DOI:10.5152/forestist.2023.22068
Forestist 2023: 73(3): 264-269

ISTANBUL UNIVERSITY CERRAHPAŞA

Original Article

# Vegetative Propagation of *Platanus orientalis* L. by Coppice Shoot Cuttings

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## ABSTRACT

Finding an effective, fast, and cheap procedure to propagate ornamental trees is a key step in the management of urban green space. *Platanus orientalis* is one of the most popular species in urban areas. The aim of this study was to estimate the effects of cutting diameter (5–10, 10–15, and 15–20 mm), cutting position (north, west, south, and east facing), and auxin treatment (0, 50, and 100 mg mL$^{-1}$) on rooting and shooting of *P. orientalis* cuttings. For these purposes, 1-year-old *P. orientalis* shoot cuttings were collected from coppice stumps stand with 1 × 1 m planting space. The results showed that cutting diameter and cutting position significantly affected rooting (number of roots and mean root length) and shooting (number of shoots and mean shoot length) traits. Higher rooting traits were obtained by using cuttings diameter in the ranges of 15–20 mm with east- and west-facing stand orientation. Auxin treatment did not show a significant effect on rooting and shooting of the prepared cuttings. Interestingly, principal component analysis ordination diagrams based on rooting and shooting traits indicated clear patterns with respect to diameter classes, while they did not show any patterns for auxin treatment and cutting position classes. In conclusion, the most suitable procedure derived from this work was using shoot cuttings of coppice stumps at diameter ranges of 15–20 mm with a high solar radiation regime.

***Keywords:*** Auxin treatment, coppice stumps, cutting diameter, solar radiation regime

## Introduction

The oriental plane tree (*Platanus orientalis* L.) is widely used as an ornamental and landscaping tree, especially in urban areas in many countries (Grolli et al., 2005; Rix & Fay, 2017). In urban areas, plants are the prime receivers of air, particularly chemical and physical soil pollution, and have a good ability to adsorb them (Grolli et al., 2005; Kaur & Nagpal, 2017). It is growing in southern and southeastern Europe in the southern half of Italy (including Sicily), Albania, Macedonia, southern Bulgaria, and Greece, as well as on the Greek islands, including Crete. It also extends to Asia, where it grows in Cyprus, Turkey, Syria, Lebanon, and Iran (Rinaldi et al., 2019). In those areas, it is widely distributed along streams and rivers and it is relatively demanding on heat (mild wet winters and warm dry summers), so in parts of those areas that usually freeze, *P. orientalis* is almost never grown (Douda et al., 2016; Kurtto et al., 2013; Rix & Fay, 2017).

For several years, plane tree has been extremely threatened by canker stain caused by *Ceratocystis platani*, which kills many thousands of plane trees in a short time, even very long-lived trees (Clérivet et al., 2000, Perucca & Gervasini, 1999, Tsopelas et al., 2017). One of the best and easier solutions to deal with canker stain could be selection and propagation of disease-resistant genotypes (Grolli et al., 2005; Pilotti, 2002).

Oriental plane tree species could be propagated by vegetative propagation and seed propagation techniques. However, seed propagation of plane trees is more difficult than vegetative propagation. Besides, the germination rate of *P. orientalis* is very low and it ranges between 30% and 40%. In addition, due to the negative impact of environmental factors, there is no possibility of germination for some small and delicate seeds. Also, oriental plane trees require specific treatments to encourage germination and special care for the young and fragile seedlings (Hartman et al., 2011). Importantly, our knowledge on vegetative propagation techniques for the multiplication of *P. orientalis* is limited. Although micropropagation can be applied for multiplication of *Platanus* species as an effective technique, it is a costly procedure and can be done only in specialized laboratories (Showkat et al., 2017). However, using stem cuttings is a convenient way to propagate *P. orientalis*, with a high

***Cite this article as:***
Rezaei, Z., Nasr, S. M. H., & Asadi, H. (2023). Vegetative propagation of *Platanus orientalis* L. by Coppice shoot cuttings. *Forestist*, 73(3), 264-269.

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***Received:*** October 14, 2022
***Accepted:*** January 6, 2023
***Publication Date:*** September 25, 2023

growth rate forming mature plants while most of the forest nurseries have the essential structures and equipment.

