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A review on *Fraxinus xanthoxyloides* (Afghan ash): An important tree species with various uses

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Abstract
This comprehensive review synthesizes the ecological, traditional, phytochemical, and management significance of *Fraxinus xanthoxyloides* (Afghan ash), a large, deciduous shrub to medium-sized tree belonging to the Oleaceae family. The species, which encompasses varieties such as var. dimorpha and var. dumosa, is found in arid and semi-arid regions spanning North Africa, Afghanistan, Pakistan, and the dry, inner valleys of the Western Himalayas. Ecologically, it thrives in challenging environments, preferring rocky slopes, ravines, and trans-Indus regions at high altitudes. Historically, Afghan ash has been a keystone multi-functional resource for local communities. It provides essential timber (for poles, beams, and agricultural tools), firewood, and is a source of spices and dyes. Its leaves and seeds are widely utilized in traditional medicine to treat conditions like bone fractures, arthritis, pain, and inflammation. These medicinal properties are supported by phytochemical studies, which confirm the presence of potent bioactive compounds, including terpenoids, coumarins, and phenolic substances, linked to its antioxidant, antimicrobial, and analgesic activities. Crucially, *F. xanthoxyloides* serves as a vital source of nutritive fodder for small ruminants, particularly during the scarce foraging period of autumn. Traditional agropastoral management systems, like pollarding, shaping, and trunk anastomosis (known as Tahboucht in the Berber language), have been developed by local inhabitants to sustainably enhance the trees' longevity, vigor, and yield of resources over sophisticated nested cutting cycles. Despite its crucial role and effective traditional management, the species faces dramatic population decline due to indiscriminate harvesting and habitat degradation, highlighting the urgent need for enhanced conservation strategies.

Keywords: *Fraxinus xanthoxyloides,* Habitat degradation, Western Himalaya

Introduction
Fraxinus xanthoxyloides Wall. (Afghan ash), a significant species within the Oleaceae (Olive family), manifests as a resilient, often multi-stemmed deciduous shrub or a medium-sized tree that can attain heights of up to 8 meters. Its geographical range is uniquely fragmented, spanning vast arid and semi-arid territories from North Africa (Morocco, Algeria) to South and Central Asia (Afghanistan, Pakistan, and the dry, inner valleys of the Western Himalayas) (Negi and Sharma, 2015; Sarfraz *et al*., 2017) [17, 19]. This xerophytic plant thrives in demanding, high-altitude environments, typically between 1,200 and 3,000 meters above sea level, tolerating extreme temperature fluctuations and preferring rocky slopes, ravines, and siliceous or limestone substrates in areas of high insolation (Rankou *et al*., 2017) [18]. The species encompasses distinct varieties, most notably *F. xanthoxyloides* var. dimorpha, a North African endemic known as 'Imts' in Berber, recognized for its dimorphic foliage that adapts to development stage and browsing, and *F. xanthoxyloides* var. dumosa, the generally dwarfed, shrubby form prevalent in the N.W. Himalayas and Afghanistan (www.treesandshrubsonline.org). Ecologically, the Afghan ash is crucial for stabilizing mountain ecosystems, often associating with Quercus and Juniperus species, yet its populations are often severely fragmented, highlighting its vulnerability. Ethnobotanically, *F. xanthoxyloides* is a keystone multi-functional resource; it supplies essential firewood and timber for construction (poles, beams) and agricultural tools, and its leaves are used for dyeing textiles. Critically, it provides a vital source of nutritive fodder for small ruminants during the sparse foraging period of autumn (Genin *et al*., 2016) [5]. Its leaves and seeds are extensively used in traditional medicine to treat conditions such as bone fractures, arthritis, pain, and inflammation (Younis *et al*., 2016) [24]. These medicinal applications are

substantiated by phytochemical studies confirming the presence of potent bioactive compounds, including terpenoids, coumarins, and phenolic substances, which correlate with its demonstrable antioxidant, antimicrobial, anti-inflammatory, and analgesic activities (M'sou and Romane, 2017) [13]. Furthermore, indigenous communities have developed sophisticated traditional agropastoral management systems, such as precise pollarding and shaping within overlapping four-year cutting cycles, and even trunk anastomosis (known as Tahboucht), which are essential for sustainably regulating resource yield, enhancing tree vigor, and ensuring the longevity of these valuable stands (Genin *et al*., 2017) [6]. Despite the effectiveness of these traditional stewardship practices, the species is currently facing a dramatic population decline due to habitat degradation and indiscriminate harvesting, underscoring the immediate need for enhanced, formally recognized conservation strategies to safeguard this vital high-mountain ash

