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Optimizing propagation techniques and timing for pecan (*Carya illinoinensis*) under Poonch condition of Jammu region

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ABSTRACT

The present experiment was carried out during 2021–22 at Krishi Vigyan Kendra-Poonch, Sher-e-Kashmir University of Agricultural Sciences and Technology, Jammu, Jammu and Kashmir with the objective to determine the technique and time of propagation in pecan (*Carya illinoinensis* Wangenh). The experiment was laid down in randomized complete block design (RCBD) with three replications. The results of the present study indicated that effects of propagation techniques and timing had a significant influence on graft take success, days to first bud burst, survival percent, plant height and number of shoot/plant, number of leaves/plant, rootstock diameter, plant spread N-S and E-W, total plant biomass. Out of different propagation techniques and timings, viz. whip grafting and four flap grafting in 2nd week of February and March, respectively patch budding and ring budding in 2nd week of July and August, respectively. The patch budding performed in August emerged as the most successful method, yielding the highest graft success (63.29%), and early bud sprouting (18.00 days), while whip grafting in March excelled in vegetative parameters, including plant height (55.20 cm), plant spread [N-S (49.00 cm), E-W (57.67 cm)], leaf count (57.33), rootstock diameter (0.66 cm), and biomass (121.00 g). Four flap grafting in February exhibited lower success rates (31.62%) and slower growth. These findings underscore the importance of selecting appropriate grafting methods and timings to optimize pecan propagation under varying climatic conditions, aiming to enhance productivity and quality in commercial cultivation practices.

Keywords: Four flap grafting, Graft success rate, Patch budding, Propagation methods, Whip grafting

The pecan (*Carya illinoinensis* Wangenh), native to the North America (Alvarez-Parrilla *et al.* 2018) and belonging to the Juglandaceae family, is esteemed as the "queen of nuts" for its value both in the wild and in cultivation (Woodroof 1979). The pecan tree has been prized for its nuts, which have been a staple in the human diet for around 10,000 years (Wells 2017). The cultivation of pecan trees began relatively recently, with the first known planting in northern Mexico at the end of the 1600s in the town of Bustamante (Sparks 2005). Pecan nuts are highly nutritious, offering 691 kcal/100 g, with 9.17% protein, 72% lipid, 13.9% carbohydrate, and 9.6% fiber (USDA 2019). They are rich in monounsaturated (60%) and polyunsaturated (32%) fatty acids, as well as tocopherols, especially dietary γ-tocopherol and varying amounts of α-tocopherol (Atanosov *et al.* 2018). The pecan nut oil is low in cholesterol and rich in antioxidants and phytosterols, which contribute to cardiovascular health (Rajaram 2001, Jose 2007, Bhardwaj 2017, Hussain *et al.* 2021). Pecans offer benefits comparable to those of almonds and walnuts. (Atanosov *et al.* 2018).

In India, pecans are cultivated in Jammu and Kashmir, Himachal Pradesh, Uttarakhand, and the Nilgiri Hills, covering approximately 1,000 ha. This crop holds immense potential for cultivation in Jammu regions where its agro-climatic conditions are favourable. Despite the favourable growing conditions in Jammu and Kashmir, pecan cultivation faces significant challenges. Trees grown from seed exhibit inconsistent growth, yield, and nut quality, hindering their commercialization. Although grafting and budding with cultivars like Mahan, Nellish, and Burkett are practiced, a lack of standardized propagation methods, coupled with challenges in nursery management, low germination rates, and long juvenile periods, limits the availability of quality planting material. This reliance on seedling propagation often results in small, thick-shelled nuts, whereas grafted trees typically produce larger, thinner-shelled nuts with superior qualities (Mehta *et al.* 2018). Pecans are low-

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input orchard trees, but uncontrolled pollination makes it difficult to reliably pass on the desirable characteristics of the parent tree through seeds. Grafting a quality scion onto compatible rootstock can create an identical tree with assured fruit quality (Onay 2000). Commercial nurseries utilize different grafting techniques, with cleft and side grafting being particularly popular for rootstocks with trunk diameters between 4 cm and 6 cm. The four-flap grafting method, successful in Oklahoma since 1975, is effective for transforming small trees and larger branches but has not been compared with other techniques like whip grafting, ring budding, and patch budding in India. To improve pecan propagation, there is a need to study and compare these methods. Achieving the highest success rates and optimal plant growth requires standardizing and optimizing propagation techniques and timing.

