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Effect of Different Hormones Concentration on *In vitro* Regeneration of Apricot Cultivars

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ABSTRACT

The use of modern breeding methods along with appropriate cultivation techniques facilitates the acquisition and multiplication of varieties that possess the desired characteristics. Therefore, efforts towards the in vitro propagation of woody plants are increasing day by day. Today, plants such as *Malus*, *Prunus*, *Pyrus*, *Ribes*, *Rubus*, etc., can be successfully propagated *in vitro*. Apricot stands out as a stubborn species among *Prunus* types for shoot regeneration and genetic transformation. In this context, this study aims to determine how different plant growth regulators affect shoot regeneration of some native apricot varieties, which hold significant importance in apricot cultivation in our country. In the conducted study, mature cotyledons of Kabaaşı, Hacıhaliloğlu, and Hasanbey apricot varieties were used along with the culture medium consisting of MS. Different doses and ratios of plant growth regulators, including BAP and TDZ, in combination with NAA and GA_3, were added to the culture media. At the end of the *in vitro* study, the callus and primordium formation rate (%), bud and shoot formation rate (%) and number of shoots per explant were recorded. According to the results, the variety with the highest callus formation was Kabaaşı, followed by Hasanbey and Hacıhaliloğlu. In all three varieties, the rate of callus formation decreased in media containing GA_3. Regarding the stage of shoot regeneration from callus, the highest shoot formation with an average of 4 shoots per explant was observed in the Kabaaşı variety in the TDZ (1.0 mgL^{-1}) + NAA (0.25 mgL^{-1}) and TDZ (1.0 mgL^{-1}) + NAA (0.50 mgL^{-1}) media. Looking at the other varieties, the highest number of shoots, 1.6 shoots per explant, was obtained from the TDZ (2.0 mgL^{-1}) + NAA (0.25 mgL^{-1}) medium in Hasanbey and Hacıhaliloğlu varieties. As a result of the findings, the Kabaaşı variety showed the best result in terms of the regeneration capacity of apricot varieties. In contrast the best regeneration medium was obtained from the combinations of TDZ and NAA.

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Introduction

The use of modern breeding methods in combination with appropriate cultivation techniques leads to results such as increased yield and the acquisition of varieties with desired traits. In fruit breeding, achieving results through classical breeding methods can be quite challenging, time-consuming, expensive, and sometimes requires the collaborative efforts of multiple researchers (Yıldırım, 2006). Approximately 600 million plants have been obtained worldwide using in vitro propagation methods for ornamental plants, fruit trees, vegetables, and geophytes (Werbrouck and Deberg, 1994). However, this approach has been limited for woody plants, including fruit-bearing species. Especially in fruit species, problems encountered in rooting and the presence of polyphenolic compounds in their tissues pose challenges for *in vitro* propagation.

The genetic changes resulting from natural or artificial hybridizations, variations in diversity and clones, and natural or artificial mutations among and within closely or distantly related species have been evaluated through selection in fruit breeding for centuries. However, specific biological, physiological, and cultivation problems unique to fruit species such as incompatibility, sterility, genetic breakdown, long period of juvenile sterility, reproduction, and special cultural practices often prolong the breeding process or make success impossible using traditional methods. In contrast, rapid advancements in biotechnology, especially since the late 20th century, enhance the effectiveness of these methods addressed within the scope of classical breeding and offer solutions to problems that hinder success. As a result, fruit species

can be characterized through genomic analyses, and their genetic structures can be rapidly and effectively modified without taxonomic restrictions using *in vitro* techniques such as genetic transfer, somaclonal variation, and somatic hybridization. Additionally, rapid, intensive, and virus-free propagation, conservation of genetic resources, rapid achievement of homozygosity, survival of hybrids through embryo culture, and testing of genotypes' reactions to various factors can be facilitated in a short period (Litz andGray, 1992; Schuerman and Dandekar, 1993; Hatipoğlu, 1999; Jain, 2001; Heslop-Harrison, 2005).