Morphology

The morphology of Fraxinus xanthoxyloides begins with its stature as a shrub or small tree, reaching a maximum height of approximately 25 feet (7.6 meters) in its natural habitat, characterized by bark that progresses from smooth and grey in younger specimens to darker and cracked with age, and further defined by its stiff branches (Negi and Sharma, 2015) [17]. Its leaves are pinnately compound, typically bearing 7 to 9 leaflets—though this number can vary widely from 3 to 13—with young growth, petioles, and the winged rachis being either downy or glabrous on the underside. The individual leaflets display size variability but are generally lanceolate or narrow-elliptic, measuring 1.25 to 2.25 inches (3.2 to 5.7 cm) in length, with some occasionally reaching 4 inches (10 cm) in an ovate or broad-elliptic shape, usually featuring bluntly toothed margins and being scarcely stalked (www.treesandshrubsonline.org). The species' phenology involves the production of small, apetalous (lacking petals), wind-pollinated flowers in short, dense panicles emerging from leaf-scars of previous year's growth between February and March; these develop into linear-oblong or spathulate fruits that mature from July to September, ripening fully during October-November and often persisting on the tree until the following spring (Genin *et al*., 2016; Negi and Sharma, 2015) [5, 17]. Natural regeneration from seed is often challenging due to seed dormancy and environmental pressures, but controlled studies have demonstrated that seed germination can be significantly improved, showing a 54.34% increase over controls, by treating them with Gibberellic acid (GA3) at 1500 ppm for 24 hours, with the optimal seed collection period determined to be between the first fortnight of October and the first fortnight of November (Negi and Sharma, 2011, 2015) [16, 17].

Phytochemical Composition and Pharmacological Validation

The phytochemical profile of F. xanthoxyloides is rich and diverse, providing a scientific basis for its extensive traditional use, with analyses revealing the presence of numerous bioactive compounds, notably coumarins, secoiridoids, phenylethanoids, lignans, flavonoids, and various simple phenolic substances (Kostova and Iossifova, 2007). Essential oils from the leaves, for instance, are credited with strong antioxidant and antimicrobial properties due to constituents like (E)-Nerolidol and eugenol, the latter demonstrating antifungal activity with minimum inhibitory concentrations (MICs) between 1.8 and 3.8 mg/mL (M'sou and Romane, 2017) [13]. Furthermore, crude methanol extracts of the leaves have been validated for potent anti-inflammatory and analgesic effects, an activity strongly linked to a high content of terpenoids (26.61%), along with significant amounts of lactam, esters, phenols, and steroids (Younis *et al*., 2016) [25]. The link between chemistry and bioactivity extends to other areas, with a robust correlation found between terpenoid content and anti-leishmanial activity, and a medium association between coumarins and insecticidal properties, alongside a demonstrated potential to mitigate cisplatin-induced testicular damage in animal models (Ijaz *et al*., 2020) [10].

Ethnobotanical Applications and Fodder Significance

The traditional uses of *F. xanthoxyloides* underscore its value as an agroforestry and livelihood species, particularly in the Moroccan High Atlas, where it serves multiple purposes, from providing firewood, timber (for poles, beams, and tool handles), and dye (from tannin-rich leaves) to offering culinary and medicinal resources (Bellakhdar, 1997; Genin *et al*., 2016) [2, 5]. Medicinally, its reported diuretic, laxative, and anti-rheumatic actions are utilized to treat human ailments like arthritis, dropsy, and cystitis, and it is widely employed in veterinary ethnopharmacology, where extracts of the wood, stem, or twigs are crucial for treating bone fractures and internal injuries in cattle (Sharma *et al*., 2016; Mukerji and Manoharachary, 2006) [, 14]. The fruits and seeds are used as spices and for their aphrodisiac qualities, notably flavoring traditional Moroccan drinks like "Khodenjal" and coffee (M'Sou, 2013) [12]. Crucially, the tree provides a significant volume of nutritive fodder during the critical autumn season (August to November) when other range forage is scarce and nutritionally deficient, making it indispensable for low-input mountain livestock farming systems (Genin *et al*., 2016) [5]. Chemical analysis of the fodder confirms its utility, showing a relatively high fiber content and a crude protein (CP) level of 83.5 g/kg DM, which exceeds the minimum 75 g/kg DM required for livestock maintenance, a nutritional quality comparable to high-potential fodder alternatives like Morus alba (mulberry) leaves.

