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Peach (*Prunus persica*) cultivation in ancient Korea: an archaeobotanical examination

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ABSTRACT

Archaeobotanical research has traditionally prioritized seed-propagated annual crops, with comparatively limited attention given to the cultivation of woody perennial plants. To address this gap, this study examines peach endocarps recovered from Korean archaeological sites to explore the social context of peach cultivation. While peach endocarps are occasionally found at prehistoric sites, evidence for their cultivation in the region before 100 BC remains limited. Although the social conditions necessary for arboriculture—long-term land investment and territoriality—were established at many prehistoric sites, fruit tree cultivation did not emerge until after 100 BC. Peach endocarps from Sinchang-dong (ca. 14 BC–AD 243) exhibit traits indicative of incomplete domestication—elongated and compressed, yet relatively small—suggesting an early cultivation stage or the harvesting of feral forms. In contrast, later peach endocarps are significantly larger, elongated, and compressed, resembling modern cultivars. The inclusion of peaches as burial goods after approximately 100 BC highlights their symbolic values, which potentially facilitated the expansion of peach cultivation across the Korean Peninsula during the first millennium AD.

1. Introduction

Trees are vital to human sustenance and contribute significantly to landscapes and cultural symbolism. However, tree management and cultivation remain relatively underexplored in archaeobotanical research. Korean archaeological studies have traditionally focused on seed-propagated annual crops, such as rice (*Oryza sativa* L.), millets (*Setaria italica* (L.) P. Beauvois and *Panicum miliaceum* L.), wheat (*Triticum aestivum* L.), and legumes (*Glycine* max (L.) Merr. and *Vigna angularis* (Willd.) Ohwi & H. Ohashi) (Ahn, 2010; Crawford and Lee, 2003; Kim, 2013; Kim et al., 2013; Lee, 2011; Lee et al., 2011). Since 2010, research has increasingly examined human interactions with perennial woody plants, such as chestnut (*Castanea*), cedar (*Cryptomeria*), zelkova (*Zelkova*), and azalea (*Rhododendron*), through palynological and anthracological analyses (Ahn, 2020; Kim, 2011; Kim and Park, 2014; Li, 2022). Building on this shift, this study focuses on the peach tree (*Prunus persica* (L.) Batsch), a major fruit-bearing species in East Asia.

The history of peach cultivation in ancient Korea remains poorly understood. As noted by Ahn (2015), it is unclear whether the Korean Peninsula fell within the natural range of wild peach ancestors, which may have comprised multiple species now presumed extinct (Fuller and Stevens, 2019; Yazbek and Al-Zein, 2014; Zheng et al., 2014). Peach remains recovered from prehistoric Korean sites, therefore, represent a range of possibilities: extinct wild progenitors, transitional domesticates, fully domesticated varieties, or feral types that reverted from cultivation. Peach endocarps recovered from Korean archaeological sites exhibit considerable morphological variation. Researchers have tentatively identified them as *Prunus persica* or *P. davidiana* (Carrière) Franch., while observing gradual differences in shape (Ahn, 2015). If peaches were non-indigenous to the Korean Peninsula but introduced from elsewhere, crucial questions remain regarding the timing of their introduction, the development of local peach cultivation, and their cultural and symbolic significance in antiquity.

Building on previous research in the domestication of tree crops, this study examines peach cultivation in ancient Korea. Domestication processes are known to involve selective pressures for desirable traits, such as increased fruit flesh, resulting in morphological changes in seed size and shape (Bacilieri et al., 2017; Dighton et al., 2017; Fuller, 2018; Gros-Balthazard et al., 2016; Goldschmidt, 2013; Li et al., 2024; Liphschitz et al., 1996; Newton et al., 2014; Pagnoux et al., 2015; Rivera

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et al., 2014; Terral et al., 2004; Ucchesu et al., 2017). In peaches, domestication syndromes are characterized by larger endocarps, which are correlated with increased mesocarp mass (Fuller, 2018; Su et al., 2015; Zheng et al., 2014). Additional traits include elongated, compressed endocarps with pointed apices (Fuller, 2018; Zheng et al., 2014), although some traits may have preceded intentional human selection (Su et al., 2015). These morphological characteristics provide a basis for evaluating archaeological peach remains: endocarp size aids in identifying domesticated specimens, while shape variation provides insight into varietal differentiation.

The relationship between arboriculture and social complexity is a recurring focus in archaeological research (Fuller and Stevens, 2019; Gilman, 1981; Langgut, 2024; Langgut and Garfinkel, 2022; Pérez-Jordà et al., 2017). Fruit tree cultivation demands long-term land tenure and sustained landscape investment, conditions closely linked to the development of complex social systems. Throughout the Holocene, populations on the Korean Peninsula developed varying relationships with their surrounding landscapes. During the Chulmun period (8000–1500 BC), communities were residentially sedentary but frequently underwent group fission and relocation (Kim, 2022). In the subsequent Mumun (1500–1 BC) and Proto–Three Kingdoms (AD 1–300) periods, fully sedentary agricultural communities developed, characterized by the cultivation of diverse annual crops and water management systems. From around AD 300, state-level societies emerged, marked by intensified landscape management and expanded territorial control (Yi, 2022). These shifts indicate that the social incentives and conditions for fruit tree cultivation varied over time; investment in tree crops was possibly shaped by specific socioeconomic and symbolic contexts.

In East Asia, the peach is one of the most frequently referenced fruit trees in historical records and mythological narratives. These sources highlight its significance beyond consumption, underscoring its symbolic relation with wealth, longevity, and protection against evil (Ahn, 2015; Lu, 2012; Qu, 2007; Wang, 1999). As an early-flowering species, the peach marks the arrival of spring, symbolizing the end of winter and contributing to the creation of vibrant, flower-filled landscapes (Ji and Liang, 2006; Wang, 2014; Yao, 2011). Therefore, the importance of the peach lies not only in its value as a food resource but also as a symbol and agent in shaping culturally meaningful landscapes.

Building on previous archaeobotanical research, this study aims to compare the morphometric data from peach endocarps and situate the findings within archaeological, historical, ethnographic frameworks. By integrating multiple lines of evidence, this study could provide new insights into peach cultivation and its cultural significance in ancient Korea.

2. Archaeological background

2.1. Peach: classification and botanical remains

Peach (*Prunus persica* (L.) Batsch), a member of the Rosaceae family, belongs to the subgenus *Amygdalus* (Bielenberg et al., 2009). According to the Korean National Arboretum database (2024), the Korean Peninsula hosts over 20 species of *Prunus*, including apricot (*P. armeniaca*), Japanese apricot (*P. mume*), cherry (*P. tomentosa*), and plum (*P. salicina*). The origins of cultivated peach remain uncertain, as no wild populations have been identified, and its wild ancestors are presumed extinct (Zheng et al., 2014; Yu et al., 2018). High genetic diversity observed in Chinese peach varieties supports the hypothesis of an early and prolonged cultivation history in the region, possibly originating in the Yangtze River basin (Bielenberg et al., 2009; Huang et al., 2008; Yoon et al., 2006; Zheng et al., 2014).

The peach endocarp is lignified, ovate, and laterally compressed, with an acute apex and an obtuse base. It features a deep vascular bundle canal groove on the dorsal side and a ridge on the ventral side, both extending from apex to base. Peach (*P. persica*) and its closely related species (e.g., *P. mira*, *P. kansuensis*, *P. ferganensis*, and *P. davidiana*) have relatively large endocarps (typically >1.5 cm in length) with deeply furrowed and pitted surface. The geographical ranges of *P. mira*, *P. kansuensis*, and *P. ferganensis* are limited to western China, and these species have not been documented on the Korean Peninsula (Bassi and Monet, 2008; Korean National Arboretum, 2024). *P. davidiana* is a wild species native to northeastern China; however, its presence on the Korean Peninsula in prehistory remains uncertain (Ahn, 2015). Its endocarps are globose, less pointed, and smaller than those of *P. persica*. Archaeological specimens from Korean sites exhibit morphological traits intermediate between *P. davidiana* and *P. persica*, complicating species-level identification.