Significant differences in regeneration capacity and percentage can be observed among different varieties of the same species. This indicates that regeneration capacity is highly genotype-dependent and is genetically controlled. Regeneration protocols have been developed from different tissues of various *Prunus* species, including leaves, immature cotyledons, mature cotyledons, stem pieces, and hypocotyls (Canlı and Tian, 2008a; Canlı and Tian 2008b; Canlı and Tian, 2009a; Canlı, 2009b). Due to the low capacity of woody plants to regenerate from a single cell, obtaining transgenic forms of commercially proven varieties with specific characteristics through genetic transfer has not been successful (Marcotrigiano and Gradziel, 1997; Canlı and Tian, 2008a; Canlı and Tian, 2008b; Canlı and Tian, 2009a). Transgenic *Prunus* plants are heavily reliant on efficient regeneration techniques from transduced cells. Adventitious regeneration is an essential step in applying genetic engineering techniques to plant breeding. Despite recent reports of successful regeneration and transformation in various species, fruit trees remain among the most challenging to produce adventitious shoots. *In vitro* adventitious shoot regeneration from mature explants of *Prunus* species has been limited, although some *Prunus* species have shown success in obtaining adventitious shoots from their leaves.

Apricot (*Prunus armeniaca* L.) is a widely cultivated stone fruit with significant genetic variability in wild varieties. Apricot improvement focuses mainly on fruit quality and resistance. However, traditional apricot breeding approaches are limited because of their complicated genetic structure and extended reproductive and cycle times. Furthermore, due to its highly heterozygous nature, seed material is used in the production of selected clones. Adventitious shoot regeneration in apricots has been reported from immature cotyledons (Lane and Cossio, 1986; Pieterse, 1989; Machado et al., 1992; Goffreda et al., 1995) mature seed-derived hypocotyls (Wang et al., 2011), and leaves of several genotypes. In this context, our study aims to determine an appropriate plant regeneration protocol using cotyledon leaves from mature embryos of Kabaaşı, Hasanbey, and Hacıhaliloğlu apricot cultivars.

Materials and Methods

Plant Material

The study was conducted in the Biotechnology Laboratory of Selçuk University's Department of Horticulture, Faculty of Agriculture. Seeds of Kabaaşı, Hasanbey, and Hacıhaliloğlu apricot cultivars were used as plant materials in the study. The seeds of these cultivars were obtained from the Malatya Apricot Research Station. Kabaaşı variety is a dried apricot variety that was discovered as a result of a selection study conducted in Malatya in the 1970s. It ripens in the second week of July. It has been widely cultivated in Malatya and its surroundings in recent years. Hasanbey variety is a table apricot variety that ripens in the first week of July in Malatya, while Hacıhaliloğlu variety is a dried and table apricot variety that ripens in the second week of July in Malatya (Özçağıran et al., 2005). Mature cotyledons obtained from seeds of the varieties were used as the explant source to determine the highest shoot regeneration (Mendi et., 2010).

Methods

Murashige and Skoog (1962), (MS) basal medium were used as the basic nutrient medium for shoot regeneration protocol. For shoot regeneration, BAP (6-Benzylaminopurine) and TDZ (Thidiazuron) were added to the basal media at concentrations of 1.0, 1.5, and 2.0 mgL^{-1}, and two different concentrations of GA_3 (Gibberellic acid) (0.25 and 0.5 mgl^{-1}) and NAA (1-Naphthaleneacetic acid) (Table 1). (Canlı and Tian, 2008a; Wang et al., 2011).

Cotyledons were obtained from seeds of mature fruits. Seeds extracted from mature fruits were cleaned and stored at 4°C for 3 months. Afterward, the hard shell was cracked, and the embryos inside were taken out and subjected to surface sterilization into laminar flow cabinet.

Table 1. Cytokinin, auxin, and GA_3 combinations

Treatments		BA ($mg\ l^{-1}$)	TDZ (mgl^{-1})	GA_3 (mgl^{-1})	NAA (mgl^{-1})
0	T_0	-	-	-	-
1	T_1	1.0	-	-	-
2	T_2	1.5	-	-	-
3	T_3	2.0	-	-	-
4	T_4	-	1.0	-	-
5	T_5	-	1.5	-	-
6	T_6	-	2.0	-	-
7	T_7	1.0	-	0.25	-
8	T_8	1.5	-	0.25	-
9	T_9	2.0	-	0.25	-
10	T_{10}	-	1.0	0.25	-
11	T_{11}	-	1.5	0.25	-
12	T_{12}	-	2.0	0.25	-
13	T_{13}	1.0	-	0.50	-
14	T_{14}	1.5	-	0.50	-
15	T_{15}	2.0	-	0.50	-
16	T_{16}	-	1.0	0.50	-
17	T_{17}	-	1.5	0.50	-
18	T_{18}	-	2.0	0.50	-
19	T_{19}	1.0	-	-	0.25
20	T_{20}	1.5	-	-	0.25
21	T_{21}	2.0	-	-	0.25
22	T_{22}	-	1.0	-	0.25
23	T_{23}	-	1.5	-	0.25
24	T_{24}	-	2.0	-	0.25
25	T_{25}	1.0	-	-	0.50
26	T_{26}	1.5	-	-	0.50
27	T_{27}	2.0	-	-	0.50
28	T_{28}	-	1.0	-	0.50
29	T_{29}	-	1.5	-	0.50
30	T_{30}	-	2.0	-	0.50

