in Kober 5BB and 420A rootstocks than the control treatments. Besides, the cutting thicknesses were specified by Turkish Standards Institute as 7-10 mm for the ideal 1st size saplings and as 4-7 mm for the 2nd size saplings. For a well lignification in cuttings, hearth/wood dimeter ratio should be taken as 1/2 [28]. Cutting thickness and lignification have significant effects on sapling quality.

In a previous study carried out to evaluate the adaptation capability of grapevine rootstocks to Van ecological conditions, 5BB rootstock yielded the best results for grafting wood weight and the rootstocks of 5BB, 420A and 41B yielded the best results for lignification [27]. The present study was conducted to investigate the effects of different indole-butyric acid (IBA) doses, different rooting media and cutting thicknesses on rooting ratios and root qualities of 41B, 5 BB and 420 A American rootstocks recommended for Van region of Turkey.

MATERIALS and METHODS

A year-old ligneous cuttings of 41B, 5 BB and 420A rootstocks adapted to Van region were used as the plant of the present study. The cuttings were 35 cm long and there were 3-5 buds over them. Then, the cuttings were divided into three groups as of thin (4-7 mm), medium (8-10 mm) and thick (10-12 mm) based on their thickness. Except for the top bud, the other buds were atrophied. Indole –butyric acid (IBA) hormone treatments were applied in four different doses (control, 1000, 2000, 3000 and 4000 ppm) through dipping the cuttings into the hormone solution for 3 seconds. Three different rooting media [Perlite, Perlite+Sand (1:1), Perlite+Sand+Soil (1:1:1)] were used. Experiments were conducted in randomized blocks split plots experimental design with 3 replications with 30 cuttings in each replication [29] The cuttings were planted into rooting media in April and removed in October.To determine the effects of treatments on rooting and root quality, the parameters of rooting ratio (%), number of roots, root length (cm) and root weight (g) were determined. Resultant data were statistically analyzed with Statgraphics (Graphics Software System, STCC, Inc. USA) statistics software.

RESULTS

Rooting ratios

Among the experimental factors, the effects of rootstock, hormone, rooting media and cutting thickness on rooting ratios were found to be significant. The differences in rooting ratios of the rootstocks were significant ($P<0.05$). The greatest rooting ratio was observed in 5BB rootstock (56,13%). The greatest positive effects of applied hormone doses were observed in 2000 ppm dose (60,8%). According to multiple range test, the most positive effect of rooting media on rooting ratio was observed in perlite medium (62,8%). While thick cuttings (10-12 mm) had the greatest effect on rooting ratio (55,70%), it was followed by medium cuttings (8-10 mm) with 55,39%.

Considering the effects of rootstock-hormone interactions on rooting ratios, 2000 ppm hormone dose yielded the best results on 41B rootstock with 60.0%, on 5BB rootstock with 62,72% and on 420A rootstock with 59,20%. With regard to rootstock-rooting medium interactions, perlite medium had the greatest effects on rooting ratios for all rootstocks.The rooting ratio was identified as 58,20% for perlite+41B combination, 70.20% for perlite+5BB combination and 59,42% for perlite+420A combination. The best rooting ratio was obtained from medium cuttings in 41B and 420A rootstocks and from thick cuttings in 5BB rootstock. The rooting ratio was identified as 53,66% for medium cutting+41B combination, 54,66% for medium cutting+420A combination, 59,02% for thick cutting+5BB combination. With regard to hormone-rooting medium interactions, 2000 ppm IBA+perlite combination came to forefront with a rooting ratio of 72,24%. The performance presented by each treatment in itself is provided in Table 1. With regard to effects of treatments on rooting ratios in general, perlite rooting medium, 2000 ppm IBA dose and thick cuttings were prominent with their rooting ratios.

