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GENETIC VARIABILITY AND PCA OF GROWTH AND PHYSIOLOGICAL TRAITS IN *Ulmus villosa* SEED SOURCES

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The study investigated growth performance and physiological variability among different seed sources of *Ulmus villosa,* with the aim of identifying the most productive and site-adapted seed source under field conditions in Punjab. Seeds collected from five sources in Himachal Pradesh—Suket (Mandi), Jhidi (Mandi), Kumi (Mandi), Kullu, and Nauni (Solan) were initially evaluated under nursery conditions and the best performing progenies were transplanted (August 2019) for field evaluation. In terms of growth and physiological traits, significant variations were recorded among the seed sources where progenies of S1 (Suket) and S3 (Kumi) outperformed rest of the sources in all traits and can be exploited for superior progeny selection. Moderate heritability was obtained for majority of the growth and physiological traits and was found maximum for volume index and Chlorophyll a. Similarly, genetic gain was recorded maximum for chlorophyll a followed by volume index. Highly significant positive genotypic and phenotypic correlations were also observed for volume index with DBH and plant height; plant height with DBH; number of branches with number of leaves per plant; and total chlorophyll with chlorophyll b. Principal Component Analysis identified DBH and volume index as the major contributors to diversity among the seed sources, suggesting these traits as priorities for future genetic improvement of the species.

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INTRODUCTION

Forests, the largest terrestrial ecosystems, are critical for maintaining ecological balance and mitigating the effects of climate change due to their role as both carbon sinks and sources. Their capacity to store and sequester carbon positions them as a key component of the global climate regulation system. Increasing concerns about global climate change have heightened the significance of sustainable management and preservation of forest genetic resources. The expansion of plantation forestry, particularly with fast-growing species like *Populus* spp. and *Eucalyptus* spp., reflects a global effort to reduce reliance on fossil fuels and meet biomass production demands.

However, diversifying tree species is essential for enhancing resilience and ecosystem health. Understanding the performance of different tree species under varying environment conditions, such as those in Punjab, is essential for the advancement of sustainable agroforestry systems. *Ulmus villosa*, with its fast growth rate and multiple uses in agroforestry, presents an intriguing option for cultivation in Punjab. As efforts continue to combat climate change and promote sustainable resource management, exploring and utilizing diverse tree species like *Ulmus villosa* can contribute significantly to these objectives while also providing economic and ecological benefits to local communities.

The multipurpose tree *Ulmus villosa* Brandis, commonly referred to as marn elm or cherry bark elm, is a deciduous tree belonging to the Ulmaceae family. Although elms are found all over the world, most of them are located in Southeast Asia, the subtropics of Central America, and the temperate regions of the Northern Hemisphere (POOLER & TOWNSEND, 2005). Due to their widespread uses, these are becoming endangered. Out of 35 different species of elms, only five have been identified on the Indian subcontinent: *Ulmus wallichiana*, *Ulmus villosa*, *Ulmus pumila,* and *Ulmus chumlia,* which are found in the northwestern Himalaya, and *Ulmus lanceifolia*, which is found in the northeastern parts of the country. The two species, *U. wallichiana* and *U. villosa*, are naturally found in the Kashmir valley and in some sections of Himachal Pradesh; however, their low seed viability and sporadic seed production lead to limited regeneration in the forests (THAKUR *et al.*, 2014).

This medium to large sized tree can grow up to 20–30 meters in height at altitudes of 800–2500 meters above mean sea level (SODHI *et al.*, 2023). It flowers from February to April (BHARDWAJ *et al.*, 2000). The species is commonly found in mixed deciduous forests alongside *Melia azedarach*, *Toona ciliata*, *Celtis australis*, and *Populus* spp. Though it can thrive in degraded lands and farms outside its native range, its propagation is constrained by irregular seeding behavior, low seed viability, and limited seedling availability. The species is highly valued by hill farmers for its wide array of uses, such as a reliable source of timber for construction, agricultural tools, and fuelwood. In Kashmir, it is also considered a sacred tree. Moreover, it provides excellent fodder during the lean seasons, and its fast growth rate makes it a valuable resource for farm forestry, agroforestry, and the rehabilitation of degraded lands (LONE *et al.*, 2016). Despite its ecological and economic importance, its population is declining due to overharvesting, low regeneration, and vulnerability to Dutch elm disease (DED), which is transmitted by the Elm Bark Beetle (*Scolytus kashmirensis*) in the Himalayan region (KHANDAY & BUHROO, 2015).