MATERIALS AND METHODS

The present experiment was carried out during 2021–22 at Krishi Vigyan Kendra-Poonch, Sher-e-Kashmir University of Agricultural Sciences and Technology, Jammu (33°45.969'N and 74°06.814'E; with an altitude 992 m amsl), Jammu and Kashmir. Meteorological data during the period of investigation showed annual precipitation is about 1200-1400 mm. The maximum temperature rises up to (28.67°C) during summer and minimum temperature falls to (-2.57°C) during winter.

The experiment was carried out with different time and grafting methods in pecan nut var. SKJPP25-JammuT_1. The treatments (T_1, Whip grafting in 2nd week of February; T_2, Whip grafting in 2nd week of March; T_3, Four flap grafting in 2nd week of February; T_4, Four flap grafting in 2nd week of March; T_5, Patch budding in 2nd week of July; T_6, Patch budding in 2nd week of August; T_7, Ring budding in 2nd week of July; T_8, Ring budding in 2nd week of August) were replicated thrice with 20 plants/replication and the experiment was laid down on randomized complete block design (RCBD). The seedlings for propagation studies were raised in the field at KVK, Poonch, Sher-e-Kashmir University of Agricultural Sciences and Technology, Jammu. The seedlings, approximately two-years old and about the thickness of a pencil, were selected for propagation studies based on their healthy appearance. They were utilized as rootstocks once their stems reached a diameter of 0.5 cm. To prevent desiccation due to hot weather, the bud-woods were kept moist by wrapping them in damp gunny bags until the grafting operation. For grafting, scion sticks with a minimum of 3–4 buds were utilized. To assess vegetative characteristics i.e. number of days to bud burst, per cent graft take success, percent graft survival, percentage sprouting, plant height, number of shoots/plant, number of leaves/plant, diameter of rootstock, plant spread and total plant biomass, biometric measurements were taken from five randomly chosen plants in each replication. The data on the per cent graft take success and per cent sprouting were recorded after 90 days of grafting and assessed by the formula used by Soleimani *et al.* (2010).

$$\text{Per cent graft success} = \frac{\text{Number of graft sprouted}}{\text{Total sum of grafted plants}} \times 100$$

To determine the number of days until sprouting, observations were made every other day from the grafting date until the first bud appeared, and the average of these observations was used to calculate the days to the first sprout. Plant height was measured from the ground to the tip of the stem using a measuring scale. For the number of shoots per plant, all the branches were taken into account and the average number of branches/plant was calculated**.** All cultural practices, such as fertilization, irrigation, weeding and hoeing were uniformly implemented throughout the research study. The data collected during the investigations were analyzed statistically according to the methods outlined by Panse and Sukhatme (2000).

RESULTS AND DICUSSION

Graft take success: The percentage of sprouting in pecans was significantly affected by the timing and methods of propagation. As shown in Fig. 1, the highest success rate (63.29%) was achieved with patch budding in 2nd week of August which was notably higher than any other method followed by patch budding in 2nd week of July (59.93%) and whip grafting in 2nd week of March (59.39%). However, lowest value for percent graft take success was observed in T_3 i.e. Four flap grafting in 2nd week of February (31.62%). The superior success rate of patch budding compared to other methods could be attributed due to the seamless integration of bark and larger areas of bark and cambium tissue that facilitate better contact between the stock and scion after the budding process. Likewise, Z-shaped cut in whip grafting provide additional strength and offers most cambium contact that heals quickly. The lowest percentage of successful bud-take observed four flap grafting is because the graft wood did not have sufficient time to store nutrients after being collected (Mehta *et al.* 2018). The highest success rate in patch budding aligns with Ebrahimi *et al.* (2007) for Persian walnut. Similarly, Gurjar *et al.* (2012) reported an 80–90% success rate for wedge grafting performed in guava between September and March. In the line with this, Nosrati and Khadivi-Khub (2014) found high graft success rate (80%) in walnut when patch budding during early-August. However, Thapa *et al.* (2021) found that bench grafting in walnut conducted on February 13th resulted in the highest overall graft take rates.