Number of roots

Least square difference (LSD) tests revealed that the differences in number of roots of rootstock, hormone dose, rooting medium and cutting thickness treatments were found to be significant ($P<0.05$). The greatest number of roots were obtained from 5BB rootstock (10,47). The greatest positive effect of hormone doses on number of roots was observed in 3000 ppm dose (11,10). Multiple comparison tests revealed that perlite+sand+soil rooting medium had the greatest positive effect on number of roots (9,54).

Table 1. Rooting ratios of rootstocks with different treatments (%)

Root-stocks	*Hormone* (IBA)ppm	Rooting Media								
		Perlite			Perlite+Sand			Perlite+Sand+Soil		
		Thin	Medium	Thick	Thin	Medium	Thick	Thin	Medium	Thick
41B *	**0**	33,08 zA	51,27 op	42,36 v	32,09 A	37,94 y	39,00 xy	34,12 z	33,12 zA	40,10 w
	1000	42,62 v	64,52 f	61,37 h	48,30 r	60,25 i	58,12 k	40,54 w	46,71 s	49,12 q
	2000	54,32 m	74,02 b	76,25 a	51,23 p	60,51 i	63,05 g	51,00 p	56,82 k	54,15 m
	3000	58,36 j	68,23 d	72,15 c	52,00 o	57,32 k	65,85 e	43,24 v	44,57 u	53,00 n
	4000	50,12 p	55,26 l	68,59 d	46,10 t	52,24 o	51,00 p	39,12 x	43,16 v	48,50 r
Average		**47,7**	**62,66**	**64,14**	**45,94**	**53,65**	**55,39**	**41,60**	**44,88**	**48,97**
5BB	**0**	46,10 u	59,24 klm	56,21 no	51,12 o	50,41 qr	46,10 u	36,18 A	40,21 wx	39,00 y
	1000	52,00 q	85,32 b	86,00 b	58,00 m	62,50 i	59,65 kl	46,05 u	58,36 m	50,30 rs
	2000	76,09 d	80,24 c	87,49 a	59,60 kl	59,02 lm	61,20 j	40,41 w	51,41 rs	48,71 t
	3000	68,14 g	70,19 f	80,60 c	55,12 o	53,21 p	60,00 k	37,04 z	38,90 y	42,07 v
	4000	63,20 h	71,23 e	71,00 e	49,80 s	50,17 rs	57,16 n	33,80 B	36,25 A	39,87 x
Average		**61,11**	**73,24**	**76,26**	**54,73**	**55,06**	**56,82**	**38,70**	**45,02**	**43,99**
420A	**0**	46,10 op	51,20 l	52,30 l	35,67 v	38,50 tu	39,02 t	35,00 v	33,85 w	37,54 u
	1000	49,52 m	63,85 d	61,58 e	51,25 l	60,12 f	56,41 i	38,43 tu	45,10 p	46,32 o
	2000	64,20 d	73,12 a	65,09 c	55,80 i	61,25 e	58,90 g	50,60 l	60,17 f	50,15 lm
	3000	60,00 f	65,29 c	57,00 h	53,00 k	58,71 g	51,20 l	43,90 q	45,20 p	55,12 j
	4000	59,80 f	66,20 b	56,10 i	48,76 n	53,12 k	50,19 lm	40,08 s	44,28 pq	41,84 r
Average		**55,92**	**63,94**	**58,41**	**48,90**	**54,34**	**51,14**	**41,60**	**45,72**	**46,19**

LS Mean		Medium			Thickness		
Rootstocks		**Perlite**	**Perlite+Sand**	**Perlite+Sand+Soil**	**Thin**	**Medium**	**Thick**
41 B	51,64 b	62,58 a	44,05 c	52,92 b	48,47 c	55,39 b	55,70 a
5 BB	56,13 a	*Hormone* (IBA)	**0**	**1000 ppm**	**2000 ppm**	**3000ppm**	**4000 ppm**
420 A	51,80 b		42,15 d	55,64 b	60,88 a	55,90 b	51,36 c

*The difference between the means indicated with the same letter in each section is not significant (p<0.05