There have been few attempts to propagate *P. orientalis* via cuttings (Khosrojerdi et al., 2006; Sajid et al., 2012; Vlachov, 1987; Zencirkiran & Erken, 2012). However, factors that influence the rooting response of cuttings are studied. The most important factors are the diameter of stem cutting, suitable temperature and humidity content of rooting medium, time of cuttings collection and cutting-donor shoots position on the mother plant, and auxins treatments of cuttings. Among them, diameter of stem cutting and cutting-donor shoots position on the coppice stumps have been considered as important factors (Khosrojerdi et al., 2006). Then, coppice stumps shoot is an appropriate method of vegetative propagation in *P. orientalis*. It typically comprises elevated levels of carbohydrates, hormones, and various other components, which contribute to their effectiveness in facilitating the successful rooting and shooting of cuttings in a dependable and adequate manner (Fabbri et al., 2004). Coppice stumps shoot can be developed from two types of buds including dormant buds at the base of the stump and adventitious buds that are formed from callus tissue between the bark and wood at the cut surfaces, which is common in plane trees (Buckley, 2020).

Not surprisingly, cuttings rooting in many species has been related to the cutting diameter (Hartmann et al., 2011). Dickman et al. (1980) showed that large-diameter cuttings survived better and produced taller shoots than small-diameter cuttings. Also, the carbohydrate and hormonal content were found to be proportional to the diameter of the cutting (OuYang et al., 2015). Besides, treatments with auxin have produced inconsistent results in terms of rooting increase. In some cases, auxins were effective, while in others, auxins were non-effective (Panetsos et al., 1994, Raup & Taylor, 2012; Tagipoor et al., 2015). However, it has been established that auxins play an essential role in the development of adventitious root when cuttings were treated with very low concentrations (Grolli et al., 2005).

Due to the spreading green urban spaces in many cities worldwide and considering an increase in demand for *P. orientalis*, finding an effective, fast, and cheap procedure for rooting of its cuttings seems inevitable. Therefore, the aims of this study were (i) to estimate the effects of cutting diameter, cutting-donor shoots face-orientation position on the coppice stumps stand, auxin treatment, and its interaction on rooting and shooting of cuttings; and (ii) to establish an optimum cutting propagation scheme for *P. orientalis*.

## Methods

This study was conducted in the Koludeh forest nursery area of the Forests (36°33'40.1"N 52°18'16.2"E), Range, and Watershed Management Organization, in Mahmudabad, Iran, from January to July in 2018. The climate of this region is generally semi-humid with mild winter. The altitude is 4 m with an annual rainfall of 800–1000 mm. The average annual temperature is 17.5°C. January is the coldest month of the year on average (mean temperature 3.5°C), while July is the warmest (mean temperature 30.9°C) (Ahmadloo et al., 2009).

One-year-old *P. orientalis* shoot cuttings were collected from coppice stumps stand with 1 × 1 m planting space. This coppice stumps stand with diameter range 25–35 cm had square shape (100 m × 100 m) with a 1-ha area. In total, 720 cuttings were selected. The cuttings had three nodes and 20–30 cm length. Cuttings were randomly gathered from the front-facing positions (cutting locations) on the first three rows of the stand. The face orientations of the stand were north, west, south, and east facing. In each cutting position (180 cuttings), cuttings were divided into three diameter classes 5–10, 10–15, and 15–20 mm by using calibrated vernier caliper (60 cuttings for each diameter group) and they were treated with indole-3-butyric acid (IBA) at 0, 50, and 100 mg $mL^{-1}$ for 24 hours. Thereafter, cuttings were planted on February 2018 to about 70% of their length, so that only one nod was out of the soil, in sandy (80%)-clay (20%) soil at 30 cm intervals. Mist instruments were used to maintain soil moisture and the cuttings were watered regularly.

Numbers and mean lengths of the produced roots and shoots were assessed after 72 days. The numbers and lengths of roots were counted after removing the soil from the roots carefully. The design of the experiments was $2^3$ factorial in completely randomized with five replications in which each replication had four cuttings (totally 720 cuttings are used). Analysis of variance was performed using R version 4.0.3 by $\log_{10}$ transforming to obtain a normal distribution. Means differences among treatment groups were performed using Tukey's test at $p$ =.05.

After pre-transformation by Hellinger transformation, principal component analysis (PCA) was performed to detect the variation of numbers and mean lengths of the produced roots and shoots in the treatments (cutting position, cutting Diameter, and IBA concentration). Principal component analysis was performed by R software using the vegan package (Oksanen et al., 2013).

