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Effect of Auxin Applications on Rooting and Shoot Success of Bardacık, Bursa Black and Sarılop Fig Cuttings

Berna Doğru Çokran[1,a], Tuba Bak[1,b,*], Turan Karadeniz[1,c], Levent Kırca[1,d]

[1]*Pamukkale University Faculty of Agriculture, Department of Horticulture, Çivril, Denizli/Türkiye*
[*]*Corresponding author*

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ABSTRACT

This research was conducted to determine the rooting and shoot performances of 1000 ppm IAA, IBA and NAA applications applied to cuttings in some fig cultivars. Bardacık, Bursa Siyahı and Sarılop fig cultivars were used in the research. In the variety x application interaction, the highest rooting rate occurred in Sarılop-NAA, root number in Bardacık-IBA and root length in Bursa Siyahı IBA applications. It was determined that shoot development showed the best performance in Bursa Siyahı variety with NAA application. Correlation analysis determined that cutting length and diameter significantly affected shoot development and that the longest and widest cuttings formed the most extended and thickest shoots. While IAA showed the best rooting rate performance, NAA showed the best root number and shoot length performance, and IBA showed the best root length and shoot diameter performance.

[a] *berna_dogru@hotmail.com* *https://orcid.org/0000-0003-4194-7826*
[b] *tubabak81@gmail.com* *https://orcid.org/0000-0002-4448-9704*
[c] *turankaradeniz2852@gmail.com* *https://orcid.org/0000-0003-0387-7599*
[d] *leventkirca28@gmail.com* *https://orcid.org/0000-0003-2496-9513*

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Introduction

Fig is a species belonging to the *Ficus* genus of the *Moraceae* family of the *Urticales* order. The fig has many wild and cultivated subspecies. The most important in terms of fruit cultivation is *Ficus carica* L., known as the "Anatolian fig" (Hepaksoy et al., 2004). Fig, a subtropical climate fruit, grows in the Mediterranean basin, Iran, and the region from the North Caucasus to the Caspian Sea. Fig, whose homeland is Anatolia, is thought to have spread to the other areas from there (Özbek, 1978).

It is an important fruit species that has been cultivated in Anatolia for a very long time. Türkiye, is one of the most important countries in the production and export of both dried and table figs (Çalışkan, 2012). The five main fresh fig-producing countries in the world are Türkiye, Egypt, Algeria, Morocco, and Iran. According to 2023 data, while the world's fresh fig production was 1 million 304 thousand tons, Türkiye produced 356 thousand tons (FAO, 2023).

Almost all of Türkiye's dried fig production is concentrated in the Küçük and Büyük Menderes basins in the Aegean Region. The Marmara Region is at the forefront regarding commercial fresh fig production. Although fig trees are found almost all over Türkiye, commercial production is concentrated in these two regions because of the sensitivity of fig fruit quality to ecological conditions. The most preferred among the varieties produced is the Sarılop fig variety, which stands out with its many features, and other varieties such as Bursa Siyahı, Göklop, Yeşilgüz, Morgüz and Bardacık are also grown (Özkul et al., 2022).

In fruit trees, seedling cultivation can be done by generative (seedling) and vegetative (clonal). Propagation by cuttings can be defined as creating a new plant with the same genetic characteristics as the parent plant by using stem, root or leaf parts disconnected from the parent plant (Dalkılıç et al., 2019). Cuttings are often used to propagate fig plants (Dolgun and Tekintaş, 2008; Karadeniz, 2001) and are generally easy to root; however, rapid changes in air temperature and soil moisture conditions prevent rooting and shoot growth (Kabasakal, 1990).

Plant growth regulators have emerged as a powerful tool to enhance the performance of horticultural crops, particularly fruit crops (Ghosh et al., 2022). Plant growth regulators play an essential role in the induction and initiation of roots from cuttings. Auxin initiates root formation by breaking the root apical dominance induced by cytokinin (Sivaji et al., 2014). However, the success of propagation by cuttings may be affected by the physiological state and age of the main plant, time of harvest, lignification status, different rooting ability of

each plant species (Mafrica et al., 2025), plant regulators, rooting medium, type of cutting taken from the main plant, size of cutting taken from the main plant (Rajan and Singh, 2021). Most of the commercial propagation is done by rooting with indole butyric acid (IBA); other frequently used auxins are indole acetic acid (IAA) and naphthalene acetic acid (NAA) (Fogaça and Fett-Neto, 2005). This research was carried out to reveal the effects of different growth regulators on rooting and shoot development in figs and the differences in fig varieties.

