Review

Nursery Production of *Neltuma* Genus in Arid and Semiarid Regions of Argentine: a Review

Producción en vivero del género *Neltuma* en regiones áridas y semiáridas de Argentina: una revisión

Anabella Mirtha Massa Decon, Silvina Pérez *

Originales: *Recepción:* 26/05/2025 - *Aceptación:* 17/10/2025

Index

Universidad Nacional de Cuyo. Facultad de Ciencias Agrarias. Almirante Brown 500. M5528AHB. Chacras de Coria. Mendoza. Argentina. * sperez@fca.uncu.edu.ar

Abstract

Neltuma spp. (previously known as *Prosopis spp.*) are vital for ecological restoration and sustainable forestry in arid and semiarid environments. Although extensively studied, nursery techniques are still inconsistently applied, and poorly integrated. This review synthesizes recent scientific advances in seedling cultivation under controlled conditions, focusing on seed source selection, dormancy-breaking treatments, and substrate-container interactions. This review incorporates developments concerning seed source selection, plant physiology, and nursery trials to identify knowledge gaps and propose strategies for reforestation improvement. We offer actionable guidance for nursery operators, restoration professionals, and policymakers. Future research should focus on long-term field studies, genomic tools, standardization of nursery techniques, biological interactions that improve stress tolerance, and economic feasibility, especially for under-researched species.

Keywords

seed provenance • nursery propagation techniques • substrate-container interaction • algarrobo

Resumen

Neltuma spp. (anteriormente, *Prosopis spp*.) es una especie vital para la restauración ecológica y la silvicultura sostenible en ambientes áridos y semiáridos. A pesar de décadas de investigación, las técnicas de producción en vivero para estas especies siguen siendo inconsistentes y mal integradas. El objetivo de esta revisión es sintetizar los avances científicos recientes en el cultivo de plántulas en condiciones controladas, centrándose en la selección de la fuente de semillas, los tratamientos pre-germinativos y las interacciones sustrato-contenedor. Para ello, este trabajo incorpora avances en selección del origen de semillas, fisiología vegetal y ensayos de viveros para identificar lagunas de conocimiento, y proponer un marco estratégico para mejorar la reforestación. Para ello, se ofrece orientación práctica para los operadores de viveros, los profesionales de la restauración, y los responsables de la formulación de políticas públicas. Futuras investigaciones deberían focalizarse en estudios de campo a largo plazo, herramientas genómicas, estandarización de técnicas de vivero, e interacciones biológicas que mejoren la tolerancia al estrés y la viabilidad económica, especialmente para especies subestudiadas.

Palabras clave

procedencia de semillas • técnicas de propagación en viveros • interacción sustrato-contenedor • algarrobo

Introduction

Neltuma, previously known as Prosopis spp. (Hughes *et al.*, 2022), is a dominant genus in Argentina's arid and semi-arid ecosystems (Scaglia *et al.*, 2024). Neltuma spp. play a critical role in ecological functioning and service provision (Joseau *et al.*, 2023; Oliva *et al.*, 2010; Vilela & Ravetta, 2005; Villagra *et al.*, 2005). Their particular resilience to extreme environmental conditions makes them key species for restoration initiatives (Passera, 2000; Salto *et al.*, 2019). In addition, their presence in arid woodlands significantly influences understory plant communities and supports biodiversity and pastoral systems (Cesca *et al.*, 2012; Venier *et al.*, 2023), while providing important food and pharmacological resources (Mazzuca *et al.*, 2003; Pastorino & Marchelli, 2021; Vilela & Ravetta, 2005).

Landscape natural regeneration with *Neltuma spp.* is often limited by seed predation and habitat degradation (Braun Wilke *et al.,* 2000; Lerner & Peinetti, 1996; Marone *et al.*, 2000; Milesi & Lopez de Casenave, 2004; Villagra *et al.*, 2002), making active restoration efforts essential. State incentives have promoted native species cultivation, while shortage of robust seedlings hinders reforestation efforts (Salto *et al.*, 2013).

Researchers have extensively explored the ecological, physiological, and genetic characteristics of *Neltuma spp.*. Studies have typically focused on isolated components like genetic variability (Bessega *et al.*, 2019; Darquier *et al.*, 2013), germination protocols (Bravo *et al.*, 2011; Vilela & Ravetta, 2001), or substrate and container effects (Salto *et al.*, 2013, 2016; Senilliani *et al.*, 2021). However, these approaches do not offer integrated frameworks for nursery practices, leading to high failure rates in the field (Guzmán *et al.*, 2011).

Ecological data like germination and seedling establishment rates are essential for cost-effective and evidence-based restoration planning (Perez *et al.*, 2022). Addressing these challenges requires improved propagation protocols, nursery management, and scalable, successful restoration strategies (Pastorino & Marchelli, 2021).

This review integrates recent advances in genomics, plant physiology, and nursery trials, approaches not synthesized in previous literature. This review focuses on population genetic variation, dormancy-breaking treatments, and substrate-container interactions. We also provide practical recommendations for nurseries, restoration planners, and decision-makers. Producing high-quality seedlings for sustainable forestry and ecological restoration gains particular importance when considering climate change and land degradation.

Bibliographic Search Methodology

This review covers focused literature using Google Scholar as primary engine, complemented by Scopus and SciELO for regional coverage. Although this is not a systematic review, a structured and reproducible search strategy was applied. English and Spanish keywords included "*Prosopis*", "*Neltuma*", "seedling production", "forest nursery", "seed germination", "pre-germinative treatments", "containers", "substrate", and "soil". The inclusion criteria considered peer-reviewed research conducted in arid and semi-arid regions of Argentina between 1993 and 2025 addressing nursery production, seed germination, genetic variation, substrate composition, and container design. We excluded grey literature like non-peer-reviewed reports, theses or non-relevant studies. The selection process included (I) an initial screening based on titles, (II) an abstract review for relevance, (III) a full-text reading for studies meeting inclusion criteria, (IV) data extraction and synthesis related to species, treatments, morphological traits, and genetic data. A total of 79 peer-reviewed studies were selected and analyzed. We integrate ecological, physiological, and operational insights to guide nursery practices and restoration strategies for *Neltuma spp.*.

