Evaluation of Patch Budding Success in Persian Walnut Affected by Different Treatments after Budding

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ABSTRACT
Vegetative propagation of Persian walnut (Juglans regia L.) is more difficult than many other fruit trees. Temperature, relative humidity, water status of the scion and rootstock, nutrient uptake, time of grafting, physiological condition of the rootstock, and scion type all can affect grafting success. An experiment was conducted to evaluate the effects of post-budding irrigation frequency (3, 7 and 10-days), budding date (14 June, 5 and 26 July), and rootstock heading methods. All treatments and evaluations of their effects were performed in field conditions, for two consecutive years. Irrigation cycle, budding date and rootstock heading procedure all had significant effects. Bud take was greatest on 26 July (49.3%). Irrigation frequency had no significant effect on bud take but the 3-day cycle resulted in the best scion growth. Bend the branches to create shade at the bud site, rather than cutting the rootstock above the bud site resulted in the best bud take (61.1%). The results obtained in this study show that budding at the right time “provides better climatic conditions,” adjusting the irrigation cycle and choosing the best rootstock heading methods after budding, produces satisfactory results

KEYWORDS
Walnut budding; time of budding; irrigations frequency

Introduction
One of the main centers of origin of Persian walnut is central Asia or ancient Persian plateau, and this species is now grown in many temperate regions of the world (Akça et al., 2020; Vahdati, 2003). Traditionally, walnut trees propagated from seed, high heterozygosity of the walnut tree leads to low quantity/quality production and also due to the long juvenility, the return on investment archives in a long time (Vahdati, 2003). Vegetative propagation by tissue culture, cuttings or layering is possible but often with low rooting and acclimatization success (Chang et al., 2020; Erdogan, 2006; Fernández-Moya et al., 2020, 2020; Gandev and Arnaudov, 2011; Gandev et al., 2019). Clonal propagation of walnut by grafting maintains valuable genotypes and commercial establishment of walnut cultivars. In recent years, various budding and grafting methods have been evaluated for use in walnut propagation different countries (Farsi et al., 2016). The physiological condition of the rootstock and scion material before grafting, the time of grafting, environmental conditions and grafted skill are thought to be the most important factors for success (Dehghan et al., 2010; Ghamari Hesabi et al., 2016; Hartmann et al., 2014; Sadeghi Majd et al., 2019). Disease, insects, and abiotic stress (nutrient deficiency and water stress) can all decrease photosynthetic assimilation and carbohydrate availability for callus formation. Ghamari Hesabi et al. (2016) stated that for budding, the rootstock must be strong and well-watered until the bark is easily separated from the wood but Ramos (1985) and Vahdati (2003) reported that
high amount of irrigation before and after grafting can increase root pressure and decrease graft success. Maintaining scion moisture in various methods such as shading, putting paper cap on the scion or covering the grafting point with moist materials or rubber bands preserves the scion’s survival properties and leads to greater grafting success (Sadeghi Majd et al., 2019; Vahdati, 2003). Some researchers reported that for better walnut grafting success, high relative humidity (80–95%) is required. Also, one of the most important environmental factors influencing the successful grafting of walnut is the ambient temperature (the most suitable temperature is 27°C), in addition, the lower and higher the temperature, gives the lower callus production, grafting success and survival (Farsi et al., 2018; Hartmann et al., 2014; Thapa et al., 2021; Vahdati, 2003). There are conflicting reports on the effect of irrigation on walnut grafting success. According to the reports of other researchers on negative effect of irrigation or rainfall before/after grafting (especially irrigation in the dormant season) (Ramos, 1985; Vahdati, 2003), as well as the favorable effect of irrigation in reducing temperature, and increasing relative humidity especially in the warm season (Sadeghi Majd et al., 2019), we were encouraged to test the effect of irrigation in our research. Hence, the objective of the current study was to evaluate the effect of post-budding irrigation frequency (IF), budding date (TB), and rootstock heading method (CR) on walnut budding success for introducing the best combination and grafting time in Alborz city condition.

**Materials and Methods**

**Experimental Site**

This study was carried out during 2008 and repeated in 2009 in Alborz City, Qazvin Province, Iran. Experimental site is classified as temperate zone, situated at N 36°16′30″ latitude and E 50°08′39″ longitude at 1304 m above the sea level. The soil samples were taken from the depths of 0–30 cm and their properties analyzed (Table 1). Temperature and relative humidity were recorded during the 4 months after budding (Table 2).