Considering its potential, the present study was undertaken to evaluate the growth performance and physiological variability among different seed sources of *U. villosa*, with the aim of identifying the most productive and site-adapted seed sources /progenies under field conditions in Punjab. The success of any breeding or improvement program depends on the availability of sufficient genetic variability. Since selection is a key mechanism for genetic improvement, identifying variation in growth and physiological traits is essential to achieving higher genetic gains and selecting superior genotypes for large-scale deployment.

MATERIALS AND METHODS

Location and climate of experimental site

The experiment was conducted at the research farm of the Department of Forestry and Natural Resources, Punjab Agricultural University (PAU), Ludhiana, situated in the central zone of Punjab within the northwestern plains of India. The site is geographically located at 30°54′26″ N latitude and 75°47′38″ E longitude, at an elevation of 247 meters above mean sea level. The region falls under the central agro-climatic zone, characterized by a subtropical to tropical climate. The summer months of May and June are typically the hottest, marked by high evapo-transpiration rates and persistent hot, desiccating winds. The majority of the annual rainfall (approximately 75–80%) occurs during the southwest monsoon season, from early July to mid-September, with total annual precipitation ranging from 700 to 750 mm. The winter months, particularly December and January, are the coldest, with markedly lower temperature and minimal rainfall.

Experimental material and growth conditions

An extensive survey conducted in Himachal Pradesh (India) identified five seed sources of *Ulmus villosa* from the Mandi, Kullu, and Solan districts, characterized by scattered and geographically isolated populations. Well matured seeds were collected from phenotypically superior trees and bulked for each seed source between February and March 2019, and progenies were raised under controlled nursery conditions (SODHI *et al.* 2023). In August 2019, superior progenies were transplanted into field conditions using a Randomized Complete Block Design (RCBD) with five replications consisting of four trees per plot (replication), spaced 4 m × 2 m in an East-West orientation. The details of seed sources are presented in Table 1.

Table 1. Description of Ulmus villosa seed sources used in the study:

Seed sources	Name	District	Latitude	Longitude
S1	Suket	Mandi, Himachal Pradesh	31° 51´ N	76° 88´ E
S2	Jhidi	Mandi, Himachal Pradesh	31° 82´ N	77° 17´ E
S3	Kumi	Mandi, Himachal Pradesh	31°60´ N	76° 94´ E
S4	Kullu	Kullu, Himachal Pradesh	32° 02´ N	77° 12´ E
S5	Nauni	Solan, Himachal Pradesh	31° 29´ N	76° 77´ E

Growth characteristics, including plant height and diameter at breast height (DBH), were recorded for each tree per replication in a 4-year-old plantation during June 2023. Observations on the number of branches and leaves per plant were taken in September 2023. The volume index was calculated using the D^2H relationship (square of diameter x height).

While observations for physiological characteristics *viz.*, chlorophyll a (mg/g FW), chlorophyll b (mg/g FW), total chlorophyll (mg/g FW) and carotenoid content (mg/g FW), were recorded in the laboratory of Department of Forestry and NR in the month of September, 2023. Estimation of pigment concentration was done as per the methodology given by (HISCOX and ISRAELSTAM, 1979) of using dimethyl sulphoxide for chlorophyll extraction.

Soil properties i.e, N (kg/ha), P (kg/ha), K (kg/ha), OC (%), EC (dS m^{-1}) and pH were determined once in the month of November, 2022 (Table 2). Organic carbon (OC) was calculated using potassium dichromate solution and titrates against Ferrous Ammonium Sulphate (FAS) according to (WALKLEY & BLACK, 1934). pH was measured using a pH meter as per (SAWHNEY *et al.*, 2002) in suspension by combining 25 g of soil media mixture with 50 ml of distilled water, the EC (dS/m) was assessed using a conductivity meter in the same pH suspension 24 hours later in the supernatant solution. The method (micro-kjeldahl's approach) used to estimate the amount of nitrogen readily available in the soil was given by (SUBBIAH & ASIJA'S, 1956). The available phosphorus was calculated as suggested by (OLSEN *et al.*, 1954). The available potassium in the soil was measured using flame photometric method and was extracted using 1N neutral ammonium acetate (AR grade), as suggested by (MERWIN & PEECH, 1951).