Apricot seeds were treated with a solution of 15% NaOCl with 2% Tween-20, adding 1-2 drops and shaking for 10 minutes. The sterilized seeds were washed with sterile distilled water 3-5 times. After surface sterilization, the seeds were kept in sterile distilled water for 24 hours at room temperature to initiate germination. The outer shells of the seeds at the germination initiate stage were peeled and the cotyledons were prepared by dividing them into two parts vertically, removing the embryogenic regions. Cotyledon explants were placed on petri plates with their adaxial parts in contact with the nutrient media (Canlı and Tian, 2008a).

After the cotyledon explants were cultured, the explants that lost viability were recorded, and the viability rates were calculated as percentages. In shoot regeneration, the formation rates of callus (7th days), primordia (14th days), buds (21st days), and shoots (28th days) in the explants were observed, and they were recorded and calculated as percentages.

The study used a totally randomized design with five replications, with each replication consisting of five petri dishes to determine the shoot regeneration process. In each petri dish, four explants were cultivated. At the end of the *in vitro* study, the callus and primordium formation rate (%), bud and shoot formation rate (%) and number of shoots per explant were recorded. The all data were analyzed statistically using the SPSS 23.0. All data in the present study were subjected by analysis of variance (ANOVA) and means were separated by Duncan's Multiple Range Tests at 5% level of significance.

Results and Discussion

The study aimed to determine the effect of different plant growth regulators on plant regeneration using mature seeds of Kabaaşı, Hasanbey, and Hacıhaliloğlu apricot varieties. Variations in shoot regeneration were observed among the tested 30 different media on a variety-specific basis (Table 1). In our study, no issues related to viability were encountered throughout the experiment with the cultured cotyledon explants, and each explant remained alive until the end of the study after being transferred to petri dishes. Furthermore, all the cultured explants remained clean and free from contamination until the end of the study.

Among the varieties used in the experiment, except for some media in the Hacıhaliloğlu variety, callus formation was observed in all other media. T_{24} and T_{27} treatments resulted in the maximum callus production rate of 90 percent in the Hacıhaliloğlu variety (Figure 3). In the Kabaaşı variety, callus formation occurred in all tested media. The callus formation rate varied between 50-100%. The highest callus formation values were obtained from culture media containing the following hormone combinations: T_4, T_5, T_6, T_{12}, T_{20}, T_{21}, T_{22}, T_{23}, T_{24}, T_{25}, T_{26}, T_{27}, T_{28} and T_{29} (Table 2).

Table 2. Callus and primordium formation rates in cotyledons obtained from seeds (%)

