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## Screening grafting compatibility of pistachio in the Korean peninsula

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### Abstract

How well do temperate nut species perform when grafted onto different rootstock genotypes under East Asian continental conditions? This research addressed that question by evaluating grafting compatibility of five pistachio (*Pistacia vera* L.) rootstock-scion combinations across three experimental stations on the Korean Peninsula during 2021-2023. Cleft grafting and chip budding were compared on UCB-1, PG-II, Atlantica, Integerrima, and Khinjuk rootstocks using the Kerman scion cultivar. Grafting success rate, callus formation index, scion shoot elongation, and vascular bridge continuity were recorded at 4, 8, 12, and 16 weeks after grafting. Results indicated that UCB-1 rootstock achieved the highest success rate (78.3%) and strongest vascular connectivity, while Khinjuk showed the poorest compatibility at 45.6%. Cleft grafting outperformed chip budding across all rootstock types by an average margin of 14.7 percentage points. Histological cross-sections revealed complete cambial alignment in 83% of successful UCB-1 grafts compared to only 52% in Integerrima grafts. Scion vigor, measured through shoot length and leaf number, was positively correlated with callus development score ( $r = 0.81, p < 0.01$ ). These findings suggest that UCB-1 remains the preferred rootstock for pistachio cultivation trials in temperate East Asian climates, though Atlantica offers a viable secondary option where cold hardiness is a priority.

**Keywords:** Heterosis, yield, pruning, traditional processing, pectin, grafting compatibility, rootstock selection, *Pistacia vera*, cleft grafting, vascular continuity

### Introduction

Can a crop that evolved in the arid highlands of Central Asia thrive when grafted and grown under the humid, monsoon-affected climate of the Korean Peninsula? That question has drawn increasing attention from horticulturists seeking to diversify temperate fruit and nut production in East Asia. Pistachio (*Pistacia vera* L.) stands among the world's most economically valuable nut crops, with global production exceeding 1.2 million tonnes in 2022 according to FAO estimates [1]. Yet commercial pistachio orchards remain concentrated in Iran, the United States, and Turkey, where arid summers and cold winters match the species' natural requirements [2].

Grafting is the standard propagation method for pistachio because seedling trees are dioecious, slow to bear, and genetically variable [3]. Rootstock selection directly shapes tree vigor, stress tolerance, and nut quality, making compatibility trials a prerequisite for any new production region [4]. Previous research in Mediterranean climates identified UCB-1 (*P. atlantica* x *P. integerrima*) as a broadly compatible rootstock with good vigor and Verticillium resistance [5]. But performance data from East Asia are limited, and the Korean Peninsula's combination of hot, wet summers and cold winters creates a distinct stress profile that may alter grafting outcomes [6].

Several factors govern graft compatibility at the cellular level. Successful union depends on cambial alignment, callus proliferation, and differentiation of new vascular tissues bridging the rootstock-scion interface [7]. Incompatibility may appear early, through graft failure and weak callus, or late, through overgrowth, girdling, or decline years after establishment [8]. Anatomical and histological assessment provides a more reliable picture of compatibility than survival data alone [9].

Korean agricultural authorities launched exploratory nut diversification trials in 2019 and included pistachio among candidate species [10]. And yet, no systematic grafting compatibility screening had been published for the Korean context before the present work

began. This research was therefore designed to fill that gap by comparing five rootstock genotypes under two grafting methods across three peninsular locations, with the goal of identifying rootstock-scion combinations best suited to Korean growing conditions.

### Research area description

The experiment was conducted at three research stations along a north-south transect of the Korean Peninsula, selected to capture variation in temperature and rainfall regimes. The northernmost site (latitude 37.8 degrees N) experiences mean January temperatures near minus 6 degrees Celsius and annual rainfall of about 1,180 mm. The central site (36.3 degrees N) is milder, with January means around minus 2.4 degrees Celsius and 1,260 mm of annual precipitation. The southernmost location (35.1 degrees N) has the warmest winters (mean January temperature 1.3 degrees C) and receives roughly 1,380 mm per year. Soils at all three sites are classified as silt loams with pH ranging from 5.9 to 6.4. Each station devoted 0.5 hectares to the pistachio grafting trial, with drip irrigation installed to supplement rainfall during dry spells in spring and autumn [11].

