Black Sea Journal of Agriculture
doi: 10.47115/bsagriculture. 1634441

Open Access Journal
e-ISSN: 2618 – 6578

Research Article
Volume 8 - Issue 3 : 421-426 / March 2025

INNOVATIVE APPROACHES TO INCREASE GRAFTING SUCCESS RATES IN WALNUT SEEDLING PRODUCTION: GRAFTING CLIP AND TONGUE GRAFTING MACHINE

Hakan KARADAĞ[1]*, Hakan POLATCI[2], Onur SARAÇOĞLU[1]

[1]*Tokat Gaziosmanpaşa Üniversitesi Facult of Agriculture, Department of Horticulture 60250 Tokat Türkiye*

Abstract: Walnut seedling production is essential in terms of sustainability and commercial value of the agricultural output. However, traditional grafting methods are time-consuming and labor-intensive and have problems such as high cost and low efficiency. This study tested the most preferred method of grafting walnut propagation, the tongue-and-groove graft grafting method. It aimed to accelerate the grafting process, increase efficiency, and reduce production costs. The performance of prototype clips was evaluated using field trials in the study. A portable tongue-and-groove graft machine and manual labor methods were used in the grafting processes. The study results show that the new grafting clip significantly shortens the grafting time compared to traditional methods and increases graft retention rates. In the plastic graft tie application, 75.6% of the grafts made by hand and 62.2% produced by the grafting machine were successful. In the clip application, 86.7% of the grafts made by hand and 68.9% of the grafts made by the grafting machine were successful. Compared with the traditional and modern grafting methods in the literature, it was revealed that the developed clip reduces the need for labor and offers an innovative product with commercialization potential. The study aims to contribute to a more efficient and economical grafting process in walnut cultivation and sapling production.

Keywords: Tongue grafting, Grafting clip, Grafting machine, Walnut, Sapling

***Corresponding author:** Hakan Karadağ, Tokat Gaziosmanpaşa Üniversitesi Facult of Agriculture, Department of Horticulture 60250 Tokat Türkiye
E mail: hakan.karadag@gop.edu.tr (H. KARADAĞ)
Hakan KARADAĞ https://orcid.org/0000-0002-1458-7645
Hakan POLATCI https://orcid.org/0000-0002-2071-2086
Onur SARAÇOĞLU https://orcid.org/0000-0001-8434-1782

Received: February 06, 2025
Accepted: April 20, 2025
Published: May 15, 2025

Cite as: Hakan K, Hakan P, Onur S. 2025. Innovative approaches to increase grafting success rates in walnut seedling production: grafting clip and tongue grafting machine. BSJ Agri, 8(3): 421-426.

1. Introduction

Walnut (*Juglans regia* L.) is an agricultural product with high economic and nutritional value worldwide. Walnut cultivation is becoming increasingly important due to its high nutritional content, health benefits, and value in global trade. Professional and amateur gardens established in Turkiye have provided significant production increases in recent years. According to 2023 data, 360,000 tons of walnut production was achieved in Turkiye (FAO, 2025). However, the seedling production process is one of the biggest challenges encountered in walnut production. Grafting techniques, in particular, are one of the most critical factors determining seedling quality and productivity. The success of grafting varies depending on the method used, seasonal conditions, quality of the grafting material, and application process (Zobel, 1984; Hartmann et al., 2011). Walnut is an important plant not only in terms of agricultural production but also due to its ecological and economic benefits. Its use in rehabilitating forested areas is critical for environmental sustainability due to its carbon sequestration potential and contributions to soil fertility (Vahdati and Lotfi, 2013; Preece, 2005; Reighard and Loreti, 2008). In addition, the global walnut trade is growing and is becoming a strategic export product, especially for countries such as Turkiye (FAO, 2021a). This situation increases the need for more efficient and economical grafting techniques. Grafted seedlings have become widespread in walnut cultivation, both for preventing juvenile infertility and for cultivation with standard varieties. Traditional grafting methods, especially tongue-and-groove grafting, are widely used in walnut cultivation. Although this method is preferred due to its high retention rates, the time-consuming application process and the high labor costs during grafting are among the important disadvantages (Chandel et al., 2006). The tongue-and-groove grafting method is a method that requires more dexterity and labor compared to other grafting processes. Technological developments to optimize the grafting process have attracted attention in recent years. For example, automatic and semi-automatic grafting machines play an important role in increasing the efficiency of the grafting process (Özkan, 2001). However, these machines' high costs and ineffectiveness in all conditions require developing more practical and economical solutions.