## Results

Based on the analysis of variance, cutting position and cutting diameter significantly affected the number of roots (NR), mean lengths of roots (MLR), number of shoots (NS), and mean lengths of shoots (MLS), whereas IBA concentration (IC) was not significantly affected on the four parameters. No significant interaction was found between cutting position, cutting diameter, and IBA concentration on the NR, MLR, NS, and MLS (Table 1).

According to the results, the highest NR, MLR, NS, and MLS were observed for east and west-facing cutting positions, whereas north and south-facing cuttings had the lowest. Also, the highest to lowest NR, MLR, NS, and MLS were observed to be 15–20, 10–15, and 5–10 mm, respectively (Table 2).

The PCA ordination results based on cutting position, cutting diameter, and IBA concentration treatments were visually represented in three separate diagrams (Figure 1). The first axis explained 84.5% of the variability, and the first two axes together explained 93.1% of the variability. As these diagrams show, only the difference between the cuttings and the cutting diameter was remarkable and it showed a relatively distinct scatter among the classes of the treatment (Figure 1A), whereas there was not a distinct scatter between different classes of the cutting position and IBA concentration treatments (Figure 1B and C). In addition, there was a negative correlation between the first axis and NR ($r$ = -.70), NS ($r$ = -.38), and MLS ($r$ = -.60), as well as a positive correlation between the second axis and MLR ($r$ = .97) (Figure 1D).

## Discussion

Propagating plants using cuttings has several advantages. The resulting new plants will be genetically identical to their parent therefore sharing

Table 1.
*Effects of Cutting Position , Cutting Diameter , and IBA Concentrations on Number and Length of Roots and Shoots of Cuttings in* Platanus orientalis

| | | NR | | MLR | | NS | | MLS | |
|---|---|---|---|---|---|---|---|---|---|
| | DF | Mean Square | *F* | Mean Square | *F* | Mean Square | *F* | Mean Square | *F* |
| Cutting position (CP) | 3 | 3.59 | $7.13^{**}$ | 0.23 | $2.48^{*}$ | 0.63 | $9.74^{**}$ | 2.26 | $7.09^{**}$ |
| Cutting diameter (CD) | 2 | 142.43 | $283.16^{**}$ | 7.49 | $78.96^{**}$ | 19.01 | $294.18^{**}$ | 73.05 | $229.33^{**}$ |
| IBA concentrations (IC) | 2 | 0.78 | $1.55^{ns}$ | 0.04 | $0.43^{ns}$ | 0.01 | $0.07^{ns}$ | 0.20 | $0.64^{ns}$ |
| CP × CD | 6 | 1.21 | $2.41^{ns}$ | 0.15 | $1.61^{ns}$ | 0.11 | $1.69^{ns}$ | 0.92 | $2.90^{ns}$ |
| CP × IC | 6 | 0.98 | $1.96^{ns}$ | 0.09 | $0.95^{ns}$ | 0.06 | $1.01^{ns}$ | 0.44 | $1.38^{ns}$ |
| CD × IC | 4 | 0.65 | $1.30^{ns}$ | 0.17 | $1.76^{ns}$ | 0.12 | $1.85^{ns}$ | 0.64 | $2.01^{ns}$ |
| CP × CD × IC | 12 | 0.38 | $0.76^{ns}$ | 0.06 | $0.64^{ns}$ | 0.03 | $0.51^{ns}$ | 0.37 | $1.16^{ns}$ |

*Note:* NR = number of roots; MLR = mean root length; NS = number of shoots; MLS = mean shoot length; Cutting Position = CP; Cutting Diameter = CD; IBA Concentrations = IC.
** Significant at .05; * significant at .01.