Seed Source Selection and Genetic Variation

Selecting the right seed source is crucial for successful reforestation with *Neltuma spp.* Genetic variation among populations is largely shaped by geographic and environmental gradients influencing the development of adaptive traits (Pastorino & Marchelli, 2021). As a result, seed origin directly affects morphological and physiological adaptations like seedling vigor, stress tolerance, and adaptability to local conditions (Mantován, 2002; Vega *et al.*, 2020). Intraspecific variation in traits like height, basal diameter, and salinity or drought tolerance has been widely documented, particularly in *N. alba* and *N. flexuosa* (Cony, 1996; Felker *et al.,* 2008, Fontana *et al.*, 2018; Kong *et al.*, 2023; Salazar *et al.*, 2019).

Provenance trials across Argentina consistently demonstrate that geographic origin significantly influences seedling performance in *Neltuma spp.* Notably, populations from Catamarca (*N. flexuosa*; Bessega *et al.*, 2019; Cony, 1996; Mantovan, 2002; Massa *et al.*, 2023), Formosa, Salta and Chaco (*N. alba*; López *et al.*, 2001; Venier *et al.*, 2021), have shown superior growth and stress tolerance under both nursery and field conditions. These findings are further supported by provenance trial data on superior performance of specific *Neltuma* populations across multiple species and traits relevant to restoration success (table 1, page 214).

Table 1. Seed sources for restoration: evidence from *Neltuma spp.* trials.
Tabla 1. Orígenes de semillas para la restauración: evidencia de los ensayos de *Neltuma spp.*

Specie	Origin	Observed Performance	Reference
N. alba	Ibarreta (Formosa), Castelli (Chaco), Gato Colorado (Santa Fe), Zona de Riego Río Dulce, Sumampa, Quimilí, Añatuya, and Pinto (Santiago del Estero) (Argentina)	Families from Ibarreta (Formosa) and Castelli (Chaco) showed superior diameter and height.	López *et al.*, 2001
N. alba	Santiago del Estero, Northern Salta, Western Formosa, Chaco (Argentina)	Salta excels in growth traits, while Chaco exhibits saline tolerance.	Venier *et al.*, 2021
N. chilensis	San Juan, La Rioja (Chamical, Lamadrid, Chilecito), Catamarca (Argentina)	No significant difference in germination capacity	Cony & Trione, 1998
N. chilensis	Fiambalá, Guandacol, Talampaya, Andalgalá, Astica, Belén, Villa Unión, Los Talas, Conlara, Tinogasta, Chilecito, Las Tucumanesas, Chancani, Soto, Catamarca, Patquia, Villa Dolores (Argentina) and Pama, Río Pama, Pama Alto-Bajo, ca. Mt. Patria, Mt. Patria, Agua Chica (Chile)	The spring budding pattern is associated with geographic and climatic gradients. No significant difference in shoot length, due to high intra-population variability.	Carranza *et al.*, 2000
N. chilensis	Fiambalá, Chilecito, Mogna, Villa Unión (Argentina)	Significant genetic differentiation. Most differentiated: Villa Union.	Chequer Chara *et al.*, 2021
N. ferox	Cerro Negro, Encrucijada, Yavi in the Puna region (Jujuy, Argentina)	Differences in seed protein electrophoretic patterns	Burghardt *et al.*, 2004
N. flexuosa	Bolsón de Fiambalá, B. de Pipanaco, Llanos de Catamarca, B. de Villa Unión, Chamical-Los Llanos, B. de Chilecito, L. de Angaco-Lavalle, Alvear, Nacuñán, Algarrobo del Águila-Limay Mahuida, B. de Rodeo, Río Colorado-General Conesa (Argentina)	B. de Fiambalá excels in height and basal diameter.	Cony, 1996
N. flexuosa	La Pampa, San Juan, La Rioja (Chamical, Lamadrid, Chilecito), Catamarca (Argentina)	Lamadrid displayed the highest germination capacity.	Cony & Trione, 1998
N. flexuosa	Mendoza, Catamarca, San Juan (Argentina)	Catamarca and San Juan differ in spine, total leaf, petiole, primary pinna, leaflet, fruit, and apex length.	Brizueela *et al.*, 2000
N. alba	Río Dulce Irrigation zone (Santiago del Estero), Pinto (Santiago del Estero), Castelli (Chaco), Ibarreta (Formosa) (Argentina)	Castelli and Ibarreta showed higher pod yield. Río Dulce Irrigation zone exhibited greater diameter, height and canopy diameter. Castelli was the most erect and showed resistance to *Psyllid* insects and fungal diseases.	Ewens & Felker, 2010
N. flexuosa	Bolsón de Fiambala, B. de Pipanaco, Chamical-llanos, B. de Mogna, Telteca, Ñacuñan, Río Colorado, General Conesa (Argentina)	B. de Fiambalá and Pipanaco were taller.	Maltovan, 2002
N. flexuosa	Fiambalá, Pipanaco, Mogna, Chilecito, Águila Limay (Argentina)	Fiambalá showed superior growth performance.	Bessega *et al.*, 2019
N. flexuosa	Fiambalá, Monte Comán (Argentina)	Fiambalá excelled in height.	Massa *et al.*, 2023

Recent studies highlight substantial adaptive variation across *Neltuma spp.* Genome-wide analyses in *N. alba* have revealed the molecular basis of key adaptive traits for selecting resilient genotypes (Kong *et al.*, 2023). *N. alba* shows high genetic diversity within populations and moderate differentiation among them, with local adaptation across morphotypes (Bessega *et al.*, 2015; Pastorino & Marchelli, 2021). The species also exhibits strong drought and salinity (Kong *et al.*, 2023; Velarde *et al.*, 2003; Venier *et al.*, 2021). Heritability for traits such as height and pod production suggests good potential for genetic improvement (Carreras *et al.*, 2017; Felker *et al.*, 2001). Hybridization with *N. nigra* and *N. ruscifolia* in contact zones contributes to increased variability and adaptive potential (Vega *et al.*, 2020).

N. flexuosa displays strong clinal variation in morphology and phenology along a north-south gradient, with northern populations being taller and single-stemmed, and southern ones shorter and multi-stemmed (Cony, 1996; Mantován, 2002; Massa *et al.,* 2023; Villagra *et al.*, 2005). Further, *N. flexuosa* shows high intraspecific variation in salt tolerance during germination (Cony & Trione, 1998), and traits like leaflet size exhibit high heritability (Darquier *et al.*, 2013). Genetic differentiation and local adaptation have been confirmed through SSR markers and QST-FST analyses (Bessega *et al.*, 2019; Darquier *et al.*, 2013). Hybridization with *N. chilensis* in sympatric zones further increases natural variability (Bessega *et al.*, 2022; Vega *et al.*, 2020).

