

Review

Distribution, regeneration status and nutritional analysis of *Quercus glauca* Thunberg in the Himalaya

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ABSTRACT

The present review focuses on the distribution, regeneration status and nutritive potential of *Quercus glauca* Thunberg in the Indian Himalayan region. The species is widely distributed in the northwestern Himalaya, particularly in Himachal Pradesh and Uttarakhand, where it grows in moist and shady habitats and forms an important component of evergreen broadleaf forests. It is closely associated with rural livelihoods and serves as a valuable fodder resource for livestock. The leaves of *Q. glauca* possess high nutritive value with considerable crude protein, mineral content and moderate fibre composition, making it suitable for sustaining livestock productivity in hill agroecosystems. Despite its ecological and economic importance, the species is facing serious challenges in natural regeneration due to anthropogenic disturbances, overgrazing, limited seed viability, poor dispersal and changing climatic conditions. Seed germination in *Quercus* species is influenced by several factors including seed size, altitude, time of collection and pre-sowing treatments. Physical treatments such as scarification and water soaking along with proper nursery management have been found effective in improving germination and seedling establishment. The review highlights that regeneration of *Q. glauca* is site-specific and favoured under moderate disturbance and adequate canopy gaps. However, overall regeneration remains inadequate across its natural distribution range. The study emphasizes the need for integrated management strategies focusing on habitat conservation, improvement in regeneration techniques and sustainable utilization of the species.

Keywords: *Quercus glauca*; Distribution; Regeneration; Germination; Nutritional value; Fodder tree; Seed biology

INTRODUCTION

The northwestern Himalaya forms an important part of the Indian Himalayan Region (IHR) and includes the states of Himachal Pradesh and Uttarakhand, along with the union territories of Jammu and Kashmir and Ladakh (Das and Meher 2019). The tribal and rural communities of this region are closely dependent on forests, as their livelihoods are directly linked to forest resources. Over the years, local communities have extensively utilised forests for livestock grazing, fuelwood collection and meeting their daily needs (Kumar and Gupta 2023).

In the Himalayan region, several *Quercus* species such as *Q. glauca*, *Q. leucotrichophora*, *Q. semecarpifolia* and *Q. dilatata* serve as important lifeline tree species for rural populations. These species

are mainly used during both winter and summer seasons (Shrestha 2003, Singh and Rawat 2012, Navale et al 2022). However, continuous exploitation has led to a decline in forest resources over time (Shrestha et al 2013). Therefore, conservation of available fodder resources in these hilly regions is essential for sustaining livestock (Dev et al 2006, Shekhar et al 2021).

Extensive research has been carried out on *Q. leucotrichophora*, *Q. semecarpifolia* and *Q. dilatata* by various researchers (Shrestha 2003, Singh and Rawat 2012, Ajith et al 2014, Singh et al 1992, Kala 2007, Shekhar et al 2021, Ginwal et al 2023, Muhammad et al 2023). Although several studies on *Q. glauca* are available covering different aspects (Tewari and Tewari 2021, Amare and Bhardwaj 2016, Dhanai and Panwar 2008, Amare and Bhardwaj 2017, Singh and Rawat 2012, Navale et al 2022, Sahoo et al 2016, Singh et al

2010, Pala et al 2013, Tynkevich and Volkov 2019), a comprehensive review integrating these findings is still lacking.

Fodder tree leaves generally contain higher crude protein and calcium compared to grasses and crop residues and therefore serve as an important feed resource for livestock. In this context, identification of key forage species in the IHR based on their nutritional quality is of major importance. *Q. glauca* is usually found in restricted habitats such as moist and shady areas of river basins and deep valleys (Ito et al 2007). Due to its limited distribution, selective logging, repeated lopping, low seed production, short seed viability and overgrazing, the species is facing serious challenges in natural regeneration (Singh and Singh 1987, Shrestha et al 2013).

The present review compiles available information on the ecological and agro-technological aspects, distribution, phenology, nutritional value, major threats and research gaps related to *Q. glauca* in the Indian Himalayan Region. Such a synthesis is important for guiding future research, conservation planning and management strategies. It also highlights the need for an integrated approach focusing on distribution, regeneration status, nutritional potential and anthropogenic pressures to ensure long-term sustainability of the species.

Species distribution and its association in the western Himalayan region

Q. glauca grows in secondary evergreen broadleaf forest communities at altitudes ranging from 300 to 3,100 m in the northern subtropical and warm temperate regions of Asia (Orwa et al 2009). In India, it is generally found between 1,500 and 2,500 m (Singh and Rawat 2000). The species is also common in Burma, where it occurs above 3,500 ft in association with species such as *Q. serrata*, *Schima wallichii* and *Castanopsis*, often accompanied by an undergrowth of bracken fern.