Number of days for first bud sprout: Among the different propagation methods and times, the shortest time to bud sprouting was observed with patch budding in the 2nd week of August, which took 18.00 days (Table 1). This result was statistically comparable to patch budding in the 2nd week of July, which took 21.00 days and was significantly shorter than all other methods. In contrast, the longest time to bud burst was observed with four flap grafting performed in the 2nd week of March, which took 48.00 days. The lesser time taken by the patch budding to sprout might be due to early contact of cambial layers of

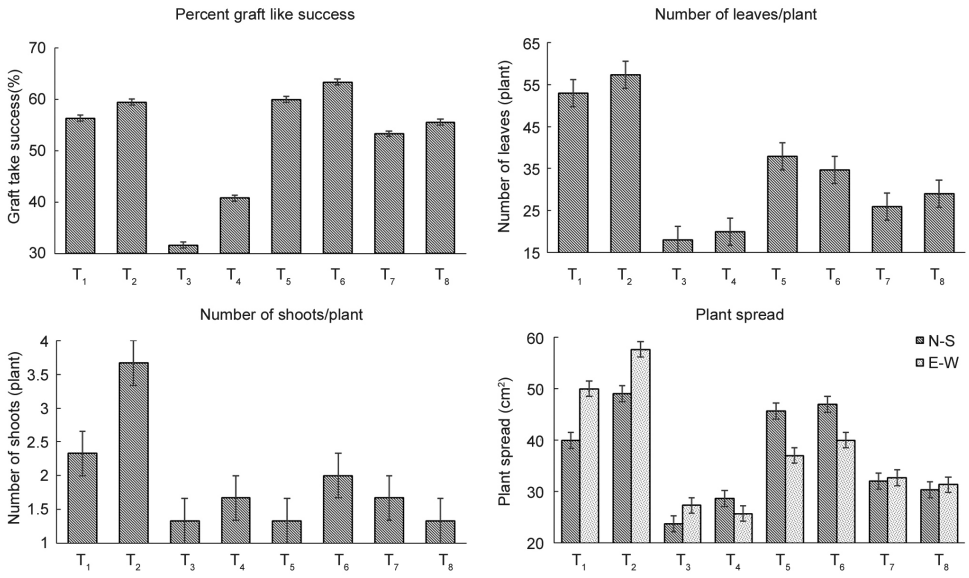

Fig. 1 Effect of different propagation methods and time on graft take success and different growth parameters.
Treatment details are given under Materials and Methods.

stock and scion. This may be due to the ideal temperature, high relative humidity and efficient sap flow in the stock and scion at this time, which supported the development of callus and early healing process. These results are consistent with comparable findings were reported by Ahmad *et al.* (2007) in walnut when budding was performed in late July. Moreover, our finding contradict with the findings of Mir and Kumar (2011) in walnut who noted an earlier bud burst (29 and 32 days), when plants were grafted during the 3rd and 4th weeks of February.