Table 2.
*Number and Length of Roots and Shoots of Cuttings in* Platanus orientalis *(Mean ± Standard Error) in Different Treatments*

| | | NR | MLR (cm) | NS | MLS (cm) |
|---|---|---|---|---|---|
| Cutting position (CP) | North facing | $19.41 \pm 1.67^{b}$ | $1.44 \pm 0.22^{b}$ | $1.15 \pm 0.08^{b}$ | $10.90 \pm 1.12^{a}$ |
| | South facing | $24.38 \pm 2.26^{b}$ | $1.38 \pm 2.26^{b}$ | $0.97 \pm 0.08^{b}$ | $8.60 \pm 1.02^{b}$ |
| | East facing | $30.53 \pm 2.38^{a}$ | $1.83 \pm 0.26^{a}$ | $1.51 \pm 0.16^{a}$ | $10.10 \pm 0.91^{a}$ |
| | West facing | $30.38 \pm 2.02^{a}$ | $2.10 \pm 0.30^{a}$ | $1.14 \pm 0.08^{b}$ | $9.90 \pm 0.95^{a}$ |
| Cutting diameter (CD) | 5–10 mm | $4.50 \pm 0.84^{c}$ | $0.30 \pm 0.13^{c}$ | $0.28 \pm 0.04^{c}$ | $2.72 \pm 0.60^{c}$ |
| | 10–15 mm | $25.02 \pm 1.80^{b}$ | $1.56 \pm 0.22^{b}$ | $1.23 \pm 0.14^{b}$ | $10.82 \pm 1.14^{b}$ |
| | 15–20 mm | $49.00 \pm 2.10^{a}$ | $3.17 \pm 0.22^{a}$ | $2.10 \pm 0.10^{a}$ | $16.10 \pm 0.95^{a}$ |

*Note:* NR = number of roots; MLR = mean root length; NS = number of shoots; MLS = mean shoot length; Cutting position = CP; Cutting diameter = CD.
Different letters indicate significant differences ($p < .05$) between treatments.

similar characteristics. In addition, tree species propagating by cuttings are easier and faster than seed (de Jesus et al., 2020; Mehra et al., 2019; Welch-Keesey & Lerner 2002). So, this method is still widely used in plant propagation.

The results of this study showed that the cuttings collected from east and west-facing stand orientation had higher NR, MLR, NS, and MLS than north and south-facing stand orientation. The solar radiation regime varies in different geographical direction and this is a fundamental influence on biological and physical processes of plants (Pierce et al., 2005; Schleppi & Paquette, 2017; Wang & Jarvis 1990). It can change photosynthesis (Raven et al., 1992), growth, carbon cycling, evapotranspiration, temperature regimes (Raven et al., 1992; Schleppi & Paquette, 2017), and structure of a tree crown such as leaf area index (LAI), leaf inclination angle (LIA), and leaf area density (LAD). Also, these changes in shade-intolerant species like *P. orientalis* are higher than shade-tolerant species (Ameztegui et al., 2012). In northern hemisphere, the amounts of solar radiation incident on south, west, and east-facing slopes are higher than north-facing slope for both summer and winter (Terjung & O'Rourke, 1984). Because of this difference, the temperature in these slopes is higher than north-facing slope. There is a strong correlation between solar radiation regime and plant processes (Andrade et al., 2018; Schleppi & Paquette, 2017). Increasing solar radiation regime and the consequent increase in temperature lead to complex responses of plants. However, in most cases, it causes an increase in plant processes (Gu et al., 2002; Wang & Jarvis 1990). In shade-intolerant species, with increasing solar radiation, photosynthesis, LAI, LAD, and growth were improved (Amthor, 2010; Pilau & Angelocci, 2015; Tombesi et al., 2015). Because of these increases, the high carbohydrate and hormonal content of the coppice stumps stand that grows in west and east facing of the stand were obvious. The rooting process is a high carbohydrate-demanding process and several studies showed that cutting rooting and shooting was positively correlated with carbohydrate content in the cutting (Al-Saqri & Alderson, 1996; Del Rio et al., 1991; Denaxa et al., 2012; Guo et al., 2009; Hansen et al., 1987; Okoro & Grace, 1976; Wiesman & Lavee, 1995). So, the high values of NR, MLR, NS, and MLS in cutting of east- and west-facing stand orientation could be related to the increase of its carbohydrate content. Because of very high solar radiation, and consequently, lack of water resources in south-facing orientation, its cuttings did not have the same behavior as east- and west-facing orientation cuttings.

