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EXPLORING SOURCE VARIATION IN *ULMUS VILLOSA* BRANDIS ACROSS THE KASHMIR HIMALAYAS: INSIGHTS INTO SEED MORPHOLOGY, GERMINATION, AND GENETIC TRAITS

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ABSTRACT

Ulmus villosa Brandis, commonly known as cherry bark elm, is a multipurpose tree species of significant ecological, economic, and cultural importance in the northwestern Himalayas. Despite its potential, limited research exists on its genetic variability and adaptability. This study explores source variation in seed morphology, germination traits, and genetic variability of *Ulmus villosa* across five districts of the Kashmir Himalayas: Anantnag, Pulwama, Budgam, Kulgam, and Srinagar. Seeds were collected from 15 sites, and their morphological traits, germination characteristics, and genetic parameters were analyzed. Results revealed significant variation among seed sources in seed dimensions, 1000-seed weight, and the proportion of filled seeds. Bijbehara (Anantnag) exhibited superior seed traits, including the highest seed length (12.91 mm), width (4.72 mm), and 1000-seed weight (5.62 g). Germination parameters such as germination percentage, germination energy, and germination value also varied significantly, with Bijbehara showing the best performance. Genetic analysis indicated moderate to high heritability and positive correlations between seed traits and germination characteristics, highlighting the influence of both environmental and genetic factors. These findings provide valuable insights into the selection of superior seed sources, paving the way for tree improvement programs, sustainable propagation, and conservation efforts for this important Himalayan species.
Keywords*: *Ulmus villosa, source variation, seed morphology, germination traits, genetic variability, Kashmir Himalayas, tree improvement, conservation, forest sustainability.

Introduction

The terrestrial environmental system depends significantly on its essential forest cover, which provides a wide range of socio-economic, environmental, and cultural benefits. These renewable resources supply timber, fuelwood, pulpwood, fodder, and non-wood products, while also supporting industries and maintaining the ecological balance necessary for food production and human well-being. However, the unsustainable exploitation of these resources has led to a considerable reduction in forest cover. Global forest loss has been substantial, with an estimated 10 million hectares of forest lost annually, including vital humid primary forests, nearly4.1% of which were lost between 2002 and 2023. In India, 2.33 million hectares of tree cover have been lostsince2000, reflecting a 6% decrease (GFW,2023). From 2015to2020, India faced deforestation rate of 668,000 hectares per year, the second-highest globally after Brazil. Moreover, 95% of India's tree cover loss from 2013 to 2023 occurred within natural forests. The decline of forest ecosystems in India has been driven by several factors, including urbanization, agricultural expansion, and climate change, with the degradation of tropical and subtropical forests in the country contributing significantly to biodiversity loss (FAO, 2020). In Jammu and Kashmir, forests cover 48% of the total geographical area, with temperate coniferous and broad- leaved species dominating the Kashmir Valley (FSI, 2021). Yet, these forests are under great strain due to human population growth, livestock grazing and excessive biotic dependence. From 2001to 2023, Jammu and Kashmir lost 4.19 k.ha. of tree cover, equivalent to a 0.39% decrease in tree cover since 2000 (GFW, 2023).

Ulmus villosa Brandis, commonly known as the cherry bark elm, is a promising multipurpose tree species that can grow to a height of 20–30 meters. It is typically found at elevations ranging from 800 to 2500 meters, with a scattered distribution across the northwestern Himalayas, extending from Hazara in Pakistan and Afghanistan to Kashmir and eastward to Kullu in Himachal Pradesh, India. It is a fast-growing and versatile tree species from the *Ulmaceae* family. It stands out among Asiatic elms due to its unique characteristics and exceptional longevity (Sodi, 2023). Growing up to a height of 25m, the tree is rather lightly and pendulously branched, the bark smooth with distinctive horizontal bands of lenticels, although it eventually becomes very coarsely furrowed. The oblong- elliptical-acute leaves are <11cm long and 5cm broad. The wind pollinated apetalous flowers appear in spring and are particularly densely clustered, the white hairs covering the perianth and ovary contrasting with the purplish anthers. The samara are elliptic, <12mm long and densely hair on both sides (Singh, 1982). This species holds significant potential for agroforestry, especially on degraded lands, due to its rapid growth and adaptability to various soil types. It provides valuable timber for light construction, fodder, medicinal bark, and ropes (Thakur & Thakur, 2016). The species finds prominence among hill farmers on the account of multifarious end uses (Lone *et al*.2016). In Kashmir,it also enjoys the status of a sacred tree (Anonymous, 2022).

Despite its economic importance, *Ulmus villosa* Brandis, has received limited research attention, particularly regarding its genetic improvement. (Thakur *et al*. 2014). The species' potential for genetic variability remains largely unexplored. Investigating seed morphology, germination behavior, and genetic traits offers insights into its adaptability and productivity (Zobel & Talbert, 1984; Bhat & Chauhan, 2003). These insights are pivotal for identifying superior genotypes, ensuring sustainable utilization, and enhancing the productivity of this valuable species (Graudal & Kjaer, 2000).