Peach endocarps are commonly recovered from archaeological sites in Korea, preserved through desiccation, carbonization, and waterlogging. In some cases, tombs contain peaches, indicating their use as funerary offerings. They are preserved under the anaerobic and dry conditions of the burial chambers. Carbonized peach endocarps have also been found in domestic contexts, though such occurrences are rare. Moreover, carbonization typically results in fragmentation or significant alteration of endocarp size and morphology. This study focuses on peach endocarps preserved under anaerobic, waterlogged conditions, such as in water canals, reservoirs, and abandoned wells, alongside those recovered from dry tomb environments. Waterlogged specimens generally retain their structural integrity and exhibit minimal morphological distortion. Size variation and deformation resulting from desiccation and waterlogging are minor compared to those observed in carbonized specimens.

2.2. Study sites

Fig. 1 illustrates the 73 archaeological sites where peach endocarps have been recovered. Of these, the 10 sites analyzed in this study are individually labeled with site numbers corresponding to those in Supplementary Material 1. The distribution is concentrated in the southern Korean Peninsula, with only a few sites identified in the north. However, this pattern reflects limited archaeological investigation in North Korea owing to political constraints, rather than a true historical absence of peach use. Of the 73 sites, only four (Sites #1–4) have reportedly yielded peach endocarps dated to before 100 BC (Supplementary Material 1). All other specimens postdate 100 BC, suggesting a sudden expansion in peach distribution during the early phase of the first millennium AD.

The earliest known specimens were recovered from a waterlogged deposit at the Ogang-ri site and are dated back to approximately 2500–2000 BC (Ahn, 2015). Other notable early findings include peach endocarps from Jodong-ri, Imam-dong Ibam, and Gonam-ri, dated between 1300 and 300 BC (Ahn, 2015; Supplementary Material 1). These early findings present similar challenges—they typically comprise only one or two peach endocarps recovered from archaeological layers or subterranean features that are susceptible to later intrusions. Moreover, their estimated dates are based on associated pottery typologies rather than radiocarbon dating. Excluding this ambiguous evidence, no definitive support is currently available for peach collection on the Korean Peninsula before 100 BC.

Peach endocarps have also been recovered from Han-style wooden-coffin tombs in Pyongyang, located in the northwestern Korean Peninsula within the territory of the Lelang Commandery (108 BC–AD 313) of the Chinese Han dynasty (Fig. 1; Supplementary Material 1). In these tombs, peach fruits were included as grave goods, possibly reflecting their symbolic relationship with longevity, immortality, and protection against evil spirits (Ahn, 2015). Following these early examples, reports of peach endocarps from the first millennium AD became increasingly common in the southern Korean Peninsula (Supplementary Material 1). Historically, the Lelang Commandery functioned as a conduit for cultural exchange between Mainland China and the southern Korean Peninsula. This channel facilitated the transmission of advanced technologies in ironworking, pottery, and agriculture, along with new belief systems and writing practices (Kim, 2010; Pai, 1992, 2000).

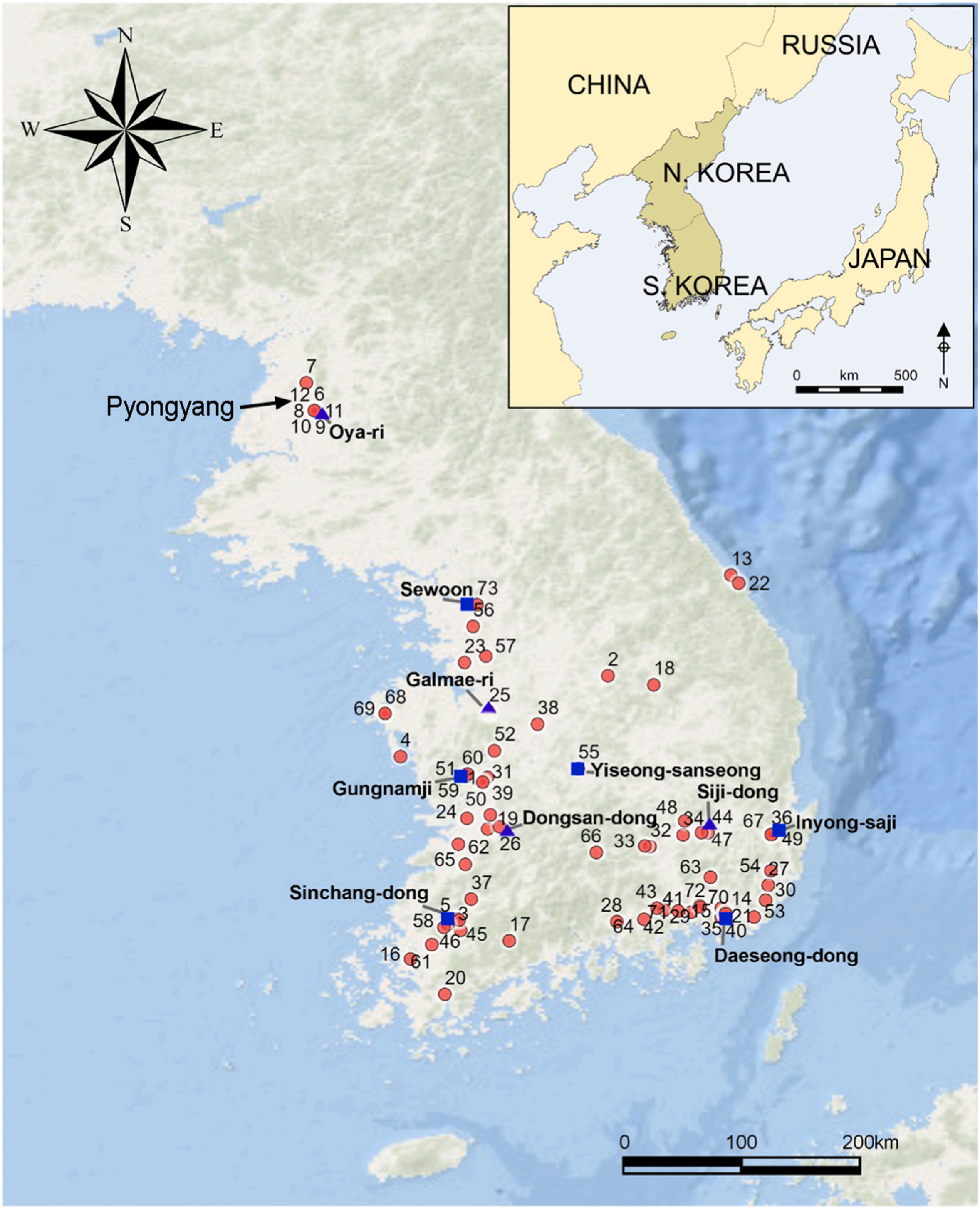

Fig. 1. Archaeological sites on the Korean Peninsula where peach endocarps have been recovered (Red circles). Blue rectangles indicate six sites where the authors directly examined peach endocarps. Blue triangles mark four sites for which measurements were obtained from published sources. Site numbers correspond to those listed in Supplementary Material 1.

Consequently, the increasing presence of peaches appears to be closely linked to these broader sociocultural transformations. The presence of peach remains at archaeological sites possibly reflects the introduction of foreign cultivars and reevaluation of their symbolic significance.

This study examines peach endocarps from 10 archaeological sites as the primary dataset (Fig. 1; Tables 1 and 2). Four sites—Sinchang-dong, Galmae-ri, Dongsan-dong, and Siji-dong—represent farming villages with diverse features, including residential structures, wells, iron workshops, pottery kilns, agricultural fields, and burials, though not all features were present at each site. These settlements date from approximately 100 BC to AD 700 (Table 1). The peach remains were recovered from waterlogged layers in abandoned canals and wells, representing discarded refuse or votive offerings left by residents (Ahn, 2015; Kim, 2023; Park, 2000; Tsuji and Nonaka, 2007; Gwangju National Museum, 2009).