Developing grafting techniques in walnut cultivation is important for increasing sectoral efficiency. Various studies have focused on different methods to increase grafting success rates. Ahmed et al. (2016) examined the effects of different grafting methods on walnut seedlings' growth and development performance and stated that some techniques provide higher success under certain conditions. Similarly, Sharma et al. (2022) evaluated the effects of the materials and binding techniques used during grafting on graft retention rates and emphasized the importance of technical improvements. Rezaee, et al. (2008) they achieved over 80% success in their work in the open field. In a similar study, Achim and Botu (1999) achieved a success rate of over 80% with the tongue-and-groove method. This study focuses on developing a new grafting clip and machine to make the walnut grafting process faster, more efficient, and less costly. The aim is for the developed clip and grafting machine to optimize the grafting process by reducing labor requirements and providing high graft retention rates. The effectiveness of the clip and the grafting machine was evaluated through field trials conducted within the scope of the study. The study results will provide innovative and applicable solutions in walnut cultivation and sapling production.

2. Materials and Methods

2.1. Plant material

One-year-old seedlings produced from *Juglans regia* L. seeds were used in grafting operations. The seedlings were supplied by a private company and stored at Tokat Gaziosmanpaşa University Agricultural Application and Research Center until the grafting date. The grafts used in grafting operations were supplied from the walnut parcel established within Tokat Gaziosmanpaşa University Agricultural Application and Research Center. The scions were prepared for grafting operations by cutting them from one-year-old branches with at least three buds. Grafting operations were carried out in the Tokat Gaziosmanpaşa University Agricultural Application and Research Center greenhouse.

2.2. Graft clips

The graft clips designed and produced by the project team are manufactured from ABS material on a 3D printer for field trials. The graft clip (Figure 1.) is formed by the union of two symmetrical parts. The two semicircular parts are joined with a reciprocal gear system to provide opening and closing features. Both parts have the same dimensions and features and are joined symmetrically. It is made of 3 mm thick hard plastic material and has an inflexible structure. The inner diameter of the hard outer surface is 3 cm, and its height is 7 cm. The locking system is easy to open and close and can be used with one hand. It is an important feature in terms of performing operations quickly and practically. It has an adjustable feature thanks to its locking system design. It is suitable for rootstocks and scions of different thicknesses. The inner material of the clip has a flexible structure, and soft polyethylene material is used. It is attached and fixed on the hard surface. Its wall thickness is 1 cm and covers the entire inner surface. The gap in the middle fully grasps the graft area. Its flexible feature ensures it surrounds the graft area and does not leave an air gap. Soft polyethylene material is long-lasting and economical.

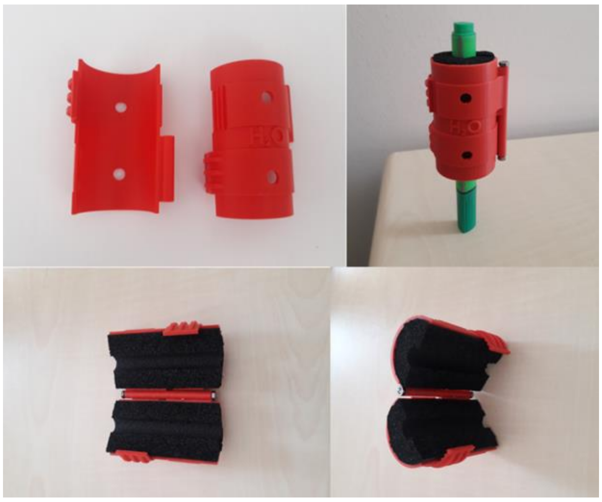

Figure 1. Grafting clip (original).

2.3. Grafting Machine

The developed grafting machine is designed to ensure that the tongue-shaped scion grafting is carried out quickly, precisely, and in a standard manner. The design and production of the machine belong to the project team and were developed to minimize the time loss and labor costs in the manual grafting process. The grafting machine is designed as a portable and easy-to-use rechargeable system. Thanks to its rechargeable structure, it can be easily used in field conditions, thus allowing mobile grafting operations without needing electricity. The machine's body is light and durable, offering an ergonomic experience for long-term use. The cutting blade of the machine (Figure 2) is specially designed and manufactured for the tongue-shaped graft technique.

Figure 2. Grafting knife design (original).