This study aims to address the critical gap in research on *Ulmus villosa* Brandis by exploring source variation across the Kashmir Himalayas. Through an analysis of seed morphology, germination characteristics, and genetic traits, this study seeks to provide a comprehensive understanding of the species' genetic potential and its adaptability to diverse ecological conditions. The findings are expected to play a pivotal role in identifying superior genotypes, facilitating mass propagation, and supporting the conservation of this important Himalayan tree species (Zobel & Talbert, 1984; Bhat & Chauhan, 2003).

Materials and Methods

The study was conducted in 2022 at the Division of Forest Biology and Tree Improvement, Faculty of Forestry, SKUAST-K, Benhama, Ganderbal, Kashmir, under controlled laboratory conditions. A systematic random sampling approach was employed across five districts of Kashmir Anantnag, Pulwama, Budgam, Kulgam, and Srinagar where middle-aged *Ulmus villosa* trees with approximately uniform dimensions were selected using the check tree method. Three sites in each district were selected for seed collection, as outlined in Table-1.

Table 1: Phenotypic characteristics of selected mother trees of *Ulmus villosa* Brandis

Source			Total Height (m)	Clear bole height (m)	DBH (cm)	Crown Spread (m)
District	Site	Location				
Anantnag	Bijbehara	33°47'60"N75°05'60"E	20.16	9.42	27.04	6.16
	Mattan	33°76'04"N75°21'00"E	18.13	10.31	30.88	5.44
	Anchidora	33°74'17"N75°16'26"E	18.22	9.95	31.43	5.42
Pulwama	Barsoo	33°95'15"N74°99'10"E	17.59	8.23	25.14	5.12
	Batpora	33°84'80"N74°86'97"E	19.91	9.28	25.02	6.33
	Kakapora	33°94'68"N74°92'96"E	18.00	8.41	27.82	6.36
Budgam	Wahabpora	34°05'63"N74°66'02"E	20.24	10.28	29.22	5.39
	Mirgund	34°02'65"N74°72'44"E	19.54	8.95	28.15	5.40
	Narbal	34°11'70"N74°67'28"E	20.52	9.07	29.77	6.46

Kulgam	Khudwani	33°70'74"N75°10'54"E	18.78	9.16	28.38	5.26
	Toolipora	33°72'40"N75°01'79"E	19.01	9.69	28.16	6.02
	Wanpora	33°76'54"N75°04'53"E	19.20	8.59	30.53	5.40
Srinagar	Shalimar	34°15'04"N74°88'25"E	20.31	10.55	28.21	6.21
	Harwan	34°39'76"N74°39'82"E	19.74	9.12	28.61	5.46
	Lal Bazar	34°14'04"N74°82'44"E	20.00	10.83	29.44	6.80

Mature seeds of *Ulmus villosa* were harvested from the selected trees in April 2022. The seeds were packed separately in muslin cloth bags, properly labeled, and transported to the Faculty of Forestry. Upon arrival, seeds were evaluated to assess seed dimensions, weight, the proportion of filled and empty seeds, and to conduct germination tests. For seed dimension determination, four replications of 10seeds were randomly selected from each source and measured using a digital caliper with millimeter precision. For weight determination, four replications of 1000 filled seeds per source were weighed using an analytical balance, following the guidelines outlined by ISTA (1966). The assessment of filled and empty seeds was conducted manually using the pinch test. Seeds were gently pressed between the fingers; filled seeds exhibited firmness and resistance to pressure, indicating the presence of a developed embryo, while empty seeds felt soft or hollow and collapsed when pressed. For germination testing four replications of100 seeds per source were placed on moistened filter paper in 90 mm Petri dishes and incubated in a seed germinator at 25 ± 1°C and 80 ± 5% relative humidity. Germination was recorded every day in allseed lots until no more germination was observed. Seed germination was defined as radicle emergence (>2mm), and germinated seeds were left in the Petri dish until normal seedlings were produced. A normal seedling is defined as growth to show developed cotyledons, hypocotyls and roots, and without visible abnormalities (ISTA2017). The germination data were analyzed using the formula by Bonner (1983), with germination energy calculated as per Williams (1985). Germination value, peak value, and mean daily germination were calculated following Czabator's method (1962). The germination process was monitored daily, with appropriate sterilization procedures to prevent contamination, and seeds were checked regularly for fungal or bacterial growth. The data obtained were analyzed for genetic parameters, including genotypic and phenotypic correlation coefficients, using R statistical software.

Results and Discussion

This study explores the variation in seed morphology, germination characteristics, and genetic traits of *Ulmus villosa* Brandis across multiple seed sources from five districts of the Kashmir Himalayas. The findings reveal significant differences in seed parameters, which have crucial implications for the development of tree improvement programs and the identification of superior seed sources for both propagation and conservation efforts in the region. Understanding this variation provides insights into optimizing *Ulmus villosa* propagation strategies and enhancing its genetic resource management.

