



# Morphological diversity among different populations of *Grewia optiva* J.R. Drumm. Ex Burret in Western Himalaya, India

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**ABSTRACT:** *Grewia optiva* is an important multipurpose tree species widely distributed in the Northwestern Himalayas. The present study aimed to assess eco-geographical variation in growth, leaf, and fruit traits across Punjab and Himachal Pradesh, India. The field surveys were conducted at twelve sites located in Hoshiarpur and Shaheed Bhagat Singh Nagar districts of Punjab and Una and Solan districts of Himachal Pradesh. At each site, trees were categorized into three diameter classes (10-20 cm, 20-30 cm, and >30 cm), with a minimum of five trees sampled per class. The significant variation was observed among locations for most traits. The plant height ranged from 3.38 m at Ballawal Saunkri to 12.72 m at Nauni. The maximum crown spread was recorded at Nauni (4.74 m) and Janauri (4.73 m). The number of primary branches did not differ significantly among locations. The secondary branches showed significant variation, with values ranging from 5.33 at Badwar to 13.67 at Dholwaha. The primary branch angle ranging from 26.33° at Bhaddi to 46.67° at Dehni. Leaf traits also varied considerably, maximum leaf length (13.86 cm), Leaf width (7.32 cm), leaf area (45.62 cm<sup>2</sup>), maximum fresh weight (76.59 g) and dry weight (38.09 g) of 100 leaves were recorded at Nauni. Fruit characteristics also showed significant variability; Fresh and dry weights of leaves were highest at Nauni and lowest at Ballawal Saunkri. Fruit traits also differed significantly; maximum fruit length (5.06 mm), width (4.30 mm), and dry weight (13.54 g) were recorded at Nauni, while Lambalahri showed maximum fruit thickness (4.20 mm) and fresh weight (21.88 g). Higher diameter classes ( $D_1$  and  $D_2$ ) consistently exhibited superior growth and biomass traits compared to  $D_3$ . Correlation analysis revealed strong positive associations among growth, leaf, and biomass parameters. The study highlights substantial phenotypic variability and identifies Nauni, Kailar, and Gaura as superior populations for selection and genetic improvement.

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## 1. INTRODUCTION

*Grewia optiva* (J.R. Drumm. ex Burret) (family Malvaceae; formerly Tiliaceae) is an important multipurpose agroforestry tree species commonly known as biul, bihul, bhimal, or dhaman, this species is widely cultivated along the bunds of agricultural fields between 500 and 2500 m elevation across the Northwestern Himalayas and the hilly tracts of southern India and Myanmar (Murasing *et al.*, 2022). In Indian subcontinent, it occurs naturally in India, Nepal, Bhutan, and Pakistan (Bhagta *et al.*, 2019). In India, it is distributed across Himachal Pradesh, Uttarakhand, Jammu and Kashmir, Punjab, and

Sikkim. *G. optiva* thrives under a broad range of environmental conditions preferring sandy loam soils with moderate moisture but capable of growing in varied soil types and tolerates temperatures between -2°C and 38°C and annual rainfall from 1200 to 2500 mm (Luna, 1996; Orwa *et al.*, 2009). *G. optiva* is a small to medium-sized deciduous tree (13-15 m tall; 0.8-1.0 m diameter), characterized by a thick ashy-white exfoliating bark and rough, stellate-hairy young shoots (Sankhyan *et al.*, 2020a). The leaves are opposite, petiolate, and ovate to broadly ovate, while the inflorescences are cymose with one to eight pale yellow or white flowers, blooming simultaneously with leaf flush during April-May (Orwa *et al.*, 2009). Its drupe fruit turns from olive-green to black upon maturation and is edible both raw and cooked (Heuzé *et al.*, 2019). Leaf shedding typically occurs in March-April, followed by fruit maturity in September and ripening by December (Chauhan *et al.*, 2021). The species tolerates frost and drought but is susceptible to fire and grazing pressures (Katoch *et al.*, 2017; Singh *et al.*, 2018). The ecologically and economically, *G.*

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*optiva* is one of the most valuable farmer-friendly agroforestry trees of the Northwestern Himalayas (Verma, 2015). It is highly preferred on agricultural field boundaries due to multiple beneficial attributes: (i) production of high-quality, palatable green fodder during winter fodder scarcity months; (ii) strong coppicing ability (Sankhyan & Bhagta, 2016; Mukherjee *et al.*, 2018; Sahoo *et al.*, 2016; Gachuri *et al.*, 2017); (iii) substantial litter contribution enhancing soil fertility (Kar *et al.*, 2019); and (iv) fiber-producing branches used for making ropes and other household products. Fiber-yielding plant species such as *G. optiva* rank second in economic importance after food crops in India (Pandey and Gupta, 2003; Negi *et al.*, 2010). Mature trees can produce 12–30 kg of leaf fodder annually (Sankhyan *et al.*, 2022), with high crude protein content (17.4–21.0 %) and >70% dry matter digestibility, making it a vital nutrient source for livestock (Bhagta & Sankhyan, 2016; Verma *et al.*, 2014). Nutritional quality, however, varies seasonally, with higher protein levels recorded in young and winter leaves relative to those in the rainy season. *G. optiva* is not a common forest species, its occurrence near villages and agricultural terraces underscores its adaptation to human-managed landscapes. Its broad elevational range indicates strong ecological adaptability to variable microclimatic and edaphic conditions. Such altitudinal and environmental heterogeneity can exert differential selection pressures on morphological and physiological traits, leading to local adaptation. Moreover, its capacity to regenerate rapidly after pruning contributes to biomass accumulation and carbon storage (Rana *et al.*, 2020). Given its wide ecological amplitude, high fodder and fiber value, and critical role in sustaining agroforestry systems, assessing morphological variation among natural populations of *G. optiva* is essential. Understanding such intraspecific variability forms the scientific basis for selection of superior genotypes for breeding and tree improvement programs. Therefore, the present study aims to evaluate the morphological diversity of *G. optiva* across different populations of the North-Western Himalaya to identify variants with desirable traits for genetic improvement and sustainable utilization.