The species is widely distributed in the outer Himalaya, extending up to about 6,000 ft and also occurring in the Khasi hills. It is found in moist habitats like valleys, along ravines and near streams. In Himachal Pradesh, its occurrence is reported in the Kangra valley near Shahpur, between Baijnath and Dhelu in Mandi district and in the Beas valley of lower Kullu. In Uttarakhand, it is found in the Kumaun hills, particularly below Ranikhet in *Pinus longifolia* forests.

Q. glauca is commonly associated with species such as *Q. incana*, *P. longifolia*, *Rhododendron arboreum*, *Pistacia integerrima*, *Pyrus pashia*, *Olea cuspidata* and *Pieris ovalifolia*. In moist localities of the western Himalaya, it is also associated with *Machilus odoratissima* and other evergreen laurels. The species is most commonly found in areas with sandstone and shale formations, where soils are deep, moist and clayey loam (Troup 1921). It prefers light to medium-textured, well-drained soils with slightly acidic to neutral pH, though it can also grow in relatively shallow and less fertile soils. The average annual rainfall requirement ranges from 1,000 to 2,900 mm, while the suitable temperature range is between 6 and 19°C. *Q. glauca* can tolerate considerable shade during its early and intermediate growth stages but requires full overhead light at maturity (Orwa et al 2009). It generally prefers humid environmental conditions for better growth and development (Lock 2001, Wangda and Ohsawa 2006).

Previous studies have reported that *Q. glauca* is commonly associated with tree species such as *Q. leucotrichophora*, *Myrica esculenta*, *Pinus roxburghii*, *Albizia* spp, *Bauhinia variegata*, *Celtis australis*, *Pistacia integerrima*, *Ficus palmata*, *Machilus duthiei*, *Punica granatum*, *Salix tetrasperma*, *Ethretia acuminata*, *Ailanthus excelsa*, *Pyrus pashia*, *Toona ciliata* and *Rhododendron arboreum*.

Some common shrubs have been reported in the area. These include *Berberis lyceum*, *Caryopteris wallichiana*, *Randia tetrasperma*, *Daphne cannabina*, *Myrsine africana*, *Lonicera quinquelocularis*, *Sageretia oppositifolia*, *Rhus cotinus*, *Rosa moschata*, *Rubus ellipticus* and *Ficus pumila*.

Phenology

Q. glauca is a large evergreen tree characterized by four-sided leafy buds, silky young shoots and sharply serrated upper leaf margins (Brandis 1874). The leaves are simple, alternate and green, with serrated margins and an elliptic to oblong-lanceolate shape. They exhibit pinnate venation, are glossy on the upper surface and glaucous and pubescent on the lower surface (Gilman and Watson 1994, Osmaston 1927). The species bears yellow flowers and produces nut-type fruits of brown colour. Seed dispersal occurs through animals, indicating zoochory as the primary mode of dispersal (Upadhaya et al 2018).

The phenology of *Q glauca* has been studied by a few researchers. Flowering generally occurs from March to May, while fruiting extends from September to January (Upadhaya et al 2018). The suitable period for seed collection is from October to December (Amare and Bhardwaj 2016). Several studies have indicated that the phenology of *Quercus* species is influenced by climate change (Joshi et al 2023, Tewari et al 2017). In *Q leucotrichophora*, shifts in phenological events, either advancement or delay, have been associated with rising temperatures (Joshi et al 2023). Early maturation of acorns has also been reported in this species due to changing climatic conditions (Tewari et al 2017).

Chand et al (2017) reported that variation in rainfall affects wood water content and wood density, which in turn influences the timing of phenophases in *Q glauca* as well as in *Q semecarpifolia* and *Q lamellosa*.

Nutritive analysis

Quercus species are widely used as fodder in different parts of the world (Castro et al 2021, Navale et al 2022, Katoch 2022, Muhammad et al 2023). Cattle and goats consume the fruits of *Q glauca* (Koireng et al 2017). Farmers generally prefer this species over *Albizia chinensis* and *Acacia catechu* due to its better acceptability and nutritive value. It serves as a good source of animal feed and contributes to improved milk production (Navale et al 2022).

The leaves of *Q glauca* have been analysed for their nutritional composition and fodder potential. The annual fodder yield has been reported as 41.04 and 51.51 kg per tree by Mukherjee et al (2018) and Navale et al (2022) respectively. The species is known for its higher yield, better nutritive value and superior quality compared to other native fodder trees of the region. In terms of nutritional composition, the leaves contain about 54.90 per cent dry matter, crude protein ranging from 9.26 to 11.60 per cent and carbohydrate content around 77.23 per cent. Other components include ether extract (4.56-5.25%), total ash (6.28-7.46%), nitrogen-free extract (36.12-55.89) and organic matter (90.60-92.55) (Makkar and Singh 1991, Makkar and Becker 1998, Sahoo et al 2016, Navale et al 2022). These values indicate that *Q glauca* provides both high fodder yield and good nutritional quality.