Graft survival percentage: A significant influence on percent survival of pecan nut was observed by different method and time of propagation. At the end of the growing season, the highest survival rate of 44.38% was recorded for whip grafting conducted in 2nd week of March followed by patch budding in 2nd week of July (41.82%) and whip grafting in 2nd week of February (41.24%). However lowest value for survival percentage was observed in four flap grafting in 2nd week of February (18.56%). Higher graft success during these months can be linked to two primary reasons firstly, the accumulation of carbohydrates (Karabulut and Celik 2022), and secondly, favourable temperature and humidity throughout and following the grafting procedure. These conditions are critical for graft survival, as they promote proper callus formation while minimizing stress on the grafts. The lower survival rate of four-flap grafts in February is likely due to reduced cambial activity and difficulty in slipping the bark, as the stock is not actively growing (Nesbitt *et al.* 2002). Higher survival rates correspond with Mehta *et al.* (2018), who demonstrated that tongue grafting conducted during the first week of March yielded the highest survival rates, with a subsequent survival rate when the procedure was carried out in the second week of March.

Plant height and number of shoots/plant: Analysis of data on the influence of propagation time and method on plant height, revealed that the highest plant height was observed with whip grafting in the second week of March (55.20 cm) (Table 1). This was statistically similar to whip grafting in the second week of February (53.00 cm). The lowest plant height was recorded with ring budding in the second week of August, measuring 22.00 cm. These results were consistent with the findings of Ahmed *et al.* (2012) in mangoes, where the maximum plant height (188.94 cm) was achieved with open field grafting on 15 March. The data on the impact of propagation time and method on the number of shoots/plant indicated in Fig. 1. The highest number of shoots in pecan propagated at various intervals, was achieved with whip grafting in the second week of February (3.67). This was significantly higher compared to all other treatments. Following this was patch budding in the second week of August (2.00). The lowest number of shoots/plant was observed with four-flap grafting in the second week of February, patch budding in the second week of July, and ring budding in the second week of August (1.33 each). The increased number of shoots may be due to favourable temperatures that promote hormone production and the mobilization of energy-producing nutrients (Singh *et al.* 2019). This, in turn, activates the dormant scion and rootstock, leading to rapid regeneration and intermingling of cambium tissues. A complete graft union ensures efficient nutrient uptake, which enhances plant growth and consequently increases plant height. These findings align with those of Lanzes *et al.* (2023) in custard apple, where softwood grafting conducted in January resulted in the highest number of shoots/plant.

Number of leaves/plant: Among the various grafting times and methods, whip grafting in the second week of March, conducted after the growing season ended, resulted in the highest number of leaves (57.33) (Fig. 1). This was statistically similar to whip grafting in the second week of February (53.00). The lowest number of leaves/plant was recorded with four-flap grafting in the second week of February. The robust plant structure likely contributed to efficient nutrient uptake, promoting faster growth after graft union. Similarly, Ahmed *et al.* (2012) found an increased number of leaves/scion in walnut plants with tongue grafting. This aligns with the findings of Wani *et al.* (2017) in Kashmir, where the highest number of leaves (42.5) was recorded on April 10th. Conversely, Mehta *et al.* (2018) reported that tongue grafting in the first week

Table 1 Effect of propagation methods and timing on the number of days to bud burst and various vegetative parameters

Propagation methods	Time of propagation	Number of days to bud sprout (days)	Plant height (cm)	Number of leaves per plant	Diameter of rootstock (cm)	Diameter of scion (cm)	Graft survival percentage	Total plant biomass (g)
Whip grafting	2nd week of February	37.67	53.00	53.00	0.65	0.48	41.24	121.00
Whip grafting	2nd week of March	39.33	55.20	57.33	0.66	0.50	44.38	119.00
Four flap grafting	2nd week of February	41.00	29.00	18.00	0.54	0.30	18.56	92.00
Four flap grafting	2nd week of March	48.00	28.00	20.00	0.52	0.32	21.05	89.00
Patch budding	2nd week of July	21.00	45.00	38.00	0.65	0.46	37.53	108.00
Patch budding	2nd week of August	18.00	41.00	34.67	0.64	0.44	41.82	104.00
Ring budding	2nd week of July	23.00	25.00	26.00	0.60	0.38	33.15	99.00
Ring budding	2nd week of August	25.00	22.00	29.00	0.62	0.41	34.68	102.00
CD (0.05%)		3.39	4.19	9.83	0.07	0.04	1.80	16.58
SE(m)		1.10	1.36	3.21	0.02	0.01	0.58	5.41

of March resulted in longer scions, thicker scions, and a higher number of leaves.