## 2. MATERIALS AND METHODS

### Study Area

In Punjab, the study sites included Hoshiarpur and Shaheed Bhagat Singh (SBS) Nagar districts, whereas in Himachal Pradesh, sampling was undertaken in Una and Solan districts (Table 1). The survey aimed to assess the morphological variation in *Grewia optiva* populations and to identify representative stands for

subsequent evaluation. *Grewia optiva* is not a common forest tree but occurs naturally along field bunds and margins. Therefore, sample trees were randomly selected from farmlands across the chosen locations to ensure adequate population coverage.

### Data Collection

Morphological observations were recorded on twelve population sites, at each site, trees were categorized into three diameter classes (10–20 cm ( $D_1$ ), 20–30 cm ( $D_2$ ), and >30 cm ( $D_3$ ), with a minimum of five trees sampled per class were randomly selected to represent intra-population variability. The Tree level traits measured included tree height, DBH, crown spread, and the number of primary and secondary branches. Tree height was measured using a Ravi altimeter, while DBH was determined using an aluminium caliper. Crown spread was measured along two perpendicular directions and averaged. The number of primary branches emerging from the main stem and the number of secondary branches were counted directly, and primary branch angles were measured following standard field procedures. Variation in leaf characteristics among populations was analyzed following the standard statistical methodologies of Robinson *et al.* (1951) and Al-Jibouri *et al.* (1958). Leaf sampling was carried out during November–December. Leaves were collected from the entire crown of each selected tree, covering different canopy positions (top, middle, and base). To capture size variability, ten fully expanded leaves from each size category were sampled per tree. Only healthy leaves free from pathogen infection, herbivore damage, or epiphyllic cover were used. Immediately after collection, leaves were wrapped in a moist cloth to prevent dehydration and shrinkage, and transported to the laboratory for analysis. The following leaf traits were measured: leaf length (cm), leaf width (cm), leaf area (cm<sup>2</sup>), and petiole length (cm). Leaf area was determined using a leaf area meter. Fruit samples were collected from the same trees used for morphological observations. Fruit characteristics measured included fruit length, width, thickness, fresh weight, and dry weight. Fruit measurement procedures followed the methodology of Kaushal (1978).

### Statistical Analysis

Data were analyzed following a Randomized Block Design (RBD) as outlined by Gomez and Gomez (1984). Analysis of variance (ANOVA) was performed to test for significant differences among populations, with significance determined at the 5% probability level ( $p < 0.05$ ). PCA and correlation (Gopinath *et al.*, 2020) identified similarities and variations in tree growth, leaf and fruit trait.

### 3. RESULTS AND DISCUSSION

#### Tree characteristics

The significant variation was observed among different locations for most of the tree characters studied. The plant height ranged from 3.38 m at Ballawal Saunkri (S<sub>4</sub>) to 12.72 m at Nauni (S<sub>11</sub>). The tallest plants were recorded at Nauni S<sub>11</sub> (12.72 m) and Kailar S<sub>12</sub> (11.20 m), which were statistically at par with each other, while Gaura (S<sub>10</sub>) (9.80 m) and Badwar (S<sub>8</sub>) (8.16 m) also recorded significantly higher plant height compared to other locations. The minimum plant height was observed at Ballawal Saunkri (S<sub>4</sub>) (3.38 m), followed by Dehni (S<sub>6</sub>) (3.60 m) and Bhaddi (S<sub>5</sub>) (3.68 m). The crown spread ranged from 2.17 m at Ballawal Saunkri (S<sub>4</sub>) to 4.74 m at Nauni (S<sub>11</sub>). The maximum crown spread was recorded at Nauni (S<sub>11</sub>) (4.74 m) and Janauri (S<sub>2</sub>) (4.73 m), which were statistically at par, followed by Dehni (S<sub>6</sub>) (4.57 m) and Dholwaha (S<sub>3</sub>) (4.28 m). The minimum crown spread was observed at Ballawal Saunkri (S<sub>4</sub>) (2.17 m). The number of primary branches

did not differ significantly among locations. However, numerically, the highest number of primary branches was recorded at Nauni (S<sub>11</sub>) (5.80), followed by Dehni (S<sub>6</sub>) and Gaura (S<sub>10</sub>) (5.40 each), while the minimum number was observed at Janauri (S<sub>2</sub>) (3.80). The secondary branches showed significant variation, with values ranging from 5.33 at Badwar (S<sub>8</sub>) to 13.67 at Dholwaha (S<sub>3</sub>). The maximum number of secondary branches was recorded at Dholwaha (S<sub>3</sub>) (13.67), which was significantly higher than most locations and at par with Ballawal Saunkri (S<sub>4</sub>) (12.00) and Nauni (S<sub>11</sub>) (11.67). The minimum number of secondary branches was observed at Badwar (S<sub>8</sub>) (5.33), followed by Dehni (S<sub>6</sub>) (6.33) and Lambalahri (S<sub>9</sub>) and Kailar (S<sub>12</sub>) (6.67 each). The primary branch angle ranging from 26.33° at S<sub>5</sub> to 46.67° at S<sub>6</sub>. The widest branch angle was recorded at S<sub>6</sub> (46.67°), which was statistically at par with S<sub>3</sub> and S<sub>11</sub> (41.67° each), while the narrowest branch angle was observed at S<sub>5</sub> (26.33°) and S<sub>8</sub> (26.67°) (Table 2). The interaction between diameter classes and population