Peach endocarps were also recovered as burial goods from Oya-ri Tomb No. 19 and Daeseong-dong Tomb No. 41 (hereafter Oya-ri and Daeseong-dong, respectively). Oya-ri comprise four wooden coffins

Table 1
Chronology summary of examined sites.

Site	Radiocarbon Age (BP)	Error (±)	Calibrated Date Range (95 %)	Dated Material	Lab Code	Date Combining Method	Estimated Date Based on Diagnostic Artifacts	Reference
Sinchang-dong	1905	56	14 BC–AD 243	Peach endocarp	KGM-IWd240010	Single date		Unpublished analysis report, Korea Institute of Geoscience and Mineral Resources (2024)
Oya-ri	N/A						ca. AD 100–200	National Museum of Korea, 2022
Galmae-ri	1888	38	AD 34–239	Charcoal	SNU05-987, 988	Weighted mean		Tsuji and Nonaka (2007)
Dongsan-dong	1890	30	AD 76–231		KGM-OWd130032	Single date		Ahn (2015)
Siji-dong	N/A						ca. AD 300–700	Park (2000)
Daeseong-dong	1690	15	AD 262–415	Peach endocarp	PLD-46474	Single date		Daeseong-dong Tombs Museum, 2023
Yiseong-sanseong			AD 470–570	Wood	Unknown	Wiggle matching		Kim (2023); Kim and Jeong (2023)
Gungnamji	1367	18	AD 644–673	Peach endocarp	SNU01-060, 061, 063, 064, 065	Weighted mean		Buyeo National Research Institute of Cultural Heritage, 1999, 2001
Inyong-saji	1070	40	AD 889–1030	Peach endocarp	SNU12-164	Single date		Gyeongju National Research Institute of Cultural Heritage, 2013
Sewoon				Dendrochronology			AD 1437 or later	Cheonggoo Institute of Archaeology, 2021

Table 2
Summary of peach endocarp measurements.

Site	*N*	Length (L)		Width (W)		Thickness (T)		L/W		W/T		L/T		L × W × T	
		M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
Sinchang-dong	470	20.57	2.26	13.27	1.38	16.48	1.83	1.55	0.12	0.81	0.04	1.25	0.07	4635.31	1564.81
Oya-ri	6	21.70	0.10	13.20	1.80	16.70	2.00	1.66	0.14	0.79	0.09	1.31	0.13	4827.00	1308.36
Galmae-ri	153	23.94	3.13	N/A	N/A	17.26	2.11	N/A	N/A	N/A	N/A	1.39	0.13	N/A	N/A
Dongsan-dong	6	26.25	5.31	N/A	N/A	19.92	2.16	N/A	N/A	N/A	N/A	1.31	0.14	N/A	N/A
Siji-dong	15	24.80	2.67	15.24	1.81	19.48	1.95	1.64	0.19	0.78	0.04	1.28	0.11	7543.96	2473.20
Daeseong-dong	243	23.87	2.71	15.11	1.59	19.32	2.14	1.58	0.14	0.78	0.05	1.24	0.06	6967.07	2027.45
Yiseong Sanseong	106	25.19	2.63	14.89	1.57	19.43	2.01	1.70	0.19	0.77	0.04	1.30	0.12	7445.44	2131.46
Gungnamji	69	23.48	3.50	14.29	1.77	17.58	2.04	1.65	0.20	0.81	0.05	1.33	0.12	6125.22	2148.87
Inyong-saji	232	23.77	4.94	14.20	1.86	17.90	2.97	1.67	0.23	0.80	0.07	1.32	0.12	6468.96	3017.67
Sewoon	23	21.73	3.54	13.32	1.51	16.31	2.12	1.64	0.20	0.82	0.09	1.33	0.12	4916.08	2424.68

Note: Length, width, and thickness are measured in millimeters (mm), and volume (L × W × T) is calculated in cubic millimeters (mm^3).

enclosed within a larger wooden and brick chamber. Located in the northwestern Korean Peninsula and dated to AD 100–200, the tomb is thought to have belonged to high-ranking individuals of the Lelang Commandery (National Museum of Korea, 2022). Daeseong-dong, a wooden-chamber tomb located in the southeastern Korean Peninsula and associated with the Gaya Confederacy, contained a pottery jar with peach endocarps dated to AD 300–400 (Daeseong-dong Tombs Museum, 2023).

Three other sites are not ordinary settlements but special-function sites associated with elites and administrative groups. Yiseong-sanseong (Yiseong Mountain Fortress) is an earthen-walled fortress with numerous storage facilities (Institute of Korean Prehistory, 2023), some of which contained peach endocarps (Kim, 2023; Kim and Jeong, 2023). Gungnamji, located in Buyeo, is a water reservoir constructed south of the Baekje palace (Buyeo National Research Institute of Cultural Heritage, 1999, 2001). Peach endocarps were recovered in its water-logged layers, which the *Samguk Sagi* (*History of the Three Kingdoms*, compiled in AD 1145) documents as being constructed in AD 634. Finally, Inyong-saji (Inyong Temple), a Buddhist temple in Gyeongju, is believed to have been related to the Silla royal family (Gyeongju National Research Institute of Cultural Heritage, 2013). The *Samguk Yusa* (*Memorabilia of the Three Kingdoms*, compiled in AD 1281) attributes its construction to the late seventh century. Peach endocarps were recovered from an abandoned well, possibly deposited as votive offerings.

Lastly, the Sewoon site refers to archaeological remains preserved beneath the Sewoon Commercial Complex in downtown Seoul. The site comprises eight distinct cultural layers formed between AD 1400 and 1940, corresponding to the period when Seoul served as the capital of the Joseon Dynasty (AD 1392–1910). Peach endocarps were recovered from a water canal associated with the earliest layer (Layer #8). Dendrochronological analysis of the wooden posts of the canal dated the outermost tree ring to AD 1437, establishing a *terminus post quem* for the peach remains (Cheonggoo Institute of Archaeology, 2021).

3. Materials and methods

Although *Prunus* remains can be preserved archaeologically as endocarps, wood, and pollen, endocarps are the most commonly recovered. Reports of wood and pollen are rare, and species-level identification is often inconclusive. Building on a previous compilation (Ahn, 2015), this study began by assembling a database of sites reporting peach endocarps. All sites with documented peach endocarp findings were included, along with data on site types and locations, detailed descriptions of related archaeological features, and estimated dates based on diagnostic artifacts and radiocarbon dating (Fig. 1; Table 1; Supplementary Material 1).

Of the peach endocarps from 10 sites examined, samples from six—Sinchang-dong, Daeseong-dong, Yiseong-sanseong, Gungnamji, Inyong-saji, and Sewoon—were directly accessible to the authors (Fig. 2; Table 1). The specimens were recovered through wet sieving of waterlogged deposits, then dried and stored at the respective research institutions. Measurements were conducted at these institutions, with all data collected by the first author (M. Kim), except for the Daeseong-dong samples, which were measured by the second author (S. Ahn). The length (L), width (W), and thickness (T) of the peach endocarps were measured using an electronic caliper, with values rounded to the nearest hundredth of a millimeter (Fig. 3; Table 2). In previous studies, these dimensions have also been referred to as height, cheek diameter, and suture diameter, respectively (Quilot et al., 2004; Zheng et al., 2014). A consistent measurement protocol was applied across all specimens, minimizing variations owing to methodological differences or inter-researcher bias.

Fig. 2. Archaeological peach endocarps from five sites: Singchang-dong (1–3); Daeseong-dong (4–6); Yiseong-sanseong (7–9); Gungnamji (10–12); and Sewoon (13–18).