Table 2. Soil properties of the experimental site at the initiation of the experiment

Soil property	Depth (cm)		
	0-15	15-50	50-100
Available N (kg/ha)	100.5	87.81	75.26
Available P (kg/ha)	21.02	28.92	31.87
Available K (kg/ha)	187.04	143.70	111.30
pH	7.99	_	_
EC (dS/m)	0.13	_	_
OC (%)	0.70	_	_

Statistical analysis

The mean data for various growth and physiological traits were subjected to statistical analysis following the guidelines for Randomized Complete Block Design (RCBD). Analysis of variance, critical differences, genetic parameters, and correlations were calculated using OPSTAT software. Principal component analysis was performed using the Statistical Package for the Social Sciences (SPSS), version 20.0.

RESULTS

Growth and physiological traits

All seed sources showed significant variations in terms of growth parameters, such as plant height (m), diameter at breast height (cm), volume index (m^3), and number of leaves, with the exception of number of branches per plant. Physiological traits *viz.*, total chlorophyll, chlorophyll a, chlorophyll b and carotenoid content also varied significantly among seed sources.

The progenies of S1 (Suket) outperformed rest of the sources in all traits and displayed maximum mean values for the growth characteristics (Table 3), namely plant height (9.86 m), DBH (11.75 cm), volume index (0.136 m^3), and number of leaves (16038). S1 (Suket) was found to be at par with S3 (Kumi) seed source for DBH (10.90 cm) and volume index (0.107 m^3). Similarly, for physiological traits, seed source S3 (Kumi) showed mean maximum value for total chl (6.01 mg/g FW) and chl b (5.65 mg/g FW), seed source S5 (Nauni) for chl a (0.34 mg/g FW). S2 (Jhidi) showed mean maximum values for carotenoid (0.09 mg/g FW).

Table 3. Effect of seed source on growth and physiological traits of Ulmus villosa under field conditions

Seed source	Plant height (m)	DBH (cm)	Volume index (m^3)	No. of branches per plant	No. of leaves per plant	Total chl (mg/g FW)	Chl a (mg/g FW)	Chl b (mg/g FW)	Carotenoid (mg/g FW)
S1 (Suket)	9.86	11.75	0.136	32.20	16038	5.23	0.22	4.85	0.04
S2 (Jhidi)	8.32	9.98	0.083	16.20	11435	5.09	0.14	4.78	0.09
S3 (Kumi)	8.94	10.90	0.107	23.20	13149	6.01	0.06	5.65	0.06
S4 (Kullu)	6.82	7.84	0.050	24.80	13473	4.81	0.21	4.67	0.05
S5 (Nauni)	9.00	10.14	0.094	19.80	12798	5.17	0.34	4.87	0.07
CD (p=0.05)	1.47	1.85	0.033	NS	1992.1	0.85	0.18	0.90	0.04

Estimates of genetic variability

Regarding variability estimates and genetic parameters (Table 4), number of leaves per plant showed widest range of values (9180-16754), in terms of coefficient of variation, Chl a exhibited maximum GCV (50.63) and PCV (69.11). In comparison to the genotypic coefficient of variation (GCV), the phenotypic coefficient of variation values was discovered to be slightly higher for every parameter. Moderate heritability was obtained for majority of the growth and physiological traits and was found maximum for volume index (0.59) and Chl a (0.54). Number of leaves (2073.43) had the highest genetic advance values. Genetic gain was recorded maximum (76.41%) for Chl a followed by volume index (49.75%).