Seed Morphology

Significant variation in seed morphology was observed among the seed sources for traits such as seed length, seed width, and 1000-seed weight (Table-2). Seed length ranged from 9.11 mm (Toolipora, Kulgam) to12.91mm (Bijbehara, Anantnag). Similarly, seed width varied from 3.00 mm (Toolipora, Kulgam) to 4.72 mm (Bijbehara, Anantnag). The highest 1000-seed weight was recorded in Bijbehara (5.62 g), followed by Mattan, Anantnag (5.44 g), whereas Toolipora exhibited the lowest value (3.96 g).

The observed variability in seed dimensions across different seed sources aligns with earlier findings, suggesting that environmental factors such as light, nutrient availability, and water significantly influence seed size and weight (Gutterman, 1992; Uma, 2015). The physical condition of parent plants also plays a crucial role in determining seed size. Larger seeds, as seen in Bijbehara, enhance seedling emergence, survival, growth, and biomass allocation compared to smaller seeds, a pattern noted in Bauhinia species (Bonfil, 1998).

Larger seeds, such as those from Bijbehara, reflect favorable growth conditions and maternal effects, making them ideal for propagation and seedling production programs. Baraloto *et al.* (2005) reported that larger-seeded species like *Eperua grandiflora* (Aubl.) Baill. and *Vouacapoua americana* Aubl.(both Caesalpiniaceae) produced larger seedlings than smaller- seeded variants. Similarly, Reich *et al.* (1994) emphasized that seed mass significantly influences seedling emergence, survival in stressful conditions, flexibility in shoot/root allometry, speed of germination, and overall growth. Studies on other species, such as *Dalbergia sissoo* (Dubey & Tripathi, 2018; Singh, 2019), *Caesalpinia sappan* (Arthanari *et al.,* 2013), *Terminalia arjuna* (Kumar, 2018), and

Azadirachta indica (Parmar, 2016), have demonstrated the influence of genotypic and environmental factors on seed traits. Seed weight is largely determined by reserve food material formed during double fertilization (endosperm) and is dominated by maternal traits. Nutrient availability during seed development and environmental factors also significantly impacts seed size and weight (Johnsen *et al.,* 1989).

Table 2: Average seed parameters of selected mother trees of *Ulmus villosa* Brandis.

Source		Seed length (mm)	Seed width (mm)	1000Seed weight (g)	Number of Filled seeds per cluster	Number of Empty seeds per cluster
District	Site					
Kulgam	Khudwani	11.11^{a}	4.12^{a}	4.92^{e}	6.71^{c}	3.31^{de}
	Toolipora	9.11^{a}	3.00^{d}	3.96^{g}	2.53^{f}	3.25^{g}
	Wanpora	10.16^{b}	3.21^{h}	4.21^{c}	4.73^{cd}	5.11^{cde}
Srinagar	Shalimar	9.16^{ef}	3.03^{c}	3.97^{m}	3.66^{e}	5.31^{de}
	Harwan	9.21^{cd}	3.13^{e}	4.04^{d}	3.70^{f}	6.28^{a}
	Lal Bazar	9.26^{g}	3.24^{e}	4.12^{k}	3.93^{d}	8.17^{a}
Anantnag	Bijbehara	12.91^{cd}	4.72^{c}	5.62^{l}	7.50^{b}	5.02^{de}
	Mattan	12.44^{cd}	4.64^{c}	5.44^{b}	7.13^{e}	1.83^{bcd}
	Anchidora	12.11^{b}	4.37^{i}	5.32^{f}	7.06^{a}	8.50^{bc}
Pulwama	Barsoo	11.81^{e}	4.31^{f}	5.17^{i}	7.02^{a}	7.71^{bcd}
	Batpora	11.20^{g}	4.16^{e}	5.06^{a}	6.90^{e}	1.24^{ef}
	Kakapora	10.76^{f}	3.67^{g}	4.63^{k}	6.30^{f}	2.74^{b}
Budgam	Wahabpora	11.10^{d}	3.91^{f}	4.86^{h}	6.43^{b}	5.20^{f}
	Mirgund	10.40^{c}	3.52^{b}	4.53^{j}	4.14^{g}	1.33^{g}
	Narbal	10.30^{h}	3.44^{j}	4.46^{i}	4.02^{e}	2.64^{g}
C.D.($p \leq 0.05$)		**0.26**	**0.06**	**0.03**	**0.20**	**0.90**