N. ferox shows early signs of genetic divergence among populations, with polymorphism in polypeptide fractions and the presence of ecotypes likely driven by environmental pressure and geographic isolation (Burghardt *et al.*, 2004).

In contrast, *N. chilensis* exhibits low genetic variation in foliar traits among provenances (Bessega *et al.*, 2022) and weak adaptive responses to macro-environmental factors. For instance, plants originating in greater longitudes were related to greater frost sensitivity and lower initial growth rates, while higher altitude and precipitation inversely correlated with frost sensitivity (Verzino *et al.*, 2003). The data suggest a general pattern where high intrapopulation variation allows acclimatation, without major genetic alterations. (Verzino *et al.*, 2003). Microsatellite analyses show low but significant genetic differentiation (Chequer Charan *et al.*, 2021), while chemical variability among populations suggests potential for differentiation in secondary metabolites (Lamarque & Guzmán, 1997). Additional studies have linked bud break phenology and germination performance to geographic and environmental stress factors (Carranza *et al.*, 2000; Cony & Trione, 1998), supporting the potential for genetic improvement through selection and breeding (Lamarque & Guzmán, 1997).

A recent study successfully designed and validated 12 provisional Seed Transfer Zones (STZs) for *N. alba* in Argentina, aimed at supporting reforestation and afforestation efforts while minimizing maladaptation risks (Orquera *et al.,* 2025). Researchers developed an Ecogeographic Land Characterization (ELC) map based on bioclimatic, edaphic, and geophysical variables (Orquera *et al.,* 2025). The STZs were validated by showing strong concordance with morphological groups derived from adaptive traits, indicating that environmental factors significantly influence species' adaptive characteristics (Orquera *et al.,* 2025). This approach provides a robust and easy-to-apply tool for germplasm collection and transfer, addressing the endangered genetic diversity of *N. alba* due to deforestation (Orquera *et al.,* 2025). Additionally, the study identified gaps in existing germplasm collections, guidance for future conservation efforts (Orquera *et al.,* 2025).

Integrating morphological and physiological knowledge about variation among provenances (Brizuela *et al.*, 2000; Mantovan, 2002) allows selection and breeding programs (Carreras *et al.*, 2017; Vega *et al.*, 2020). However, many studies are short-term and focus solely on nursery traits, without tracking long-term field performance. Methodological inconsistencies in trial conditions or the use of outdated genetic markers limit cross-study comparability, in addition to the taxonomic and geographic bias, with research concentrated on a few species and regions. Operational feasibility is also underexplored; few studies address logistical or economic challenges of sourcing seeds from high-performing provenances. These gaps challenge current recommendations and complicate the development of scalable restoration strategies.

Early selection and breeding programs should prioritize traits linked to survival under arid conditions, while also considering pod quality and yield (Felker *et al.*, 2001; Lopez Maldonado *et al.*, 2001). Thus, to ensure field survival, seed source selection must consider ecological and operational criteria like (I) expanding genomic resources to underrepresented species such as *N. ferox* and *N. ruscifolia*; (II) standardizing protocols for seed collection, storage, and evaluation; (III) integrating socioeconomic considerations, including seed availability and cost-effectiveness; (IV) linking nursery performance to field success through long-term monitoring.

Seed Pre-treatment Methods for Enhanced Germination

Neltuma spp. are primarily propagated through seeds, often exhibiting physical dormancy. In natural ecosystems, frugivorous animals consume and disperse *Neltuma spp.* seeds. However, they do not inherently promote scarification (Passera, 2000; Peinetti *et al.*, 1993) and even decrease seed germination percentage (Pratolongo *et al.,* 2003). In fact, they may even reduce seed viability, particularly for seeds that remain encapsulated within the pod or are only partially digested (Peinetti *et al.*, 1993; Ortega Baes *et al.*, 2002). As a result, natural dispersal does not reliably enhance germination, and in nursery settings, dormancy must be actively broken through mechanical or chemical scarification to ensure uniform germination (Renzi *et al.*, 2024; Vilela & Rovetta, 2001).

Dormancy levels vary significantly according to species, seed origin, harvest year, and within seed lots, highlighting the need for species- and context-specific studies (Renzi *et al.*, 2024). For instance, in *N. ferox,* germination varies with scarification method, each affecting seed coat permeability and seedling emergence differently (Ortega Baes *et al.*, 2002).

At nursery scale, scarification treatments may be chemical or physical. Chemical methods, like immersion in concentrated sulfuric acid, erode the hard seed coat and facilitate water uptake. These methods are particularly effective for species with strong dormancy, such as *N. ruscifolia* and *N. alpataco* (Abdala *et al.*, 2020; Boeri *et al.*, 2019). Meanwhile, physical methods, including nicking with a blade, abrasion with sandpaper, or soaking in hot water, are effective for species like *N. chilensis* (Killian, 2012)*, N. flexuosa, N. sericantha* (Funes *et al.,* 2009), *N. alba,* and *N. kuntzei* (Bravo *et al.*, 2011; Vilela & Ravetta, 2001), being safer and more practical for nursery-scale operations (Mathers *et al.*, 2007).

Table 2 summarizes species-specific responses to various scarification techniques. These data underscore treatment effectiveness across species and seed lots, reinforcing the need for tailored protocols. For example, germination of *N. alba* significantly increased after seed immersion in 100°C water for 24 hours (Salto *et al.*, 2016). Besides, mechanical scarification followed by soaking significantly increased germination rates in *N. flexuosa* (Brizuela *et al.*, 2000), *N. ruscifolia* shows optimal germination after 3 minutes in concentrated sulfuric acid (Abdala *et al.*, 2020), and *N. alpataco* achieves high germination rates with a 30-minute acid treatment and complete cutting of the seed coat edge (Boeri *et al.*, 2019). By selecting the appropriate pre-treatment method, nursery managers can significantly improve germination efficiency, uniformity, and overall seedling quality.

Table 2. Effective scarification techniques for *Neltuma spp*. seedling production.

Tabla 2. Técnicas efectivas de escarificación para *Neltuma spp*. en la producción de plántulas.