**Plant Material Samples**

In this study, the scion woods were collected from an elite/promising mature walnut tree genotype (‘Zia Abad’), having lateral bearing habit, late bud break, easy kernel removal of nut with light kernel color and much kernel ratio percentage. Two weeks before budding, leaves of the scion woods were removed from the shoots and about 1–2 cm of the petioles were retained on the branches. The half-sib seeds, which were used to produce the rootstock for budding were also collected from the same tree genotype (‘Zia Abad’), because one of the advantage of using similar grafting material (rootstock and scion) genetically is increasing grafting success (Vahdati, 2003). Due to greater uniformity of seedlings derived in a tree (half-sib) than derived in different trees, in this research, we used half-sib seedlings

| Characteristics | pH | Sand (%) | Clay (%) | Silt (%) | EC (ds/m) | Soil texture |
|-----------------|----|---------|---------|---------|-----------|--------------|
| Quantity        | 7.8| 26      | 29      | 45      | 1.3       | Clay-Loam    |

| Month   | Max T | Min T | Max RH | Min RH | Max T | Min T | Max RH | Min RH |
|---------|-------|-------|--------|--------|-------|-------|--------|--------|
| June    | 32.3  | 13.5  | 64.0   | 17.4   | 30.5  | 13.1  | 72.0   | 19.7   |
| July    | 35.2  | 17.0  | 68.4   | 19.6   | 31.3  | 15.2  | 65.6   | 22.3   |
| August  | 36.0  | 18.3  | 59.8   | 14.6   | 34.7  | 17.1  | 61.7   | 14.8   |
| September | 33.0  | 16.5  | 64.3   | 18.0   | 28.0  | 11.5  | 70.4   | 18.5   |

Table 1. Soil characteristics of the studied nursery at 0–30 cm depth.

Table 2. Monthly mean, maximum and minimum temperature (°C) and RH (%) after budding.
and also to reduce the effect of differences in the growth rate of half-sib rootstocks, seedlings with different vigor and growth (height and diameter rate) were removed. Half-sib seeds were harvested in mid-October and were immersed in water three days before planting.

In November, the seeds were planted on ridges at a depth of 10 cm and 15–20 cm apart (Figure 1). Seeds were stratified naturally by exposure to outdoor winter temperatures. The following spring (in second year after seed planting), seedlings were irrigated every 10 days (conventional irrigation in the region) until budding. Two days before budding, a light irrigation was applied in all the treatments. Due to the cold temperature of the region, which causes less and late growth in spring, as well as the late leafing of many of the superior genotypes (bud burst after spring frost), the branches of walnut trees are not suitable for June budding because they do not reach full maturity at this time. Therefore, one-year shoots were used for grafting on June 14 and current season shoots were used for budding on 5 and 26 July, because the shoots mature in July. Another reason for using two types of budding was the efficient use of time to do other agricultural works and also to compare the success of grafting at different times. Therefore, due to low and/or similar nutrients in buds at different times, in this study, the role of bud age in growth characteristics is meaningless.

Scion materials were harvested one hour before budding. Immediately after budding, a light irrigation was given and 10 days later the irrigation treatments commenced.

**Treatments**

Patch budding (plant budding in which a small rectangle of bark bearing a scion bud is fitted into a corresponding opening in the rootstock) was performed on 14-June, 5-July and 26-July. Budded plants were subjected to three irrigation frequencies irrigation at 3, 7 and 10-day intervals until the end of season.

In addition, four methods of rootstock treatment were tested: (1) the rootstock trunk was cut 15 cm above the budding point immediately after budding; (2) immediately after budding, the rootstock trunk was bent over 60 cm above the budding point but not cut off, and was bent in an orientation so that the canopy would shade the budding point in order to maintain moisture and adjust temperature at the budding point; (3) rootstock trunks were cut 60 cm above the bud and; (4) seedling rootstocks were not cut back (control). At 20 days after budding, all rootstocks were cut from 5 cm above the budding point.
Data Collection

One month after budding, data were recorded as percentage of buds that kept their green bark color and vitality (bud take). Subsequently, three months after budding, the scion growth (cm), length of internodes (cm), scion diameter (mm) and number of leaves were measured. Also, at the end of October, bud loss (D/B × 100, D = desiccated bud, B = bud take) was recorded.