For the samples not directly accessible to the authors (Oya-ri, Galmae-ri, Dongsan-dong, and Siji-dong), measurements were obtained from respective site excavation reports (Table 2). Here, several limitations should be acknowledged. First, comparability may be influenced by the involvement of multiple independent researchers. However, the consistent use of electronic calipers and the reporting of measurements to the second decimal place suggest that methodological discrepancies are unlikely to significantly affect inter-site comparisons. Second, the excavation reports from Galmae-ri and Dongsan-dong include only length and thickness measurements, omitting width. This omission limits assessments of elongation or compression and prevents accurate volume estimation. Third, the sample sizes from Oya-ri, Dongsan-dong, and Siji-dong are small—six, six, and fifteen endocarps, respectively—reducing the representativeness of the data (Table 2). Despite these limitations, the datasets offer valuable insights and are included in the subsequent discussion.

In addition to the archaeological specimens from Korean sites, peach endocarp measurements from the Liangzhu culture sites of Maoshan and Bianjiashan in the lower Yangtze River basin, China, were obtained from previously published research (Zheng et al., 2014). These endocarps are considered representative of an early stage of peach domestication in East Asia, exhibiting larger and more compressed forms than earlier wild types. If these specimens indeed represent the earliest domesticated peaches, subsequent samples—including those from the Korea Peninsula—possibly descended from this ancestral domesticated lineage. Consequently, traits associated with domestication syndrome (e.g., increased fruit size) are expected in the Korean samples. Deviations from this pattern may reflect local environmental adaptation and the subsequent emergence of diverse cultivated forms. Samples lacking clear domestication traits—such as smaller, more globose endocarps—are of particular interest as potential indicators of wild or feral types. In this context, the Liangzhu samples provide a critical reference point for evaluating the diversification of cultivated peach through selection, hybridization, and local adaptation.

Following data collection, the morphological characteristics of the peach endocarps were analyzed (Fig. 3). Endocarp volume, a key indicator of domestication, was approximated as length (L) × width (W) × thickness (T). Elongation was assessed using the length-to-width (L/W) ratio, with higher values indicating more elongated forms. Compression was evaluated using the width-to-thickness (W/T) ratio, where lower values denote more compressed endocarps. Finally, the length-to-thickness (L/T) ratio was used to assess the overall shape of peach endocarps in lateral view—spherical or elliptical—which is the standard orientation for examining endocarps, as they are typically positioned on their side.

4. Results

Figs. 4–6 present the results of the morphological variation analysis. Histograms and Q-Q plots of the measurement variables indicate that the sample distributions at each site generally approximate normality, with moderate deviations attributable to outliers. Independent two-sample *t*-tests were conducted between the Liangzhu culture peach specimens (China) and those from each Korean site to access significant morphological differences between the samples. Specimens showing significant differences from the Liangzhu samples—whether consistent with

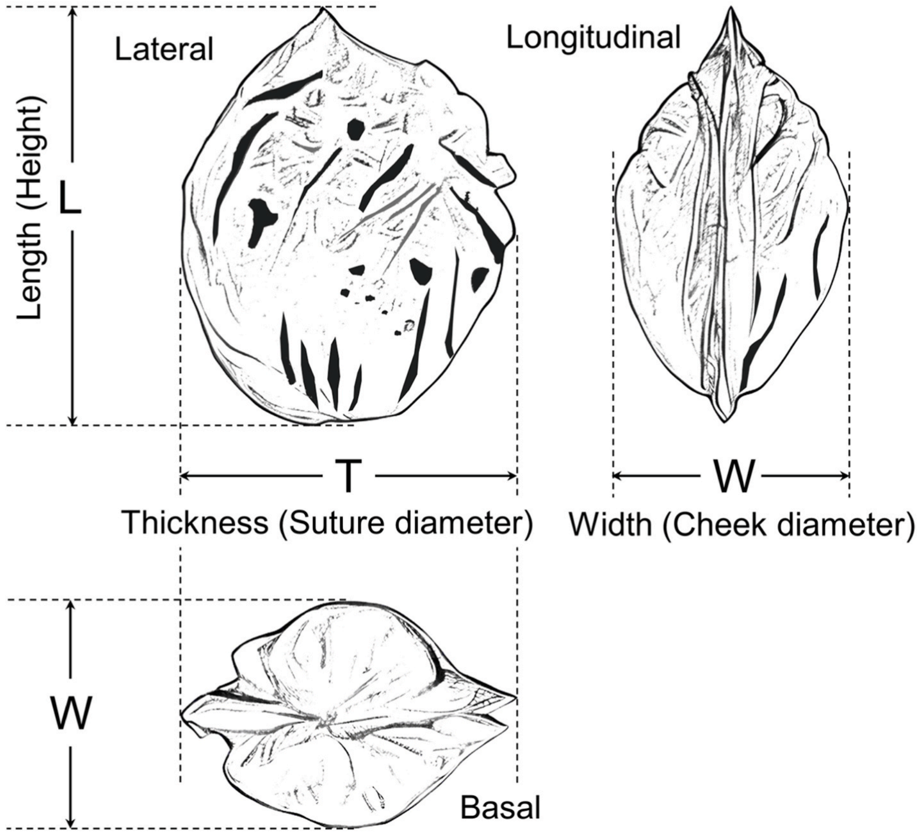

Fig. 3. Measurement of the length (L), width (W), and thickness (T) of a peach endocarp.

domestication-related changes or traits suggestive of wild varieties—are highlighted in the figures using boxplots with distinct color schemes.

The key findings of the morphological comparisons are as follows: First, peach endocarp volumes, calculated using three-dimensional measurements (L × W × T) as proxy data, are significantly larger at several sites, though certain exceptions warrant further consideration (Fig. 4). At five sites—Siji-dong, Daeseong-dong, Yiseong-sanseong, Gungnamji, and Inyong-saji—the average peach endocarp volume exceeds 5000 mm^3, indicating a general trend of size increase. However, this pattern is not consistent across all sites: *t*-test comparisons show that samples from Sinchang-dong are smaller than those from Liangzhu. The Sewoon samples, despite being the most recent, generally contain smaller peach endocarps, aside from an extreme outlier.

Second, the analyzed samples are characterized by elongated and compressed endocarps. Fig. 5 presents the L/W (top) and W/T (bottom) ratios, which reflect the degree of elongation and compression of the peach endocarps. All samples from the Korean sites exhibit significantly higher L/W ratios and lower W/T ratios than the Liangzhu specimens.

Third, L/T ratios are highly variable and show no consistent pattern across the examined sites (Fig. 6). Samples from five sites—Oya-ri, Galmae-ri, Gungnamji, Inyong-saji, and Sewoon—exhibit significantly higher values than the Liangzhu specimens, suggesting a more elongated elliptical shape in lateral view. In contrast, the remaining samples do not show a statistically significant increase relative to the Liangzhu specimens; in fact, the Sinchang-dong, Dongsan-dong, and Daeseong-dong samples display lower ratios, suggesting a more spherical lateral profile.

Fourth, the peach endocarps from Sinchang-dong exhibit anomalous features that complicate their classification compared to those of other samples. Relative to the Liangzhu specimens, the Sinchang-dong endocarps are smaller in size—a trait typically associated with wild varieties (Fig. 4). In lateral view, they also show lower L/T ratios, resulting a more spherical appearance (Fig. 6). However, the L/W and W/T ratios (Fig. 5) indicate elongation and compression. These observations raise questions about whether the Sinchang-dong samples represent fully domesticated peaches or retain certain characteristics of wild forms.