Material and Methods

Experimental Site and Preparation

This research was conducted in the Research and Application greenhouse of Pamukkale University Faculty of Agriculture. Bardacık, Bursa Siyahı, and Sarılop fig varieties were used as material.

Cuttings were prepared by making a straight cut at the base and a slanted cut at the top 1.5-2 cm above the bud so that each cutting had 4-5 buds. Data on the length and diameter of the cuttings are given in Table 1. 1000 ppm IBA, NAA and IAA were applied to the cuttings. No growth regulator was used in the control group. The auxin solution rapid immersion method (10 sec) was used on the cuttings. In this method, the base end of the prepared cuttings was treated in auxin solution for 10 sec to a depth of 3-3.5 cm. The cuttings were planted in crates in a sawdust environment in 10 repetitions on March 15, 2023 (Figure 1).

Measurements on Rooted Cuttings

After 270 days, the cuttings were removed from the crates without damaging their roots. Each application was carefully separated, and the following measurements were taken. Rooting rate (%), root number (number), root length (cm), shoot length (cm) and shoot diameter (mm) were measured for each plant. Rooting rate was determined as a percentage by dividing rooted cuttings by all cuttings. Root numbers of rooted cuttings were counted for each application and variety. Root length was obtained by measuring the longest roots in rooted cuttings and measured with a meter. Shoot length was similarly obtained by measuring the shoot with a meter. Shoot diameter was measured in mm with a digital caliper.

Statistical Analysis

Data were analyzed using ANOVA, and different letters signify significant variations. Relationships between application and cultivars were assessed through JMP Pro 17 Principal Component Analysis (PCA) and Correlation Analyses.

Results and Discussion

Impact on Rooting

The effects of different applications on rooting in Bardacık, Bursa Siyahı and Sarılop fig cuttings are given in Table 2. In the research, rooting ratio among the applications varied in variety and applications. While the highest rooting ratio was 98.63% in Sarılop variety and NAA application, the lowest was 90.90% in Bardacık variety in NAA application. Rooting was lower in control groups than application in all three fig varieties (Figure 1). However, the control groups show a high rooting ratio, although not as much as in the applications. This situation indicates that figs have a high ability to spread roots without the need for hormones. Polat et al. (2000) reported rooting ratio of 64.94% in Sarilop variety, the lowest rooting was in 01.IM.02 variety (50.00%) and 60.00% in Bursa Siyahı variety. Nale et al. (2024) determined 80.90% rooting for 1000 ppm IBA and 58.60% rooting for NAA and reported that this value was 52.33% in the control group. Kılıç et al. (2021) reported that the rooting ratio of Bursa Siyahı wood cuttings planted in the misting unit in Antakya/Hatay ecology was 100% in all applications. According to the results of this researcher, although we have lower rooting rates, it is seen that the Bursa Siyahı variety is rooted under controlled conditions under misting, and the rooting environment may produce different results. Singh and Rattanpal (2017) stated that IBA application at 1000 ppm provided 68.60% rooting. Still, the percentage of rooted cuttings increased with the concentration of IBA application (81.60% IBA 1250 ppm). When the results of other researchers were examined, it was determined that our rooting ratio values were higher in three varieties, and auxin group growth regulators increased the rooting ratio in fig cuttings.

Root numbers were 56.50 in IBA of Bardacık variety. In the Bursa Siyahı variety, NAA application produced the most roots, 47.67. Sarılop variety had fewer root numbers than all the other varieties.

Figure 1. Figs cuttings planted into the sawdust, and rooted cuttings in the greenhouse.

Table 1. Cutting lengths and diameters of Bardacık, Bursa Siyahı and Sarılop fig cuttings.