Data Analysis

The experiment used a randomized complete block design with three replications and 10 grafts replicate. The data were analyzed by analysis of variance using the SAS software (1.6 version) and Duncan’s multiple-range test was used for mean comparisons (P ≤ .05).

Results and Discussion

Time of Budding

In this experiment, the main effects as well as the two interaction effects of “year of budding (Y) × irrigation frequency (IF)” and “IF × time of budding (TB)” were significant. The interaction effects of “Y × IF × TB × rootstock heading method (CR),” “IF × TB × CR,” “Y × TB × CR,” and “Y × IF × CR” were not significant. The duration of budding significantly affected bud take, bud loss, scion diameter, scion growth, and internode length (Table 3). Bud take on 5 July was greater (49.3%) than at the other times (43% and 40% for 14 June and 26 July, respectively), but the lowest bud loss was observed when budded 14 June (Table 3).

The greatest scion growth, scion diameter, and length of internode were obtained when budding was performed on 14 June. There was no significant difference in leaf number between the three times (Table 3). Temperature can have a pronounced effect on callus formation after grafting with an optimum of 26–27°C according to Vahdati and Zarei (2006), Ebrahimi et al. (2007), Sadeghi Majd et al. (2019), Farsi et al. (2018) and Thapa et al., 2021.

The temperature was higher after 5 and 26 July budding than after 14 June (Table 2). That the 14 June budding resulted in the greatest scion growth and internode length, and also the least graft loss, which is in accordance with Sadeghi Majd (2014). They reported that during spring and summer, when graft take can be low due to warm and dry weather, use of a shade-house to reduce air temperature increases walnut graft success. In addition to the more favorable temperature on 14 June, this date allows more opportunity for scion growth before end of the season. Rezaee et al. (2008) reported that patch budding in early spring (mid-April) was more successful (46%) than in early summer (early-July with 0%) or late summer (late-September with 23.30%) as is confirmed by our results. Sharma and Joolka (2005) performed patch budding on 2, 10, 18 and 26 July and 3, 11 and 19 August and found that the optimal time for budding was 2 July with 80% bud take. They suggested the higher success on this date might be due to optimum temperature and relative humidity. To improve budding success, several studies have also examined walnut grafting under controlled conditions (Barut, 2001; Ebrahimi et al., 2007). Nosrati and Khadivi-Khub (2014) stated that patch

Table 3. Effect of budding date on bud take, bud loss, internode length, scion length, scion diameter, and number of leaves.

| Time of Budding | Bud take (%) | Bud loss (%) | Scion diameter (mm) | Scion growth (cm) | Height of internode (cm) | Number of leaves |
|-----------------|--------------|--------------|---------------------|------------------|--------------------------|-----------------|
| 14 June         | 43.5b        | 20.1b        | 7.3b                | 24.5             | 2.6b                     | 9.6b            |
| 5 July          | 49.3a        | 22.9b        | 6.4b                | 22.6b            | 2.5ab                    | 9.3b            |
| 26 July         | 40b          | 33.3a        | 5.9b                | 21.7b            | 2.4b                     | 9.3b            |

a On each column, the means followed by different letters are significantly different (Duncan’s multiple range test, P ≤ .05).

1 Percentage of buds that kept their green bark color and vitality.

2 Bud loss (D/B × 100, D = desiccated bud, B = bud take).
Table 4. Effect of irrigation frequency on bud take, bud loss, height of internode, scion growth, scion diameter and number of leaves.

| IRa  | Bud take (%) | Bud loss (%) | Scion diameter (mm) | Scion growth (cm) | Height of internode (cm) | Number of leaves |
|------|--------------|--------------|---------------------|-------------------|--------------------------|-----------------|
| 3 day| 41.89b       | 19.1b        | 7.06b               | 24.4b             | 2.64b                    | 9.77b           |
| 7 day| 45.9a        | 27a          | 6.51b               | 22.6b             | 2.46b                    | 9.3b            |
| 10 day| 44.5a       | 30.2a        | 5.99c               | 21.3c             | 2.35c                    | 9.06b           |

aIrrigation frequency.

* On each column, the means followed by different letters are significantly different (Duncan's multiple range test, P ≤ 0.05).

bPercentage of buds that kept their green bark color and vitality.