**Table 1: Geographical parameters of sites of *Grewia optiva* in Punjab and Himachal Pradesh**

Sr. No.	Locations	Code	Locations	Altitude	Latitude/Longitude
1	Patiari	S1	Hoshiarpur	239 m	31°73'06"N 75°90'74"E
2	Janauri	S2		239 m	31°73'06" N 75°90'74"E
3	Dholwaha	S3		239 m	31°73'64" N 75°87'37"E
4	Ballawal Saunkhri	S4	SBS Nagar	355 m	31°06'05" N 76°27'26"E
5	Bhaddi	S5		263 m	31°13'51" N 76°35'87"E
6	Dehni	S6		296 m	30°48'66" N 75°69'79"E
7	Bangana	S7	Una	558 m	31°63'20" N 75°34'37"E
8	Badwar	S8		558 m	31°61'38" N 76°35'79"E
9	Lambalahri	S9		510 m	31°46'84" N 76°27'76"E
10	Gaura	S10	Solan	2086 m	30°90'39" N 77°09'69"E
11	Nauni	S11		1300 m	31°27'77" N 76°94'37"E
12	Kailar	S12		1502 m	30°91'27" N 77°07'97"E

**Table 2: Morphological variations in tree characteristics among different locations of *Grewia optiva***

Locations	Tree characters				
	Plant height (m)	Crown spread (m)	Primary branches (Nos.)	Plant Secondary Branches (Nos.)	Plant Primary Branches Angle (°)
Patiari	4.08 ± 0.24 <sup>b</sup>	3.23 ± 0.28 <sup>f</sup>	4.00 ± 0.71 <sup>a</sup>	8.67 ± 1.45 <sup>cde</sup>	33.67 ± 1.86 <sup>bc</sup>
Janauri	4.38 ± 0.39 <sup>fg</sup>	4.73 ± 0.48 <sup>a</sup>	3.80 ± 0.84 <sup>a</sup>	9 ± 1.53 <sup>bcd</sup>	30.67 ± 0.67 <sup>bcd</sup>
Dholwaha	5.5 ± 0.33 <sup>ef</sup>	4.28 ± 0.51 <sup>abc</sup>	5.20 ± 0.84 <sup>a</sup>	13.67 ± 1.65 <sup>a</sup>	41.67 ± 1.67 <sup>a</sup>
Bhaddi	3.68 ± 0.47 <sup>g</sup>	4.10 ± 0.41 <sup>abcd</sup>	4.60 ± 1.14 <sup>a</sup>	10.33 ± 1.55 <sup>bcd</sup>	26.33 ± 1.86 <sup>d</sup>
Tibba Nangal	3.6 ± 0.22 <sup>g</sup>	4.57 ± 0.59 <sup>ab</sup>	5.40 ± 0.89 <sup>a</sup>	6.33 ± 1.45 <sup>ef</sup>	46.67 ± 2.67 <sup>a</sup>
Ballawal Saunkri	3.38 ± 0.28 <sup>g</sup>	2.17 ± 0.21 <sup>g</sup>	5.20 ± 1.92 <sup>a</sup>	12 ± 1.83 <sup>ab</sup>	35 ± 2.89 <sup>b</sup>
Bangana	6.62 ± 0.65 <sup>de</sup>	3.33 ± 0.52 <sup>ef</sup>	4.40 ± 1.34 <sup>a</sup>	9 ± 1.15 <sup>bcd</sup>	32 ± 1.16 <sup>bcd</sup>
Badwar	8.16 ± 0.47 <sup>c</sup>	3.91 ± 0.57 <sup>bcd</sup>	4.60 ± 1.14 <sup>a</sup>	5.33 ± 0.67 <sup>f</sup>	26.67 ± 1.97 <sup>d</sup>
Lambalahri	7.8 ± 0.84 <sup>cd</sup>	3.72 ± 0.49 <sup>cdef</sup>	4.40 ± 1.52 <sup>a</sup>	6.67 ± 1.90 <sup>ef</sup>	33.33 ± 1.37 <sup>bc</sup>
Gaura	9.8 ± 1.92 <sup>b</sup>	3.86 ± 0.12 <sup>cdef</sup>	5.40 ± 1.14 <sup>a</sup>	7.67 ± 0.67 <sup>def</sup>	28.33 ± 2.37 <sup>cd</sup>
Nauni	12.72 ± 1.23 <sup>a</sup>	4.74 ± 0.96 <sup>a</sup>	5.80 ± 0.84 <sup>a</sup>	11.67 ± 1.20 <sup>abc</sup>	28.33 ± 1.67 <sup>cd</sup>
kailar	11.2 ± 1.79 <sup>a</sup>	3.47 ± 0.41 <sup>def</sup>	5.00 ± 1.00 <sup>a</sup>	6.67 ± 2.19 <sup>ef</sup>	41.67 ± 1.17 <sup>a</sup>
CD (0.05)	1.19	0.66	NS	2.76	5.21