Table 4. Variability estimates and genetic parameters for growth traits of Ulmus villosa seed sources under field conditions

Characters/ Parameters	Mean	Range	CV	Coefficient of Variance		Heritability (Broad sense)	Genetic Advance	Genetic gain (% of mean)
				Genotypic	Phenotypic			
Plant height (m)	8.59	4.81 – 10.20	13.01	11.70	17.79	0.43	1.36	15.86
DBH (cm)	10.12	4.45 – 12.17	13.88	12.98	19.10	0.46	1.84	18.17
Volume index (m^3)	0.0941	0.115-0.151	26.19	31.44	40.92	0.59	0.0468	49.75
No. of branches per plant	23.24	16.20–32.20	41.90	10.68	16.58	0.41	14.04	14.16
No. of leaves per plant	13378.60	9180 -16754	11.29	11.23	16.76	0.45	2073.43	15.50
Total chl (mg/g FW)	5.26	4.19 – 6.60	9.93	7.61	11.32	0.45	0.55	10.53
Chl a (mg/g FW)	0.19	0.02 – 0.50	46.15	50.63	69.11	0.54	0.15	76.41
Chl b (mg/g FW)	4.96	3.87 – 6.33	14.35	6.67	11.53	0.33	0.39	7.94
Carotenoid (mg/g FW)	0.06	0.02 – 0.11	31.31	28.69	43.83	0.43	0.02	38.76

Correlation studies

Table 5. Genotypic and phenotypic correlation among growth and physiological traits of Ulmus villosa seed sources under field conditions

Characters		DBH	Plant height	Volume index	No. of branches per plant	No. of leaves per plant	Chl a	Total chl	Chl b
DBH (cm)	G								
	P								
Plant height (m)	G	0.999*							
	P	0.846 **							
Volume index (m^3)	G	0.997**	0.995**						
	P	0.949 **	0.931 **						
No. of branches per plant	G	0.584 NS	0.460 NS	0.686 NS					
	P	0.163 NS	0.432 *	0.429 *					
No. of leaves per plant	G	0.578 NS	0.466 NS	0.683 NS	0.999 **				
	P	0.162NS	0.424 *	0.427 *	0.998 **				
Chl a (mg/g FW)	G	-0.113 NS	0.143 NS	0.003 NS	0.264 NS	0.266 NS			
	P	-0.169 NS	-0.037 NS	-0.126 NS	0.052 NS	0.054 NS			
Total chl (mg/g FW)	G	0.736 NS	0.646 NS	0.628 NS	0.101 NS	0.100 NS	-0.713 NS		
	P	0.381 NS	0.275 NS	0.335 NS	-0.099 NS	-0.091 NS	-0.380 NS		
Chl b (mg/g FW)	G	0.611 NS	0.489 NS	0.485 NS	-0.066 NS	-0.061 NS	-0.773 NS	0.998 *	
	P	0.213 NS	0.143 NS	0.199 NS	0.026 NS	0.031 NS	-0.4124 *	0.881 **	
Carotenoid (mg/g FW)	G	-0.382 NS	-0.317 NS	-0.521 NS	-1.111 *	-1.100 *	-0.166 NS	-0.203 NS	-0.247 NS
	P	-0.026 NS	-0.175 NS	-0.233NS	-0.652**	-0.666 **	-0.009 NS	-0.014 NS	0.026 NS

*significant at 5 % level of significance, +*significant at 1 % level of significance

Highly significant positive genotypic and phenotypic correlation were observed (Table 5) among most of the important growth traits. Volume index was found to be genotypically and phenotypically correlated with DBH (0.997, 0.949) and plant height (0.995, 0.931). Plant height and DBH were also significantly and positively correlated with each other (0.999, 0.846). Similarly, significantly positive correlation was also found between number of branches with number of leaves per plant (0.999, 0.998). Among physiological characters, highly significant positive correlation was found for photosynthetic pigments i.e., total chlorophyll with chlorophyll b (0.998, 0.881).

Principal component analysis

It was observed that (Table 6) three out of eleven components had Eigen value more than unity which explained 78.88 per cent of the total variation. Eigen values are presented in Fig 1. The first main component accounted for the highest variance at 39.37%, with high positive loadings for number of leaves per plant (0.525), number of branches (0.491), chlorophyll *a* (-0.087), and carotenoids (-0.007). These traits reflect the plant's photosynthetic potential and vegetative development, indicating their relevance in assessing physiological performance and canopy structure. The second major component, explained 21.64 per cent of the total variation which had the highest loadings for chlorophyll *b* (0.178), which highlights its distinct influence on pigment diversity and light utilization efficiency. The third major component, which accounted for 17.97 per cent of the overall variation, showed maximum loading for plant height (0.755), diameter at breast height (0.988), volume index(0.942), and total chlorophyll content(0.321) which are directly linked to growth vigor and biomass production, emphasizing the significance of these growth parameters in differentiating between the different tree sources.