Specie	Chemical treatment	Physical treatment	Reference
N. alba, N. chilensis, N. flexuosa	Sulfuric acid 1N for 15 min, followed by washing and soaking in water	**Nicking seeds with a razor blade. Thermal treatment (with boiling water)**	Vilela & Ravetta, 2001
N. alpataco	**Sulfuric acid at** different durations (2, 5, 10, 20, 30, 40, 50, and 60 min)	Mechanical scarification by partial and **total cutting of the seminal cover edge**	Boeri *et al.*, 2019
N. kuntzei	Not Applicable	Nicking of the seed coat, **mechanical scarification, soaking in room temperature water, and soaking in boiling water**	Bravo *et al.*, 2011
N. ruscifolia	**Concentrated sulfuric acid for 3 min**	Cutting the seed coat, mechanical scarification, immersion in water at room temperature, and immersion in hot water	Abdala *et al.*, 2020

Bold font indicates treatments significantly increasing germination.

Los tratamientos en negrita han aumentado significativamente la germinación.

This review identifies several methodological limitations and inconsistencies in *Neltuma spp.* seedlings propagation techniques. For instance, germination trials often vary in experimental conditions like temperature, light exposure, water quality, and seed storage duration, hindering cross-study comparisons. While chemical scarification (especially with sulfuric acid) is frequently cited as effective, few studies address its operational risks, environmental impact, or feasibility in low-tech nursery settings. Physical methods, though safer, often show variable effectiveness depending on species and seed lots.

Moreover, the response of *Neltuma spp.* to microbial or enzymatic pre-germinative treatments has been poorly explored. These eco-friendly approaches could offer sustainable solutions for large-scale propagation (Zare *et al.*, 2011). Literature focuses on a few well-studied species, with insufficient data on taxa like *N. ruscifolia* and *N. alpataco,* which may have distinct dormancy mechanisms. Recent studies on endophytes in legumes suggest that microbial interactions can enhance germination and seedling vigor by enzymatically softening seed coats or hormonal signaling (Greeshma *et al.*, 2025). These approaches could offer sustainable, low-risk alternatives to chemical scarification, particularly in low-tech nursery settings.

In conclusion, seed pre-treatment is a critical step in overcoming dormancy and ensuring uniform germination in *Neltuma spp*. However, current practices remain poorly integrated and highly species-specific. Future research should (I) develop standardized and scalable protocols for species-specific seed sources, (II) conduct comparative trials assessing both germination success and downstream seedling performance, (III) explore and evaluate eco-friendly alternatives for cost-effectiveness and operational feasibility. A more holistic and evidence-based approach to seed pre-treatment will enhance efficiency, safety, and sustainability of *Neltuma* seedling production for ecological restoration in arid and semi-arid ecosystems.

Integrated Effects of Container and Substrate on Seedling Development in *Neltuma spp.*

The interaction between container and substrate often exceeds the sum of their contributions, significantly influencing seedling growth and development in *Neltuma spp.* (Salto *et al.*, 2013, 2016). A high-quality substrate may underperform in a poorly designed container, and vice versa (Salto *et al.*, 2016). Therefore, nursery design must consider both physico-chemical and biological requirements.

Container design should particularly consider volume, shape, and material (table 1, supplementary material). These characteristics affect root architecture, water dynamics, and operational efficiency (Mathers *et al.*, 2007; Senilliani *et al.*, 2021). Choosing between bare root and container stock types also affects seedling performance, with containerized systems often offering advantages in survival and establishment under challenging site conditions (Grossnickle & El-Kassaby, 2016). Moreover, morphological and physiological traits of *N. alba* seedlings are highly responsive to nursery management, reinforcing the importance of optimizing environmental and operational variables to enhance plant quality (Senilliani *et al.*, 2021).

Substrate selection is critical for root development and seedling vigour (table 2 in the supplementary material for comparative data). Physical and chemical properties like porosity, water retention, aeration and electrical conductivity directly influence root development and nutrient uptake (Vence *et al.*, 2013; Vilela & Ravetta, 2001). Soil texture plays a critical role in seedling growth rate of *N. flexuosa*, *N. argentina* and *N. alpataco* when comparing clay *versus* sandy soils (Villagra & Cavagnaro, 2000; Piraino & Roig, 2024). Flooding-prone soils, like those with shallow clayey horizon and high sodium content, can significantly decrease germination in *N. nigra* (Pratolongo *et al.*, 2003). Similarly, high electrical conductivity inhibits germination in *N. argentina* and *N. pallida* (Velardem *et al.*, 2003; Villagra, 1997), and reduce germination rates in *N. alpataco*, a species adapted to salinity (Villagra, 1997). Commonly used substrates include composted pine bark, perlite, peat, and vermiculite, as well as locally available organic materials like vermicompost, with strong potential to enhance seedling quality while reducing costs (Massa *et al.*, 2023; Mathers *et al.*, 2007).

Table 3 illustrates how container–substrate combinations shape the morphological quality of *Neltuma* seedlings (detailed container and substrate specifications are provided in Tables 1 and 2, supplementary material). Across trials, larger containers (*e.g.*, 250-270 cm^3) consistently supported greater height, root collar diameter, and biomass accumulation, particularly when paired with well-aerated substrates such as composted pine bark mixed with perlite or vermiculite (Salto *et al.*, 2016; Senilliani *et al.*, 2021). Soil-based substrates also performed well, especially in multi-cell trays, enhancing root collar diameter and overall seedling robustness (Salto *et al.*, 2013). These results show that container size and structure must align with substrate properties like porosity and water retention, to support optimal plant development (Salto *et al.*, 2016). Taller containers require substrates with higher water retention, while shorter ones benefit from more aerated mixes (Mathers *et al.*, 2007). *N. alba* seedlings grown in 250 cm^3 ribbed containers filled with a 1:1 mix of composted pine bark and perlite achieved superior height, root collar diameter, and biomass allocation (Senilliani *et al.*, 2021). Similarly, *N. nigra* performed best in seedling tubes and multi-cell trays filled with soil or a 2:1:1 mix of pine bark, perlite, and vermiculite. Soil consistently yielded the highest morphological quality (Salto *et al.*, 2013).