sites showed a consistent increasing trend for all tree growth characteristics. Higher diameter classes ( $D_2$  and  $D_3$ ) recorded greater values for plant height, crown spread, number of primary and secondary branches, and primary branch angle across most sites compared to  $D_1$ . Among the population sites,  $S_{10}$  and  $S_{12}$  generally exhibited higher values for most parameters, indicating better growth performance at these locations (Fig 1. a-e). The growth differences were attributed to soil properties, microclimate, and genetic adaptation. Factors such as soil texture, nutrient availability, light intensity, temperature, and humidity played a crucial role in tree development, influencing root growth, photosynthesis efficiency, and overall plant vigor. The results are in align with the findings of Thakur *et al.* (2020) who found that, *Grewia optiva* clone SI-10 exhibited superior height (5.97 m) and primary branches (5.97). Sankhyan *et al.* (2020 a) reported height variations from 3.85 m to 9.54 m and crown spread from 1.86 m to 5.08 m, demonstrating similar variability. Additionally, Sankhyan *et al.* (2019) observed height ranging from 4.67 m to 9.20 m, while Singh *et al.* (2021b) found substantial variation in *Toona ciliata*, including a maximum tree height of 28.70 m and a diameter of 33.05 cm. Paray *et al.* (2017) documented variation in *Salix alba* across Kashmir, while Khobragade *et al.* (2013) identified differences in *Terminalia species* across Madhya Pradesh and Maharashtra. Other studies, such as those by Dhiman (2018) and Kumari (2015), have also reported site-dependent differences in tree morphology, further confirming the role of environmental and genetic influences on tree growth. Similar results were observed by Gupta (2012) and Sankhyan *et al.* (2013) in *Anogeissus latifolia*, Bhagta (2015) in *Grewia optiva*, and Poonam *et al.* (2012) in *Bauhinia variegata* plus tree progenies for morphological parameters across different locations.

### Leaf characteristics

The significant variation was observed among locations for most of the leaf characteristics. The leaf length ranged from 9.14 cm at Patiari ( $S_1$ ) to 13.86 cm at Nauni ( $S_{11}$ ). The maximum leaf length was recorded at Nauni ( $S_{11}$ ) (13.86 cm), which was statistically at par with Kailar ( $S_{12}$ ) (13.18 cm) and Gaura ( $S_{10}$ ) (12.94 cm), followed by Lambalahri ( $S_9$ ) (12.60 cm). The minimum leaf length was observed at Patiari  $S_1$  (9.14 cm), which was statistically similar to Janauri  $S_2$  (9.98 cm) and Bhaddi  $S_5$  (9.96 cm). The widest leaves width was recorded at Nauni  $S_{11}$  (7.32 cm), which was statistically at par with Kailar  $S_{12}$  (7.08 cm) and Gaura  $S_{10}$  (6.98 cm). The minimum leaf width was observed at Patiari  $S_1$  (5.26 cm) and Janauri  $S_2$  (5.28 cm). The

maximum leaf area was recorded at Nauni  $S_{11}$  (45.62  $\text{cm}^2$ ), which was significantly higher than most locations and at par with Kailar  $S_{12}$  (43.46  $\text{cm}^2$ ). Higher leaf area was also observed at Gaura  $S_{10}$  (41.72  $\text{cm}^2$ ) and Lambalahri  $S_9$  (40.80  $\text{cm}^2$ ). The minimum leaf area was recorded at Patiari  $S_1$  (30.80  $\text{cm}^2$ ). The Petiole length did not differ significantly among locations, however, numerically, the highest petiole length was observed at Janauri  $S_2$  (1.10 cm), while the minimum values were recorded at Bangana  $S_7$  and Gaura  $S_{10}$  (0.92 cm each). The maximum fresh weight was recorded at Nauni  $S_{11}$  (76.59 g), which was statistically at par with Dholwaha  $S_3$  (74.22 g) and Gaura  $S_{10}$  (72.42 g). The minimum fresh weight was observed at Ballawal Saunkri  $S_4$  (50.85 g). The dry weight of 100 leaves also varied significantly across locations, ranging from 22.95 g at Ballawal Saunkri  $S_4$  to 38.09 g at Nauni  $S_{11}$ . The highest dry weight was recorded at Nauni  $S_{11}$  (38.09 g), followed by Gaura  $S_{10}$  (34.53 g) and Dehni  $S_6$  (31.12 g), while the lowest dry weight was observed at Ballawal Saunkri  $S_4$  (22.95 g) and Patiari  $S_1$  (24.06 g) (Table 3).

The interaction between diameter classes and population sites showed that diameter classes ( $D_2$ ) recorded greater values for Leaf length, leaf width, Leaf area, Petiole length and fresh and dry weight of 100 leaves followed by  $D_3$  and minimum in  $D_1$ . Among the population sites,  $S_{10}$  and  $S_{12}$  generally exhibited higher values for most parameters, indicating better growth performance at these locations (Fig 2. a-e). These variations align with previous studies, which attribute leaf morphological differences to environmental factors such as altitude, temperature, and nutrient availability (Thakur *et al.*, 2022). Leaf traits are known to adapt to local environmental conditions, as observed by Sankhyan *et al.* (2019) in *Grewia optiva*, where significant differences in leaf area and petiole length were reported across different sites. The influence of altitude on leaf morphology has also been demonstrated in *Quercus* species, where leaf size decreases with increasing altitude (Singh *et al.*, 2021b). Sharma and Gupta (2018) further highlighted the role of temperature, light availability, and soil nutrients in determining leaf traits in *Toona ciliata*. Since leaf size influences key physiological processes like photosynthesis, transpiration, and respiration, it is closely linked to environmental adaptations (Leigh *et al.*, 2017). Similar findings by Sankhyan *et al.* (2020) in *Grewia optiva* reported a leaf length range of 8.94-15.87 cm, leaf width of 5.36-9.88 cm, and leaf area of 44.95-123.49  $\text{cm}^2$ , reinforcing the current observations. Additionally, Thakur *et al.* (2022) noted maximum leaf length (17.38 cm) and width (11.6 cm) in clone HA-4 and the highest leaf area (129.89  $\text{cm}^2$ ) in