The fibre composition of the species also plays an important role in determining its digestibility.

Hemicellulose and cellulose contents have been reported as 12.15 and 25.46 per cent respectively (Navale et al 2022). The acid detergent fibre content ranges from 40.42 to 70.50 per cent, neutral detergent fibre from 52.57 to 69.40 per cent and crude fibre around 24.01 per cent (Makkar and Singh 1991, Sahoo et al 2016, Navale et al 2022). These values suggest moderate fibre levels, which help maintain proper rumen function along with acceptable digestibility.

Overall, the combination of yield, protein content and fibre composition makes *Q glauca* a valuable fodder resource for livestock systems in the Himalayan region.

In addition to macronutrients, the mineral composition of *Q glauca* further enhances its feeding value. The phosphorus content ranges from 0.06 to 0.25 per cent, potassium around 1.20 per cent and calcium between 1.40 and 2.95 per cent. The leaves also contain important trace elements such as copper (17.91 ppm), iron (684.63 ppm), zinc (22.88-37.00 ppm) and manganese (264.99 ppm) (Navale et al 2022). These minerals play a vital role in maintaining animal health and productivity.

However, the presence of anti-nutritional factors in *Q glauca* should also be considered. Phenolic compounds (8.39%), tannins (6.09-9.03%), nitrates (7.85 ppm) and saponins (14.59%) have been reported in the leaves (Navale et al 2022). Although these compounds may provide certain beneficial effects such as antioxidant and antimicrobial properties, they can adversely affect feed intake, digestibility and nutrient utilization when present in higher amounts. Therefore, proper management and balanced feeding practices are necessary to ensure optimum utilization of this species.

Overall, the high fodder yield, good nutritional composition and rich mineral content make *Q glauca* an important and sustainable fodder resource for Himalayan livestock systems, though its anti-nutritional components need to be managed carefully for effective utilization.

Natural regeneration

Seed production in adequate quantities, effective seed dispersal, successful germination and proper seedling establishment are essential for the natural regeneration of any species (Khanna 1981). Regeneration studies assume greater importance in

mountain forests, where lack of natural regeneration is a major concern (Krauchi et al 2000). The problem of poor regeneration has been reported in several *Quercus* species.

In *Q. leucotrichophora*, poor natural regeneration has been attributed to anthropogenic disturbances, early seed maturation, prolonged drought and premature seed fall (Bhatt et al 2015). Regeneration of this species was found to be highest in moderately disturbed sites, indicating that mild disturbances may favour regeneration (Prasad et al 2015). Similarly, Vetaas (2000) suggested that in *Q. semecarpifolia*, canopy gaps created by limited lopping may promote regeneration rather than hinder it. Singh et al (2018) also reported lower seedling density of *Q. leucotrichophora* in undisturbed stands on south-facing aspects compared to moderately and highly disturbed stands. This was attributed to higher radiation on south-facing slopes, which reduces soil moisture and adversely affects seedling emergence and establishment (Singh et al 2018). In addition, climate change has led to early maturation of acorns in *Q. leucotrichophora*, which may negatively affect its natural regeneration (Tewari et al 2017).

Q. glauca is a moderately light-demanding species and regenerates well in gaps and open spaces (Troup 1921). However, poor natural regeneration has been reported in this species due to factors such as human pressure, low light availability, reduced soil moisture and limited nutrients (Amare and Bhardwaj 2017). Higher regeneration was observed in moist and nutrient-rich sites, whereas it declined with increasing soil pH, available phosphorus and solar radiation, indicating a strong influence of site conditions on regeneration. Upreti et al (1985) also reported sporadic and poor regeneration in *Q. glauca*, mainly due to anthropogenic disturbances and consumption of acorns by Himalayan langurs.

No regeneration of *Q. glauca* was observed in sacred and protected forest areas of the Garhwal Himalaya, which was attributed to the absence of canopy gaps and limited light availability (Pala et al 2013). Dhanai and Panwar (2008) studied sapling density across different aspects and altitudes and reported variation in regeneration. Better regeneration was observed on north-west and south-east aspects, possibly due to relatively lower biotic and abiotic stress (Singh and Rawat 2012). Low regeneration of *Q. glauca* has also been reported by Amare and Bhardwaj

(2017). Upadhaya et al (2018) observed a large number of fallen fruits around parent trees, indicating poor seed dispersal due to lack of dispersing agents. Since the seeds undergo winter dormancy, they remain exposed to pests and predators for a longer period, further reducing regeneration success (Upadhaya et al 2018). Overall, natural regeneration of *Q. glauca* remains inadequate and requires further attention, as germination and seedling establishment are the most critical stages in the life cycle of the species (Korner 1998). Maintenance of adequate canopy gaps through proper management of forest biomass may help in improving regeneration of the species.