In summary, the analyzed peach endocarps exhibit substantial morphological variation, resisting simple generalization. This is particularly evident in the L/T ratios, with lateral profiles ranging from nearly spherical to elongated ellipses. Nevertheless, all archaeological specimens are generally characterized by elongated and compressed morphologies, as reflected in their L/W and W/T ratios. Endocarps from Siji-dong, Daeseong-dong, Yiseong-sanseong, Gungnamji, and Inyong-saji are significantly larger, while those from Sinchang-dong, Oya-ri, and Sewoon are smaller.

5. Discussion

5.1. Origins of peach cultivation

The evidence compiled in this study reveal a prolonged scarcity of peach remains prior to 100 BC, followed by a sudden increase in cultivated peaches during the first millennium AD (Supplementary Material 1). Although peach endocarps have been reported at sites dating to approximately 2500–2000 BC and 1300–300 BC—corresponding to the Chulmun and Mumun (or Bronze Age) periods, respectively—their precise dating remains uncertain. The possibility that these peach endocarps represent later inclusions has not been ruled out. In this context, the recent reassessment of peach endocarps from the Ikiriki site in Japan is particularly significant. Initially thought to date back 7000–6000 years to the Jomon period based on associated layers, these endocarps are recently radiocarbon-dated to between 300 BC and AD 300, aligning with the Yayoi period (Kudo et al., 2021). Whether peach cultivation occurred on the Korean Peninsula prior to 100 BC remains an unresolved question requiring further investigation.

The Sinchang-dong and Oya-ri samples exhibit similar morphological traits that are intermediate between those of wild and domesticated

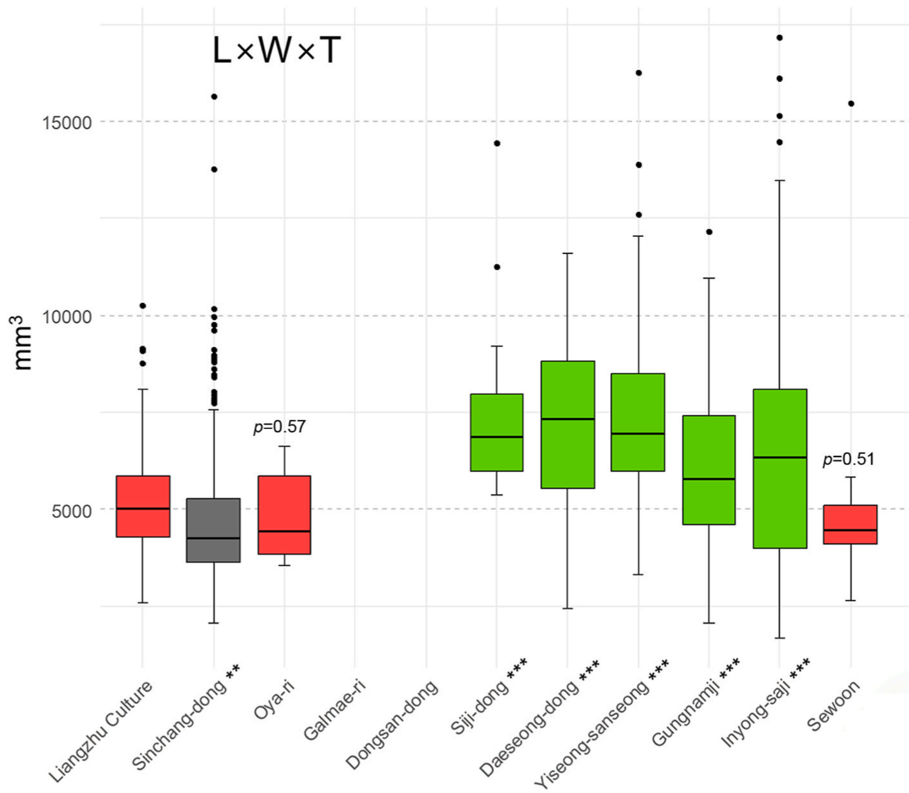

Fig. 4. Comparison of peach endocarp volumes. Red boxplots represent Liangzhu culture and Korean sites with no statistically significant difference from the Liangzhu sample. Green boxplots indicate sites with significantly larger endocarps. The grey boxplot represents the Sinchang-dong site, with significantly smaller endocarps than those of the Liangzhu culture. Statistical significance was assessed using *t*-tests at the 95 % confidence level. Asterisks indicate significance levels in one-to-one comparisons with the Liangzhu sample ($p < 0.05$ *, <0.01 **, <0.001 ***). P-values >0.05 are reported numerically.

peaches. Their smaller size relative to the Liangzhu specimens complicates their classification as fully domesticated. However, like other specimens from later periods, they display elongated and compressed endocarps—morphological traits associated with domestication in peaches (cf. Fuller, 2018; Zheng et al., 2014). The Sinchang-dong samples are radiocarbon-dated to 14 BC–AD 243 (95 % CI), while the Oya-ri specimens are dated to approximately AD 100–200 based on associated burial goods (Table 1). These findings suggest that the period between 100 BC and AD 300 may represent an early phase of peach cultivation in the region, during which communities either initiated active cultivation or collected feral varieties.

Following this period, fully domesticated peaches appear at five archaeological sites: Siji-dong, Daeseong-dong, Yiseong-sanseong, Gungnamji, and Imyong-saji. The samples from these sites are characterized by large, elongated, and compressed endocarps, indicative of cultivated varieties. These remains are dated to AD 300–1000 (Table 1), spanning the Three Kingdoms (AD 300–668) and Unified Silla (AD 668–935) periods. This evidence indicates that cultivated peaches were established by the emergence of early states on the Korean Peninsula.

Although the dataset confirms that peaches were cultivated by at least AD 300, notable morphological variation—both between and within sample sets—must be considered. The small size of the Sewoon endocarps is particularly noteworthy, as this site dates to AD 1437 or later and represent the most recent samples (Table 1). Several sites exhibit a wide range of endocarp sizes, with especially pronounced volumetric variation in the Inyong-saji specimens (Fig. 4). These findings indicate that, although peach cultivation was established after AD 300, multiple varieties or cultivars with distinct morphological and horticultural characteristics were likely in use.

Historical records further support the presence of multiple peach varieties on the Korean Peninsula. For instance, *Domundaejak*, a 1611 compendium of local products and delicacies, documents five distinct peach varieties available in the region (Heo, 2022). Similarly, the agricultural manual *Haedong Nongseo*, compiled in the late 18th century, describes nine types and notes the widespread cultivation of diverse peach varieties (Seo, 2008). Trade and cultural exchange with Chinese regions possibly contributed to the introduction of additional peach varieties during historical periods. The considerable diversity of peach types documented historically is also evident in the archaeological record, suggesting that such variation dates back to the earliest phases of peach cultivation.

5.2. Socioecological conditions for peach cultivation

The following sections situate the present analysis within the broader context of archaeological and historical research, examining the socioecological conditions and social implications of peach cultivation on the Korean Peninsula in antiquity. Fruit tree cultivation requires the fulfillment of specific socioeconomic and ecological prerequisites, including specialized horticultural skills (e.g., pruning, grafting, and pest management), alongside alignment with existing subsistence strategies and technological capacity for post-harvest handling (e.g., the storage and distribution of perishable fruits) (Harris et al., 2004; Liu et al., 2022; Spiegel-Roy, 1986). Long-term land tenure and investment are crucial prerequisites (Fuller and Stevens, 2019; Gilman, 1981; Langgut, 2024; Langgut and Garfinkel, 2022; Pérez-Jordà et al., 2017). Unlike annual crops, fruit trees require several years to mature before bearing their first fruits and can continue producing for decades. Therefore, in communities anticipating frequent relocations or lacking secure land rights, the incentive for investing in tree cultivation is minimal.