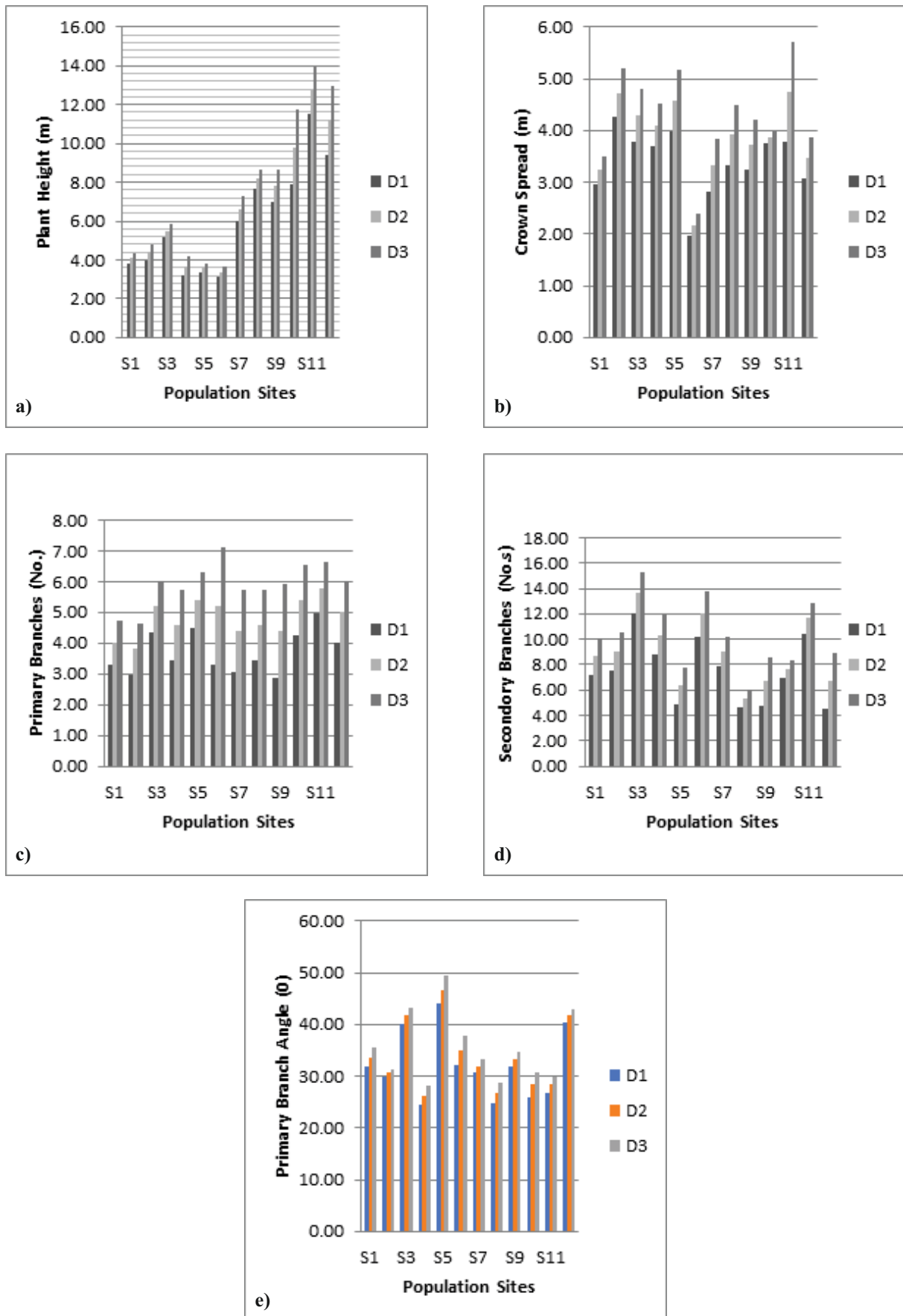


Fig. 1. Interaction effects of tree characteristics between diameter classes and population sites: (a) plant height, (b) crown spread, (c) primary branches, (d) secondary branches, and (e) primary branch angle.