*Values sharing same letter are statistically non-significant at 5%

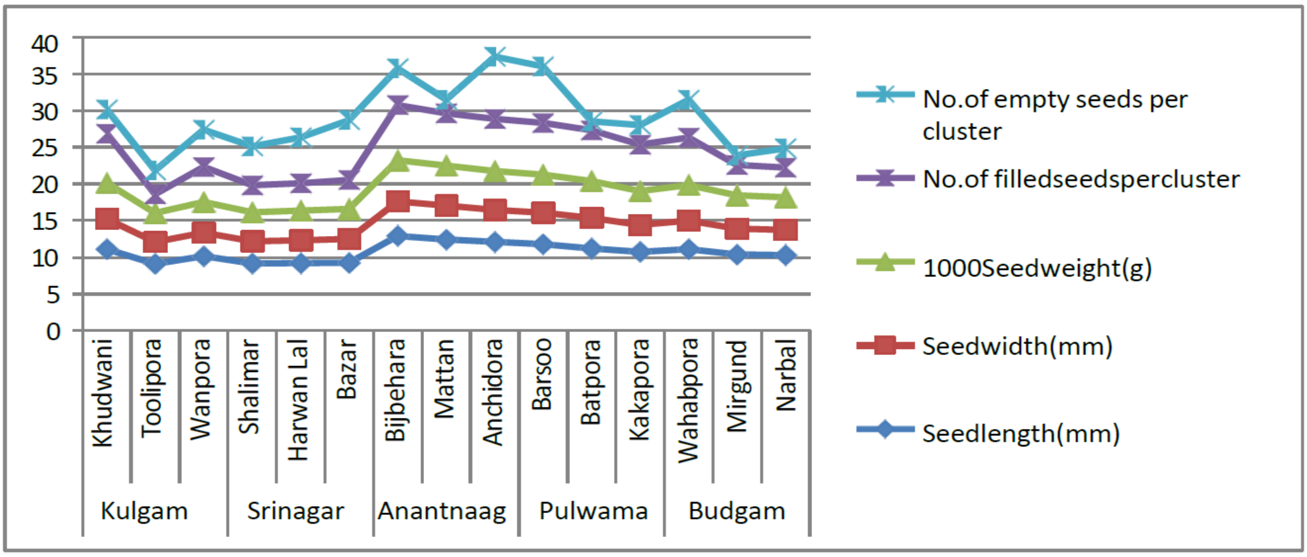


Fig. 1: Average seed parameters of selected mother trees of *Ulmus villosa* Brandis.

Variation in the average number of filled and empty seeds per cluster was also significant. Bijbehara recorded the highest number of filled seeds (7.50), whereas Toolipora recorded the lowest (2.53). Anchidora, Anantnag, recorded the maximum number of empty seeds per cluster (8.50), which could be attributed to factors such as wind pollination a critical determinant of seed quality and production (Yadav *et al.,* 2011; Woods *et al.,* 1989).

Seed Germination

Germination tests revealed significant differences among seed sources in germination percentage, germination energy, germination value, peak value, and mean daily germination (Table-3). Seeds from Bijbehara exhibited the highest germination percentage (84.30%), germination energy (56.64), and germination value (11.37), followed by Mattan, Anantnag. In contrast,Toolipora seeds had the lowest germination percentage (65.33%) and germination value (1.32).

The germination behavior of forest tree species often varies with provenance, as previously reported by Gupta and Sehgal (1999). The higher germination rates observed in Bijbehara suggest the presence of favorable environmental conditions and positive maternal effects during seed development, which likely enhance seed vigor and improve the potential for seedling establishment (Gutterman, 1992). Similar results have been reported in other studies, such as those by Thakur & Thakur (2015) on *Melia azedarach*, Ambalal (2016) on *Bauhinia variegata*, and Ginwal *et al.* (2004) on *Eucalyptus camaldulensis*, where seed source variation significantly influenced germination traits. The high germination energy observed in Bijbehara seeds reflects their vitality and ability to support consistent and rapid seedling emergence (Wu *et al.,* 2024). In contrast, the lower performance of Toolipora seeds may be linked to factors such as nutrient deficiencies, unfavorable climatic conditions, or stress factors during seed development, all of which can negatively affect seed vigor.

The relationship between seed size and germination performance is well-documented, highlighting a trade-off between producing numerous small seeds with limited reserves and fewer larger seeds with abundant resources (Ekpo, 2004). Larger seeds, tend to have higher germination rates, likely due to their greater nutrient reserves, which provide additional energy for successful germination (Cideciyan, 1982; Ekpo, 2004). Additionally, several studies have demonstrated that germination performance is influenced by both the genetic origin of seeds and the local environmental conditions where seed maturation occurs (Loha *et al.,* 2006; Gush *et al.,* 2011). This effect, known as the provenance effect, has been observed in various plant species and is influenced by environmental factors that impact seed production, further affecting germination (Benowiez *et al.,* 2000; Benowiez *et al.,* 2001; Gera *et al.,* 2002; Mkonda *et al.,* 2003). These environmental variations can exert significant ripple effects on seed germination (Aref *et al.,* 2011)

Table 3: Seed germination parameters of selected mother trees of *Ulmus villosa* Brandis