Therefore, the maintenance of peach orchards would have required stable, long-term tenure systems that extended beyond simple sedentary lifestyles. Peach trees typically begin bearing fruit two to three years

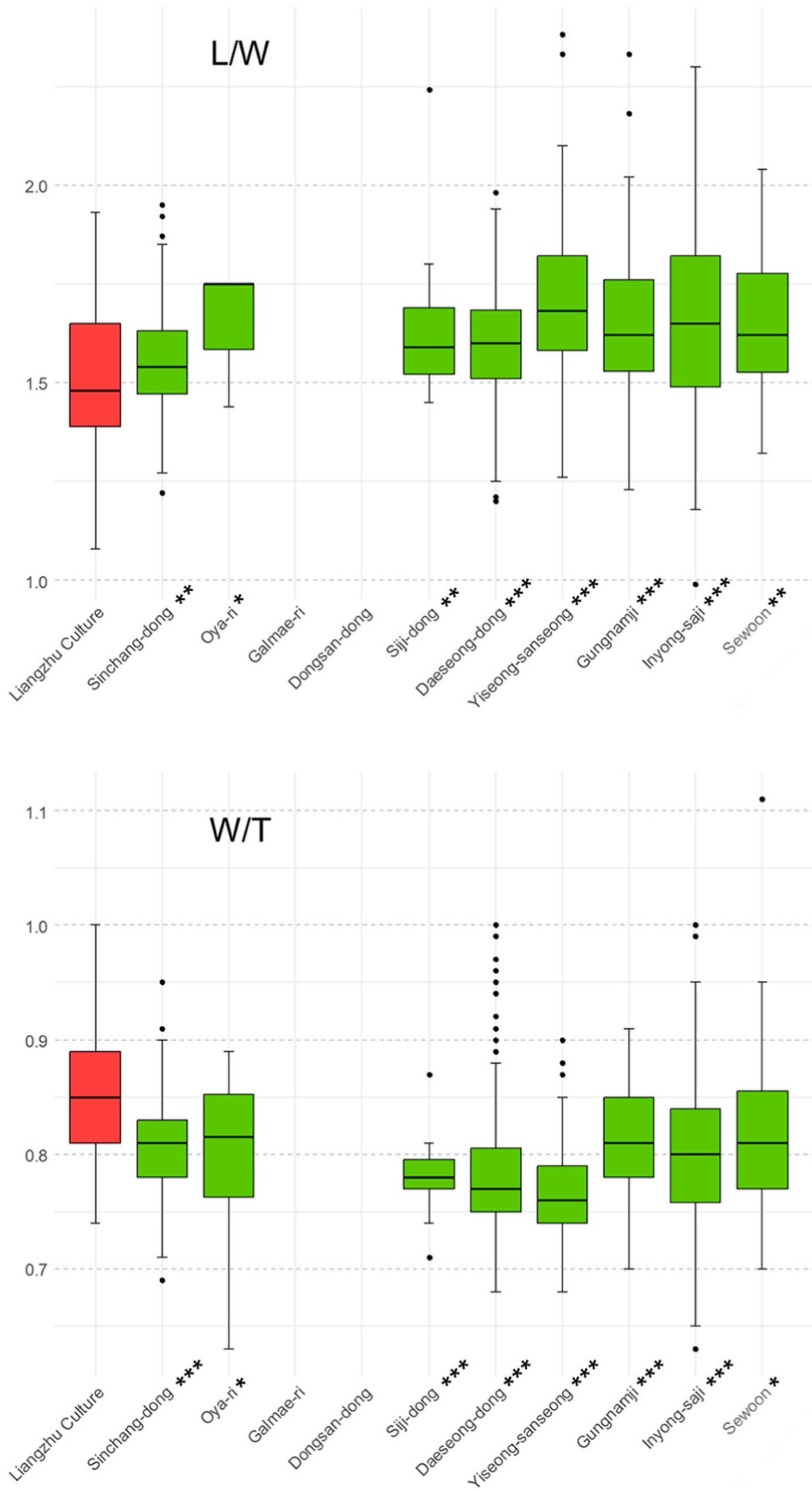

Fig. 5. Comparison of peach endocarp L/W (top) and W/T (bottom) ratios. Red boxplots represent the ratios of peaches from the Liangzhu culture. Green boxplots indicate sites with ratios significantly different from those of the Liangzhu sample. Statistical significance was assessed using *t*-tests at the 95 % confidence level. Asterisks indicate significance levels in one-to-one comparisons with the Liangzhu sample ($p < 0.05$ *, <0.01 **, <0.001 ***).

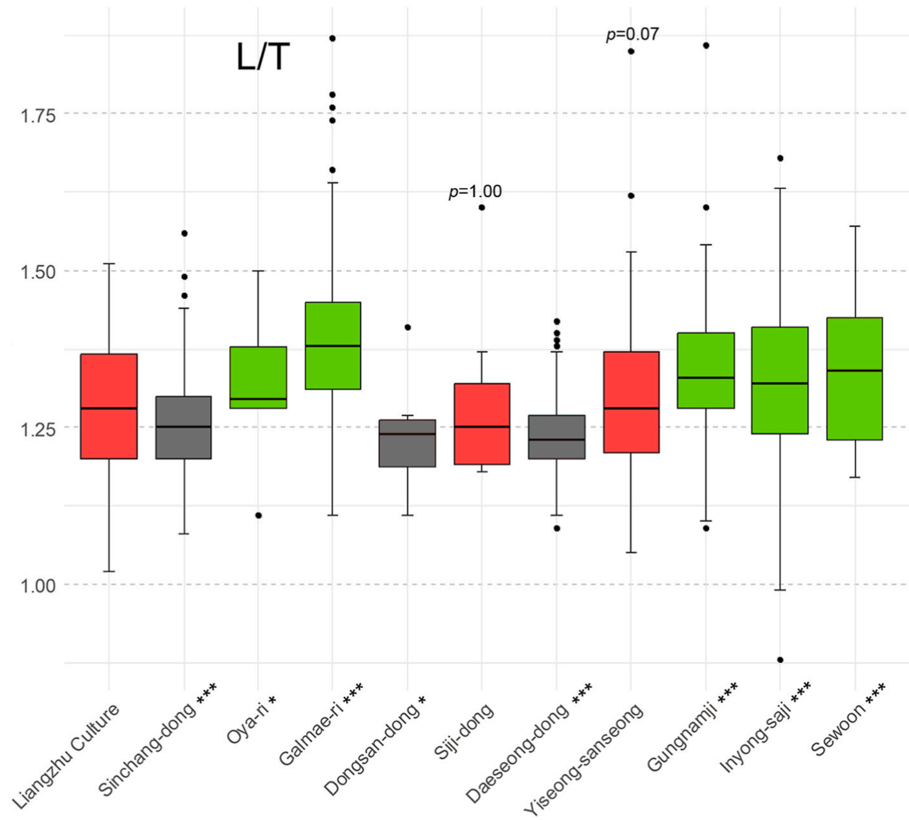

Fig. 6. Comparison of L/T ratios of peach endocarps. Red boxplots represent Liangzhu culture sites and Korean sites with no statistically significant difference from the Liangzhu sample. Grey boxplots indicate sites with significantly lower ratios, while green boxplots represent sites with significantly higher ratios compared to those of the Liangzhu culture. Statistical significant was assessed using *t*-tests at the 95 % confidence level. Asterisks indicate significance levels in one-to-one comparisons with the Liangzhu sample ($p < 0.05$ *, <0.01 **, <0.001 ***). P-values >0.05 are reported numerically.

after planting, with grafted trees producing even earlier (Rieger, 2006; Okie, 1984). Under normal conditions, they reach peak productivity around year 10, after which their yields gradually decline (Bassi and Monet, 2008). These factors suggest that farmers anticipated a cultivation horizon of at least a decade or more for peach cultivation, accounting for both the onset of fruiting and the eventual decline in yield.

The crucial question arising from this observation is not simply when prehistoric populations on the Korean Peninsula adopted sedentary lifestyles (i.e., lacked residential mobility) but when they developed strong territoriality and long-term land commitment spanning decades, a condition essential for the emergence of arboriculture.