T	Callus Formation Rates (%)				Primordium Formation Rates (%)			
	Kabaaşı	Hasanbey	Hacıhaliloğlu	Mean	Kabaaşı	Hasanbey	Hacıhaliloğlu	Mean
T_0	0h	0m	0l	0.00i	0i	0l	0g	0.00k
T_1	50g	30hi	40i	40.00f	45h	25i	35f	35.00g
T_2	70f	35h	35j	46.67ef	60fg	30h	30f	40.00f
T_3	80d	65d	80c	75.00b	70de	55d	70ab	65.00cd
T_4	100a	0m	0l	33.33g	100a	0l	0g	33.33g
T_5	100a	25j	0l	41.67f	100a	25i	0g	41.67f
T_6	100a	50f	0l	50.00e	100a	40g	0g	46.67f
T_7	75e	30i	30k	45.00ef	60fg	30h	30f	40.00f
T_8	85c	30i	30k	48.33ef	75d	30h	30f	45.00f
T_9	95b	65d	75d	78.33b	85c	55d	65bc	68.33c
T_{10}	85c	0m	0l	28.33h	55g	0l	0g	18.33j
T_{11}	95b	0m	0l	31.67g	90bc	0l	0g	30.00gh
T_{12}	100a	0m	0l	33.33g	100a	0l	0g	33.33g
T_{13}	85c	20k	0l	35.00g	60fg	10k	0g	23.33hi
T_{14}	85c	15l	0l	33.33g	65ef	10k	0g	25.00h
T_{15}	75e	50f	50h	58.33cd	65ef	45f	45e	51.67e
T_{16}	75e	0m	0l	25.00h	65ef	0l	0g	21.67i
T_{17}	75e	0m	0l	25.00h	65ef	0l	0g	21.67i
T_{18}	95b	0m	0l	31.67g	85c	0l	0g	28.33h
T_{19}	95b	15l	30k	46.67ef	85c	15j	30f	43.33f
T_{20}	100a	45g	55g	66.67c	90bc	45f	55d	63.33cd
T_{21}	100a	85b	85b	90.00a	95ab	75a	75a	81.67a
T_{22}	100a	35h	35j	56.67d	100a	30h	30f	53.33e
T_{23}	100a	70c	70e	80.00b	100a	60c	60cd	73.33b
T_{24}	100a	90a	90a	93.33a	100a	70b	70ab	80.00a
T_{25}	100a	65d	65f	76.67b	85c	60c	60cd	68.33c
T_{26}	100a	85b	85b	90.00a	95ab	75a	75a	81.67a
T_{27}	100a	90a	90a	93.33a	100a	75a	75a	83.33a
T_{28}	100a	55e	30k	61.67cd	100a	50e	30f	60.00d
T_{29}	100a	85b	75d	86.67ab	100a	70b	60cd	76.67ab
T_{30}	75e	50f	70e	65.00c	65ef	45f	55d	55.00e
Mean	86.94a	38.23b	36.13b	53.76	79.35a	33.06b	31.61b	48.01