Table 3. Comparative effects of container-substrate combinations on morphological traits in *Neltuma spp.*

Tabla 3. Efectos comparativos de las combinaciones de contenedor-sustrato sobre los rasgos morfológicos en *Neltuma spp.*

Specie	Substrate Composition	Physical/ Chemical Characteristics	Type of Container	Volume (cm^3)	Height (mm)	Diameter (mm)	Observed Performance	Reference
N. alba	Composted pine bark and perlite (3:1)	TP (>85%), AP (55-70%), WR (20-30%)	TC	250	137	64	Seedlings grown in larger containers with a 1:1 mix were taller and had largest root collar diameter, and aerial/root biomass values.	Senilliani *et al.*, 2021
	Composted pine bark and perlite (1:1)	TP (32-51%), AP (20-21%), WR (11-30%)	TC	125	150	40		
N. alba and *N. nigra*	Soil	TP (46-52%), AP (43-48%), WR (3-4%)	IST	100	140	35	Soil consistently produced the largest root collar diameter and seedling height in both trays and seedling tubes, outperforming all other substrate combinations.	Salto *et al.*, 2013
			MCT	90	90	40		
	Composted pine bark	TP (51-69%), AP (32-45%), WR (19-25%)	IST	100	140	35		
			MCT	90	90	40		
	Composted pine bark and soil (1:1)	TP (41-66%), AP (36-61%), WR (5-8%)	IST	100	140	35		
			MCT	90	90	40		
	Composted pine bark, perlite and vermiculite (2:1:1)	TP (60-65%), AP (27-35%), WR (27-33%)	IST	100	140	35		
			MCT	90	90	40		
	Perlite and vermiculite (1:1)	TP (63-67%), AP (40-45%), WR (18-27%)	IST	100	140	35		
			MCT	90	90	40		

TC (Truncated cone with internal ribs), MCT (Multi-cell trays), IST (Individual seedling tubes), TP (Total Porosity), AP (Aeration Porosity), WR (Water retention).

TC (Cono truncado con nervaduras internas), MCT (Bandejas multiceldas), IST (Tubos de plántulas individuales), TP (Porosidad total), AP (Porosidad de aireación), WR (Retención de agua).

Table 3 (page 218), shows the best results for high-porosity substrates (*e.g.*, pine bark + perlite + vermiculite) paired with 100-140 cm^3 containers (Salto *et al.*, 2016; Senilliani *et al.*, 2021). Soil-based substrates consistently produced the largest root collar diameters, particularly in seedling tubes (Salto *et al.*, 2013). These interactions confirm that neither container nor substrate alone determines seedling quality; rather, their combination must be optimized based on species-specific responses. This reinforces the need for integrated nursery planning, considering physical infrastructure and biological requirements.

Beyond physical factors, the role of beneficial microbial interactions remains underexplored in *Neltuma spp.* nursery systems. Mycorrhizal associations can improve soil properties, like total biological activity, electrical conductivity, pH, and organic matter content (Sagadin *et al.*, 2023; Salto *et al.*, 2019, 2024). Multi-omic approaches can help select microbial inoculants with particular functional traits like growth promotion, abiotic stress tolerance, or improved nutrient uptake (Greeshma *et al.*, 2025). Considering *Neltuma spp.*, this technology could improve inoculation efficiency and overall seedling quality.

Despite these advances, several knowledge gaps remain. Few studies have tracked long-term field performance, and economic analyses of substrate and container choices are scarce (Oumahmoud *et al.*, 2023). Moreover, the role of microbial inoculants like mycorrhizal fungi is underexplored. Future research should prioritize (I) long-term, field-based evaluations to link nursery performance with restoration success, (II) cost-benefit analyses to assess scalability and economic feasibility of nursery practices, (III) integration of microbial inoculants to enhance seedling vigor and stress tolerance, and (IV) assessment of synergistic effects among bio-inoculants, substrates and container types.

Conclusion

Despite decades of research on *Neltuma* species, implementing effective nursery production techniques remains a challenge. Although breeding programs have identified superior traits and seed sources, their application in nursery practices remains limited due to poor standardised seed collection protocols, storage, pre-germinative treatments, and seedling management.

This review proposes several actionable insights ready to apply. For instance, nursery operators can (I) select seed sources based on provenances with superior performance under nursery and field conditions, (II) apply species-specific pre-germinative treatments validated for *N. alba*, *N. flexuosa*, and *N. ruscifolia,* and (III) optimize container-substrate combinations. Furthermore, restoration planners and policymakers are encouraged to (I) establish regional seed banks with documented provenance data, (II) promote training programs to disseminate evidence-based nursery practices, and (III) utilize ecogeographic tools such as Seed Transfer Zones (STZs) to guide germplasm collection and minimize maladaptation risks.

Enhanced propagation and restoration potential of *Neltuma spp.,* should prioritize (I) long-term field trials linking nursery performance with restoration success, (II) integration of genomic tools beyond *N. alba*, (III) standardization of nursery protocols across regions and species, (IV) exploration of biological interactions, including microbial inoculants and (V) evaluation of economic feasibility to guide scalable restoration strategies.

With coordinated action across science, practice, and policy, *Neltuma spp.* can become a cornerstone of climate-resilient restoration in arid and semi-arid ecosystems.

Supplemmentary material

https://docs.google.com/document/d/109syPEwVsHZFEAnRr_oR_X3qRIAHivVa/edit?usp=sharing&ouid=111310786017351827239&rtpof=true&sd=true

References

Abdala, N. R., Bravo, S., & Acosta, M. (2020). Germinación y efectos del almacenamiento de frutos de *Prosopis ruscifolia* (Fabaceae). *Bosque (Valdivia)*, *41*(2), 103-111. https://www.scielo.cl/pdf/bosque/v41n2/0717-9200-bosque-41-02-103.pdf

Bessega, C., Pometti, C., Ewens, M., Saidman, B. O., & Vilardi, J. C. (2015). Improving initial trials in tree breeding using kinship and breeding values estimated in the wild: the case of *Prosopis alba* in Argentina. *New Forests*, *46*, 427-448. https://doi.org/10.1007/s10342-016-0948-9

Bessega, C., Cony, M., Saidman, B. O., Aguiló, R., Villagra, P., Alvarez, J. A., & Vilardi, J. C. (2019). Genetic diversity and differentiation among provenances of *Prosopis flexuosa* DC (Leguminosae) in a progeny trial: Implications for arid land restoration. *Forest Ecology and Management*, *443*, 59-68. https://www.sciencedirect.com/science/article/pii/S0378112719302440

Bessega, C., Vilardi, J. C., Cony, M., Saidman, B., & Pometti, C. (2022). Low genetic variation of foliar traits among *Prosopis chilensis* (Leguminosae) provenances. *Journal of Plant Research*, *135*(2), 221-234. https://link.springer.com/article/10.1007/s10265-022-01378-9

Boeri P., Gazo M. C., Barrio D., Failla M., Dalzotto, D., Sharry, S. (2019). Optimum germinative conditions of a multipurpose shrub from Patagonia: *Prosopis alpataco* (Fabaceae). *Darwiniana, nueva serie*, *7*(2), 199-207. https://dx.doi.org/10.14522/darwiniana.2019.72.817

Braun Wilke, R. H., Picchetti, L. P., & Guzmán, G. F. (2000). *Prosopis ferox* gris: Estado actual de su conocimiento. *Multequina*, *9*(2), 19-34.