Table 6. Principal components for growth and physiological characteristics in Ulmus villosa

Characters	Principal components		
	1	2	3
DBH (cm)	0.180	0.917	0.988
Plant height (m)	0.524	0.722	0.755
Volume index (m^3)	0.364	0.873	0.942
No. of branches per plant	0.491	0.188	0.073
No. of leaves per plant	0.525	0.192	0.124
Total chl (mg/g FW)	-0.004	0.263	0.321
Chl a (mg/g FW)	-0.087	-0.200	-0.135
Chl b (mg/g FW)	-0.012	0.178	0.159
Carotenoid (mg/g FW)	-0.007	-0.045	-0.025
Eigen value	4.319	2.381	1.977
Per cent of variability (%)	39.367	21.643	17.968
Cumulative per cent of variability (%)	39.267	60.910	78.878

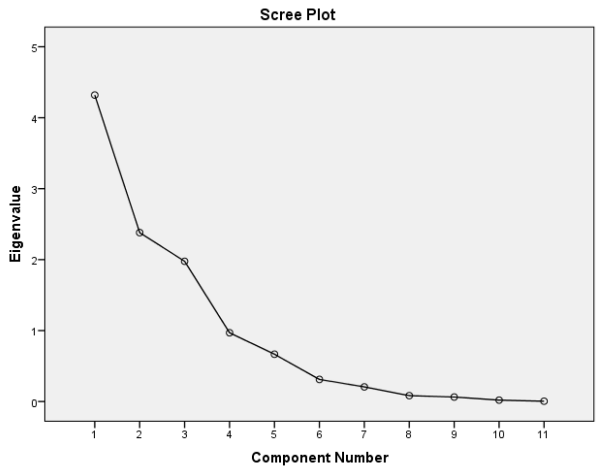

Fig.1 Scree plot based on principal component analysis

DISCUSSION

The present study revealed significant differences in growth and physiological characteristics among seed sources of *Ulmus villosa*, suggesting the presence of considerable genetic variability. Such variation is commonly observed in species with natural distributions across ecologically diverse regions, where populations are likely to have undergone local adaptation (MEEK *et al.*, 2023). Since all progenies in this trial were grown under uniform environmental conditions, the observed differences in growth traits are presumed to be genetically controlled rather than environmentally induced, corroborating earlier findings by SINGH and POKHRIYAL (2002).

The analysis of variance further substantiated this genetic variability, with statistically significant differences observed across seed sources for various growth parameters. These results are consistent with those of RAMESH and KHURANA (2003), who reported notable variation in diameter at breast height (DBH) among different provenances of *Populus alba* across Jammu & Kashmir and Himachal Pradesh. Similar patterns of provenance-based variation have been documented in other species, including *Quercus leucotrichophora* (NAUTIYAL *et al.*, 2000; SAKLANI *et al.*, 2012), *Ailanthus chinensis* (DHANAI, 2002), *Celtis australis* (SINGH, 2003), *Prunus serotina* (ESEN *et al.*, 2007), and *Pongamia pinnata* (SHIVANNA *et al.*, 2007). The consistency of these findings across diverse species reinforces the importance of genetic variation in determining growth potential and environmental adaptability. These insights highlight the value of selecting genetically superior and site-adapted seed sources for plantation and conservation programs, especially in variable field conditions as in the Punjab region of India.