The best results for number of roots were obtained from medium cuttings (8-10 mm) (9,38) and it was followed by thick cuttings (10-12 mm) (9,33). With regard to effects of rootstock-hormone interactions on number roots, it was observed that 3000 ppm dose yielded the best results in 41B (10,33) and 420A (9,02) rootstocks and 4000 ppm dose in 5BB (14,18) rootstock.Considering the rootstock-rooting medium interactions, it was observed that perlite+sand+soil medium had positive impacts on number roots in 41B (9,3) and 420A (8,52) rootstocks and perlite+sand medium in 5BB (10,95) rootstock. The greatest number of roots was obtained from thick (10-12 mm) cuttings of 41B (9,56) and 420A (7,89) rootstocks and from medium cuttings (8-10 mm) of 5BB (11,59) rootstock. With regard to hormone-rooting medium interactions, 4000 ppm hormone dose and perlite+sand+soil medium were prominent with their number of roots (11,78) (Table 2).With regard to number of roots, the best result (19,54) was obtained from perlite+sand+soil medium of 4000 ppm hormone dose of medium cuttings of 5BB rootstock. In 41B rootstock, the best results (12,83) was obtained from perlite+sand medium of 3000 ppm dose of thick cuttings. In 420A rootstock, the best result (13,49) was obtained from perlite+sand medium of 4000 ppm dose of medium cuttings. The performance presented by each treatment in itself is provided in Table 2. With regard to effects of treatments on number of roots in general, perlite+sand+soil rooting medium, 2000 ppm hormone dose and medium cuttings were prominent with their number of roots.

Root lengths

According to LSD test results, the differences in root lengths of rootstock, hormone dose, rooting medium and cutting thickness treatments were found to be significant (P<0.05). Considering the entire factors together, it was observed that 420A root stock had the greatest root length value (17,19 cm). With regard to applied hormone doses, the best result was observed in 2000 ppm dose with a root length value of 18,16 cm. Multiple regression tests revealed that perlite rooting medium had the best result with a root length of 16,66 cm. With regard to effects of cutting thickness on root lengths, thick cuttings (10-12 cm) yielded the best results with a root length value of 16,68 cm. The 3000 ppm dose had positive effects on root length of 41B (16,39 cm) rootstock and 2000 ppm dose on root lengths of 5BB (18,38 cm) and 420A (19,78 cm) rootstocks. Among the rootstock-rooting medium combinations, the most positive effects were observed in perlite medium of all rootstocks. In rootstock-perlite combinations, the root length was observed as 14,85 cm in 41B rootstock, 16,76 cm in 5BB and 18,35 cm in 420A rootstock. Considering the effects of rootstock-cutting thickness interactions, it was observed that thick cuttings (10-12 cm) yielded the best results as 15,13 cm in 41B rootstock, 16,35 cm in 5BB and 18,55 cm in

420A rootstock. In hormone-rooting medium interactions, 2000 ppm dose + perlite medium was prominent with a root length value of 19,75 cm. The performance presented by each treatment in itself is provided in Table 3. With regard to effects of treatments on root lengths in general, perlite rooting medium, 2000 ppm hormone dose and thick cuttings were prominent with their root lengths (Table 3).