Rootstock diameter: The greatest rootstock diameter was noted in T_2 (whip grafting in the 2nd week of March) at 0.66 cm, which was statistically similar to T_1 (whip grafting in the 2nd week of February) at 0.65 cm, T_5 (patch budding in the 2nd week of July) at 0.65 cm, T_6 (patch budding in the 2nd week of August) at 0.64 cm, T_7 (ring budding in the 2nd week of July) at 0.60 cm, and T_8 (ring budding in the 2nd week of August) at 0.62 cm. The minimum diameter was in T_4 (four flap grafting in the 2nd week of March) at 0.52 cm. The larger rootstock diameter can be attributed to the enhanced growth of the graft union, which likely facilitated more efficient nutrient and water uptake, promoting strong growth. Similar findings were reported by Hussain *et al.* (2016) in chestnut and Patil *et al.* (2017) in custard apple, who noted the maximum rootstock girth (11.43, 11.63, and 11.88 mm) when grafting was performed on February 16th.

Plant spread N-S and E-W: Plant Spread (NS-EW direction) of pecan nut was influenced by different method and time of propagation as presented (Fig. 1) showed significant differences. The maximum plant spread in the north-south direction was recorded in T_2 (whip grafting in the 2nd week of March) at 49.00 cm, followed by T_6 (patch budding in the 2nd week of August) at 47.00 cm and T_5 (patch budding in 2nd week of July) at 45.67 cm. In the east-west direction, T_2 also had the maximum spread (57.67 cm), followed by T_1 (whip grafting in the 2nd week of February) at 50.00 cm. The minimum spread in both directions was in T_3 (four flap grafting in the 2nd week of February) at 23.67 cm (N-S) and 27.33 cm (E-W). The increased plant spread can be attributed to the use of healthy, mature scion sticks rich in carbohydrates and other biochemical constituents, which resulted in early sprouting and enhanced food assimilation, promoting plant growth in both vertical and horizontal directions (Chalise *et al.* 2021). Furthermore, favourable weather conditions during the grafting period may have activated swollen buds and increased the number of leaves, leading to vigorous vegetative growth and a consequently wider plant canopy (Lanzes *et al.* 2023). The increased plant spread during August might be driven by optimal *p*H and soil moisture, which enhance nutrient absorption (Nosrati and Khadivi-Khub 2014). The canopy spread (N-S, E-W) showed a positive correlation with weather parameters (Ghosh *et al.* 2021), indicating that favourable weather conditions, such as high humidity and moderate temperatures, contributed to the expansion of the plant's canopy spread. Chalise *et al.* (2021) found that the effect of grafting dates on plant spread was significant and the highest plant spread was observed with grafting on March 22nd, followed by March 15th and April 5th.

Total plant biomass: The data on total plant biomass from different vegetative propagation methods and times is summarized in Table 1. The highest total plant biomass was recorded in T_1 (whip grafting in the 2nd week of February) at 121.00 g, statistically similar to T_2 (whip grafting in the 2nd week of March) at 119.00 g and T_5 (patch budding in the 2nd week of July) at 108.00 g. The lowest biomass was in T_4 (four flap grafting in the 2nd week of March) at 89.00 g. The results align with Roshan *et al.* (2013) findings in mango and Aswar (2013) in sapota. The increase in total biomass can be attributed to the greater plant height and the number of leaves, which contribute to higher carbohydrate production necessary for the plant's vegetative growth, ultimately leading to increased biomass.

Based on the results of the present investigation, it is concluded that whip grafting, performed in the 2nd week of March and February, demonstrated superior performance across key parameters such as graft survival percentage, number of shoots per plant, plant height, number of leaves per plant, rootstock diameter, and biomass. Therefore, this time and method of pecan propagation can be recommended to meet the growing demand for high-quality plant material in commercial cultivation practices propagation.

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