Features	Application	Bardacık	Bursa siyahı	Sarılop
Cutting length (cm)	IBA	28.18	47.02	26.52
	NAA	27.94	49.37	26.37
	IAA	27.03	48.70	26.37
	Control	27.03	27.95	24.78
Cutting diameter (mm)	IBA	18.64	18.28	18.55
	NAA	10.40	15.57	17.61
	IAA	12.44	11.86	18.98
	Control	10.24	11.84	17.37

Table 2. Applications and rooting status of Bardacık, Bursa Siyahı and Sarılop fig cuttings.

Features	Application	Bardacık	Bursa Siyahı	Sarılop	Mean
Rooting Ratio (%)	IBA	93.75 c	96.62 b	96.39 b	95.58 B
	NAA	90.90 d	98.16 ab	98.63 a	95.89 B
	IAA	98.52 a	97.56 ab	97.60 ab	97.89 A
	Control	86.95 e	94.06 c	92.95 c	91.32 C
	Mean	92.52 B	95.59 A	96.39 A	
Root Number (piece)	IBA	56.50 a	19.00 cd	5.00 cd	26.83 B
	NAA	30.86 bc	47.67 ab	7.00 d	28.51 A
	IAA	23.70 cd	18.80 cd	7.50 cd	16.67 B
	Control	18.20 cd	4.70 d	4.50 d	9.13 B
	Mean	32.31 A	22.54 B	6.00 C	
Root Length (cm)	IBA	33.66 abc	56.00 a	20.50 bc	36.72 A
	NAA	21.98 bc	21.27 bc	23.48 bc	22.24 BC
	IAA	27.03 abc	45.70 ab	20.93 bc	31.22 AB
	Control	19.25 c	20.07 c	19.06 bc	19.46 C
	Mean	25.48 B	35.76 A	20.99 B	

Table 3. Effects of different applications on shoot development in Bardacık, Bursa Siyahı and Sarılop fig cuttings.

Features	Application	Bardacık	Bursa Siyahı	Sarılop	Mean
Shoot length (cm)	IBA	26.55 b	69.79 a	19.90 b	38.75 A
	NAA	19.31 b	98.53 a	18.93 b	45.59 A
	IAA	26.62 b	83.20 a	19.25 b	43.02 A
	Control	17.57 b	31.44 b	17.64 b	22.22 B
	Mean	22.51 B	70.74 A	18.93 B	
Shoot diameter (cm)	IBA	8.05 ab	9.38 a	6.25 bc	7.89 A
	NAA	5.61 bc	9.43 a	6.23 bc	7.09 A
	IAA	5.51 bc	4.03 c	6.05 bc	5.19 B
	Control	5.38 bc	3.95 c	5.89 bc	5.07 B
	Mean	6.13 A	6.69 A	6.10 A	

Applications in all varieties created better root numbers than the control group (Table 2, Figure 2).

Singh and Rattanpal, (2017) reported that 36.40 root numbers were obtained in IBA and the number of roots increased as the dose increased. Kılıç et al. (2021) determined the root scale for root number in their research and stated that root number <20 pieces as weak rooting, root number 21-50 pieces as medium, 51-70 pieces as good rooting, and extensive root number >71 pieces as very good rooting. This research, according to the scale Kılıç et al. (2021), it is seen that the Bardacık variety rooted moderately in all applications except control, and the Bursa Siyahı variety showed weak rooting except NAA application. The weak root number was determined in the Sarılop variety control and all applications. Although fig is a fruit type that roots easily, it provides the metabolism of various variables such as growth period and amount, age of the variety, cutting, and environment.