Although the Chulmun culture (ca. 8000–1500 BC) is generally regarded as sedentary, evidence for sustained land ownership and management remains limited. Aside from a few large settlements in the central-western Korean Peninsula, most Chulmun sites were small, typically comprising only a few pithouses (Kim et al., 2015; Kim, 2022). Archaeological evidence suggests that, regardless of settlement size, these communities frequently underwent cycles of fission, fusion, and relocation (Kim, 2022). Although generally considered sedentary—assuming that inhabitants did not relocate within a single year—and despite repeated use of certain resource extraction sites, such as shell middens, evidence for long-term, stable settlements with strong territorial control is limited.

The Chulmun people cultivated annual crops such as foxtail millet (*Setaria italica*) and broomcorn millet (*Panicum miliaceum*), which had short growing cycles of approximately 60–100 days, required minimal labor, and thrived in diverse soil conditions (Lee, 2011). However, the lack of secure land tenure potentially discouraged fruit tree cultivation, which demands significant long-term investment and sustained commitment to both land and trees.

During the subsequent Mumun period (ca. 1500–1 BC), long-term land tenure became established at many sites, as evidenced by fortified settlements, dolmens, and the development of wet paddy systems (Yi, 2022)—all indicating sustained commitment to specific tracts of land. These features show that several previously unmet preconditions for peach cultivation were now in place, particularly at some large, long-occupied settlements. However, current archaeobotanical evidence does not indicate that this transformation led to peach cultivation or the broader adoption of arboricultural practices. Despite extensive archaeobotanical research on the Mumun period, available data primarily reflect the cultivation of annual crops including rice (*Oryza sativa*), wheat (*Triticum aestivum*), barley (*Hordeum vulgare*), soybean (*Glycine max*), red bean (*Vigna angularis*), and millets, alongside the collection of wild fruits (Lee, 2011). Whether peach cultivation was truly absent during the Mumun period remains an unresolved question requiring further investigation with more comprehensive datasets. If arboricultural practices were not adopted, it becomes crucial to examine whether all necessary socioecological preconditions were indeed fulfilled and, if so, why the cultivation of perennial woody plants was not pursued despite its apparent feasibility.

5.3. New symbolic codes and the introduction of peach cultivation

The adoption of peach cultivation between approximately 100 BC and AD 300 was facilitated by strengthened territorial control and long-term investment in the landscape. Archaeological evidence further demonstrates that this transition also coincided with the introduction of new technologies and symbolic systems. The earliest definitive evidence for peaches on the Korean Peninsula comes from peach endocarps recovered from Chinese Han-style tombs dating to the Lelang Commandery period (108 BC–AD 313). Subsequently the presence of peach remains increased at archaeological sites (Fig. 1; Supplementary

Material 1). The Lelang Commandery, an administrative and military outpost of the Chinese Han dynasty located near modern-day Pyongyang in the northwestern Korean Peninsula, functioned as a major hub for interregional cultural interaction and exchange (Pai, 1992, 2000). The inclusion of peaches as burial goods in Han-style tombs illustrates that peaches were introduced to the Korean Peninsula not only as edible commodities but also as objects imbued with symbolic meaning.

Eight Han-style wooden-coffin tombs containing peach endocarps as burial goods have been excavated in Pyongyang, representing the earliest evidence of peach offerings in mortuary contexts on the Korean Peninsula (Ahn, 2015). Among them, the Oya-ri tomb is significant for its peach endocarps and a depiction of Xiwangmu, the mythological deity associated with peach symbolism (National Museum of Korea, 2022). The tomb comprises four wooden coffins enclosed within a large wooden chamber, further encased by brick chambers. The brick enclosure created a sealed, low-moisture, and anaerobic environment conducive to the preservation of organic materials. Preserved items included skeletal remains, lacquerware, wooden figurines, and remnants of peach and chestnut. Peach remains were recovered near the foot of the deceased in the third coffin, alongside a bronze mirror placed on a wooden lacquerware plate.

The bronze mirror found alongside the peach endocarps bears intricate depictions of deities and mythological beings on its non-reflective side, accompanied by 56-character Chinese inscription (Fig. 7). Among the figures is Xiwangmu, the Queen Mother of the West, a deity revered in ancient Chinese traditions as the goddess of immortality (Cahill, 2000; Irwin, 1990; James, 1995). The inscription confirms her identity, reinforcing her symbolic significance. In Chinese mythology, Xiwangmu is revered as the guardian of the Peaches of Immortality, cultivated in her celestial garden. According to legend, these mystical peaches were believed to confer eternal life and were presented at divine banquets to sustain the immortality and authority of the gods. The inclusion of peaches in tombs, alongside artifacts linked to Xiwangmu, suggests their symbolic function, expressing aspiration for eternal life, vitality, and a prosperous afterlife.

Extensive archaeological and historical research has examined the relationship between the Han dynasty's Lelang Commandery and sociocultural transformations in the southern Korean Peninsula (Barnes, 2001; Davey, 2019; de Benedittis, 2022; Kim, 2010; Lee, 2009; Pai, 1992, 2000). Although initially established as a military and administrative outpost, Lelang also functioned as an economic and diplomatic hub, facilitating the circulation of prestige goods, luxury items, and

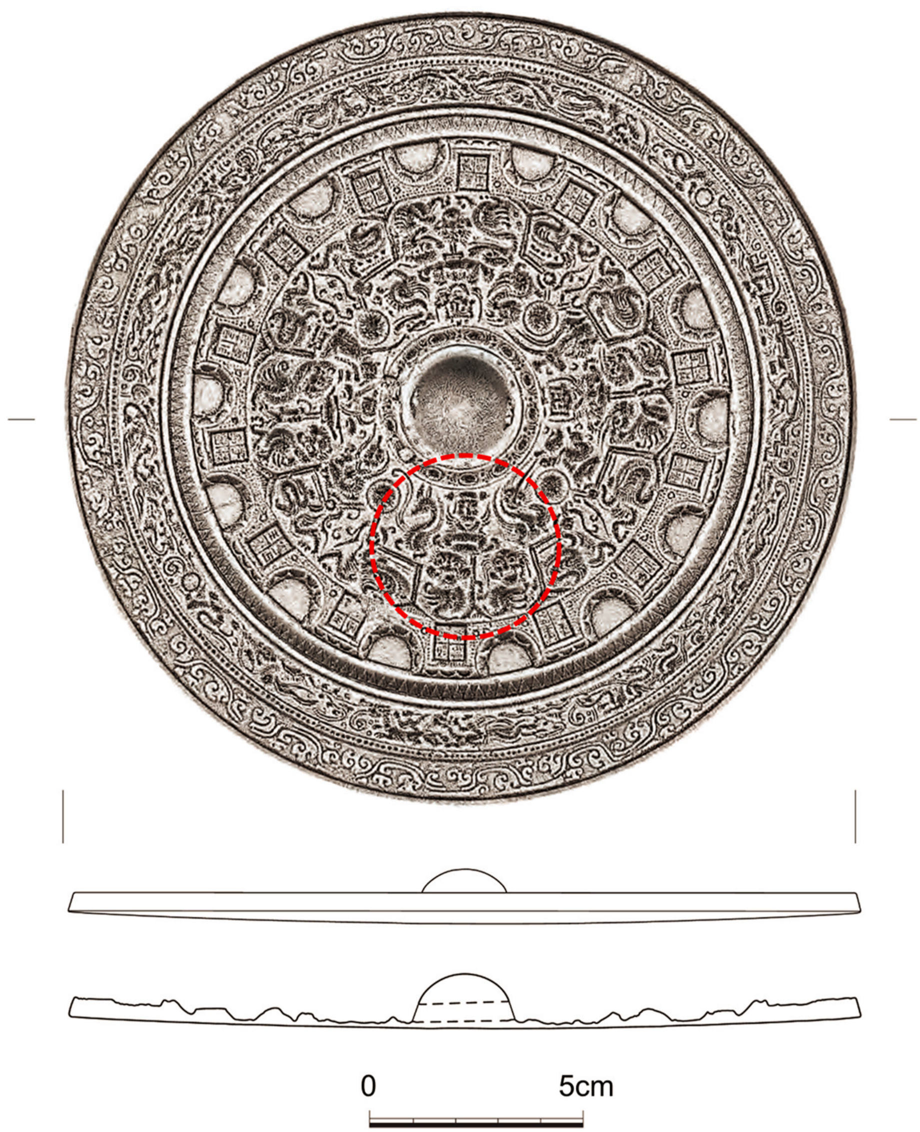

Fig. 7. Bronze mirror from Oya-ri Tomb No. 19. The reverse side features depictions of deities, mythological animals, and inscriptions. The red circle highlights Xiwangmu, the goddess associated with the Peaches of Immortality. (Source: National Museum of Korea, 2022