Bravo, S., Abdala, R., Abraham, F., & Pece, M. (2011). Treatments to improve germination of *Prosopis kuntzei*. *Seed Technology*, 55-62. https://www.jstor.org/stable/45133802

Brizuela, M. M., Burghardt, A. D., Tanoni, D., & Palacios, R. A. (2000). Estudio de la variación morfológica en tres procedencias de P*rosopis flexuosa* y su manifestación en cultivo bajo condiciones uniformes. *Multequina*, *9*(1), 7-15. https://www.scielo.org.ar/scielo.php?pid=S1852-73292000000100002&script=sci_abstract&tlng=en

Burghardt, A. D., Espert, S. M., & Braun Wilke, R. H. (2004). Variabilidad genética en *Prosopis ferox* (Mimosaceae). *Darwiniana, nueva serie*, *42*(1-4), 31-36. https://www.scielo.org.ar/scielo.php?pid=S0011-67932004000100003&script=sci_arttext&tlng=pt

Carranza, C., Verzino, G., Di Rienzo, J., Ledesma, M., & Joseau, J. (2000). Componentes de la variación adaptativa en *Prosopis chilensis*: el índice de brotación. *Multequina*, *9*(1), 55-64. https://www.scielo.org.ar/scielo.php?pid=S1852-73292000000100007&script=sci_arttext

Carreras, R., Bessega, C., López, C. R., Saidman, B. O., & Vilardi, J. C. (2017). Developing a breeding strategy for multiple trait selection in *Prosopis alba* Griseb., a native forest species of the Chaco Region in Argentina. *Forestry: An International Journal of Forest Research*, *90*(2), 199-210.

Cesca, E. M., Villagra, P. E., Passera, C., & Alvarez, J. A. (2012). Effect of *Prosopis flexuosa* on understory species and its importance to pastoral management in woodlands of the Central Monte Desert. *Revista de la Facultad de Ciencias Agrarias. Universidad Nacional de Cuyo*, *44*(2), 207-219. https://revistas.uncu.edu.ar/ojs3/index.php/RFCA/article/view/6305/5109

Chequer Charan, D., Pometti, C., Cony, M., Vilardi, J. C., Saidman, B. O., & Bessega, C. (2021). Genetic variance distribution of SSR markers and economically important quantitative traits in a progeny trial of *Prosopis chilensis* (Leguminosae): implications for the 'Algarrobo' management programme. *Forestry: An International Journal of Forest Research*, *94*(2), 204- 218.

Cony, M. A. (1996). Genetic variability in *Prosopis flexuosa* DC, a native tree of the Monte phytogeographic province, Argentina. *Forest Ecology and Management*, *87*(1-3), 41-49.

Cony, M. A., & Trione, S. O. (1998). Inter- and intraspecific variability in *Prosopis flexuosa* and *P. chilensis*: seed germination under salt and moisture stress. *Journal of Arid Environments*, *40*(3), 307-317.

Darquier, M. R., Bessega, C. F., Cony, M., Vilardi, J. C., & Saidman, B. O. (2013). Evidence of heterogeneous selection on quantitative traits of *Prosopis flexuosa* (Leguminosae) from multivariate QST-FST test. *Tree Genetics & Genomes*, *9*, 307-320. https://link.springer.com/article/10.1007/s11295-012-0556-x

Ewens, M., & Felker, P. (2010). A comparison of pod production and insect ratings of 12 elite *Prosopis alba* clones in a 5-year semi-arid Argentine field trial. *Forest Ecology and Management*, *260*(3), 378-383.

Felker, P., Ewens, M., Velarde, M., & Medina, D. (2008). Initial evaluation of *Prosopis alba* Griseb clones selected for growth at seawater salinities. *Arid Land Research and Management*, *22*(4), 334-345.

Felker, P., Lopez, C., Soulier, C., Ochoa, J., Abdala, R., & Ewens, M. (2001). Genetic evaluation of *Prosopis alba* (algarrobo) in Argentina for cloning elite trees. *Agroforestry Systems*, *53*, 65-76. https://link.springer.com/article/10.1023/A:1012016319629

Fontana, M., Pérez, V., & Luna, C. (2018). Efecto del origen geográfico en la calidad morfológica de plantas de *Prosopis alba* (Fabaceae). *Revista de Biología Tropical*, *66*(2), 593-604. https://www.scielo.sa.cr/scielo.php?pid=S0034-77442018000200593&script=sci_arttext

Funes, G., Díaz, S., & Venier, P. (2009). La temperatura como principal determinante de la germinación en especies del Chaco seco de Argentina. *Ecología austral*, *19*(2), 129-138.

Greeshma, K., Arutselvan, R., Teja, T. R., Baishnabi, D., & Chaudhary, S. (2025). Endophytes and Microbiome: Modern Techniques in Sustainable Crop. *Multi-omics Approach to Investigate Endophyte Diversity*, 103.

Grossnickle, S. C., & El-Kassaby, Y. A. (2016). Bareroot *versus* container stocktypes: a performance comparison. *New Forests*, *47*(1), 1-51.

Guzmán, A., Coronel de Renolfi, M., & Pece, M. G. (2011). Determinación de fallas en la siembra comercial de Algarrobo blanco (*Prosopis alba*) en un vivero de Santiago del Estero. *Quebracho (Santiago del Estero)*, *19*(1), 46-53. https://www.scielo.org.ar/scielo.php?pid=S1851-30262011000100006&script=sci_arttext

Hughes, C. E., Ringelberg, J. J., Lewis, G. P., & Catalano, S. A. (2022). Disintegration of the genus *Prosopis* L. (Leguminosae, Caesalpinioideae, mimosoid clade). *PhytoKeys*, *205*, 147. https://pmc.ncbi.nlm.nih.gov/articles/PMC9849005/

Joseau, M. J., Rodriguez Reartes, S., & Frassoni, E. J. (2023). Advances in the Use of *Neltuma* (ex *Prosopis*) Pods for Human and Animal Consumption. Pand their properties for human and animal food. In M. Hasanuzzaman (Ed.), *Production and utilization of legumes - Progress and prospects*. *IntechOpen*. https://www.intechopen.com/chapters/86609

Killian, S. (2012). Técnicas de germinación de *Prosopis chilensis* Moll Stuntz. *Biología en Agronomia*.