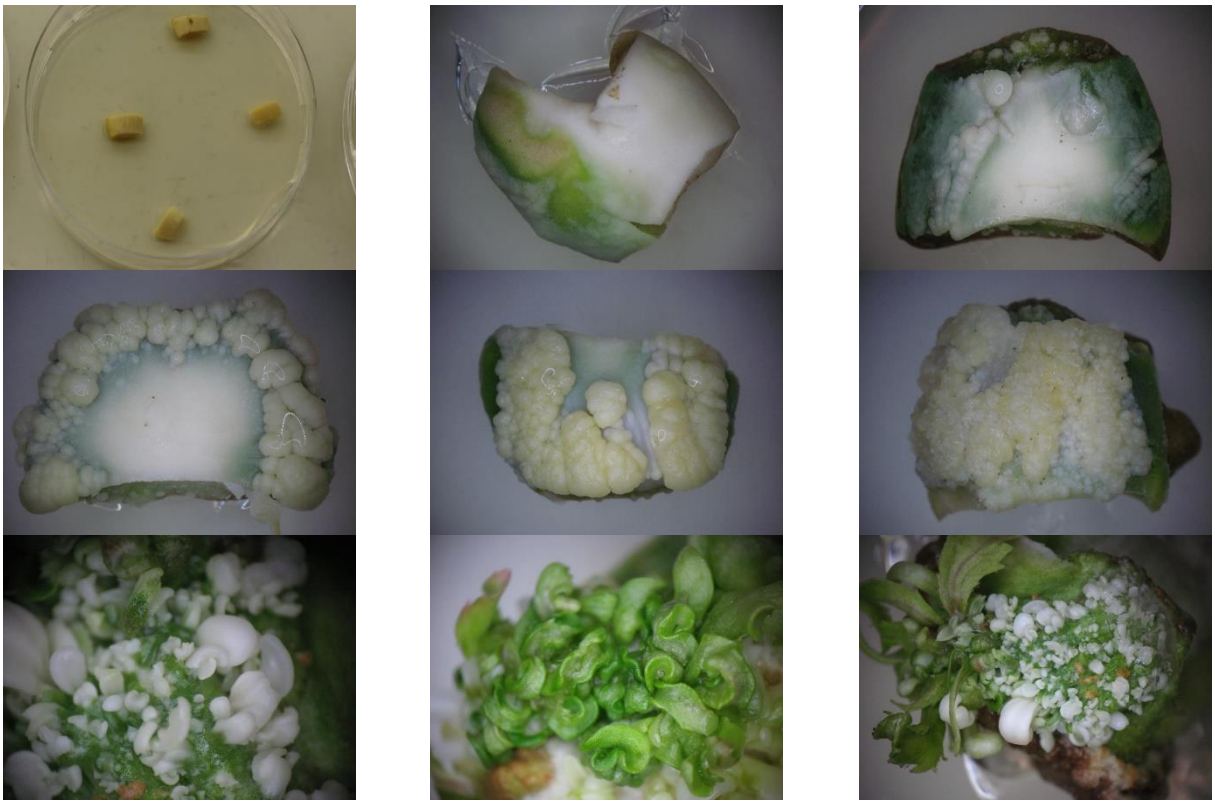

Figure 1. Developmental stages of regeneration in Kabaaşı apricot variety

The culture media containing BA (1.0 mgL^{-1}) obtained the lowest callus formation percentage at 50% (Figure 1). In the Hasanbey variety, the callus formation rate ranged from 0-90% in all tested media. Increasing concentrations of BA and TDZ in the media increased the callus formation rate. The highest callus values were obtained from culture media containing hormone combinations in T_{24} and T_{27} treatments. The lowest callus formation (0%) was obtained from T_0, T_{10}, T_{11}, T_{12}, T_{16}, T_{17}, T_{18}, T_{23}, T_{24}, T_{25} treatments (Figure 2). In a study conducted by Erturan (2008) on apricot varieties, the highest callus formation of 84.51% was achieved with the application of 2,4-D (4 mgL^{-1}) + BA (0.1 mgL^{-1}) (Table 2). Furthermore, Erturan reported that higher doses of BA and TDZ (4 mgL^{-1}) in the treatments stimulated embryogenic callus formation. Consistent with these results, our study demonstrated that high callus formation was achieved with higher concentrations of BA and TDZ, and their combinations with NAA. In the Kabaaşı variety, callus formation occurred in all tested conditions, while combinations of BA at doses of 1.5 mgL^{-1} and 2.0 mg L^{-1} with NAA at concentrations of 0.25 mgL^{-1} and 0.50 mgL^{-1}, as well as combinations of TDZ at doses of 1.5 mg L^{-1} and 2.0 mgL^{-1} with NAA at concentrations of 0.25 mgL^{-1} and 0.50 mgL^{-1}, resulted in 100% callus formation. However, in Hasanbey and Hacıhaliloğlu varieties, no callus formation was observed in combinations of TDZ with GA_3. The highest callus formation of 90% was achieved in T_24 and T_{27} treatments (Table 2). Similarly, Birsin et al. (2001) reported that callus formation and regeneration capacity varied among different varieties and types. In another study, Taştepe (2011) indicated that the optimal concentration for callus formation from leaves and petioles in the Fern strawberry variety was 1.0 mgL^{-1} of 2,4-D.

When examining the primordium formation rates in the Kabaaşı apricot variety, it was observed that the callus formed in T_4, T_5, T_6, T_{22}, T_{23}, T_{24}, T_{27}, T_{28} and T_{29} treatments were transformed into primordia at a rate of 100% (Table 2). The lowest primordium formation rate of 45% was obtained in the BA (1.0 mgL^{-1}) treatment. In the Hasanbey variety, the highest percentage of primordium formation from the formed callus was 75% in the T_{21}, T_{26} and T_{27} treatments. In the media formed by TDZ (1.0 mgL^{-1}) and combinations of TDZ with GA_3, no callus formation was observed, and therefore no primordium formation occurred. Similarly, in the Hacıhaliloğlu apricot variety, the highest primordium formation from the callus was 75% in the T_{21}, T_{26} and T_{27} treatments (Table 2). No primordium formation was observed in the media formed by combinations of TDZ and BA with GA_3.

In the Kabaaşı variety, all plant growth regulator concentrations resulted in the formation of primordia, and the highest bud formation rate was observed in the environments of T_{17}, T_{18}, T_{21}, T_{25}, T_{26}, T_{27}, T_{28} and T_{29} with a rate of 100% (Table 2). The lowest rate was obtained from the BA (1.0 mgL^{-1}) treatment (Figure 1). The bud formation rates in Hasanbey and Hacıhaliloğlu varieties ranged from 0% to 60%. The bud formation rate in both cultivars was 60% in media containing hormone concentrations in T_{15} and T_{27} treatments. In the Kabaaşı apricot variety, shoot formation was observed at a rate of 100% in the media containing T_{25} and T_{26} treatments (Table 3). The lowest shoot formation rate of 20% was obtained from the BA (1.0 mgL^{-1}) treatment. The highest shoot formation in Hasanbey and Hacıhaliloğlu apricot varieties was 40% in the T_{27} media (Table 3).