The present study showed that the application of IBA was not significantly effective on rooting and shooting of the cuttings (NR, MLR, NS, and MLS). The literature review indicates that there is no clear explanation for rooting and shooting responses to auxin application (Dirr & Heuser, 1987; Panetsos et al., 1994; Raup & Taylor, 2012; Tagipoor et al., 2015). However, in species of *Platanus* genus, it seems that the application of IBA appeared to be ineffective or negative on rooting responses

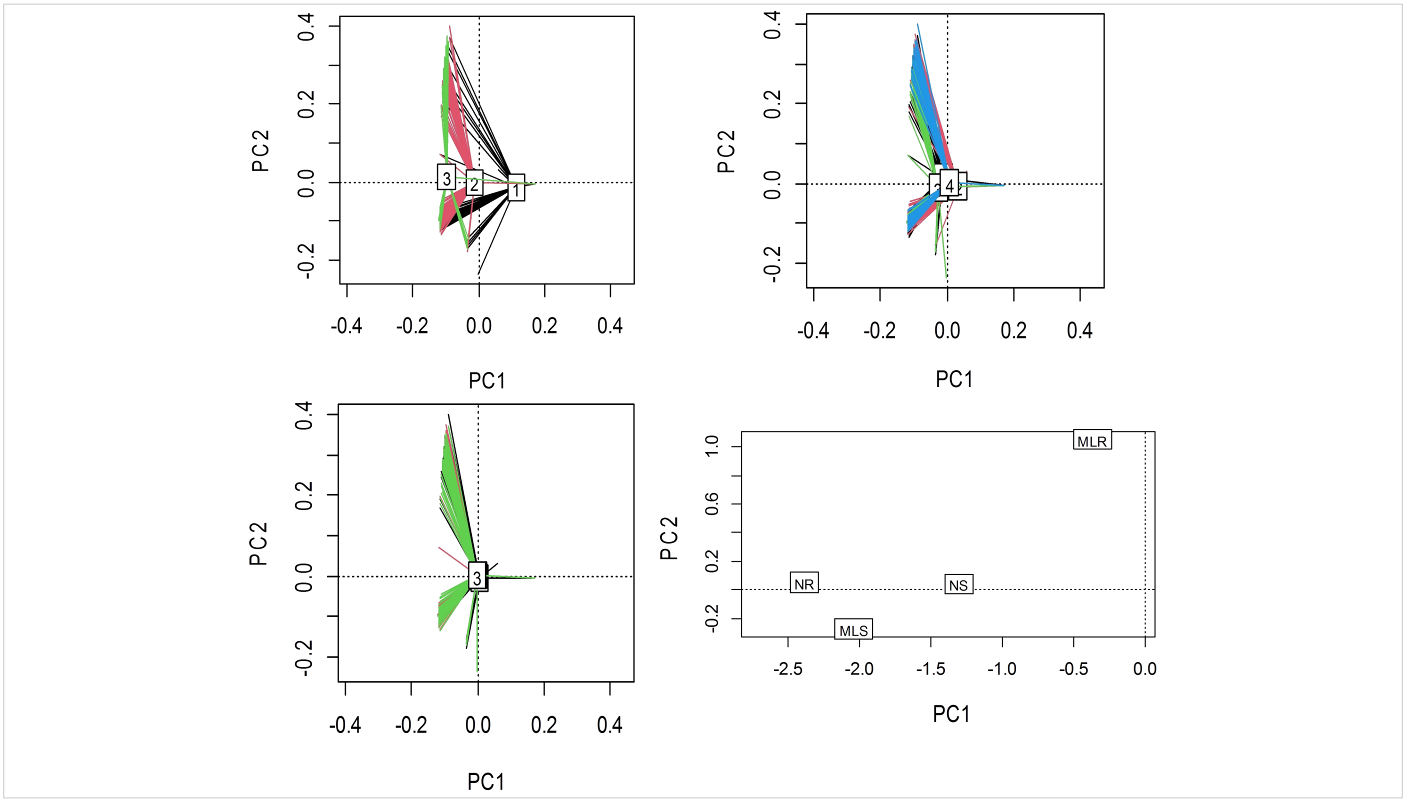


Figure 1.
*The PCA Ordination Diagram Based on NR, MLR, NS, and MLS of Cuttings in the Different Treatments. (A) Cutting Position (1: North Facing, 2: South Facing, 3: East Facing, and 4: West Facing Positions), (B) Cutting Diameters (1: 5–10 mm, 2: 10–15 mm, and 3: 15–20 mm), (C) IBA Concentrations (1: 0 mg $mL^{-1}$, 2: 50 mg $mL^{-1}$, and 3: 100 mg $mL^{-1}$). (D) Relationships Between NR, MLR, NS, and MLS and two first axes of PCA. PCA, principal component analysis; NR, number of roots; MLR, mean lengths of roots; NS, number of shoots; MLS, mean lengths of shoots; IBA, indole-3-butyric acid.*