The cutting mechanism is optimized to create a precise and symmetric tongue angle. Since it is important for the rootstock and the scion to fit together perfectly in a tongue-shaped graft, the cutting angle of the blade is adjusted to create a standard and smooth surface. One of the most important components of the grafting machine is the sensor-controlled cutting mechanism. The sensors inside the machine complete the cutting process by moving the blade back and forth in the cutting area. This way, a standard and error-free tongue cut can be made in a single move without the operator manually cutting (Figure 3).

Figure 3. Grafting machine (original).

In the traditional tongue-and-groove technique, one of the most significant advantages of this developed machine is that cutting errors and time losses that vary depending on the operator's manual dexterity are prevented.

2.4. Method

The grafting operations were carried out using the standard tongue-and-groove graft grafting method. Since ensuring the diameter compatibility of the rootstock and grafts is a critical factor in successful graft retention rates, seedlings and grafts with similar thickness (8-12 mm diameter) were selected in both methods. Hand grafting: The traditional tongue-and-groove graft method was applied manually. The grafts were carefully shaped with a sharp grafting knife and placed on the rootstock.

Machine grafting: A tongue-and-groove cut was made in a single move using a grafting machine, and the graft was placed on the rootstock. The grafting area has a cutting area of approximately 4-5 cm. The graft clip was designed to be 7 cm long to ensure complete graft closure. After the grafting operation was completed, the operator closed the clip's locking system with one hand and performed the binding process. The graft clip's soft inner texture allowed it to adapt to rootstocks fully and grafts with different diameters without leaving any air gaps.

The trial was designed in a randomized plot design with three replications according to the factorial design. Three hundred seedlings were used, with 50 seedlings in each replication. All grafting operations were carried out on the same day and under similar environmental conditions, and the operations were carried out in the greenhouse to minimize the effect of external factors.

2.5. Data Collection and Analysis Method

The following parameters were measured to evaluate the effectiveness of the grafting operations:

- Grafting time: The time spent for manual and machine grafting operations was compared in seconds.
- Tie-up time (seconds): The duration of the tie-up operations with plastic grafting tie and grafting clip was measured.
- Graft efficiency (%): Graft retention rates were recorded by observing specific periods after grafting.
- Graft awakening times (in days): The effect of different tying methods was evaluated by considering the time when the first bud burst occurred.

In this study, the differences in success rates between two different methods (hand grafting and machine grafting) and two different fixation materials (graft tie and clips) used in walnut grafting were statistically analyzed using the chi-square test.

3. Results

Within the scope of the study, grafting, tying time, grafting efficiency, and grafting awakening times were evaluated to determine the grafting clip and the grafting machine's grafting performance.

Grafting and Tying Times: In the study, while the traditional manual grafting process took an average of 140 seconds, this time was reduced to 33 seconds with the developed grafting machine (Table 1). In the traditional method, the cutting time was measured as 118.87 ± 2.10 seconds and the tying time as 23.30 ± 0.88 seconds. In contrast, the cutting time with the grafting machine was determined as 21.03 ± 0.83 seconds and the tying time as 12.60 ± 0.41 seconds. These findings reveal that the grafting machine significantly accelerated the cutting and tying processes.

Table 1. Cutting times according to cutting methods

Graft Cutting Method	Cutting Time (s)	Tying Time (s)	Total (s)
Hand cutting	118.87 ± 2.10	23.30 ± 0.88	142.85
Machine cutting	21.03 ± 0.83	12.60 ± 0.41	33.63

Grafting efficiency: As a result of the chi square analysis, it was determined that there was no significant interaction between the grafting method and the grafting tie application. In the samples where graft ties were used, there was no statistically significant difference between the success rates of hand grafting and machine grafting (χ^2 = 1.30, P=0.255). This result shows that both methods have similar success rates with graft ties.

In the samples where clips were used, the hand grafting method showed higher retention success. The p-value obtained as a result of the chi-square test was 0.076, and although this value was not significant at the 5% significance level, it was at a level that could be considered significant at the 10% level (χ^2 = 3.15). This situation suggests that the hand grafting method may be more successful than the machine method in grafting with clips. In both the plastic grafting tie and clip application, a higher retention rate was obtained from the grafting done by hand than the grafting done by the grafting machine. In the plastic graft tie application, 75.6% of the grafts made by hand and 62.2% of the grafts made by the grafting machine were successful. In the clip application, 86.7% of the grafts made by hand and 68.9% of the grafts made by the grafting machine were successful. In other words, in both tying methods, grafts made by hand gave better results than grafts made by the grafting machine. When the average values are taken into account, 81.1% of the grafts made by hand and 65.6% of the grafts made by the grafting machine were successful. When the general success of the methods was evaluated, a significant difference was found between hand vaccination and machine. The hand vaccination method showed statistically higher retention success than the machine method (χ^2 = 4.80, P=0.028). This difference is significant at 5% significance level and shows the general effectiveness of hand vaccination. (Table 2).