Table 3. Bud and shoot formation rates in apricot cultivars (%)

	Bud Formation Rates (%)				Shoot Formation Rates (%)			
	Kabaaşı	Hasanbey	Hacıhaliloğlu	Mean	Kabaaşı	Hasanbey	Hacıhaliloğlu	Mean
T_0	0m	0l	0j	0.00k	0m	0i	0h	0.00h
T_1	35l	15i	20h	23.33h	20l	10g	5g	11.67f
T_2	50j	25h	25g	33.33f	30j	10g	10f	16.67e
T_3	65h	45d	55b	55.00c	35i	20e	25c	26.67cd
T_4	50j	20i	20h	30.00fg	35i	10g	5g	16.67e
T_5	70g	25h	25g	40.00e	45g	10g	5g	20.00de
T_6	80e	40e	50c	56.67c	50f	20e	20d	30.00c
T_7	50j	10k	0j	20.00h	30j	5h	0h	11.67f
T_8	55i	10k	0j	21.67h	35i	5h	0h	13.33f
T_9	50j	35f	35f	40.00e	35i	10g	10f	18.33e
T_{10}	75f	10k	15i	33.33f	50f	5h	5g	20.00de
T_{11}	85d	35f	40e	53.33c	60d	15f	15e	30.00c
T_{12}	90c	55b	55b	66.67b	65c	25d	25c	38.33b
T_{13}	80e	45d	45d	56.67c	55e	15f	15e	28.33cd
T_{14}	90c	55b	55b	66.67b	70b	25d	25c	40.00b
T_{15}	95b	60a	60a	71.67a	70b	30c	35b	45.00ab
T_{16}	85d	0l	0j	28.33g	60d	0i	0h	20.00de
T_{17}	100a	20i	0j	40.00e	70b	10g	0h	26.67cd
T_{18}	100a	30g	0j	43.33de	40h	15f	0h	18.33e
T_{19}	65h	0l	0j	21.67h	50f	0i	0h	16.67e
T_{20}	80e	0l	0j	26.67g	70b	0i	0h	23.33d
T_{21}	100a	0l	0j	33.33f	25k	0i	0h	8.33g
T_{22}	40k	0l	0j	13.33j	35i	0i	0h	11.67f
T_{23}	55i	0l	0j	18.33i	35i	0i	0h	11.67f
T_{24}	70g	0l	0j	23.33h	40h	0i	0h	13.33f
T_{25}	100a	20i	20h	46.67d	100a	10g	10f	40.00b
T_{26}	100a	50c	50c	66.67b	100a	20e	20d	46.67ab
T_{27}	100a	60a	60a	73.33a	70b	40a	40a	50.00a
T_{28}	100a	35f	20h	51.67c	65c	20e	10f	31.67c
T_{29}	100a	50c	40e	63.33b	60d	35b	15e	36.67bc
T_{30}	50j	35f	45d	43.33de	35i	15f	20d	23.33d
Mean	73.06a	25.32b	23.71b	40.70	49.68a	12.26b	10.16b	24.03