Source		Seed germination (%)	Germination energy	Germination value	Peak value	Mean daily germination
District	Site					
Kulgam	Khudwani	75.56^{abcdef} (8.69)	42.00^{k}	9.21^{g}	2.31^{h}	2.28^{ef}
	Toolipora	65.33^{cdef} (8.08)	31.11^{n}	1.32^{i}	1.12^{m}	1.12^{g}
	Wanpora	70.83^{abcdef}(8.41)	36.33^{g}	5.35^{de}	1.90^{c}	1.51^{de}
Srinagar	Shalimar	66.47^{def}(8.15)	32.87^{m}	2.34^{jk}	1.14^{n}	1.13^{i}
	Harwan	67.33^{ef}8.20)	34.33^{o}	3.69^{j}	1.63^{k}	1.24^{j}
	Lal Bazar	70.24^{ab}(8.38)	35.26^{b}	4.94^{b}	1.77^{b}	1.42^{b}
Anantnag	Bijbehara	84.30^{abc}(9.18)	56.64^{c}	11.37^{c}	3.78^{d}	3.01^{b}
	Mattan	82.00^{abcde}(9.05)	52.66^{f}	11.27^{ef}	3.50^{g}	2.85^{c}
	Anchidora	80.27^{abcd}(8.95)	51.11^{d}	10.66^{d}	3.30^{f}	2.76^{c}
Pulwama	Barsoo	78.00^{a}(8.83)	48.00^{a}	10.03^{a}	2.87^{a}	2.45^{a}
	Batpora	76.21^{g}(8.72)	46.21^{i}	9.89^{k}	2.32^{l}	2.38^{k}
	Kakapora	73.00^{abcdef}(8.54)	40.65^{e}	7.92^{f}	2.09^{e}	2.03^{d}
Budgam	Wahabpora	75.40^{abcdef}(8.68)	41.32^{h}	8.81^{g}	2.13^{e}	2.18^{f}
	Mirgund	72.87^{bcdef}(8.53)	39.98^{j}	7.30^{hi}	2.08^{j}	1.95^{gh}
	Narbal	71.62^{f}(8.46)	37.64^{l}	6.42^{h}	2.00^{i}	1.77^{h}
C.D.($p \leq 0.05$)		**2.19**	**2.25**	**0.47**	**0.14**	**0.14**

*Figures in the Parenthesis are sine transformed values and values sharing same letter are statistically non-significant at 5%