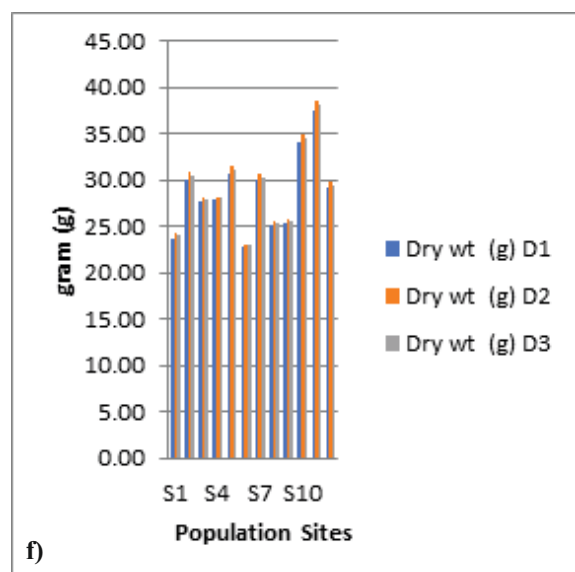
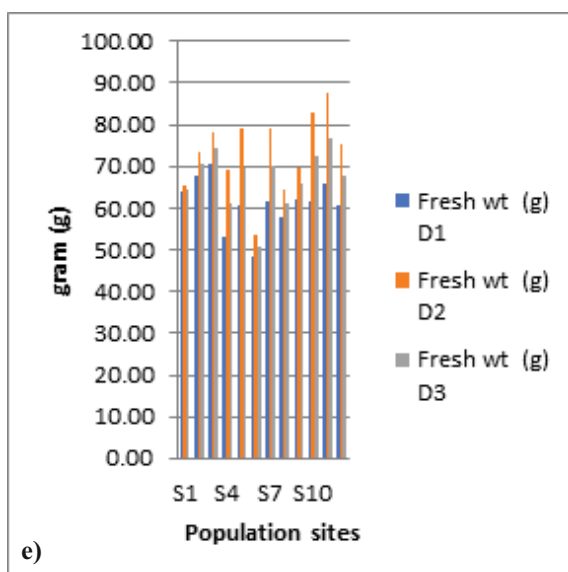
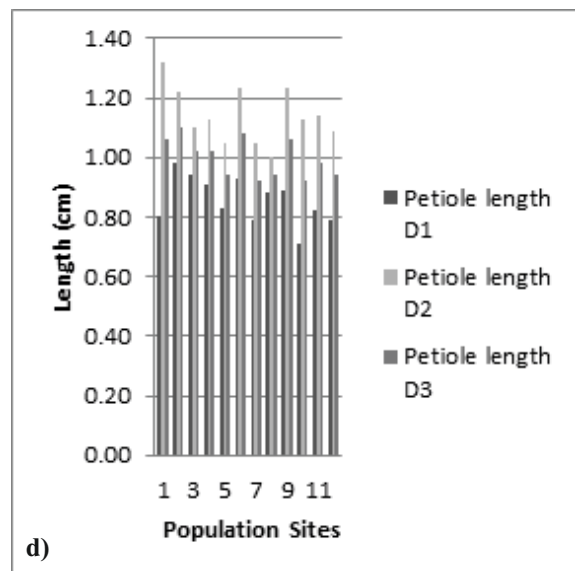
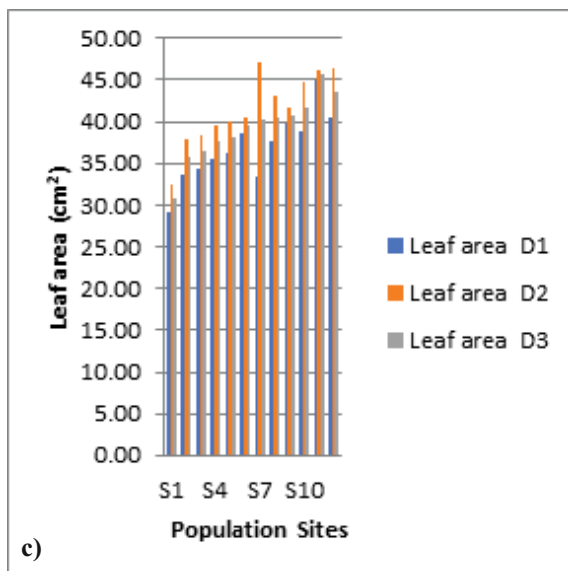
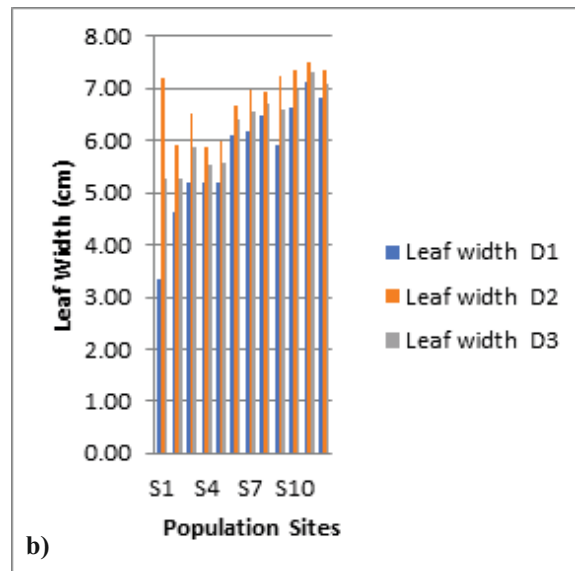
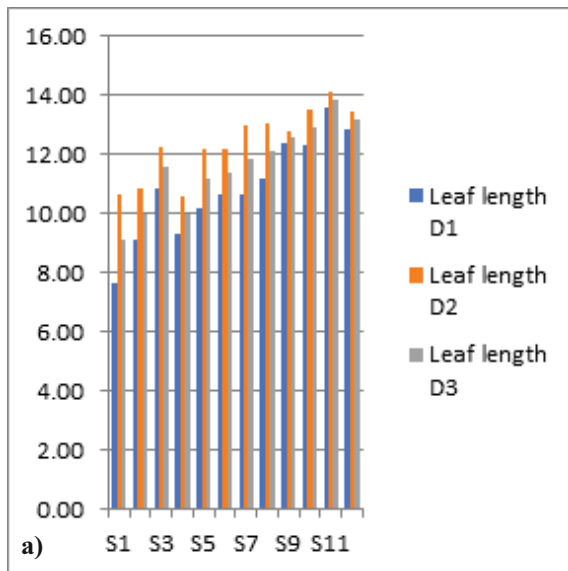


Fig. 2. Interaction effects in Leaf characteristics between diameter classes and population sites: (a) Leaf length, (b) Leaf width, (c) Leaf area, (d) petiole length, (e) Fresh weight and (f) Dry weight.

clone HA-2 of *Grewia optiva*. The present findings are further supported by the works of Bhagta (2015), Sankhyan *et al* (2019), and Thakur (2021), demonstrating significant diversity in leaf traits within *Grewia optiva*.