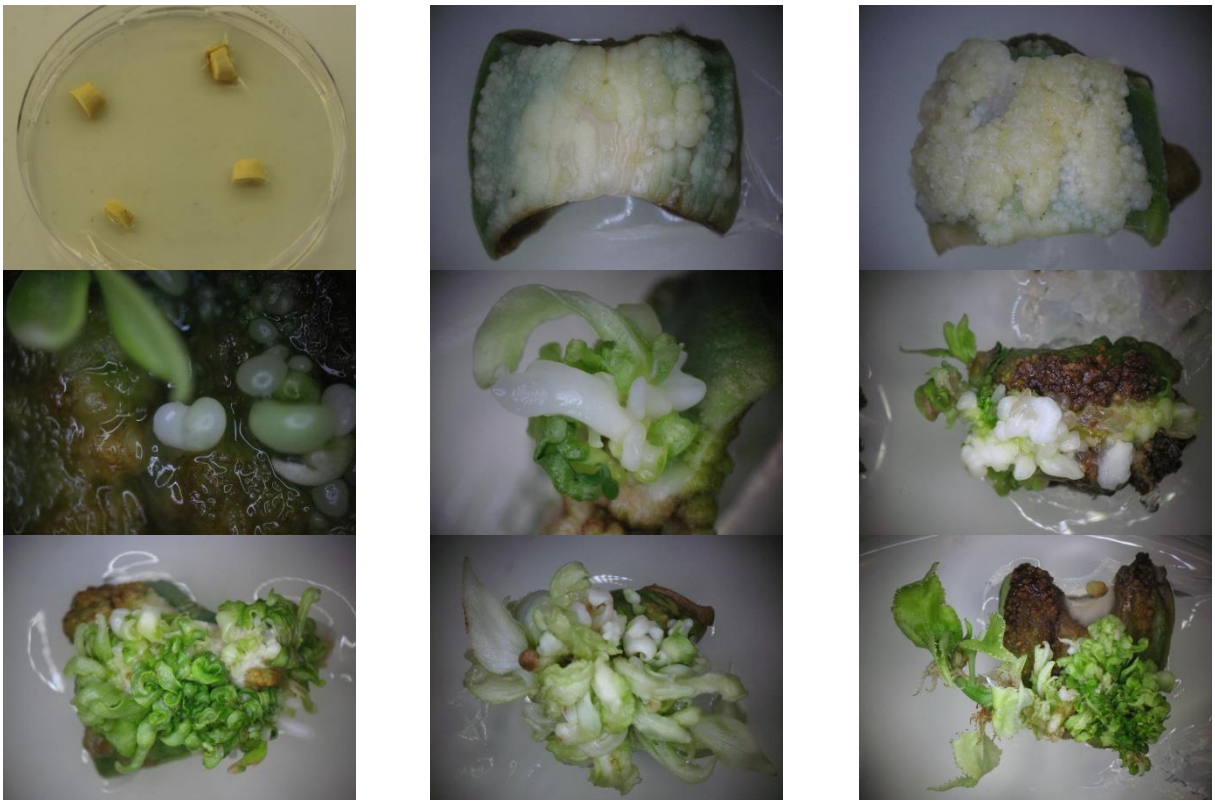

Figure 2. Developmental stages of regeneration in Hasanbey apricot variety

The lowest shoot formation rates were observed in the media where TDZ and BA were combined with NAA in the Hasanbey variety and where BA and TDZ were combined with NAA and GA_3 in the Hacıhaliloğlu variety (Figure 2 and 3). In *in vitro* studies, it has been reported by various researchers that plant growth regulators added to the nutrient medium are among the factors that most significantly affect adventitious shoot regeneration, and a high rate of adventitious shoot regeneration can be achieved by properly balancing the auxin-cytokinin ratio in the nutrient medium (Özcan et al., 1993; Özcan et al., 1996; Sancak, 1999; Uranbey et al., 2003). Bhaskaran and Smith (1990) have reported that the genotype variation in callus formation and plant regeneration could be associated with differences in endogenous hormone levels.

The number of shoots obtained from the callus formed by the varieties used in the study remained very low in different media. In the Kabaaşı variety, the highest average number of shoots per explant was obtained as 4.0 shoots per explant in the media of T_{25} and T_{26} treatments The lowest average number of shoots was obtained as 0.8 shoots per explant in the BA (1.0 mgL^{-1}) treatment. Shoots were obtained from the media containing combinations of BA with NAA and GA_3 in Hasanbey and Hacıhaliloğlu apricot varieties. The highest number of shoots in both varieties was obtained as 1.6 shoots per explant in the T_{27} media (Table 4). Similar to our results, Matt and Jahle (2005) reported that they obtained the best results from the DKW/WPM (1:1) medium supplemented with TDZ and NAA for cherry varieties 'Schneiders' and 'Regina'. Similarly, Taştepe (2011) reported that they achieved regenerated plants only from leaf petiole explants and at a dose of 1.0 mgL^{-1} TDZ in strawberry studies. In their research on sweet cherries, Bhagwat and David Lane (2004) reported that regeneration rates of 71.4% in 'Lapins' variety and 54.0% in 'Sweetheart' variety were achieved in a culture medium supplemented with 2.27 µM or 4.54 µM TDZ and 0.27 µM NAA. Many researchers hand emphasized the requirement of TDZ for effect and adventitious shoot regeneration in woody plants and its superior efficacy compared to BAP in shoot regeneration in apricot and other woody species (Escalettes and Dosba, 1993; Leblay et al., 1990; De Bondt et al., 1996; Dinani, 2018). Similarly, Hammatt and Grant (1998) and Sarwar and Sirvin (1997) stated that TDZ results in more effective shoot regeneration than BAP. However, Tang et al. (2002) recorded that BAP is more effective than TDZ. In our study, similar to other studies, shoot regeneration was achieved in the three apricot varieties using high concentrations of TDZ and combinations with NAA.