Sustainable Traditional Management Systems

The enduring health and productivity of *Fraxinus xanthoxyloides* populations are not merely coincidental but are instead the direct result of sophisticated traditional agropastoral management techniques developed and meticulously practiced by local communities, particularly in the Moroccan High Atlas. These methods represent a nuanced, generational understanding of the species' ecology, creating a characteristic silvo-pastoral landscape where the trees continuously yield vital resources. This sustainable stewardship is anchored in complex, nested cutting cycles meticulously designed to optimize the output of various products. For instance, fodder leaves are regenerated through overlapping four-year cutting cycles, where only a quarter of the trees within a designated parkland are subjected to pollarding annually. This calculated, rotational harvesting ensures a persistent and manageable supply of leafy branches, which are then grazed directly by small ruminants like sheep and goats, securing essential nutrition during scarce foraging months (Genin *et al*., 2018) [6]. Beyond fodder, management extends to timber production: calibrated poles necessary for roofing (approximately 7 cm in diameter) require an eight-year growth cycle, while the strongest poles are intentionally retained for up to 30 years to eventually yield large construction beams. Crucially, these practices involve more than just harvesting; they include specialized horticultural techniques like shaping and trunk anastomosis, known locally as Tahboucht in Berber. This technique involves deliberately grafting or fusing branches and

stems, which fundamentally enhances the tree's vigor, resource output, and overall longevity, ultimately leading to four distinct, visible tree morphologies in managed stands: large anastomosed trunk trees, multi-stemmed or coppice trees, single-stemmed trees, and naturally shrub-like trees. Despite the undeniable effectiveness and ecological merit of this indigenous forest management system, it often remains unrecognized and unsupported by formal Moroccan forest and agriculture authorities, leaving this crucial heritage system vulnerable to external pressures and decline.

Advanced Traditional Management and Conservation Imperatives for *Fraxinus xanthoxyloides*

The sustained productivity and ecological resilience of Fraxinus xanthoxyloides stands in the Berber regions of the High Atlas are intricately linked to a sophisticated and centuries-old traditional management practice known as Tahboucht. This term, deriving from the verb Habouch—meaning 'to educate' or 'to mother'—encapsulates a holistic, protective, and enhancing approach to agroforestry. The core practice involves the initial construction of stonewalls around young trees to shield them from intense browsing by sheep and goats until they reach an inaccessible height of approximately 1.5 to 2 meters. This protection allows the coppice shoots emerging from the tree's collar to grow unimpeded. Following this protective phase, a selective process is implemented: only the most vigorous and straightest sprouting stems—typically numbering between 3 and 12—are retained.

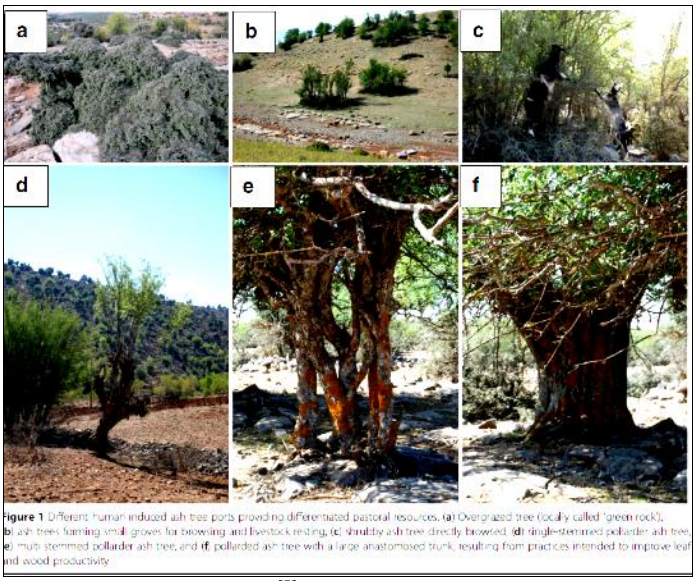

Figure 1 Different human induced ash tree ports providing differentiated pastoral resources. (a) Overgrazed tree (locally called 'green rock'), (b) ash trees forming small groves for browsing and livestock resting, (c) shrubby ash tree directly browsed, (d) single-stemmed pollarded ash tree, (e) multi-stemmed pollarded ash tree, and (f) pollarded ash tree with a large anastomosed trunk, resulting from practices intended to improve leaf and wood productivity