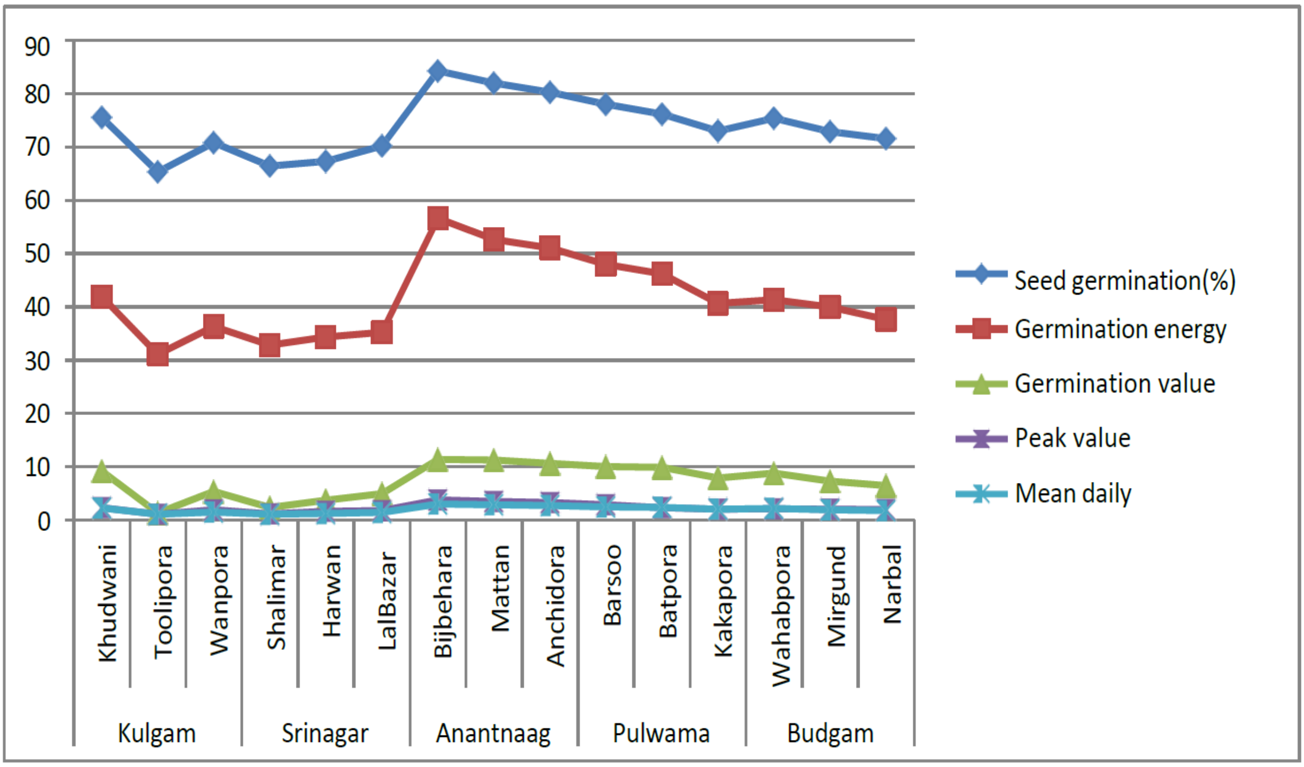


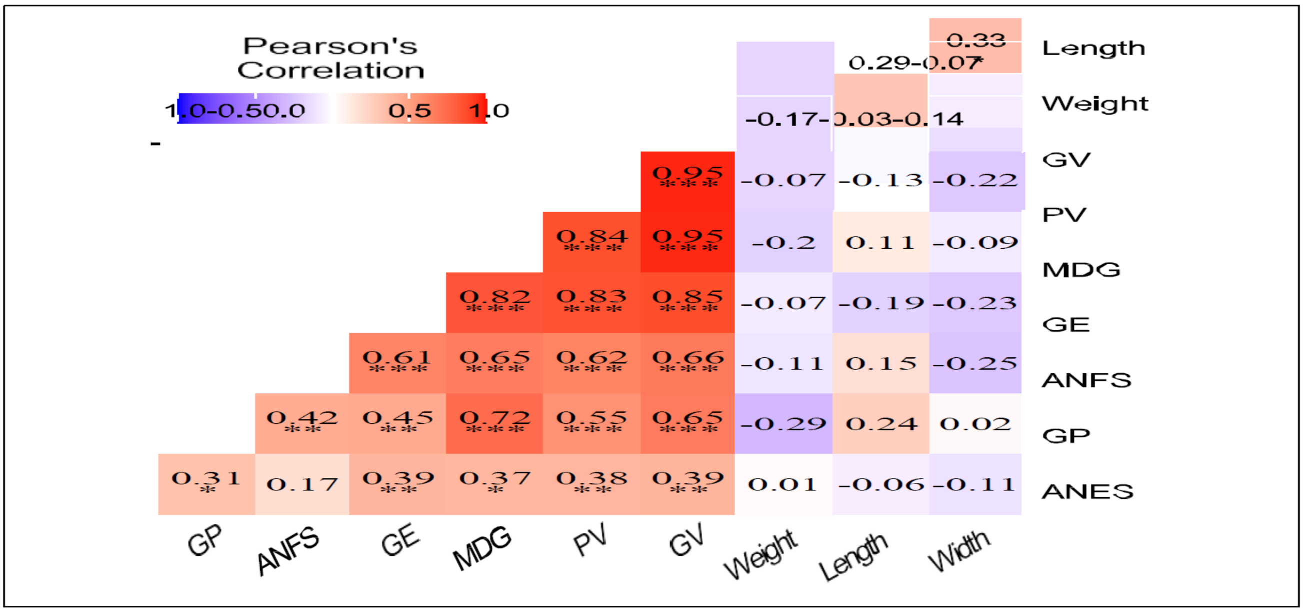
Fig. 2: Average seed germination parameters of selected mother trees of *Ulmus villosa* Brandis

Simple Correlation Studies

The analysis of various seed traits (Plot-1) highlights their collective influence on the quality and performance of *Ulmus villosa* seeds. These associations provide valuable insights into the genetic framework governing seed traits and identify key parameters for simultaneous improvement. Selection for one trait often triggers correlated changes in others, thereby enhancing the efficiency of breeding strategies.

Germination Value (GV) emerged as a critical trait, exhibiting strong positive correlations with mean daily germination (MDG,r=0.95) and germination energy (GE,r=0.85).These findings emphasize the role of GV in ensuring faster and more synchronized germination, leading to uniform seedling emergence. Similarly, Peak Value (PV) displayed significant positive relationships with MDG(r=0.84) and GE (r=0.83), establishing it as a reliable indicator of germination vigor and efficiency in assessing seed performance. Germination Percentage (GP) showed moderate correlations with MDG (r=0.72), PV(r=0.55), GE (r = 0.45), and the average number of filled seeds (ANFS, r=0.72), under scoring its relevance as a measure of seed viability and its connection to other germination traits. Additionally, ANFS demonstrated a moderate correlation with GP(r=0.72), highlighting the importance of filled seeds in determining the germination potential of a seed source.

The strong correlations among GV, MDG, and GE underscore their interdependence and importance in predicting seedling vigor,while traits like GP and PV play complementary roles in determining seed quality and performance. However, some trait combinations exhibited weak or non-significant correlations, suggesting that these are influenced more by environmental factors than by genetic ones.



Plot - 1

Where: GV - *Germination Value*, PV - *Peak Value*, MDG - *Mean Daily Germination*, GE - *Germination Energy*, ANFS - *Average Number of Filled Seeds*, GP - *Germination Percentage*, ANES - *Average Number of Empty Seeds.*

Similar relationships between different germination parameters have been reported in previous studies, such as those by Msuya and Stefano (2010) and Patil *et al.* (2011) in *Pongamia pinnata*. Generally, changes in one germination parameter tend to correspond with complementary trends in others,as noted by Santana and Ranal (2006).Similar correlations have also been observed in *Pinus wallichiana* (Rawat and Bakshi, 2011), *Pongamia pinnata* (Kumar *et al.,* 2015), and *Melia dubia* (Kumar *et al.,* 2022).