Table 2. Grafting success rates of saplings tied with grafting ties and grafting clips

	Chi-Square Value (χ^2)	Degrees of Freedom (df)	P-value	
Grafting Tie	1.30	1	0.255	Not significant
Grafting Clip	3.15	1	0.076	Significant at 10%
Hand Cutting vs Machine Cutting	4.80	1	0.028	Significant

***=** A statistically significant difference exists between the groups (P<0.05).

Graft awakening times: After the grafting operations, the grafting areas were closed with a classic grafting tie and clip (Figure 4). Depending on the binding materials used, a difference of approximately nine days was observed between the first bud burst dates. An average of nine days of late awakening was detected in seedlings using grafting clips. Late awakening did not negatively affect the graft take rates. This situation shows that the protective effect of the clip on the grafting area compensates for the delay in awakening times. In addition, the delay in awakening times may have contributed to the more robust and durable development of the grafted seedlings. This finding reveals that using clips plays both a protective and supportive role in the grafting processes.

Figure 4. Seedling grown with grafting clip (original).

4. Discussion

This study evaluated the effectiveness of a new grafting clip and machine developed to optimize grafting processes in walnut (*Juglans regia* L.) cultivation. The findings show that significant time savings can be achieved in grafting processes, and graft retention rates can be increased. The findings obtained in the study revealed that traditional grafting processes performed manually took an average of 140 seconds, while grafting processes performed with the developed grafting machine took an average of 33 seconds. It is stated that traditional grafting methods are labor and time-intensive processes (Gandev, 2007; Hartmann et al., 2011). In particular, the tongue grafting method requires precise cutting of the grafting area and appropriate binding materials (Polat and Ordek, 2008). This result shows that a significant increase in efficiency is provided in grafting processes. Many studies indicate that automatic and semi-automatic grafting machines shorten grafting times. In their studies, Akça and Palazoğlu (2022) achieved success with the semi-automatic Akça vaccination machine (93.00%). In March, the highest vaccination success rate (100.00%) was determined in the tongue vaccination and Akça vaccination machine method (90.00%) in the plastic greenhouse environment. The omega vaccination success rate in the plastic greenhouse environment varied between 15.00% and 25.00%. Özkan (2001) stated that automatic grafting machines reduce grafting times by 50-60%. However, the 33-second time obtained in this study is relatively low compared to other studies in the literature. Yilmaz et al. (2020) reported that the average grafting time with a similar machine was 45 seconds. A study by Zhang et al. (2017) determined that automatic grafting machines accelerated the grafting process by compared to traditional hand grafting and increased labor efficiency. This difference can be explained by the cutting blade's special design and the developed machine's sensor technology. In addition, a significant decrease in tying times was observed. While the tying time was 23.30 seconds on average when a classic plastic grafting tie was used, this time decreased to 12.60 seconds with the grafting clip. This finding shows that the practical use of the clip accelerates the grafting process. Similarly, Demirtas et al. (2019) examined the effect of different tying techniques on grafting times and stated that flexible tying materials can be applied faster. The time savings provided by the grafting machine can provide a significant advantage, especially in large-scale seedling production facilities. In traditional methods, the grafting process is both time-consuming and labor-intensive. This can negatively affect production capacity, especially when seasonal conditions are limited. The use of a grafting machine accelerates this process and allows more seedlings to be grafted in a short time.

Graft retention rates are one of the most critical parameters in evaluating grafting success. In this study, the retention rate of hand-made grafting was 81.1%, while the retention rate of grafting with a grafting machine was 65.6%. These results show that traditional hand-made grafting has a higher success rate. Studies have shown that hand-made grafting can succeed with the correct technique and applications. However, the physical pressure created by mechanized systems in the grafting area and differences in cutting sensitivity can reduce success rates (Gandev, 2019).