Table 2. Number of roots in different treatments

Root-stocks	*Hormone* (IBA) ppm	Rooting Media								
		Perlite			Perlite+Sand			Perlite+Sand+Soil		
		Thin	Medium	Thick	Thin	Medium	Thick	Thin	Medium	Thick
41B *	**0**	4,38 xy	5,41 vwx	5,18 wx	4,56 xy	5,94 vw	6,10 v	3,96 y	5,82 vw	6,14 v
	1000	8,21 t	9,87 jkl	10,24 ghij	8,33 t	9,95 jkl	9,12 pq	7,61 u	9,27 nop	9,61 lmn
	2000	9,42 mnop	10,56 fg	11,38 c	9,27 nop	10,46 fgh	12,40 b	8,52 st	9,96 jk	10,35 ghi
	3000	9,26 op	11,15 cd	9,86 kl	9,45 mno	10,97 de	12,83 a	8,80 qr	10,23 hij	10,41 gh
	4000	8,73 rs	10,72 ef	9,14 p	9,28 nop	9,86 kl	10,56 fg	8,42 t	9,64 lm	10,15 ij
Average		8	9,54	9,16	8,18	9,44	10,20	7,46	8,98	9,33
5BB	**0**	6,54 klm	8,41 jkl	6,85 klm	6,12 lm	6,37 lm	6,28 lm	5,86 lm	6,29 lm	5,53 m
	1000	8,20 kl	7,97 kl	8,12 kl	7,16 kl	9,91 jk	9,16 jk	6,81 klm	7,43 kl	7,68 kl
	2000	9,78 jk	10,70 hij	11,20 ghi	8,42 jk	10,22 ij	11,34 gh	8,36 kl	8,21 kl	9,10 jk
	3000	10,23 ij	11,66 fg	11,74 fg	9,13 jk	18,14 b	16,55 c	15,42 d	17,40 b	15,24 d
	4000	10,54 hij	12,33 f	10,14 j	11,16 ghi	19,31 a	13,24 e	15,60 d	19,54 a	15,72 d
Average		9,06	10,21	9,61	8,40	12,79	11,31	10,41	11,77	10,65
420A	**0**	5,10 hijk	4,72 ijk	4,54 jk	5,38 hijk	5,20 hijk	5,42 hijk	4,26 k	4,88 ijk	5,23 hijk
	1000	5,82 hijk	5,41 hijk	5,60 hijk	6,61 hij	6,84 hi	7,56 gh	5,34 hijk	5,11 hijk	6,25 hij
	2000	6,25 hij	6,17 hij	6,47 hij	7,19 h	7,23 h	10,81 cd	6,12 hij	5,83 hij	7,96 fgh
	3000	6,32 hij	7,95 fgh	8,11 fgh	8,63 ef	12,14 b	12,20 b	8,14 fgh	7,20 h	10,45 d
	4000	7,12 h	8,49 fg	7,26 h	7,82 gh	13,49 a	11,27 c	7,82 gh	7,92 fgh	9,27 e
Average		6,12	6,55	6,40	7,13	8,98	9,45	6,34	6,19	7,83

LS Mean		**Medium**			**Thickness**		
Rootstocks		**perlit**	**Perlite+Sand**	**Perlite+Sand+Soil**	**Thin**	**Medium**	**Thick**
41 B	8,92 b	8,29 c	8,77 b	9,54 a	7,90 b	9,38 a	9,33 a
5 BB	10,47 a	*Hormone (IBA)*	**0**	**1000 ppm**	**2000 ppm**	**3000ppm**	**4000 ppm**
420 A	7,22 c		5,57 e	7,75 d	9,03 c	11,10 a	10,91 b

*The difference between the means indicated with the same letter in each section is not significant ($p<0.05$).

Table 3. Root lengths of rootstocks in different treatments (cm)