These findings provide practical guidance for improving the seed traits of *Ulmus villosa.*

Breeding programs can prioritize traits with strong correlations, enabling simultaneous improvements across multiple parameters. This strategy enhances the adaptability, productivity, and quality of *Ulmus villosa* plantations, while also supporting their conservation and large-scale propagation efforts.

Genetic Parameters

The analysis of phenotypic and genotypic coefficients of variation (PCV and GCV), heritability, genetic advance, and genetic gain (Table-4) highlighted the genetic variability of seed traits. Traits such as seed weight, number of filled seeds, and germination percentage exhibited high heritability values ranging from 0.61 to 0.77, indicating strong genetic control. Genetic advance was highest for germination percentage (16.03), followed by germination energy (9.91), whereas seed width exhibited the lowest genetic advance (1.17).

The high heritability values observed, coupled with substantial genetic advance in traits such as the number of filled seeds and germination percentage, indicate that these traits are primarily governed by additive genetic factors. This genetic architecture underscores the suitability of these traits for improvement through selection in breeding programs. Comparable findings have been reported in *Jatropha curcas* (Ginwal *et al.,* 2005), *Pinus wallichiana* (Rawat & Bakshi, 2011), and *Dalbergia sissoo* (Singh, 2019), where high genetic gain facilitated advancements in seed quality.

The maximum genetic gain was observed for mean daily germination (65.83%),followed by the average number of empty seeds (48.84%). These findings suggest that traits with high genetic gain, such as germination efficiency and filled seed count, are ideal targets for breeding programs aimed at enhancing the productivity and quality of *Ulmus villosa* plantations. The results align with Falconer & Mackay (1996) observations, emphasizing the effectiveness of simple selection methods in achieving significant genetic improvement.

The role of genetic variability in tree improvement and conservation has been highlighted by previous studies, such as those on *Celtis australis* in India (Kumar *et al.,* 2018; Kumar *et al.,* 2021b), *Magnolia officinalis* in China (Zheng *et al.,* 2009), and

Tamarindus indica in Bangladesh (Azad *et al.,* 2014). These studies emphasize that genetic variation is essential for ensuring evolutionary adaptability and resilience to environmental changes (Booth & Grime, 2003).

In *Ulmus villosa*, the observed high genetic variance and genetic gain for traits such as germination percentage and filled seed count reinforce their potential for improvement through selection. The high genotypic coefficient of variation (GCV), combined with significant genetic advance for specific seed sources, suggests that selecting superior individuals at a 5% selection intensity could lead to substantial genetic gains. Similar findings have been reported by Murali (1997) and Saleem *et al.* (1994) in other species, further supporting these conclusions.

The observed genetic variability in *Ulmus villosa* plays a pivotal role in shaping its seed and morphological traits, as previously reported by (Singh & Pokhriyal, 2000). Such variability is critical for enhancing growth and productivity ,especially in the context of challenges posed by climate change (Dawson *et al.,* 2011). Thus, the findings of this study provide a robust foundation for utilizing genetic variability in seed and seedling traits to drive targeted breeding and conservation efforts for *Ulmus villosa*.

Table 4: Genetic Parameters of Various Seed Traits in *Ulmus villosa* Brandis

Seed Parameters	PCV	GCV	Heritability	Genetic advance	Genetic gain
Seed Length(mm)	7.77	6.21	0.71	1.73	15.50
Seed Width(mm)	15.03	13.75	0.75	1.17	30.84
Seed weight(g)	12.37	11.12	0.77	1.23	25.47
Av.no of filled seeds	51.09	46.36	0.77	4.94	17.71
Av.no of empty seeds	27.37	21.29	0.68	2.55	48.84
Seed Germination%	37.90	33.25	0.72	16.03	20.27
Mean daily Germination	38.64	35.92	0.65	1.43	65.83
Peak value	24.70	20.56	0.71	1.28	42.11
Germination energy	33.28	24.36	0.61	9.91	22.34
Germination value	61.29	56.06	0.69	7.36	44.65