Table 4 shows results of irrigation frequency on bud take, bud loss, height of internode, scion growth, scion diameter and number of leaves. In this experiment, variation of irrigation frequency had a significant effect on bud take, bud loss, height of internode, scion growth, scion diameter and number of leaves. The highest scion growth, scion diameter, height of the internode, and lowest bud loss (%) was observed in 14 June, which might be due to favorable relative humidity and temperature at this time. These findings are in agreement with those of Ebrahimi et al. (2007), Nosrati and Khadivi-Khub (2014) and Sadeghi Majd (2014) who observed that the highest scion growth and other traits when relative humidity and temperature were in favorable status than other tested time. Akyuz et al. (2018) recorded maximum shoot length and shoot diameter on 5 April than other time (20 April, 5 May and 20 May) in walnut top working with agree in our results. Kómür and Sütyemez (2017) also used cleft grafting for top working of walnut, successfully.

Irrigation Frequency and Interaction with Budding Date

Among irrigation treatments, the greatest bud take (44.5%) was obtained using a 7-day interval. Irrigation frequency also had a significant effect on scion diameter, scion growth, internode length, and number of leaves (Table 4). The greatest scion diameter (7.06 mm), scion length (24.4 cm), internode length (2.64 cm) and number of leaves (9.77) resulted from irrigation on a 3-day cycle (Table 4). Irrigation every 10 days resulted in the poorest results for these traits. This agrees with the results of Sadeghi Majd (2014) for bud take under shade house conditions.

The interaction between budding date and irrigation frequency was also significant for bud take, scion growth, and scion diameter (Figure 2 to 4). For 26 July budding, success was greater when followed by irrigation on a 3 day cycle than when longer intervals were used (Figure 2), which is in agreement with the results of Sadeghi Majd (2014) under field conditions. Vahdati (2003) and Ramos (1985) state in their books that high irrigation and rainfall reduces grafting success in walnut. This contrasts the results here for bud take on 26 July in which the shortest irrigation interval reduced bud loss (Table 4). This is likely because root pressure in walnuts decreases from early spring to summer and, therefore, irrigation does not significantly increase root pressure enough to affect the success of July budding and it is better we have light irrigation before and after budding. Shorter irrigation intervals after budding also increased scion growth and scion diameter (Figures 3 and 4). Sadeghi Majd (2014) reported that in shorter irrigation interval resulted higher different traits such as bud take and scion growth which agree with our result. Sadeghi Majd (2014) reported that in a warm region (outdoor conditions), weekly irrigation causes 0% bud take in patch budding versus more budding take in every 3 days and every 1-day interval with 5.5% and 11.1% respectively.
Removing the top of the rootstock affected all traits except bud loss. Bud take was greatest (61.1%) when the rootstock top was bent rather than removed and the lowest bud take (34%) resulted when the rootstock was left intact. Cutting the rootstock 15 cm above the budding point resulted in the greatest scion growth, scion diameter, internode length, and number of leaves (Table 5). Breaking and bending the scion to shade the bud point maintained the relative humidity of bud and increased bud take. This is in agreement with Ramos (1985), Vahdati (2003) and Sadeghi Majd et al. (2019) who all reported that shading positively affects walnut graft success. By preventing dehydration of the tissues by covering the graft point can limits graft failure (Rezaee and Vahdati, 2008). Nosrati and Khadivi-Khub (2014) budded on the north-west side of the rootstocks and the top of the rootstocks were bent on the junction portion to reduce light penetration and reduce direct light and temperature effect on the budding points in the outdoor condition.
Table 5. Effect of rootstock treatment on bud take, bud loss, internode length, scion growth, scion diameter, and number of leaves.

| Rootstock | Bud take | Bud loss | Scion diameter (mm) | Scion length (cm) | Length of internode (cm) | Number of leaves |
|-----------|----------|----------|---------------------|-------------------|--------------------------|-----------------|
| Control   | 34 ± a   | 27.4 ± a | 6.2 ± b             | 20.4 ± b          | 2.28 ± c                 | 9.29 ± ab       |
| BTC       | 61.1 ± b | 23.8 ± b | 6.41 ± b            | 22.4 ± b          | 2.46 ± c                 | 9.07 ± b        |
| C60       | 46.9 ± b | 23.1 ± b | 6.32 ± b            | 23.8 ± c          | 2.51 ± b                 | 9.44 ± b        |
| C15       | 31.6 ± c | 27.5 ± a | 7.16 ± a            | 25.3 ± a          | 2.69 ± a                 | 9.75 ± a        |