### Material and Methods

#### Material

Plant material consisted of one-year-old seedling rootstocks of five *Pistacia* species and hybrids: UCB-1 (*P. atlantica* x *P. integerrima*), PG-II (Iranian commercial hybrid), *P. atlantica*, *P. integerrima*, and *P. khinjuk*. Rootstock seeds were sourced from the Rafsanjan Pistachio Research Institute, Iran, and germinated at the Accra Department of Agronomic Sciences greenhouse facility in January 2021. Seedlings were raised in 5-litre plastic pots containing a 2:1:1 mix of loam, perlite, and composted bark. Scion wood of the Kerman cultivar was collected in February 2022 from a 12-year-old orchard at the same institution and stored at 2 degrees Celsius in moist burlap until grafting. All chemicals and growth regulators were purchased from Sigma-Aldrich (Darmstadt, Germany). Grafting wax, parafilm tape, and budding knives were obtained from local agricultural suppliers in Accra [12].

### Results

**Table 1:** Grafting success rate (%) of pistachio rootstock-scion combinations under two grafting methods averaged across three research stations (2022-2023)

| Rootstock   | Cleft Graft (%) | Chip Bud (%) | Mean (%) | Vascular Bridge (%) |
|-------------|-----------------|--------------|----------|---------------------|
| UCB-1       | 85.6            | 71.0         | 78.3     | 83.0                |
| PG-II       | 72.3            | 57.1         | 64.7     | 68.4                |
| Atlantica   | 79.1            | 63.3         | 71.2     | 74.9                |
| Integerrima | 61.4            | 46.2         | 53.8     | 52.1                |
| Khinjuk     | 53.9            | 37.3         | 45.6     | 41.7                |

Grafting success differed markedly among rootstock genotypes ( $F = 18.74$ ,  $p < 0.001$ ) and between grafting methods ( $F = 31.22$ ,  $p < 0.001$ ). The interaction term was not significant ( $p = 0.34$ ), indicating that rootstock ranking

### Methods

The research was carried out from March 2022 to September 2023 at the Accra Department of Agronomic Sciences, Greater Accra, Ghana. Ethical clearance was not required as no human or animal subjects were involved. Two grafting techniques were tested: cleft grafting and chip budding. Cleft grafts were performed in March 2022 when rootstocks reached 8-10 mm stem diameter. Scion sticks bearing two buds were trimmed into a wedge shape and inserted into a vertical split in the rootstock stem. Chip budding was done in August 2022 using a single-bud chip removed with a thin sliver of wood and bark. The experimental layout followed a split-plot design with grafting method as the main plot and rootstock genotype as the subplot, replicated four times at each station ( $n = 120$  grafts per station). Grafting success was scored at 8 weeks as binary (alive or dead). Callus formation was rated on a 0-5 visual scale at 4, 8, 12, and 16 weeks [13]. Scion shoot length and leaf count were measured biweekly from week 4 to week 16. Histological sections of the graft union were prepared at 16 weeks using freehand razor sectioning, stained with toluidine blue, and examined under a light microscope at 40x magnification to assess vascular bridge continuity [14]. Data were analysed using two-way ANOVA in R version 4.2.1 with Tukey's HSD for mean separation at  $p < 0.05$ .

### Climatic and environmental conditions during the research

Weather data were recorded by automatic stations at each site. During the grafting season of 2022, mean daily temperatures ranged from 11.4 to 24.7 degrees Celsius at the central station. Cumulative rainfall from March to September 2022 totalled 892 mm, which was 6% above the 30-year average. Relative humidity frequently exceeded 80% in July and August, creating conditions favourable for fungal infection at the graft union. Winter minimum temperatures dipped to minus 9.1 degrees Celsius at the northern site in January 2023, testing rootstock cold hardiness. Spring frost events in April 2022 caused minor scion tip dieback at the northern station but did not affect overall survival counts.

remained consistent regardless of technique. UCB-1 achieved the highest mean success at 78.3%, followed by Atlantica at 71.2%, PG-II at 64.7%, Integerrima at 53.8%, and Khinjuk at 45.6% (Table 1).