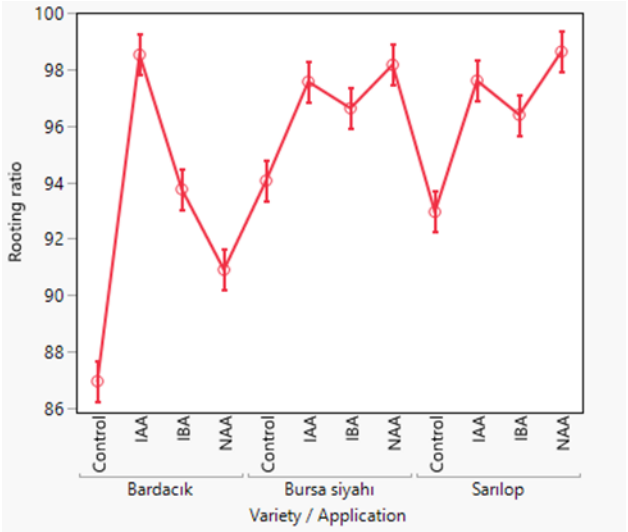

Figure 2. Effects of fig varieties and applications on rooting ratio LSMeans Plot.

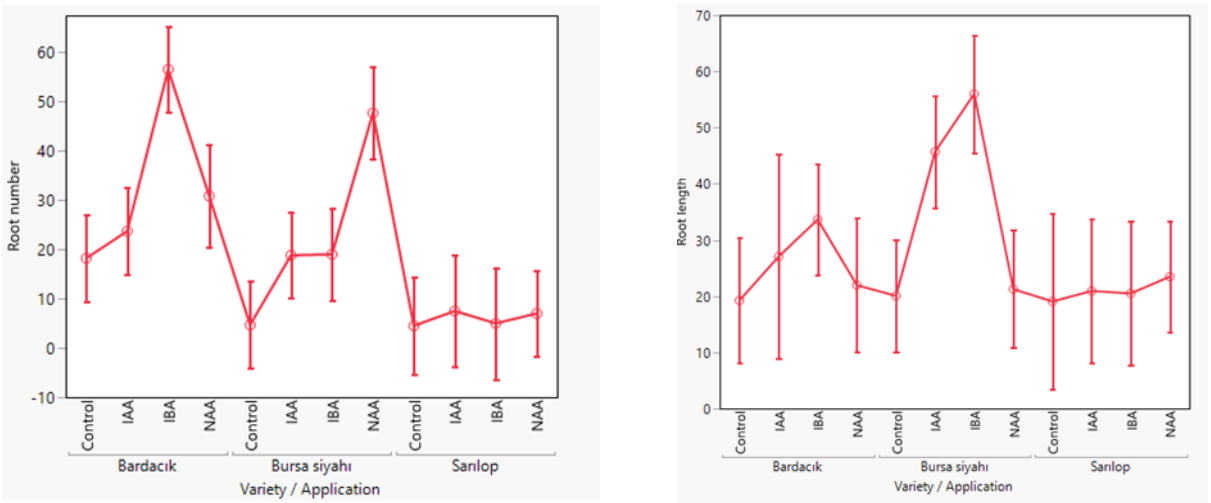

Figure 3. Root number and root length of fig varieties and applications LSMeans Plot

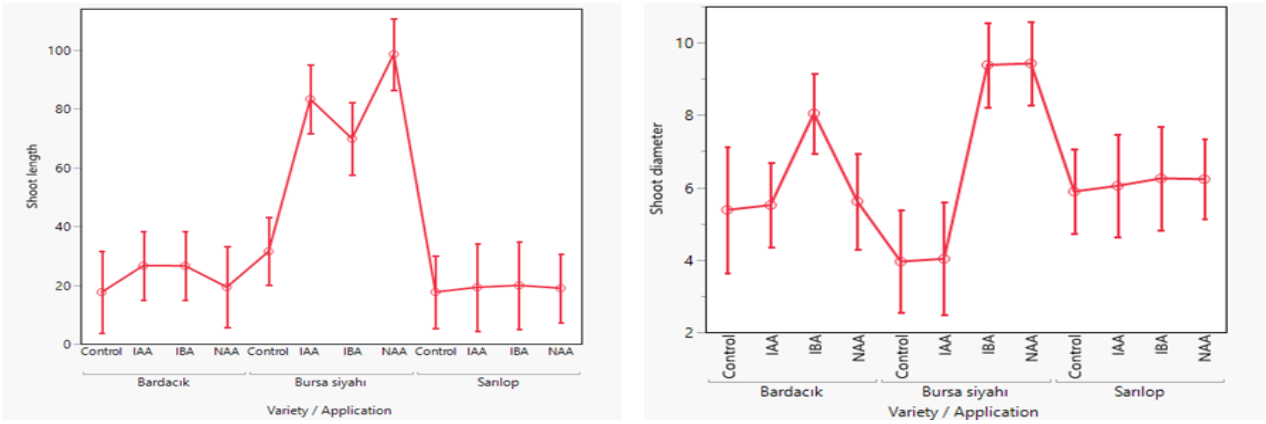

Figure 4. Shoot length and shoot diameter of fig varieties and treatments LSMeans Plot.