(Grolli et al., 2005; Panetsos et al., 1994; Tagipoor et al., 2015; Zencirkiran & Erken, 2012). It has been shown that auxins make a cutting to root that does not contain enough natural hormone, and using auxin treatment for the cutting that has enough auxin content did not produce a better rooting and consequently shooting response. Considering ineffective auxin (IBA) application on cutting rooting results in Platanus genus species, even in very low concentrations (ranging from 0.025 to 0.2 mg $mL^{-1}$) (Grolli et al., 2005), confirming the hypothesis that *P. orientalis* cutting has enough natural hormone. So, using auxin treatment leads to a toxic concentration in cuttings with ineffective or negative effect on rooting results of *P. orientalis* cutting.

As expected, NR, MLR, NS, and MLS were increased with the increase in cutting diameter. Cuttings rooting and shooting in many species have also been found to be related to the cutting diameter (Gehlot et al., 2015; Hartmann et al., 2011; Khosrojerdi et al., 2006; OuYang et al., 2015). Moreover, the hormonal and carbohydrate content were found to be related to the cutting diameter (OuYang et al., 2015). On the other hand, the root formation in cutting is a multi-step process that required a high energy level (De Klerk et al., 1999). Therefore, one of the most important reasons for an appropriate shooting and rooting of 15–20 mm cuttings of *P. orientalis* could be a higher carbohydrate level stored there. Furthermore, the hormonal content and other rooting-inducing factors in larger cutting are higher compared to the smaller ones, which leads to a reduced rooting and shooting level (OuYang et al., 2015; Palanisamy & Kumar 1997).

The PCA ordination diagrams based on NR, MLR, NS, and MLS values showed that there were clear patterns with respect to diameter classes (5–10, 10–15, and 15–20 mm), whereas it did not show clear patterns at IBA concentrations and cutting position classes. Although, the cutting position in ANOVA had significant effects on NR, MLR, NS, and MLS separately. However, it did not reveal a clear pattern when considering the variable together. So the results of the present study emphasize that cutting diameter is the most important factor in propagation of *P. orientalis* by cutting. These results agreed with previous studies that have already found the effect of cutting diameter on rotting and shooting of *P. orientalis* and other species (Gehlot et al., 2015; Hartmann et al., 2011; Khosrojerdi et al., 2006; OuYang et al., 2015; Tate et al., 2018). Also, the results of the analysis showed that MLR had a positive correlation with the second axis that explained 8.6% of variability and it had a different behavior than NR, NS, and MLS. So, it may be not a good criterion for cutting rooting of *P. orientalis*.

## Conclusion

In general, the results of this study provide a procedure for propagating *P. orientalis* by cuttings. However, further studies are needed to verify these findings regarding propagation of *P. orientalis* in industrial-scale production. One-year-old *P. orientalis* shoot cuttings from coppice stumps with diameter ranging from 15 to 20 mm could be recommended for propagating *P. orientalis*. Finally, to improve cuttings rooting and shooting, it is better to collect cuttings from shoots that had a higher solar radiation regime. Also, auxin treatment is ineffective for the propagation of *P. orientalis* by cuttings.

**Peer-review:** Externally peer-reviewed.

**Author Contributions:** Concept – S.M., H.N., Z. R.; Design – S.M., H.N.; Supervision – S.M., H.N.; Resources – S.M., H.N., Z.R.; Materials – S.M., H.N., Z.R.; Data Collection and/or Processing – H.A., Z.R.; Analysis and/or Interpretation – H.A., Z.R.; Literature Search – H.A., Z.R.; Writing Manuscript – H.A., Z.R.; Critical Review – H.A.

**Acknowledgments:** This study was supported by a grant from Sari Agricultural Sciences and Natural Resources University. The authors would like to thank Mr. Seyed Reza Hejazi and Mr. Naser Roshan Tabari for their help in fieldwork. Seyedmehdi Hossaini Nasr provided valuable feedback on an earlier version of the manuscript.

**Declaration of Interests:** The authors have no conflict of interest to declare.

**Funding:** This research was supported by Sari Agricultural Sciences and Natural Resources University.

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