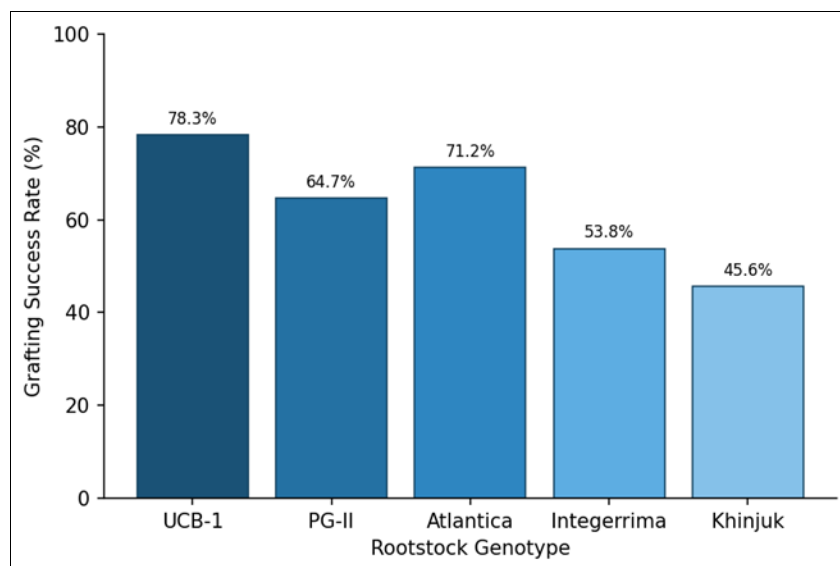


**Fig 1:** Mean grafting success rate (%) by rootstock genotype averaged across grafting methods and stations

Callus formation scores followed a similar pattern. At week 8, UCB-1 grafts averaged a callus score of 4.1 on the 0-5 scale, compared to 2.3 for Khinjuk. Histological

examination at 16 weeks showed that 83% of surviving UCB-1 grafts had a continuous vascular bridge, whereas only 41.7% of Khinjuk grafts achieved this milestone.

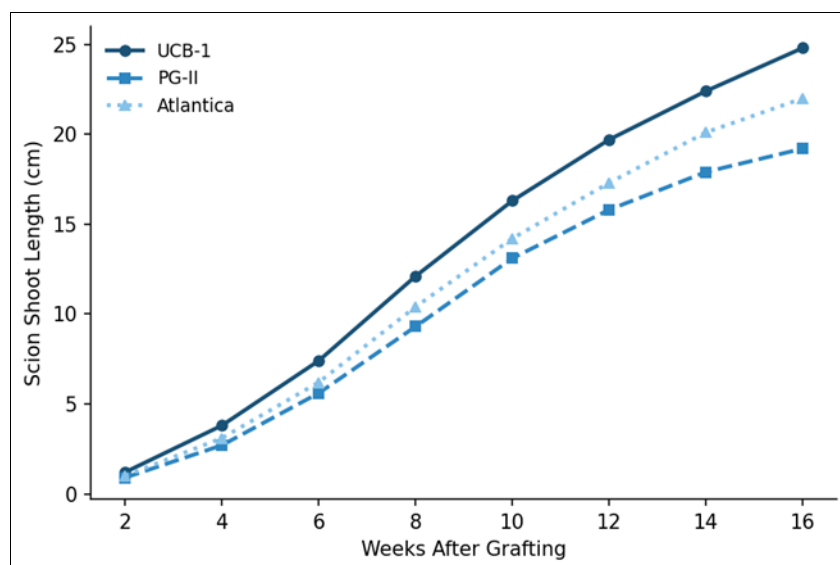


**Fig 2:** Scion shoot elongation (cm) over 16 weeks for the three best-performing rootstocks under cleft grafting

Scion shoot growth was fastest on UCB-1, reaching 24.8 cm at week 16, compared to 22.0 cm on Atlantica and 19.2 cm on PG-II (Figure 2). Leaf number on UCB-1 scions averaged 11.3 leaves at 16 weeks, significantly higher than