Root-stocks	*Hormone* (IBA)ppm	Rooting Media								
		Perlite			Perlite+Sand			Perlite+Sand+Soil		
		Thin	Medium	Thick	Thin	Medium	Thick	Thin	Medium	Thick
41B *	0	9,58 l	11,23 kl	12,56 jkl	10,12 l	12,31 jkl	9,80 l	12,70 jkl	13,61 ijk	12,03 kl
	1000	12,51 jkl	16,25 defg	15,81 fgh	13,60 jk	15,26 gh	12,30 kl	12,00 kl	12,07 kl	13,86 ij
	2000	15,98 fg	18,07 ab	17,54 bc	15,30 gh	17,75 abc	16,83 cdef	13,74 ij	15,62 gh	16,00 fg
	3000	16,20 efg	17,12 bcd	18,63 a	17,00 cde	16,04 fg	17,42 bc	13,00 jk	14,85 hi	17,26 bcd
	4000	13,00 jk	13,25 jk	15,00 h	12,90 jkl	13,10 jk	16,15 fg	11,50 kl	12,75 jkl	15,80 gh
Average		13,45	15,18	15,91	13,78	14,89	14,50	12,59	13,78	14,99
5BB	0	13,40 ijklm	15,71 hij	16,00 hi	10,82 m	13,20jklm	11,59 m	11,00 m	14,85 ij	12,05 m
	1000	15,26 ij	20,60 c	17,15 gh	14,20 ij	17,45 fgh	16,23 hi	11,70 m	12,42 m	13,55 ijkl
	2000	18,50 ef	24,12 a	20,50 c	16,82 h	18,70 de	18,00 efgh	14,67 ij	16,34 hi	17,50 fgh
	3000	16,20 hi	18,06 efgh	21,85 b	13,00 klm	18,23 efg	19,78 c	13,06 klm	14,72 ij	16,74 hi
	4000	15,36 ij	14,11 ij	19,54 cd	10,52 m	16,42 hi	16,15 hi	12,85 lm	13,72 ijk	13,98 ij
Average		15,74	18,52	19,01	13,07	16,80	16,35	12,66	14,41	14,76
420A	0	16,10 hij	19,20 defg	14,56 ijk	11,30 l	13,87 jkl	13,07 kl	13,00 kl	14,87 ij	12,60 l
	1000	18,24 fgh	24,36 b	19,42 def	16,35 hi	18,50 fgh	17,36 ghi	15,07 ij	17,10 hi	13,80 jkl
	2000	20,25 d	28,71 a	22,30 c	17,34 ghi	20,09 d	19,78 de	16,82 hi	18,90 efg	16,72 hi
	3000	19,00 efg	21,12 d	23,80 b	15,36 ij	16,47 hi	16,42 hi	14,30 ijk	19,22 def	16,00 ij
	4000	17,62 gh	17,10 hi	16,47 hi	12,89 kl	14,50 ijk	17,58 gh	12,24 l	19,06 efg	15,08 ij
Average		18,24	22,10	19,31	14,65	16,69	16,84	14,29	17,83	14,84

LS Mean		Medium			Thickness		
Rootstocks		perlit	Perlite+Sand	Perlite+Sand+Soil	Thin	Medium	Thick
41 B	14,34 c	16,66 a	15,66 b	14,71 c	14,54 c	15,81 b	16,68 a
5 BB	15,50 b	*Hormone (IBA)*	0	1000 ppm	2000 ppm	3000ppm	4000 ppm
420 A	17,19 a		13,06 e	15,60 c	18,16 a	17,16 b	14,41 d

*The difference between the means indicated with the same letter in each section is not significant (p<0.05).

Root weights

According to LSD test results, the differences in root weights of rootstock, hormone dose, rooting medium and cutting thickness treatments were found to be significant (P<0.05). Considering the entire factors together, it was observed that 5BB rootstock had the greatest root weight value (2,26 g). With regard to applied hormone doses, the best result was observed in 3000 ppm dose with a root weight value of 2,69 g. Multiple regression tests revealed that perlite rooting medium had the best result with a root weight of 2,28 g.With regard to effects of cutting thickness on root weights, thick cuttings (10-12 cm) yielded the best results with a root weight value of 2,28 g. With regard to effects of rootstock-hormone dose interactions, it was observed that 3000 ppm dose yielded the best results with 2,72 g in 41B, 2,80 g in 5BB and 2,54 g in 420A rootstocks. Among the rootstock-rooting medium interactions, perlite+sand+soil medium had positive effects in 41B rootstock (1,95 g) and perlite medium in 5BB (2,59 g) and 420A (2,40) rootstocks.Considering the effects of rootstock-cutting thickness interactions, it was observed that thick cuttings (10-12 cm) presented the best performance with 2,07 g in 41B, 2,59 g in 5BB and 2,17 g in 420A rootstocks. In hormone-rooting medium interactions, 2000 ppm dose + perlite medium was prominent with a root weight value of 3,12 g (Table 4). When the effects of all treatments were assessed separately based on the rootstock, it was observed that the greatest root weight in 5BB rootstock (5,22 g) was obtained from perlite rooting medium + medium cutting + 2000 ppm dose, the greatest value in 420A (3,83 g) rootstock was obtained from perlite + medium cutting + 1000 ppm dose and the greatest value in 41B rootstock (3,76 g) was obtained from perlite+sand + medium cutting + 3000 ppm dose. The performance presented by each treatment in itself is provided in Table 4. With regard to effects of treatments on root weights in general, perlite rooting medium, 2000 ppm hormone dose and thick cuttings were prominent with their root weights.