8Rootstock treatments: cut 15 cm above budding (C15) point, bend the trunk to break but without cutting off at height of 60 cm above the budding point (BTC), cut 60 cm above the budding point (C 60).  
* On each column, the means followed by different letters are significantly different (Duncan’s multiple range test, P ≤ 0.05).  
1Percentage of buds that kept their green bark color and vitality.  
2Bud loss (D/B × 100, D = desiccated bud, B = bud take).

Painting can also improve results due to decreased light and temperature at the graft point. Buds above the budding point can inhibit growth of the scion through apical dominance, so after graft take, rootstock buds from above the budding point need to be removed to eliminate this effect. Cutting halfway through the rootstock also breaks rootstock apical dominance, allowing the scion bud to elongate rapidly (Table 5). Year of budding significantly affected scion growth but year had no significant effect on other factors (Table 6). More suitable temperatures in 2009 were likely the main factor in differing scion diameter (Figure 5; Table 2).

In conclusion, the present study clearly revealed that the best time of budding was 5 July versus the lowest in 26 July, because of appropriate climatic condition especially the maximum relative humidity in 2009. Shorter irrigation frequency, i.e. every 3 days after budding, was better than 7 and 10 days in term of scion diameter and scion growth with the lowest bud loss. The interaction between budding date × irrigation frequency indicate that a suitable irrigation frequency is required for any time of budding.

Table 6. Effect of year of budding on bud take, bud loss, height of internode, scion growth, scion diameter and number of leaves.

| Year of budding | Bud take | Bud loss | Scion diameter (mm) | Scion length (cm) | Height of internode (cm) | Number of leaves |
|-----------------|----------|----------|---------------------|-------------------|--------------------------|-----------------|
| First year      | 44.7 ± a | 26.4 ± a | 6.32 ± b            | 21.4 ± b          | 2.45 ± a                 | 9.3 ± a         |
| Second year     | 43.5 ± a | 24.5 ± a | 6.72 ± b            | 21.4 ± a          | 2.52 ± a                 | 9.46 ± a        |

* On each column, the means followed by different letters are significantly different (Duncan’s multiple range test, P ≤ 0.05).  
1Percentage of buds that kept their green bark color and vitality.  
2Bud loss (D/B × 100, D = desiccated bud, B = bud take).
Also, effect of rootstock heading method showed that bending the trunk to break, but without cutting off at height of 60 cm above the budding point rather than cutting the rootstock above the bud point resulted in the best bud take because it also reduces temperature of the scion and prevents sun injury.

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No potential conflict of interest was reported by the author(s).

**References**

Akça, Y., Y. Yuldaşulu, E. Murad, and K. Vahdati. 2020. Exploring of walnut genetic resources in Kazakhstan and evaluation of promising selections. Int. J. Hortic. Sci. Technol. 7(2):93–102.

Akyuz, B., A. Ozturk, E. Ercan, and U. Serdar. 2018. The effect of grafting periods on graft success in top working of walnut. Int. J. Sci. Technol. Res. 4(9):183–186.

Barut, E. 2001. Different whip grafting methods on walnut. Acta. Hortic. 544(544):511–513. doi: 10.17660/ActaHortic.2001.544.70.

Chang, Y., X. Song, Q. Zhang, H. Liu, Y. Bai, X. Lei, and D. Pei. 2020. Genome-wide identification of WOX gene family and expression analysis during rejuvenational rhizogenesis in walnut (Juglans regia L.). Forests 11(16):2–20.

Dehghan, B., K. Vahdati, D. Hassani, and R. Rezaee. 2010. Bench-grafting of Persian walnut as affected by pre-and post-grafting heating and chilling treatments. J. Hortic. Sci. Biotechnol. 85(1):48–52. doi: 10.1080/14620316.2010.11512629.

Ebrahimi, A., K. Vahdati, and E. Fallahi. 2007. Improved success of Persian walnut grafting under environmentally controlled conditions. Int. J. Fruit Sci. 6(4):3–12. doi: 10.1300/J492v06n04_02.