Kong, W.; Wang, Y.; Liu, Y.; Zhang, Y.; Zhang, Y.; Zhang, X. (2023). Genome and evolution of *Prosopis alba* Griseb., a drought and salinity tolerant tree legume crop for arid climates. *Plants, People, Planet*, *5*(6), 933-947. https://doi.org/10.1002/pei3.100

Lamarque, A. L., & Guzmán, C. A. (1997). Seed chemical variation in *Prosopis chilensis* from Argentina. *Genetic Resources and Crop Evolution*, *44*(6), 495-498.

Lerner, P., & Peinetti, R. (1996). Importance of predation and germination on losses from the seed bank of calden (*Prosopis caldenia*). *Rangeland Ecology & Management/Journal of Range Management Archives*, *49*(2), 147-150.

López, C., Maldonado, A., & Salim, V. (2001). Variación genética de progenies de *Prosopis alba. Investigación agraria. Sistemas y recursos forestales*, *10*(1), 59-68.

Mantovan, N. G. (2002). Early growth differentiation among *Prosopis flexuosa* DC provenances from the Monte phytogeographic province, Argentina. *New Forests*, *23*, 19-30. https://link.springer.com/article/10.1023/A:1015608430967

Marone, L., Horno, M. E., & Solar, R. G. D. (2000). Post-dispersal fate of seeds in the Monte desert of Argentina: patterns of germination in successive wet and dry years. *Journal of Ecology*, *88*(6), 940-949.

Massa, A.; Quagliariello, G.; Martinengo, N.; Calderón, A.; Pérez, S. 2023. Growth and slenderness index in sweet algarrobo, *Neltuma flexuosa*, according to the vermicompost percentage in the substrate and seed origin. *Revista de la Facultad de Ciencias Agrarias. Universidad Nacional de Cuyo, 55*(2): 12-19. DOI: https://doi.org/10.48162/rev.39.105

Mathers, H. M., Lowe, S. B., Scagel, C., Struve, D. K., & Case, L. T. (2007). Abiotic factors influencing root growth of woody nursery plants in containers. *HortTechnology*, *17*(2), 151-162.

Mazzuca, M., Kraus, W., & Balzaretti, V. (2003). Evaluation of the biological activities of crude extracts from Patagonian *Prosopis* seeds and some of their active principles. *Journal of herbal pharmacotherapy*, *3*(2), 31-37.

Milesi, F. A., & Lopez De Casenave, J. (2004). Unexpected relationships and valuable mistakes: non-myrmecochorous *Prosopis* dispersed by messy leafcutting ants in harvesting their seeds. *Austral Ecology*, *29*(5), 558-567.

Oliva, M., Alfaro, C., & Palape, I. (2010). Evaluación del potencial tecnológico de galactomananos del endospermo de semillas de *Prosopis sp.* para el uso en la industria de alimentos. *Agriscientia*, *27*(2), 107-113. https://www.scielo.org.ar/scielo.php?pid=S1668-298X2010000200006&script=sci_arttext

Orquera, R. M.; Marinoni, L.; Velazquez, M. A.; Pensiero, J. F.; Lauenstein, D. L.; Vega, C.; Zabala, J. M. (2025). Design of seed transfer zones and assessment of germplasm collections of Neltuma alba for reforestation and afforestation purposes in Argentina. *New Forests, 56*(1), 10. https://link.springer.com/article/10.1007/s11056-024-10072-8

Ortega Baes, P., de Viana, M. L., & Sühring, S. (2002). Germination in *Prosopis ferox* seeds: effects of mechanical, chemical and biological scarificators. *Journal of arid environments*, *50*(1), 185-189. https://www.sciencedirect.com/science/article/pii/S0140196301908596

Oumahmoud, M.; Alouani, M.; Elame, F.; Tahiri, A.; Bouharroud, R.; Qessaoui, R.; El Boukhari, A.; Mimouni, A.; Koufan, M. (2023). Effect of shading, substrate, and container size on Argania spinosa growth and cost–benefit analysis. *Agronomy*, *13*(10), 2451. https://doi.org/10.3390/agronomy13102451

Passera, C. B. (2000). Fisiología de *Prosopis spp. Multequina*, *9*(2), 53-80. https://www.scielo.org.ar/pdf/multeq/v9n2/v9n2a04.pdf

Pastorino, M. J., & Marchelli, P. (2021). *Low Intensity Breeding of Native Forest Trees in Argentina*. Springer: Berlin/Heidelberg, Germany. https://link.springer.com/content/pdf/10.1007/978-3-030-56462-9.pdf

Peinetti, R., Pereyra, M., Kin, A., & Sosa, A. (1993). Effects of cattle ingestion on viability and germination rate of calden (*Prosopis caldenia*) seeds. *Rangeland Ecology & Management/Journal of Range Management Archives*, *46*(6), 483-486.

Pérez, D. R., Ceballos, C., & Oneto, M. E. (2022). Costos de plantación y siembra directa de *Prosopis flexuosa* var. depressa (Fabaceae) para restauración ecológica. *Acta botánica mexicana*, (129). https://www.scielo.org.mx/scielo.php?pid=S0187-71512022000100500&script=sci_ arttext

Piraino, S.; Roig, F. A. 2024. Landform heterogeneity drives multi-stemmed *Neltuma flexuosa* growth dynamics. Implication for the Central Monte Desert forest management. *Revista de la Facultad de Ciencias Agrarias. Universidad Nacional de Cuyo. 56*(1): 26-34. DOI: https://doi.org/10.48162/rev.39.120

Pratolongo, P., Quintana, R., Malvárez, I., & Cagnoni, M. (2003). Comparative analysis of variables associated with germination and seedling establishment for *Prosopis nigra* (Griseb.) Hieron and *Acacia caven* (Mol.) Mol. *Forest ecology and management*, *179*(1-3), 15-25.

Renzi, J. P., Quintana, M., Bruna, M., & Reinoso, O. (2024). Environmental drivers of seed persistence and seedling trait variation in two *Neltuma* species (Fabaceae). *Seed Science Research*, 1-8. https://doi.org/10.1017/S0960258524000205

Sagadin, M. B., Salto, C. S., Cabello, M. N., & Luna, C. M. (2023). Respuesta micorrícica a la aplicación de inóculos de hongos micorrícicos arbusculares nativos en simbiosis con *Neltuma alba*. *Revista de Ciencias Forestales*, *31*, 1-2.