DISCUSSION and CONCLUSION

The differences in rooting ratios, number of roots, root lengths and root weights of rootstocks were found to be significant (P<0.05). Rooting ratios and root qualities of cuttings significantly varied with rootstocks, hormone doses, rooting media and cutting thicknesses. In general, 5BB rootstock yielded better rooting ratios, number of roots and root weights than 420A and 41B rootstocks. Compared to control treatment, IBA treatments increased rooting ratio, number of roots, root length and root weight of each three rootstocks. Among the rooting media, the best results for rooting ratio, root length and root weight were obtained from perlite medium and the best results for number of roots were obtained from perlite+sand+soil medium. Organic matter content of this mixture might have increased the number of roots in this medium. Effects of all factors on rooting ratios and root qualities of American rootstocks in general are provided in Table 5.It was observed that American rootstocks exhibited different responses against

hormone treatments. Ehrlinger and Howel [25] reported that 3000 ppm IBA treatments increased number of roots in 6 out of 9 grapevine cultivars.Kelen and Demirtaş [27] indicated compared to control treatment that 1000, 2000 and 3000 ppm IBA doses increased rooting ratios, root lengths, number of roots and root weights of 420A rootstock planted in perlite+sand medium.

Table 4. Root weights of rootstocks in different treatments (g)

Root-stocks	*Hormone* (IBA) ppm	Rooting Media								
		Perlite			Perlite+Sand			Perlite+Sand+Soil		
		Thin	M e d i - um	Thick	Thin	Medium	Thick	Thin	Medium	Thick
41B *	0	0,79 s	0,82 s	1,07 rs	0,85 s	1,03 s	1,26 qrs	0,96 s	0,90 s	1,08 rs
	1000	1,13 rs	1,20 rs	1,89 klmn	1,22 rs	1,35 pqr	1,90 klmn	1,42 pq	1,33 qr	1,45 pq
	2000	1,96 klm	2,85 de	2,22 ghi	1,50 op	3,24 b	2,66 f	2,32 g	2,24 gh	2,64 f
	3000	2,25 gh	3,04 c	2,96 cd	1,88 klmn	3,76 a	2,85 de	2,10 ij	2,80 e	2,80 e
	4000	1,80 n	1,98 kl	2,00 jk	1,60 o	2,14 hi	2,00 jk	1,85 mn	2,11 i	2,33 g
Average		1,586	1,98	2,03	1,41	2,30	2,13	1,73	1,88	2,06
5BB	0	1,10 pq	1,56 nop	1,78 mno	0,98 q	1,12 pq	1,30 p	1,32 p	1,36 p	1,23 pq
	1000	1,77 no	3,19 f	2,84 h	1,65 no	2,86 h	2,33 j	1,35 p	1,03 q	1,55 op
	2000	2,65 i	5,22 a	4,56 b	2,00 lm	2,15 k	2,94 gh	2,12 kl	2,39 j	2,07 kl
	3000	2,02 klm	1,78 no	3,70 d	2,15k	3,98 c	3,42 e	2,55 i	3,04 fg	2,60 i
	4000	2,13 k	1,40 p	3,10 f	1,80 mn	2,28 j	3,09 f	2,07 kl	1,82 mn	2,37 j
Average		1,93	2,63	3,20	1,72	2,48	2,62	1,88	1,93	1,96
420A	0	1,23 pqrs	1,57 opq	1,63 op	1,10 rs	0,96 s	1,32 pqr	1,23 qrs	0,90s	1,02 s
	1000	2,32 ijk	3,86 a	2,30 jk	1,65 op	2,51 hi	2,30 jk	1,40 pq	1,34 pqr	1,55 pq
	2000	2,86 cd	3,10 b	2,62 fgh	1,80 o	2,22 kl	2,86 cd	2,70 efg	2,34 ijk	2,10 lm
	3000	2,55 h	2,40 ij	2,55 h	1,97 n	2,74 def	2,97 bc	3,00 b	2,10 lm	2,60 gh
	4000	2,30 jk	2,74 def	1,96 n	2,04 mn	2,00 mn	2,10 lm	1,98 n	2,04 mn	2,78 de
Average		2,25	2,73	2,21	1,71	2,09	2,31	2,06	1,74	2,01