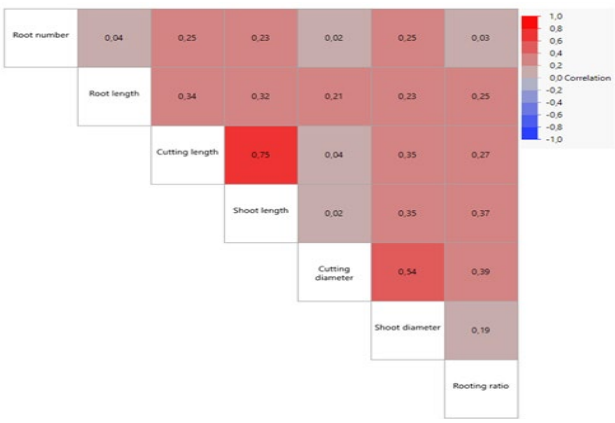

Figure 5. Correlation graph of the examined features.

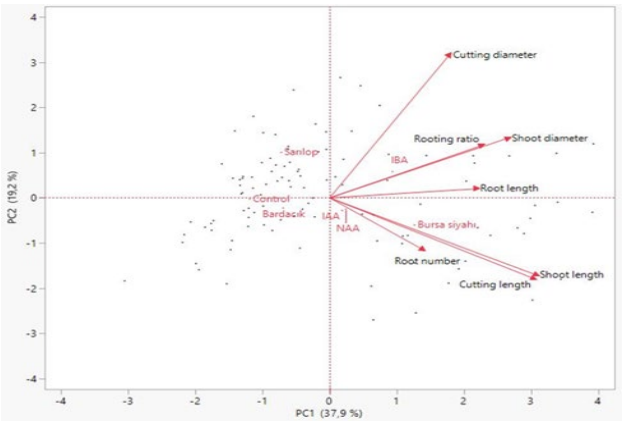

Figure 6. Biplot principal component analysis of fig varieties and applications.

It was determined that NAA applications resulted in better results than other applications, especially in Bursa Siyahı regarding (mean 28.51) root numbers, and this situation is confirmed by the reports of Khalid and Ahmed (2022) that rooting was significantly increased with NAA application.

This research, root lengths varied between 56.00 cm (Bursa Siyahı IBA) and 20.50 cm (Sarılop IBA) in applications. In general, it was observed that Bursa Siyahı varieties formed longer roots than other varieties. In terms of applications, IBA formed longer roots. It was observed that root lengths provided more extension compared to the control groups in all applications (Figure 3). Kumar et al. (2025) obtained 22.667 roots with IBA and 18.933 roots with NAA. Kılıç et al. (2021) reported that the longest roots in Bursa Siyahı variety were in IBA-applied cuttings. The findings of the researchers are parallel to our findings. This explains why IBA is still widely used today. Basuchaudhuri (2021) reported that IBA may still be the best hormone in a wide concentration range today.

Shoot Development

Shoot lengths showed significant differences in the applications of growth regulators. Bursa Siyahı developed much longer shoot lengths than Bardacık and Sarılop varieties. Bursa Siyahı produced shoots of IBA 69.76 cm,

NAA 98.53 cm and IAA 83.20 cm in length. Bursa Siyahı even had long shoots in the control group. These values are better than the applications of the other two varieties. (Table 3, Figure 4). This situation reveals that the shoot development of the Bursa Siyahı fig variety, especially in the control groups, can produce longer shoots than the other varieties (mean 70.74 cm), even though no growth regulators were applied. It is observed that there are differences in terms of the interaction between varieties and applications in terms of shoot diameter. It is observed that the widest shoot diameter is in Bursa Siyahı variety in IBA (9.38 cm) and NAA (9.43 cm) applications. Again, it was determined that the shoot diameter of Bardacık fig variety in IBA application was 8.05 cm (Table 2). It is observed that applications with other varieties give lower results in terms of shoot diameter development. The formation of more shoots with growth regulators may be due to the strong root system of IBA, which increases nutrient uptake, and this percentage increases plant height and shoot diameter by allowing the plant to absorb more nutrients (Kumar et al., 2024).