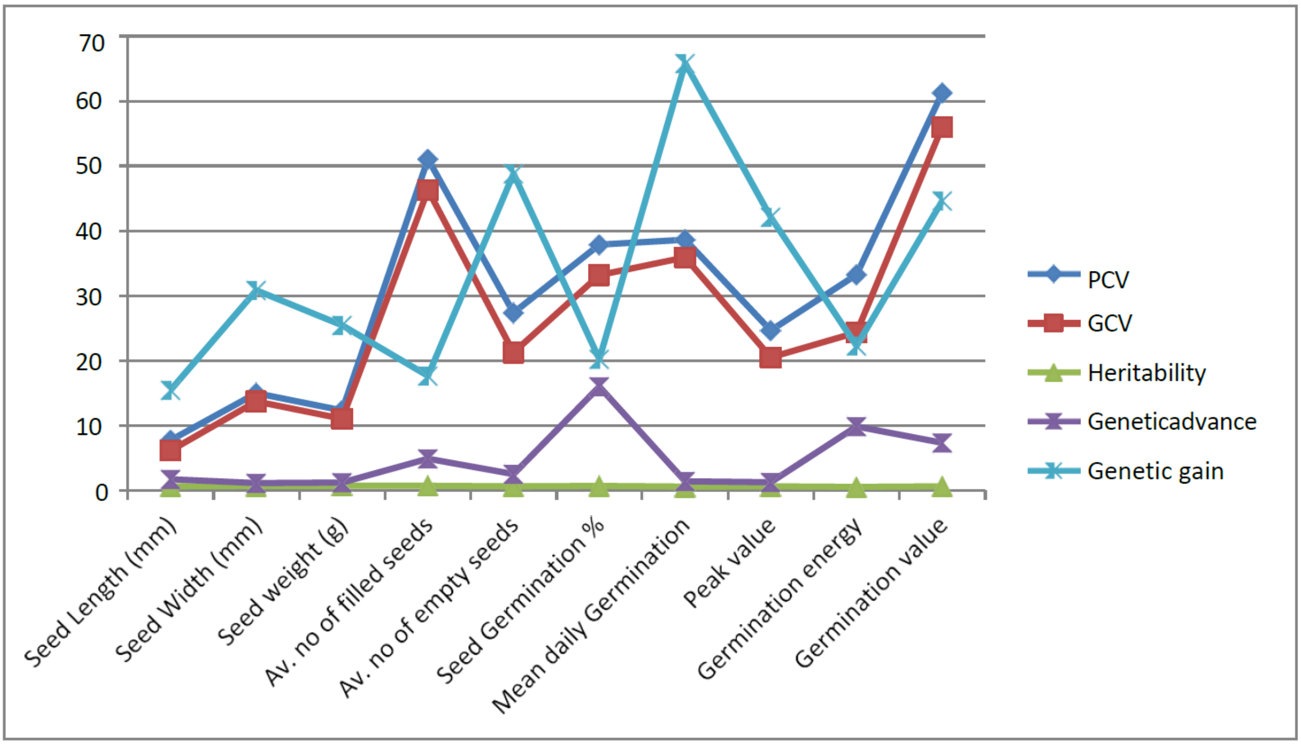


Fig. 3: Genetic parameters of seed traits of selected mother trees of *Ulmus villosa* Brandis

Summary

This research focuses on the genetic variation of *Ulmus villosa* Brandis, a multipurpose tree species from the Kashmir Himalayas, aiming to explore seed morphology, germination characteristics, and genetic traits. The study collected mature seeds from selected trees across five districts of Kashmir, using systematic random sampling and analyzed various seed parameters such as seed length, width, weight, and germination potential. The findings revealed significant variation in seed morphology, with differences observed in seed dimensions, weight, and the proportion of filled versus empty seeds. Larger seeds,such as those from Bijbehara, were found to have better seedling emergence and growth potential, underlining the influence of environmental factors and maternal effects on seed characteristics. These findings are valuable for optimizing seed propagation strategies and genetic resource management, crucial for both conservation and tree improvement programs.

Conclusion

Based on the findings from the study, it can be concluded that significant variation exists in the seed morphology, germination characteristics, and genetic traits of *Ulmus villosa Brandis* across different sources in the Kashmir Himalayas. This variation holds critical implications for tree improvement programs, especially concerning the selection of superior seed sources for propagation and conservation efforts.

The study highlighted substantial differences in seed size, weight, and germination behavior among the selected seed sources. Larger seeds, particularly those from the Bijbehara region, were associated with enhanced seedling emergence, growth, and biomass allocation, reflecting the positive influence of maternal traits and favorable environmental conditions. These larger seeds are likely to perform better in propagation efforts, especially in seedling production and afforestation programs, and should be prioritized in future efforts to improve *Ulmus villosa* regeneration. Moreover, the study's examination of seed germination dynamics, including germination energy and mean daily germination, revealed promising variations across sources.

This information is critical for optimizing germination techniques, improving seedling survival rates, and ensuring the successful establishment of *Ulmus villosa* in both natural and agroforestry systems. The significant genetic diversity observed in the morphological traits of *Ulmus villosa* emphasizes the importance of selecting appropriate seed sources for genetic improvement. The findings underscore the need for further research to explore the genetic potential of this species, as it holds substantial promise for agroforestry applications, especially on degraded lands. In addition, its adaptability to diverse ecological conditions positions *Ulmus villosa* as a valuable species for reforestation and biodiversity conservation in the region.

Finally, the insights gained from this study will support the development of sustainable forest management strategies, enabling the identification of superior genotypes that are well- suited to the region's climatic and ecological conditions. It also emphasizes the critical role of *Ulmus villosa* in the ecological restoration of degraded landscapes, as well as in providing multiple socio-economic benefits,including timber, fodder,and medicinal products. By understanding the variability in seed characteristics, this research provides the groundwork for developing improved propagation methods, enhancing genetic resource management, and fostering the long-term conservation of *Ulmus villosa* in the Kashmir Himalayas.

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Conflict of interest

There is no conflict of interest among the authors.

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