### Fruit characters

The study revealed significant variations in fruit morphological traits across different locations, including fruit length, width, thickness, fresh weight, and dry weight (Table 4). The maximum fruit length (5.06 mm) was recorded at S<sub>11</sub>, which was statistically similar to S<sub>12</sub> (4.94 mm), S<sub>10</sub> (4.86 mm), S<sub>9</sub> (4.82 mm), and S<sub>8</sub> (4.96 mm), whereas the shortest was observed at S<sub>1</sub> (3.68 mm), comparable to S<sub>5</sub> (3.82 mm). Similarly, the highest fruit width was recorded at S<sub>11</sub> (4.30 mm), followed by S<sub>12</sub> (3.94 mm) and S<sub>10</sub> (3.96 mm), while the smallest was at S<sub>2</sub> (3.08 mm). The

maximum fruit thickness was found at S<sub>9</sub> (4.20 mm), which was statistically similar to S<sub>11</sub> (4.02 mm) and S<sub>10</sub> (3.98 mm), whereas the lowest was observed at S<sub>4</sub> (3.22 mm). The highest fresh fruit weight (21.88 g) was recorded at Lambalahri S<sub>9</sub>, which was statistically at par with S<sub>10</sub> (21.52 g) and S<sub>11</sub> (21.84 g), whereas the lowest was found at S<sub>1</sub> (20.04 g). The highest dry fruit weight was recorded at S<sub>11</sub> (13.54 g), comparable to several other locations, while the lowest was at S<sub>6</sub> (11.76 g) (Table 4). The interaction between diameter classes and locations showed a consistent increasing trend in all fruit parameters. Fruit length, width, thickness, fresh weight, and dry weight increased progressively from D<sub>1</sub> to D<sub>3</sub> across all locations, indicating a positive influence of diameter on fruit development. The highest values were generally recorded in D3 at locations like Nauni, Lambalahri,

**Table 3: Morphological variations in Leaf characteristics among different locations of *Grewia optiva***

Locations	Leaf characteristics					
	Leaf length	Leaf width	Leaf area	Petiole length	Fresh Weight of 100 Leaves (g)	Dry Weight of 100 Leaves (g)
Patiari	9.14 ± 1.50 <sup>f</sup>	5.26 ± 1.93 <sup>e</sup>	30.8 ± 1.64 <sup>s</sup>	1.06 ± 0.26 <sup>a</sup>	64.68 ± 0.62 <sup>ab</sup>	24.06 ± 0.35 <sup>h</sup>
Janauri	9.98 ± 0.87 <sup>f</sup>	5.28 ± 0.65 <sup>e</sup>	35.8 ± 2.05 <sup>f</sup>	1.10 ± 0.12 <sup>a</sup>	70.80 ± 2.81 <sup>ab</sup>	30.447 ± 0.38 <sup>d</sup>
Dholwaha	11.56 ± 0.72 <sup>e</sup>	5.86 ± 0.65 <sup>cde</sup>	36.4 ± 2.07 <sup>ef</sup>	1.02 ± 0.08 <sup>a</sup>	74.22 ± 3.72 <sup>a</sup>	27.947 ± 0.22 <sup>f</sup>
Bhaddi	9.96 ± 0.62 <sup>f</sup>	5.54 ± 0.35 <sup>e</sup>	37.6 ± 2.07 <sup>def</sup>	1.02 ± 0.11 <sup>a</sup>	61.06 ± 8.08 <sup>bc</sup>	28.057 ± 0.09 <sup>f</sup>
Tibba Nangal	11.16 ± 1.01 <sup>e</sup>	5.58 ± 0.40 <sup>de</sup>	38.2 ± 1.92 <sup>odef</sup>	0.94 ± 0.11 <sup>a</sup>	69.84 ± 9.26 <sup>ab</sup>	31.117 ± 0.45 <sup>c</sup>
Ballowal Saunkri	11.4 ± 0.76 <sup>e</sup>	6.4 ± 0.28 <sup>bcd</sup>	39.6 ± 0.89 <sup>cde</sup>	1.08 ± 0.15 <sup>a</sup>	50.85 ± 2.56 <sup>c</sup>	22.947 ± 0.16 <sup>i</sup>
Bangana	11.82 ± 1.16 <sup>de</sup>	6.56 ± 0.40 <sup>abc</sup>	40.16 ± 6.86 <sup>bcd</sup>	0.92 ± 0.13 <sup>a</sup>	70.34 ± 8.72 <sup>ab</sup>	30.367 ± 0.40 <sup>d</sup>
Badwar	12.12 ± 0.92 <sup>cde</sup>	6.72 ± 0.23 <sup>ab</sup>	40.48 ± 2.72 <sup>bcd</sup>	0.94 ± 0.06 <sup>a</sup>	61.08 ± 3.20 <sup>bc</sup>	25.337 ± 0.26 <sup>g</sup>
Lambalahri	12.60 ± 0.19 <sup>bcd</sup>	6.58 ± 0.67 <sup>abc</sup>	40.8 ± 0.98 <sup>bcd</sup>	1.06 ± 0.17 <sup>a</sup>	65.93 ± 3.66 <sup>ab</sup>	25.7 ± 0.21 <sup>g</sup>
Gaura	12.94 ± 0.61 <sup>abc</sup>	6.98 ± 0.36 <sup>ab</sup>	41.72 ± 2.96 <sup>bc</sup>	0.92 ± 0.21 <sup>a</sup>	72.42 ± 10.60 <sup>ab</sup>	34.53 ± 0.50 <sup>b</sup>
Nauni	13.86 ± 0.26 <sup>ba</sup>	7.32 ± 0.18 <sup>a</sup>	45.62 ± 0.55 <sup>a</sup>	0.98 ± 0.16 <sup>a</sup>	76.59 ± 10.79 <sup>a</sup>	38.087 ± 0.49 <sup>a</sup>
Kailar	13.18 ± 0.30 <sup>ab</sup>	7.08 ± 0.27 <sup>ab</sup>	43.46 ± 2.90 <sup>ab</sup>	0.94 ± 0.15 <sup>a</sup>	67.94 ± 7.19 <sup>ab</sup>	29.53 ± 0.34 <sup>c</sup>
CD (0.05)	1.04	0.85	3.55	NS	10.44	0.39