However, the retention rates of grafting with a grafting machine are higher than other automatic grafting machines in the literature. Gürcan et al. (2017) reported that the retention rates of grafts made with automatic grafting machines were 50-60%. The retention rate of 65.6% obtained in this study demonstrates the success of the developed machine. Manual grafts provided higher retention rates in walnut grafting, but automatic systems were advantageous regarding time-saving. The findings of this study support this view.

When plastic graft tie was used as the graft binding material, a success rate of 68.9% was obtained, and when the developed graft clip was used, a success rate of 77.8% was obtained. Among the graft binding methods, clips provided a retention rate of approximately 9% higher than the plastic graft tie. This finding reveals that the graft clip provided a higher success rate than traditional binding materials. It is stated in the literature that binding materials are effective in graft success (Vahdati and Lotfi, 2013; Vahdati et al., 2019). Similarly, Gandev (2019) examined the effect of different binding techniques on graft retention rates and stated that flexible binding materials provided higher success rates. The flexible internal structure of the clip used in this study supports these results. In addition, Vahdati and Lotfi (2013) stated that air exposure of the graft site may negatively affect graft success. The structure of the clip that limits air circulation may have provided an advantage in this respect.

Graft awakening times are another important indicator of grafting success. This study observed an average of nine days of late awakening in seedlings using grafting clips. This may be associated with the clip covering the grafting site completely and limiting air circulation. However, this late awakening did not negatively affect graft take-up rates. Although similar findings are not found in the literature, Hartmann et al. (2011) stated that air exposure to the grafting site may negatively affect graft success. Therefore, the structure of the clip that limits air circulation may increase graft take-up rates while extending the awakening times. In addition, Yılmaz et al. (2020) stated that graft awakening times may vary depending on the grafting method and environmental conditions. In this study, the fact that clip use extended the awakening times supports this view. It is thought that this delay resulting from the use of clip material will reduce the risk of damage from late spring frosts that may occur after the grafting process is carried out in open fields. The findings of this study, when compared to other studies in the literature, reveal both similarities and differences. Soleimani et al. (2010), and Hartmann et al. (2011) stated that the methods and materials used in the grafting processes significantly affect the success of the graft. Similarly, this study's grafting method and the binding material significantly affected graft retention rates. However, the grafting clip and machine developed in this study provided higher success rates than other automatic grafting systems in the literature. In addition, Mır and Kumar (2011) emphasized that the development of grafting techniques in walnut cultivation plays a critical role in increasing sectoral efficiency. The study presented findings supporting this view. The developed grafting clip and machine significantly contributed to walnut cultivation by accelerating the grafting processes and increasing the retention rates. In addition, FAO (2021b) stated that the global walnut trade is growing, and countries need innovative solutions to compete in this field. This study offers a practical and applicable solution for this need.

5.Conclusion

This study evaluated the effectiveness of a new grafting clip and machine developed to improve grafting processes in walnut cultivation. The findings show a significant decrease in grafting times, and increased graft retention rates were achieved. While the grafting clip provided higher retention rates than the plastic grafting tie, the grafting machine significantly accelerated the grafting process. Although the machine's efficiency is 15% lower, it is thought to be advantageous thanks to the time and labor savings obtained. These results provide innovative and applicable solutions in walnut cultivation and seedling production. In future studies, it is recommended that the clip and machine be tested in different ecological conditions and larger-scale trials be conducted.

Author Contributions

Percentages of the authors' contributions are present below. All authors reviewed and approved final version of the manuscript.

	H.K.	H.P.	O.S.
C	33	34	33
D	33	34	33
S	33	34	33
DCP	33	34	33
DAI	33	34	33
L	33	34	33
W	33	34	33
CR	33	34	33
SR	33	34	33
PM	33	34	33
FA	33	34	33

C= concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision, PM= project management, FA= funding acquisition.

Conflict of Interest

The authors declared that there is no conflict of interest.

Ethical Consideration

Ethics committee approval was not required for this study because there was no study on animals or humans.

Acknowledgments

We would like to thank Gaziosmanpaşa University Agricultural Application and Research Center for providing the graft scions, This article was obtained from the "Development of New Type Semi-Automatic Grafting Machine And Grafting Clip" project numbered 2190172, supported by "The Scientific and Technological Research Council of Turkiye" (TÜBİTAK)

References

Achim GH, Botu I. 1999. Results in walnut propagation by using different methods. Acta Hortic, 544: 503-509.