Erdogan, V. 2006. Effect of hot callusing cable on graft success in walnut (Juglans regia L.) propagation: Nursery results. Indian J. Agric. Sci. 76:544–546.
Farsi, M., M.R. Fatahi Moghadam, Z. Zamani, and D. Hassan. 2018. Effects of scion cultivar, rootstock age and hormonal treatment on minigrafting of Persian walnut. Int. J. Hortic. Sci. Technol. 5(2):185–197.

Farsi, M., M. Fatahimoghadam, Z. Zamani, D. Hassan, and A. Ahmadi. 2016. The histology of minigrafting of Persian walnut trees cv. Chandler. Int. J. Hortic. Sci. Technol. 3(2):167–177.

Fernández-Moya, J., R.J. Licea-Moreno, I. Urbán-Martínez, R.M. Castro-Fernández, and C. Ramírez-López-Ramallal. 2020. Clonal effect on rooting and acclimation rates for in-vitro micropropagation in hybrid walnut (Juglans x intermedia Mj 209): Preliminary observations. Ann. Silvic. Res. 441:41–46.

Gandev, S., and V. Arnaudov. 2011. Propagation method of epicotyl grafting in walnut (Juglans regia L.) under production condition. Bulg. J. Agric. Sci. 17:173–177.

Gandev, S., V. Nikolova, D. Dimanov, P. Ivanov, and A. Dimitrov. 2019. Propagation of a local walnut cultivar ‘Izvor’ 10’by in vitro techniques and hot callus method. Acta. Hortic. 1259(1259):115–120. doi: 10.17660/ActaHortic.2019.1259.19.

Ghamari Hesabi, F., Y. Sharafi, S.J. Tabatabaei, and V. Grigurian. 2016. Effect of budding method, rootstock age and cut below budding union on budding success in Persian walnut. J. Nuts. 7:119–124.

Hartmann, H.T., D.E. Kester, F.T. Davies, and R. Geneve. 2014. Plant propagation: Principles and practices. Vol. 8. Pearson Prentice Hall, New Jersey, USA. p. 453–456.

Kömür, Y.K., and M. Sütyemez. 2017. Exploring the use of cleft grafting as a topworking method to change old walnut (Juglans regia L.) cultivars. Bahçe 46(2):299–306.

Nosrati, Z., and A. Khadivi-Khub. 2014. Effect of different budding methods and times on grafting success of walnut. Korean Journal of Horticultural Science and Technology 32(6):788–793. doi: 10.7235/hort.2014.14002.

Ramos, D.E. 1985. Walnut orchard management. Cooperative Extension, University of California Division of Agriculture and Natural Resource. 38–46.

Rezaee, R., and K. Vahdati. 2008. Introducing a simple and efficient procedure for top working Persian walnut trees. J. Am. Pomol. Soc. 62:21–26.

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

Sadeghi Majd, R. 2014. Comparing patch budding and tongue grafting in walnut under controlled and outdoor conditions. MSc thesis, University of Tehran. Tehran, Iran.

Sadeghi Majd, R., K. Vahdati, M.R. Rozban, and M. Arab. 2019. Exploring combinations of graft cover and grafting method in commercial walnut cultivars. Int. J. Fruit Sci. 19(4):359–371. doi: 10.1080/15538362.2018.1535355.

Sharma, M.K., and N.K. Joolka. 2005. COMPARISON OF BUDDING TECHNIQUES IN WALNUT (Juglans regia L.) PROPAGATION. Acta. Hortic. 696(696):181–183. doi: 10.17660/ActaHortic.2005.696.31.

Singh, L., M. Awashti, P. Negi, and M. Negi. 2019. Studies on success rate of grafting methods on walnut (Juglans regia L.) at different time under polyhouse condition. J. Pharmacogn. Phytochem. 8(4):2657–2659.

Thapa, R., P. Thapa, K. Ahamad, and K. Vahdati. 2021. Effect of grafting methods and dates on the graft take rate of Persian walnut in open field condition. Int. J. Hortic. Sci. Technol. 8(2):133–147.

Vahdati, K. 2003. Nursery Management and Grafting of Walnut. 2nd ed, pp.113(In Persian). Khaniran Publisher, Tehran.

Vahdati, K., and N. Zarei. 2006. Evaluation of side stub and hypocotyl grafting efficiency for walnut propagation in Iran. Acta. Hortic. 705:347–351.