Correlation Analysis

The correlation analysis results of the examined fig varieties and applications on the examined traits are given in Figure 5. A positive and very significant correlation was observed between shoot length and cutting length, as well as shoot diameter and cutting diameter, and these values were determined to be 0.75 and 0.54, respectively. It is observed that although the rates of other correlations among the examined traits were low, positive correlations occurred.

There were positive and significant correlations between root number and cutting length, shoot length, and shoot diameter. Again, positive and significant correlations were observed between the rooting ratio and root length, cutting length, cutting diameter, shoot length.

The cutting diameter had the most significant effect on root length. It was determined that shoot diameter and root length parameters had positive and significant correlations for all examined traits. It was determined that cutting diameter and length positively affected shoot length and shoot diameter in the applications in the fig varieties we examined. Mafrica et al. (2025) reported that distal and longer cuttings taken from two-year-old branches exhibited superior rooting success, increased biomass, and extensive root development compared to shorter and apical cuttings. They also found that long cuttings could increase soluble sugar and starch levels in woody tissues. Our results are partially similar to the researchers' findings.

Principal Component Analysis (PCA)

PCA analysis of the examined traits, varieties and applications is given in Figure 6. In the PCA analysis, PC1 explains 37.9% and PC 2 19.2%, and it is seen that the total PC analysis represents 57.1%. In the PCA analysis, rooting ratio, root length, shoot diameter, and cutting diameter are in the first region, while root number, shoot length, and cutting length are in the second region. It is seen that rooting rate and shoot diameter are very close to each other, especially from the examined traits. Similarly, it is observed that cutting and shoot lengths are in the same direction and close to each other. When the PCA analysis is reviewed in terms of varieties, it is seen that Bursa Siyahı is in the second region and root number, shoot and cutting length are closer. While it is seen that Bardacık and Control groups are in the 3rd region, Sarılop variety is seen to be separated from other varieties and applications and is in the fourth region. When the PCA analysis is evaluated in terms of applications, it is seen that the IBA application is in the first region, while the IAA and NAA applications are determined to have vectors in the second region and the opposite direction. It is seen that the IBA application of PCA analysis is positioned differently from all other applications.

Conclusion

Fig is a fruit that roots easily. In our research, it was determined that all applications showed better results than the control groups. However, the fact that results similar to our findings were obtained even in the control groups may suggest that figs need less growth regulators for rooting performance. However, some growth regulators may be applied for rooting success, strong shoot development, healthy seedlings, and commercial production. In the PCA analysis, it may be thought that the IBA application is far from the IAA and NAA applications, and rooting rate and shoot diameter are especially closely related to IBA. The correlation analysis determined that cutting length and diameter significantly affect shoot development, and the longest and widest cuttings form the most extended and thickest shoots. According to our research findings, 1000 ppm is an ideal dose for rooting fig cuttings, and IAA is more effective, especially in increasing the rooting rate. It may be said that NAA applications may be practical for root number and shoot length characteristics, and IBA applications may be helpful for root length and shoot diameter. However, of course, in addition to these, rooting can be affected by many other factors such as variety, ecological factors, cutting type, environment, and the effect of growth regulators.

Declarations

Ethical Approval Certificate

This study did not require any ethics committee decision/report.

Author Contribution Statement

TB and BDÇ: Research, Methodology, Data curation, Visualization. Writing of original draft. LK: Procurement of materials, Methodology. TB: Writing, review, and editing, TK: Methodology, Supervision, review, and editing. All authors have read and approved the manuscript.

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Conflict of Interest

The authors declare no conflict of interest.

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