ritual paraphernalia of Chinese origin throughout the southern peninsula. Researchers have proposed that the Han court possibly implemented a policy of reverse tribute, distributing gifts to local chieftains as a strategic means to secure peace, assert influence, and shape regional politics (Barnes, 2001).

Archaeological evidence indicates that the southern Korean Peninsula was part of an extensive diplomatic and trade network, as reflected in the diversity of artifacts including bronze mirrors (both Han-imported and locally imitated), coins, seals, jade ornaments, lacquerware, iron weapons, horse gear, and chariot fittings. Han-style ceramics, particularly wheel-made pottery, are also commonly found. Tombs and associated grave goods from this period reflect cultural hybridization, where Han-style artifacts coexisted with indigenous elements (de Benedittis, 2022; Davey, 2019). Although interregional exchange predates the establishment of Lelang (Lee, 2009), this period marked a significant intensification of cultural contact, enabling local communities to integrate external influences into their sociocultural frameworks.

The growing presence of peach endocarps dated to AD 1–300 in the southern Korean Peninsula aligns with the emergence of Han-related artifacts in regions beyond the direct influence of the Lelang Commandery (Ahn, 2015). Artifacts such as pottery, iron vessels, and chariot fittings associated with Han Chinese culture have been identified at sites including Sinchang-dong and in the tombs of Daeseong-dong and Imdang-dong. Despite variations in burial practices at Daeseong-dong and Imdang-dong—wooden coffins, burial jars, and wooden-chambered tombs—all contain peach endocarps in varying quantities. Their presence in elite burials, beyond the reach of direct Lelang administration, reflects the cultural transmission of symbolic meanings associated with peaches, particularly as emblems of immortality, longevity, and renewal.

5.4. Prized fruit and blossoms

Beyond their symbolic significance, circumstantial evidence suggests that peaches were highly valued in ancient Korea. During the first millennium AD, peaches were among the largest and juiciest fruits available in the southern Korean Peninsula. Archaeobotanical findings indicate that other commonly consumed fruits at the time included wild grape (*Vitis*), wild kiwi (*Actinidia*), and raspberry (*Rubus*). Peaches were distinguished by their large size, sweetness, and juiciness, though these traits possibly varied with cultivation practices and local growing conditions. While other fruits, such as persimmons (*Diospyros kaki* Thunb.), also produced large, sweet yields, archaeobotanical evidence for this species remains limited. Peaches were possibly considered ideal for display at banquets or feasts, where their sweetness, succulence, size, and blushful color could be ostentatiously presented as symbols of wealth and prosperity.

Another defining feature of peach trees relevant to their symbolic and aesthetic roles in shaping landscapes is their precocious flowering. This phenomenon refers to plants blooming in early spring before leaf emergence, allowing flowers to maximize sunlight exposure without competition from foliage. On the Korean Peninsula, with its distinct four-season climate, numerous plants exhibit precocious flowering, contributing to the striking transformation of the landscape during the transition from winter to spring. Among these are *Prunus* species, such as Japanese apricot (*Prunus mume* (Siebold) Siebold & Zucc.) and cherry (*Prunus jamasakura* Siebold ex Koidz.), with peach trees possibly becoming a prominent addition during the first millennium AD. Traditionally, peach trees have been powerful symbols of spring, embodying renewal, beauty, and vitality in gardens and landscapes (An, 2006).

Consistent with this observation, peach trees are frequently referenced in historical records. In the *Samguk Sagi*, they are repeatedly mentioned, particularly in accounts of unseasonal flowering (Kim, 2012). Although the early accounts in the *Samguk Sagi* are often considered unreliable (Shultz, 2004)—with many interpreting these accounts symbolically rather than literally—they suggest that peach trees were commonly cultivated nearby. More specifically, peaches were potentially grown in palace gardens and private courtyards for their edible fruit and their symbolic and aesthetic value.

6. Conclusions

This study investigates peach remains from Korean archaeological sites to explore the history of peach cultivation and its cultural significance in the region. Analysis of the spatiotemporal distribution and biometric comparisons of peach endocarps from 10 archaeological sites reveals a sudden and widespread adoption of cultivated peaches around the beginning of the first millennium AD. However, the peach endocarps from Sinchang-dong (ca. 14 BC–AD 243) are challenging to classify as fully domesticated, as many retain the small size typical of wild or feral types. Despite the uncertain domestication status of samples from 100 BC to AD 300, the broader pattern indicates a prolonged scarcity of peach remains from the onset of the Holocene, followed by a significant increase in their presence around the beginning of the first millennium AD, suggesting a relatively brief transitional phase from wild to cultivated forms.

Samples dated to AD 300–700 are clearly characterized by large, elongated, and compressed peach endocarps resembling cultivated varieties, though size and morphological variation persist. Particularly, considerable lateral shape variation with significant differences in elongation and compression is observed even within individual archaeological sites. This morphological diversity may reflect the existence of multiple peach varieties, dating back to early domestication stages. While absent in earlier records, references to distinct peach varieties begin to appear in historical documents by the 16th century AD.

The earliest securely dated peach remains in the region were recovered from Han-style tombs of the Lelang Commandery, and from waterlogged layers at the Sinchang-dong site, which yielded artifacts reflecting Han Chinese cultural influence (e.g., coins, Lelang-related pottery, and chariot fittings). These findings show that the introduction of peach cultivation on the Korean Peninsula was closely linked to the transmission of symbolic systems adopted by local populations. In Han China, peaches symbolized longevity, immortality, and protection against evil. In contrast to the commonly recovered wild fruits from archaeological sites on the southern Korean Peninsula—wild grape (*Vitis*), wild kiwi (*Actinidia*), and raspberry (*Rubus*)—peaches were notably large, succulent, sweet, and bore blush-colored skin, making them well-suited for rituals and banquets. Their early-blooming flowers also contributed to symbolic landscape formation, particularly during the transition from winter to spring. Beyond their nutritional value, peaches potentially held cultural and symbolic significance in ancient Korean societies, which may have facilitated their cultivation and dissemination.

These conclusions remain provisional, as they are based on currently available data. Further research is required to elucidate the history of peach cultivation and its cultural significance. It is reasonable to hypothesize that peach cultivation dates back to the Mumun period (1500–1 BC). This hypothesis is supported by evidence of long-term settlements, territorial stability, and substantial resource control—factors conducive to sustained agricultural investments such as fruit tree cultivation. These socioecological conditions, absent in earlier periods, appear to have emerged after approximately 1500 BC. However, current archaeological evidence does not suggest an immediate association between these developments and the adoption of arboricultural practices. Broader datasets and continued research are needed to clarify these questions.

CRediT authorship contribution statement

Minkoo Kim: Writing – review & editing, Writing – original draft, Supervision, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Sohyeon Ahn:** Data curation. **Brian Li:** Conceptualization.

Declaration of competing interest

The author affirms that there are no competing financial interests or personal relationships that could have influenced the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.quaint.2025.109966.

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