Salazar, P. C., Navarro-Cerrillo, R. M., Cruz, G., Grados, N., & Villar, R. (2019). Variability in growth and biomass allocation and the phenotypic plasticity of seven *Prosopis pallida* populations in response to water availability. *Trees*, *33*, 1409-1422. https://link.springer.com/article/10.1007/s00468-019-01868-9

Salto, C. S., García, M. A., & Harrand, L. (2013). Influencia de diferentes sustratos y contenedores sobre variables morfológicas de plantines de dos especies de *Prosopis*. *Quebracho (Santiago del Estero)*, *21*(2), 90-102.

Salto, C. S., Harrand, L., Javier Oberschelp, G. P., & Ewens, M. (2016). Crecimiento de plantines de *Prosopis alba* en diferentes sustratos, contenedores y condiciones de vivero. *Bosque (Valdivia)*, *37*(3), 527-537. https://www.scielo.cl/scielo.php?pid=S0717-92002016000300010&script=sci_arttext

Salto, C. S., Melchiorre, M., Oberschelp, G. P. J., Pozzi, E., & Harrand, L. (2019). Effect of fertilization and inoculation with native rhizobial strains on growth of *Prosopis alba* seedlings under nursery conditions. *Agroforestry Systems*, *93*, 621-629. https://link.springer.com/article/10.1007/s10457-017-0156-8

Salto, C. S., Sagadin, M. B., & Harrand, L. (2024). Inoculación de *Neltuma alba* con hongos micorrícicos arbusculares: efectos sobre el crecimiento y las variables edáficas en Entre Ríos, Argentina. *Bosque (Valdivia)*, *45*(2), 283-294.

Scaglia, J. A.; Flores, D. G.; Tapia, R.; Martinell, M. 2024. Effects of geomorphology and distribution of water sources for livestock on the floristic composition and livestock receptivity of the Arid Chaco. *Revista de la Facultad de Ciencias Agrarias. Universidad Nacional de Cuyo. 56*(1): 12-25. DOI: https://doi.org/10.48162/rev.39.119

Senilliani, M. G., Acosta, M., Oliet, J., & Brassiolo, M. (2021). Atributos morfológicos y fisiológicos de *Prosopis alba* Griseb en vivero con diferentes sustratos y contenedores. *Quebracho (Santiago del Estero)*, *29*(2), 92-101. https://www.scielo.org.ar/scielo.php?pid=S1851-30262021000200092

Vega, C., Teich, I., Acosta, M. C., Lopez Lauenstein, D., Verga, A., & Cosacov, A. (2020). Morphological and molecular characterization of a hybrid zone between *Prosopis alba* and *P. nigra* in the Chaco region of northwestern Argentina. *Silvae Genetica*, *69*, 44-54. https://sciendo.com/pdf/10.2478/sg-2020-0007

Velarde, M., Felker, P., & Degano, C. (2003). Evaluation of Argentine and Peruvian *Prosopis* germplasm for growth at seawater salinities. *Journal of Arid Environments*, *55*(3), 515-531.

Vence, L. B. (2008). Disponibilidad de agua-aire en sustratos para plantas. *Ciencia del suelo*, *26*(2), 105-114.

Vence, L. B., Valenzuela, O. R., Svartz, H. A., & Conti, M. E. (2013). Elección del sustrato y manejo del riego utilizando como herramienta las curvas de retención de agua. *Ciencia del suelo*, *31*(2), 153-164. https://www.scielo.org.ar/scielo.php?pid=S1850-20672013000200002&script=sci_arttext

Venier, P., Funes, G., Teich, I., López Lauenstein, D., & Lascano, R. (2021). Provenance matters: variability under saline stress in young plants of four populations of a *Prosopis* (mesquite) species from dry forests of Argentina. *Canadian Journal of Forest Research*, *51*(9), 1263-1270.

Venier, P., Ferreras, A. E., Lauenstein, D. L., & Funes, G. (2023). Nurse plants and seed provenance in the restoration of dry Chaco forests of central Argentina. *Forest Ecology and Management*, *529*, 120638. https://www.sciencedirect.com/science/article/pii/S0378112722006326

Verzino, G., Carranza, C., Ledesma, M., Joseau, J., & Di Rienzo, J. (2003). Adaptive genetic variation of Prosopis chilensis (Mol) Stuntz: Preliminary results from one test-site. *Forest ecology and Management*, *175*(1-3), 119-129.

Vilela, A. E., & Ravetta, D. A. (2001). The effect of seed scarification and soil-media on germination, growth, storage, and survival of seedlings of five species of *Prosopis* L. (Mimosaceae). *Journal of Arid Environments*, *48*(2), 171-184.

Vilela, A. E., & Ravetta, D. A. (2005). Gum exudation in South-American species of *Prosopis* L. (Mimosaceae). *Journal of arid environments*, *60*(3), 389-395. https://www.sciencedirect.com/science/article/pii/S0140196304001302

Villagra, P. E. (1997). Germination of *Prosopis argentina* and *P. alpataco* seeds under saline conditions. *Journal of Arid Environments*, *37*(2), 261-267.

Villagra, P. E., & Cavagnaro, J. B. (2000). Effects of clayish and sandy soils on the growth of *Prosopis argentina* and *P. alpataco* seedlings. *Ecología Austral*, *10*(2), 113-121.

Villagra, P. E., Marone, L., & Cony, M. A. (2002). Mechanisms affecting the fate of *Prosopis flexuosa* (Fabaceae, Mimosoideae) seeds during early secondary dispersal in the Monte Desert, Argentina. *Austral Ecology*, *27*(4), 416-421.

Villagra, P. E., Boninsegna, J. A., Alvarez, J. A., Cony, M., Cesca, E., & Villalba, R. (2005). Dendroecology of *Prosopis flexuosa* woodlands in the Monte desert: Implications for their management. *Dendrochronologia*, *22*(3), 209-213.

Zare, S., Tavili, A., & Darini, M. J. (2011). Effects of different treatments on seed germination and breaking seed dormancy of *Prosopis koelziana* and *Prosopis juliflora*. Journal of Forestry Research, 22, 35-38. https://link.springer.com/article/10.1007/s11676-011-0121-8

Acknowledgements

INTA EEA Junin, Mendoza, received funding in the first call for the National Forest Restoration Plan framed in the ForestAr 2030 platform of the National Ministry of Environment and Sustainable Development, Argentina.