Genetic variation is the foundation of any breeding program, as it allows for the selection of superior individuals and the development of genotypes with desired traits. The observed variability among *Ulmus villosa* seed sources presents an opportunity to leverage naturally adapted populations for the development of improved planting material. In particular, seed sources that demonstrated both high performance and adaptability (Suket and (Kumi), are particularly valuable for breeding and reforestation efforts. This aligns with the broader principle of site-specific provenance/seed source selection, where breeding materials are matched to optimal environments, enhancing survival and productivity across diverse ecological conditions. However, the success of these breeding programs ultimately depends on the extent of genetic variability within the breeding population (SHARMA *et al.,* 2021). Sufficient genetic diversity is essential to capture a broad spectrum of traits that confer adaptability, which allows for the selection of individuals best suited to specific environmental conditions. Without adequate genetic variation, the potential for achieving substantial improvements in growth, resilience, and productivity may be constrained.

The total genetic variability arises from both additive and non-additive gene effects, emphasizing the importance of thoroughly evaluating genetic diversity before making selection decisions. As selection is the primary mechanism driving genetic improvement, it can only be effectively applied when sufficient variability is present. Key genetic parameters such as heritability and genetic advance provide critical insights into the proportion of phenotypic variance that is heritable and the expected genetic improvement from selection. The highest heritability estimates and genetic gains were recorded for the volume index (0.59; 49.75%) and chlorophyll a (0.54; 76.41%).

The significance of genetic gain in physiological parameters such as chlorophyll a is particularly notable. Chlorophyll a plays a critical role in photosynthesis, which is essential for energy production and overall plant growth. The higher genetic gain in Chl a suggests substantial potential for enhancing the photosynthetic efficiency of *Ulmus villosa* through selection. Improved chlorophyll content could directly contribute to increased plant growth, enhanced stress tolerance, and improved overall productivity, particularly under varying environmental conditions. Additionally, the high heritability of Chl a indicates that phenotypic selection can be a highly effective tool for improving this trait. Consequently, Chl a represents a promising target for breeding programs focused on enhancing the physiological performance and resilience of *Ulmus villosa*.

High heritability, particularly when paired with high genetic gain, suggests that additive gene action is predominant, indicating that phenotypic selection can be an effective tool for improving specific traits. However, high heritability alone does not always guarantee significant genetic gain, especially when variability is limited or environmental factors exert strong influences. Thus, the combined consideration of both heritability and genetic gain offers a more reliable foundation for making informed, effective selection decisions (JOHNSON *et al.,* 1955).

The results of this study are consistent with those of GUPTA *et al.* (2012), who reported high coefficients of variability, genetic advance, and genetic gain for leaf number in *Acacia catechu* across various provenances. Similarly, DHILLON *et al.* (2009) observed medium heritability for diameter (40.76–85.08%) and height (52.07–76.25%) in *Melia azedarach* across different growth stages. CHOUDHARY *et al.* (2016) reported exceptionally high genotypic and phenotypic coefficients of variation in willows, with plant height exhibiting the highest genotypic coefficient (291.21%) and leaf number showing the highest phenotypic coefficient

(291.52%). The highest heritability (99.79%) and genetic gain (114.3%) were also recorded for plant height, confirming its potential as a key selection trait.

Understanding the interrelationships among traits is equally critical for devising effective breeding strategies, and correlation analysis is a useful tool for this purpose. Genotypic correlations are generally higher than their phenotypic counterparts, indicating intrinsic genetic associations or pleiotropic effects at the gene level. Such associations suggest that selecting for one trait may indirectly influence others, thus requiring that correlated traits be given due consideration in selection strategies to ensure comprehensive genetic improvement.

The current findings support this view, revealing strong interrelationships among several growth and physiological traits in *Ulmus villosa*. Similar patterns have been reported in related species: ORLOVIC *et al.* (2003) documented highly significant positive correlations among growth and physiological traits in white willow, while SHARMA *et al.* (2017) reported a significant positive correlation between the number of branches per plant and basal diameter in *Salix* clones. PALIAL and THAKUR (2021) also observed significant correlations among morpho-physiological traits in *Salix* species, affirming the robustness of such associations.