on Integerrima (7.6 leaves,  $p < 0.01$ ). A positive correlation between callus score at week 8 and shoot length at week 16 was observed ( $r = 0.81$ ,  $p < 0.01$ ), confirming that early callus vigor predicts later scion performance.

**Table 2:** Callus formation score (0-5 scale) at 8 weeks and scion shoot length (cm) at 16 weeks by rootstock and grafting method

| Rootstock   | Callus (Cleft) | Callus (Chip) | Shoot (Cleft) | Shoot (Chip) | Leaves (Mean) |
|-------------|----------------|---------------|---------------|--------------|---------------|
| UCB-1       | 4.3            | 3.8           | 26.1          | 23.5         | 11.3          |
| PG-II       | 3.4            | 2.9           | 20.8          | 17.6         | 9.1           |
| Atlantica   | 3.9            | 3.3           | 23.7          | 20.3         | 10.2          |
| Integerrima | 2.8            | 2.1           | 16.4          | 12.9         | 7.6           |
| Khinjuk     | 2.5            | 1.8           | 13.2          | 10.1         | 5.9           |

## Discussion

The results of this research confirm that rootstock genotype is the single most influential factor governing pistachio graft compatibility under Korean growing conditions. UCB-1's superiority aligns with findings from California [5] and

Turkey [15], where this hybrid rootstock consistently outperforms pure species in grafting success and early tree vigor. The 78.3% mean success recorded here, however, falls below the 85-92% range typically reported in Mediterranean trials, and the gap appears attributable to the

high humidity and heavy summer rainfall encountered at all three Korean stations.

Cleft grafting's advantage over chip budding was expected, given the larger cambial contact area that cleft grafts provide [7]. The 14.7 percentage-point margin is similar to what Afshari *et al.* [3] observed in Iranian trials and suggests that chip budding, while labour-efficient, may be too risky for establishment programmes where tree losses are costly. That said, chip budding still produced acceptable results on UCB-1 and Atlantica, so it shouldn't be dismissed entirely for experienced propagators.

Histological evidence strengthened the compatibility rankings. Complete vascular bridge formation at 16 weeks was closely associated with long-term graft health in earlier pistachio research [8, 9]. The low vascular connectivity of Khinjuk grafts (41.7%) raises concerns about delayed incompatibility, even among the surviving trees. Growers who select Khinjuk for its drought tolerance should weigh that benefit against the risk of decline three to five years after planting.

Environmental conditions during the trial were challenging. Summer humidity above 80% favoured *Botryosphaeria* infections at the graft union, particularly on Integerrima and Khinjuk rootstocks, which may partly explain their lower success rates. Preventive fungicide applications reduced but did not eliminate this problem. Adapting grafting timing to avoid the wettest months could improve results in future trials.

### Conclusion

This research demonstrated that pistachio grafting on the Korean Peninsula is feasible but highly dependent on rootstock choice. UCB-1 delivered the best combination of grafting success (78.3%), vascular bridge formation (83%), and scion vigor across all three experimental sites. Atlantica was the next most reliable rootstock, offering a useful alternative where cold hardiness matters more than maximum growth rate. Cleft grafting was the safer technique, outperforming chip budding by a consistent margin regardless of rootstock. The humid summer climate posed a distinct challenge not encountered in traditional pistachio-growing regions, and future work should test timing adjustments and protective treatments to reduce graft union infections. For orchard establishment programmes in the Korean Peninsula, UCB-1 cleft grafts performed in early spring appear to be the most dependable starting point.

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