(**Source:** Genin *et al.*, 2016) [5]

These selected stems are repeatedly lopped, a form of pollarding, specifically to increase their diameter and overall strength. Crucially, these stems are then manually shifted and joined together as closely as possible. Over time, these stems fuse through a natural grafting process known as anastomosis, resulting in a unique, single large trunk composed of multiple interconnected stem compartments.

Ecological and Biogeochemical Benefits of Tahboucht

Local inhabitants firmly believe that this anastomosis technique, which some researchers term a form of 'semi-ontogenetic rejuvenation' (Ferrini, 2006), significantly enhances the tree's productivity and longevity (Genin *et al.*, 2018) [6]. Scientific studies have validated these traditional claims, demonstrating that anastomosed trees exhibit markedly superior performance compared to their non-fused counterparts. For instance, research by Genin revealed that trunk anastomosis facilitates a remarkable 36 percent increase in leaf production following a four-year exploitation cycle, simultaneously boosting the trees' overall robustness and lifespan. The practice yields substantial belowground benefits as well, with anastomosed plants contributing to greater soil biological activity. The resulting increased biomass production enriches the soil significantly, indicated by phosphorus (P) levels six times greater and Total Organic Carbon (TOC) levels twice as high when compared to soil beneath non-anastomosed trees. Furthermore, the enhanced vitality leads to a 37 percent increase in the degree of mycorrhization, improving nutrient and water uptake. This demonstrates that the aerial enhancement achieved through Tahboucht is inextricably linked to crucial improvements in the species' belowground traits and surrounding soil quality.

Nested Cutting Cycles and Policy Implications

Tahboucht is not a standalone practice but is integrated into a larger, sophisticated system involving shaping and pollarding that defines the characteristic agropastoral parklands of the Moroccan High Atlas (Fakhech *et al.*, 2020) [4]. This system utilizes nested cutting cycles that correspond to three distinct resource tiers or 'floors'—fodder, poles, and beams—which are collected sequentially. This meticulously planned exploitation method achieves several sustainable outcomes: 1) it guarantees a diverse supply of resources collected annually from living trees; 2) it ensures the production of 'calibrated' goods by actively shaping resprouts directly on the tree; and 3) it allows for a precise estimation of the forage available each year. This model reinforces the idea that pollarded trees are known to survive longer than unmanaged trees (Mansion, 2010). Given their technical and ecological efficiency, researchers like Genin *et al.* (2016) [5] strongly recommend that these traditional management approaches be formally included in policymaking. With the growing global interest in agroforestry systems (Bhagwat *et al.*, 2008), these long-established indigenous methods can serve as a vital foundation for developing modern technological itineraries that successfully integrate sustainable agriculture, resource production, and ecological stewardship.

Conservation Challenges and Future Outlook

Despite the efficacy of traditional management in enhancing the tree's resilience, the overall population of the endangered Fraxinus xanthoxyloides has faced a dramatic decline in recent decades. This decline is attributed to a confluence of threats, including indiscriminate harvesting for domestic and commercial purposes, intensive grazing pressure, large-scale deforestation, escalating human activities, and severe deterioration in habitat quality, all compounded by the adverse effects of climate change (Rankou *et al.*, 2017) [18]. The principle that moderate levels of disturbance can boost biodiversity and ecological function is only sustainable when harvesting is controlled and habitats are protected. Therefore, the species urgently requires comprehensive protection and the integration of sustainable harvesting practices within formal forest management frameworks. Recognizing and supporting the Tahboucht system is not merely an act of cultural preservation; it is a vital, evidence-based conservation strategy necessary for the long-term survival and propagation of this multi-functional ash species.

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