Seed germination

The continuous decline in the regeneration of *Quercus* species is a matter of serious concern. Irregular fruiting behaviour, seed predation by animals (Troup 1921) and rapid loss of seed viability during storage (Chalupa 1995) have further aggravated the problems associated with both natural and artificial regeneration. Therefore, several studies have been undertaken to enhance the germination potential of *Quercus* species.

In *Q. leucotrichophora*, seed germination has been reported to vary with the altitude of seed collection. Higher germination was observed in seeds collected from lower altitudes compared to those from higher altitudes (Bhatt and Ram 2005, Bisht et al 2022). However, Tamta and Singh (2018) reported contrasting results, where seeds from higher altitudes exhibited better germination, which was attributed to their relatively larger seed size. Seed size has been recognized as an important factor influencing germination in *Quercus* species (Karki et al 2018, Pandey et al 2017). In *Q. floribunda*, larger seeds showed superior germination compared to smaller ones (Karki et al 2018). Similarly, in *Q. leucotrichophora*, higher germination was recorded in larger seeds (Pandey et al 2017).

Pre-sowing treatments have also been found to significantly influence germination behaviour in *Quercus* species (Pandey and Tamta 2013, Negi and Rawal 2019). Treatments such as scarification and cold stratification have been reported to improve germination in *Q. serrata* and *Q. semecarpifolia* (Pandey and Tamta 2013). Soaking seeds in water for 48 hours was also found beneficial for improving germination in *Quercus* species including *Q. glauca*, *Q. leucotrichophora* and *Q. lanuginosa* (Negi and

Rawal 2019). In addition, Purohit et al (2009) reported potassium nitrate (KNO_3) as an effective treatment for enhancing germination in *Q. glauca* and *Q. leucotrichophora*.

Earlier studies on *Q. glauca* indicate that seed germination is generally low and requires a longer duration to complete the germination process (Upreti et al 1985, Amare and Bhardwaj 2017, Pala et al 2013). Germination is also influenced by the time of seed collection. The optimum period for collecting mature acorns varies from September (Purohit et al 2009) to November (Zulfiqar et al 2015), depending upon location and prevailing climatic conditions. Among pre-sowing treatments, scarification has been reported to be more effective than stratification (Zulfiqar et al 2015, Purohit et al 2009).

Under favourable conditions, germination of healthy and mature seeds of *Q. glauca* ranges between 43.3-63.3 per cent (Singh et al 2010). The application of farmyard manure at 5 tonnes per ha has been recommended to improve both germination and seedling growth. Maximum germination (51.8%) was recorded in media enriched with farmyard manure. The species also performs well under shaded nursery conditions, where higher germination, survival and better seedling growth have been observed (Amare and Bhardwaj 2016). Regular watering is essential to maintain adequate moisture in nursery beds (Singh et al 2010).

Overall, the use of physical pre-sowing treatments along with shaded nursery conditions appears to be more effective than chemical treatments for successful artificial propagation. Since the seeds of *Q. glauca* are short-lived and lose viability rapidly during storage (Purohit et al 2009), it is advisable to use freshly collected seeds rather than stored ones for better germination.

CONCLUSION

Quercus glauca is an ecologically and economically important tree species of the Himalayan region, providing valuable fodder and supporting rural livelihoods. The species exhibits good nutritional potential with high fodder yield, favourable protein content and adequate mineral composition, making it an important resource for livestock feeding. However, natural regeneration of the species is poor due to multiple factors such as anthropogenic pressure, low

seed viability, poor dispersal, unfavourable site conditions and climate change. Seed germination is influenced by seed size, altitude, collection time and pre-sowing treatments and can be improved through appropriate management practices such as scarification, water soaking and maintenance of suitable nursery conditions. The study indicates that regeneration of *Q. glauca* is better in moist, nutrient-rich sites and under moderate disturbance with sufficient canopy gaps. Therefore, conservation and management strategies should focus on maintaining suitable habitat conditions, reducing anthropogenic pressure and promoting effective regeneration practices. An integrated approach involving ecological understanding, nutritional evaluation and sustainable utilization is essential to ensure long-term conservation and productivity of the species in the Himalayan region.

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