Table 4. Number of shoots per explant in apricot cultivars (pcs)

	Kabaaşı	Hasanbey	Hacıhaliloğlu	Mean
T_0	0.00l	0.00g	0.00f	0.00i
T_1	0.80k	0.40efg	0.20ef	0.47g
T_2	1.20ijk	0.40efg	0.40def	0.67f
T_3	1.40hij	0.80cde	1.00bc	1.07d
T_4	1.40hij	0.40efg	0.20ef	0.67f
T_5	1.80fgh	0.40efg	0.20ef	0.80e
T_6	2.00efg	0.80cde	0.80cd	1.20c
T_7	1.20ijk	0.20fg	0.00f	0.47g
T_8	1.40hij	0.20fg	0.00f	0.53g
T_9	1.40hij	0.40efg	0.40def	0.73e
T_{10}	2.00efg	0.20fg	0.20ef	0.80e
T_{11}	2.40cde	0.60def	0.60cde	1.20c
T_{12}	2.60cd	1.00bcd	1.00bc	1.53b
T_{13}	2.20def	0.60def	0.60cde	1.13c
T_{14}	2.80bc	1.00bcd	1.00bc	1.60b
T_{15}	2.80bc	1.20abc	1.40ab	1.80a
T_{16}	2.40cde	0.00g	0.00f	0.80e
T_{17}	2.80bc	0.40efg	0.00f	1.07d
T_{18}	3.20b	0.60def	0.00f	1.27c
T_{19}	1.60fgh	0.00g	0.00f	0.53g
T_{20}	2.00efg	0.00g	0.00f	0.67f
T_{21}	2.80bc	0.00g	0.00f	0.93d
T_{22}	1.00jk	0.00g	0.00f	0.33h
T_{23}	1.40hij	0.00g	0.00f	0.47g
T_{24}	1.60fgh	0.00g	0.00f	0.53g
T_{25}	4.00a	0.40efg	0.40def	1.60b
T_{26}	4.00a	0.80cde	0.80cd	1.87a
T_{27}	2.80bc	1.60.a	1.60a	2.00a
T_{28}	2.60cd	0.80cde	0.40def	1.27c
T_{29}	2.40cde	1.40ab	0.60cde	1.47b
T_{30}	1.40hij	0.60def	0.80cd	0.93d
Mean	2.05a	0.49b	0.41b	0.98

Figure 3. Developmental stages of regeneration in Hacıhaliloğlu apricot cultivar

Conclusions

This study demonstrated the possibility of shoot regeneration in apricot varieties; however, the regeneration capacity may vary among different varieties. The variety with the highest shoot regeneration capacity in this study was Kabaaşı, followed by Hasanbey and Hacıhaliloğlu varieties. Considering the regeneration performance of Kabaaşı, it can be compared with other varieties or genotypes under consideration for regeneration studies, as it has comparable regeneration potential. Among the cytokinins used in the study, TDZ was more successful in shoot regeneration than BA. Therefore, TDZ is recommended for use in future studies. Furthermore, the low values observed for shoot regeneration in relation to varieties in this study may be attributed to the low concentrations of TDZ and BA used, suggesting that increasing the doses of these cytokinins could yield higher regeneration rates. Based on the obtained results, it was observed that adding GA_3 to the culture medium resulted in either very low or no shoot regeneration. Therefore, the inclusion of GA_3 in regeneration experiments is not recommended. Although TDZ and NAA combinations yielded promising results in this study, the data indicated that shoot regeneration varied among varieties. In this context, it is recommended to consider using other auxins from the same group as NAA as alternatives in combination with NAA for better shoot regeneration.

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