Principal Component Analysis (PCA) effectively identified key growth and physiological traits that contribute significantly to the genetic variability among *Ulmus villosa* seed sources. Three principal components (PC1, PC2, and PC3), each with Eigen values greater than one, collectively accounted for a substantial proportion of the total variation. Traits such as plant height, diameter at breast height (DBH), and volume index recognized as reliable indicators of early biomass accumulation and long-term yield potential were loaded strongly on PC3, highlighting their pivotal role in defining productivity. PC1 was primarily characterized by the number of branches, number of leaves per plant, chlorophyll a, and carotenoids, indicating a composite of morphological and physiological vigor. PC2 was dominated by chlorophyll b, pointing to photosynthetic efficiency. These trait groupings suggest that selection strategies targeting high values for plant height, DBH, and total chlorophyll, combined with foliar traits, may enhance both growth performance and physiological resilience. The results provide a focused framework for breeders to prioritize traits that are not only genetically variable but also functionally linked to improved productivity under field conditions.

These findings support the use of PCA as a valuable tool in deconstructing complex trait variability and offer actionable insights for breeding. Prioritizing traits such as plant height, DBH, volume index, and chlorophyll content can facilitate the development of robust and high-performing genotypes suited for varying agro-climatic zones. The results suggest that these traits should be prioritized in selection and breeding programs to maximize genetic gain. The utility of PCA in unraveling complex trait variation aligns with findings from earlier research. THAKUR and THAKUR (2015) reported that two out of twelve principal components with Eigen values greater than one accounted for 75.69% of the total variation. SHARMA *et al.* (2019) reported that five of nineteen components accounted for 82.85% of the variability in growth and biomass traits of *Salix* clones, all with Eigen values above one. Similarly trait clustering and dominance of growth-related components have been reported in *Populus nigra* (ISIK and TOPLU, 2004) and in willow (SHARMA *et al.*, 2019), further validating the importance of growth and physiological traits in defining genetic divergence and productivity.

CONCLUSIONS

This study revealed significant genetic variability among *Ulmus villosa* seed sources, with S1 (Suket) and S3 (Kumi) outperforming others in growth performance. Moderate heritability was observed for majority of the traits, with the highest values for volume index and chlorophyll *a*. Number of leaves showed the highest genetic advance, while chlorophyll *a* and volume index exhibited the maximum genetic gain, indicating strong potential for improvement through selection. Significant positive correlations were found between volume index, DBH, and plant height, suggesting that selecting one of these traits could enhance related traits. Principal component analysis further identified DBH and volume index as key contributors to genetic diversity. Future research should focus on multi-location evaluations and long-term performance monitoring of selected seed sources to confirm stability and adaptability across varying environmental conditions. These efforts will further strengthen breeding strategies and conservation programs for *Ulmus villosa*.

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GENETSKA VARIJABILNOST I PCA RASTA I FIZIOLOŠKIH OSOBINA KOD IZVORA SEMENA *Ulmus villosa*

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Izvod

Studija je ispitivala performanse rasta i fiziološku varijabilnost među različitim izvorima semena vrste *Ulmus villosa,* sa ciljem identifikacije najproduktivnijeg i najprilagođenijeg lokaciji izvora semena u poljskim uslovima u Pendžabu. Seme sakupljeno iz pet izvora u Himačal Pradešu - Suket (Mandi), Džidi (Mandi), Kumi (Mandi), Kulu i Nauni (Solan) je prvobitno procenjeno u rasadniku, a potomci sa najboljim rezultatima su presađeni (avgust 2019) za poljsku procenu. Što se tiče rasta i fizioloških osobina, zabeležene su značajne varijacije među izvorima semena, gde su potomci S1 (Suket) i S3 (Kumi) nadmašili ostale izvore u svim osobinama i mogu se iskoristiti za superiornu selekciju potomstva. Umerena heritabilnost je dobijena za većinu osobina rasta i fizioloških osobina i pronađena je maksimalna za indeks zapremine i hlorofil a. Slično tome, genetski dobitak je zabeležen maksimalno za hlorofil a, a zatim za indeks zapremine. Veoma značajne pozitivne genotipske i fenotipske korelacije su takođe primećene za indeks zapremine sa DBH i visinu biljke; visinu biljke sa DBH; broj grana sa brojem listova po biljci; i ukupan hlorofil sa hlorofilom b. Analiza glavnih komponenti identifikovala je DBH i indeks zapremine kao glavne doprinose raznolikosti među izvorima semena, što sugeriše ove osobine kao prioritete za buduće genetsko poboljšanje vrste.

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