Ahmed N, Singh SR, Srivastava KK, Shagoo PA. 2016. Standardization of efficient propagation technique for production of quality planting material in walnut. Indian J Hortic, 73: 177-182.

Akça Y, Palazoğlu R. 2022. Determination of performance of new graft machine for faster grafting of walnut (Juglans regia L.). Gaziosmanpasa J Sci Res, 11(1): 108-117.

Chandel JS, Gautam DR, Sharma NC. 2006. Chip budding: an excellent method of propagation of walnut (Juglans regia L.). Acta Hortic, 705: 335-339.

Demirtaş İ, Yılmaz M, Özkan Y. 2019. Ceviz aşılama tekniklerinin aşı tutma oranları üzerine etkisi. Tarım Bilim Derg, 25(3): 345-352.

FAO. 2021a. FAO statistical yearbook 2021: world food and agriculture. Rome, Food and Agriculture Organization of the United Nations, Rome, Italt, pp: 28.

FAO. 2021b. Ceviz üretimi ve ticareti: küresel trendler. FAO . Roma, Italy, pp:256.

FAO. 2025. https://www.fao.org/faostat/en/#data/QCL (accessed date: February 6, 2025).

Gandev S. 2007. Budding and grafting of the walnut (Juglans regia L.) and their effectiveness in Bulgaria (Review). Bulg J Agric Sci, 13: 683-689.

Gandev S. 2019. Propagation of walnut (Juglans regia L.) under controlled temperature by the methods of omega bench grafting, hot callus and epicotyl grafting. Agr Sci, 15(2): 105-108.

Gürcan K, Şen SM, Aydın B. 2017. Farklı aşı yöntemlerinin ceviz fidanlarının büyüme performansı üzerine etkileri. Bahçe, 46(2): 123-130.

Hartmann HT, Kester DE, Davies FT. 2011. Plant propagation: principles and practices. Pearson Education, Boston, USA, pp: 880.

Mır M, Kumar A. 2011. Effect of different methods time and environmental conditions on grafting in walnut. Int J Farm Sci, 1(2): 17-22.

Özkan M. 2001. Effect of different application on grafting under controlled conditions of walnut. Acta Hortic, 544: 515-520.

Polat AA, Ordek GO. 2008. Increasing grafting success rate on walnut. Acta Hortic, 772: 253-256.

Preece JE, Read PE. 2005. The biology of horticulture: an introductory textbook, John Wiley Sons, Hoboken, USA, pp: 528.

Reighard GL, Loreti F. 2008. Rootstock development. The peach: botany, production and uses, CAB International, Wallingford, USA, pp: 193-220.

Rezaee R, Vahdati K, Grigoorian V, Valizadeh M. 2008. Walnut grafting success and bleeding rate as affected by different grafting methods and seedling vigour. J Hortic Sci Biotechnol, 83(1): 94-99. https://doi.org/10.1080/14620316.2008.11512352

Sharma C, Thapa R, Thapaliya KP, Ghimire MS. 2022. Exploring combination of grafting time and scion cultivar in walnut grafting success under open field condition. Heliyon, 8: e12485.

Soleimani A, Rabiei V, Hassani D. 2010. Effect of different techniques on walnut (J. regia L.) grafting. J Fd Agric Environ, 8(29): 544-546.

Vahdati K, Arab MM, Sarikhani S, Sadat-Hosseini M, Leslie CA, Brown PJ. 2019. Advances in persian walnut (Juglans regia L.) breeding strategies. In: Advances in plant breeding strategies: nut and beverage crops. Springer, Cham, Switzerland, pp: 401-472. https://doi.org/10.1007/978-3-030-23112-5_11

Vahdati K, Lotfi N. 2013. Walnut grafting: techniques and challenges. Acta Hortic, 981: 179-185. https://doi.org/10.17660/ActaHortic.2013.981.17

Yılmaz M, Demirtaş İ, Özkan Y. 2020. Ceviz yetiştiriciliğinde aşılama tekniklerinin karşılaştırılması. Tarım Orman Derg, 16(2): 89-97.

Zhang JK, Chu T, Zhang T, Yin Q, Kong T, Liu Z. 2017. Development status and analysis of automatic grafting technology for vegetables. Nongye Jixie Xuebao, 48(3): 1-13. https://doi.org/10.6041/j.issn.1000-1298.2017.03.001

Zobel BJ, Talbert JT. 1984. Applied forest tree improvement. John Wiley and Sons, New York, USA, pp: 505.