LS Mean		Medium			Thickness		
Rootstocks		perlit	Perlite+Sand	Perlite+Sand+Soil	Thin	Medium	Thick
41 B	1,90 c	2,28 a	1,92 c	2,09 b	1,81 c	2,20 b	2,28 a
5 BB	2,26 a	*H o r m o n e (IBA)*	0	1000 ppm	2000 ppm	3000ppm	4000 ppm
420 A	2,12 b		1,17 e	1,88 d	2,60 b	2,69 a	2,14 c

*The difference between the means indicated with the same letter in each section is not significant ($p<0.05$).

Table 5. Prominent values about the effects of treatments on rooting ratios and root qualities

	Rooting rate	Root number	Root length	Root weight
Medium	Perlite	Perlite+Sand+Soil	Perlite	Perlite
Hormone	2000 ppm	4000 ppm	2000 ppm	3000 ppm
Thickness	Thick	Medium	Thick	Thick
Rootstock	5 BB	5 BB	420 A	5 BB

Çelik and Gargın [30] reported less number of roots, root fresh and dry weights for 110R rootstock than for 41B and 420A rootstocks. Researchers also indicated that hormone doses and cutting thicknesses did not have significant effects on rooting ratios, but 3000 ppm hormone dose increased rooting ratio of 41B rootstock. It was also reported that root lengths of 41B and 110R rootstocks were higher with medium cuttings. Current findings in general were complying with the results of those earlier studies.

Current findings revealed that perlite rooting medium yielded quite well outcomes with regard to rooting ratio, root length and root weight. On the other hand, perlite+sand+soil medium had positive outcomes for number of roots. While the greatest increases in rooting ratio and root lengths were observed with 2000 ppm IBA treatment, the dose of 4000 ppm was prominent with regard to number of roots and 3000 ppm with regard to root weight. With regard to cutting thickness, thick cuttings were prominent and they were closely followed by medium ones. Current findings comply with the results of Geczi [31], Maltabar et al. [32], Karakır and Kısmalı [33], Kelen and Demirtaş [27], Çelik and Gargın [30] indicating varying rooting ratios and root qualities with rootstocks and rooting mediums and comply with the results of Çelik [6], Alley [34], Chapman and Hussey [35], Kafalı [36], Kelen and Demirtaş [27], Çelik and Gargın [30]indicating such varying outcomes with rootstocks and hormone doses.

Sapling yield is influenced by several factors in sapling production. Especially the age of grapevines from which the cuttings were taken [28]; healthy grafting material and sufficient nutrient levels [37] and moisture content of cuttings are the prominent factors. It was observed that entire factors considered in this study had significant effects on rooting and root qualities of American rootstocks.

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