**Table 4: Morphological variations in fruit characteristics among different locations of *Grewia optiva***

Locations	Fruit length	Fruit width	Fruit thickness	Fresh weight of fruits (100 g)	Dry weight of fruits (100 g)
Patiari	3.68 ± 0.26 <sup>f</sup>	3.08 ± 0.25 <sup>f</sup>	3.44 ± 0.42 <sup>cd</sup>	20.04 ± 0.22 <sup>e</sup>	12.76 ± 0.15 <sup>bc</sup>
Janauri	4.22 ± 0.426 <sup>d</sup>	3.34 ± 0.34 <sup>def</sup>	3.92 ± 0.16 <sup>ab</sup>	20.82 ± 0.08 <sup>bc</sup>	12.82 ± 0.19 <sup>bc</sup>
Dholwaha	4.46 ± 0.39 <sup>cd</sup>	3.56 ± 0.42 <sup>cde</sup>	3.98 ± 0.13 <sup>ab</sup>	21.58 ± 0.29 <sup>ab</sup>	13.02 ± 0.16 <sup>abc</sup>
Bhaddi	3.82 ± 0.26 <sup>ef</sup>	3.24 ± 0.21 <sup>ef</sup>	3.96 ± 0.18 <sup>ab</sup>	21.58 ± 0.27 <sup>ab</sup>	13.26 ± 0.33 <sup>ab</sup>
Tibba Nangal	4.18 ± 0.31 <sup>de</sup>	3.38 ± 0.35 <sup>def</sup>	3.86 ± 0.06 <sup>abc</sup>	21.42 ± 0.23 <sup>b</sup>	11.76 ± 1.06 <sup>d</sup>
Ballowal saunkri	4.4 ± 0.39 <sup>d</sup>	3.66 ± 0.45 <sup>cde</sup>	3.22 ± 0.34 <sup>d</sup>	20.3 ± 0.55 <sup>de</sup>	12.86 ± 0.20 <sup>abc</sup>
Bangana	4.52 ± 0.57 <sup>bcd</sup>	3.72 ± 0.56 <sup>bcd</sup>	3.68 ± 0.46 <sup>bc</sup>	20.36 ± 0.50 <sup>de</sup>	12.56 ± 1.06 <sup>c</sup>
Badwar	4.96 ± 0.15 <sup>a</sup>	4.16 ± 0.38 <sup>ab</sup>	3.94 ± 0.23 <sup>ab</sup>	20.88 ± 0.045 <sup>c</sup>	13.32 ± 0.55 <sup>ab</sup>
Lambalahri	4.82 ± 0.19 <sup>abc</sup>	4.14 ± 0.29 <sup>ab</sup>	4.2 ± 0.20 <sup>a</sup>	21.88 ± 0.08 <sup>a</sup>	13.00 ± 0.20 <sup>abc</sup>
Gaura	4.86 ± 0.22 <sup>ab</sup>	3.96 ± 0.39 <sup>abc</sup>	3.98 ± 0.41 <sup>ab</sup>	21.52 ± 0.33 <sup>ab</sup>	13.12 ± 0.40 <sup>abc</sup>
Nauni	5.06 ± 0.11 <sup>a</sup>	4.3 ± 0.25 <sup>a</sup>	4.02 ± 0.51 <sup>ab</sup>	21.84 ± 0.06 <sup>a</sup>	13.54 ± 0.36 <sup>a</sup>
kailar	4.94 ± 0.06 <sup>a</sup>	3.94 ± 0.11 <sup>abc</sup>	3.76 ± 0.37 <sup>bc</sup>	20.54 ± 0.35 <sup>cd</sup>	13.08 ± 0.52 <sup>abc</sup>
CD (0.05)	0.39	0.47	0.42	0.37	0.68

and Badwar. The differences were statistically significant, confirming a strong interaction effect between diameter class and location on fruit characteristics (Table 5). These variations can be attributed to differences in environmental conditions, genetic potential and site-specific factors influencing fruit development. Similar findings were reported by Sankhyan *et al.* (2020), who observed significant variability in *Grewia optiva* fruit characteristics, with fruit length ranging from 5.50–6.25 mm, fruit width from 4.61–5.10 mm, fruit thickness from 4.32–5.40 mm, fresh weight of 100 fruits between 20.01–23.31 g, and dry weight from 12.27–15.44 g. Thakur *et al.* (2022) further highlighted genetic variations in different clones, where clone SI-10 exhibited the highest fresh fruit weight (22.17 g) and clone CH-3 had the maximum dry weight (15.56 g). Similar trends were also reported by Bhagta (2015) and Bhatt (2010) in *Grewia optiva*, as well as by Sankhyan *et al.*, (2019) and Bhagta *et al.* (2015) in open-pollinated seedling seed orchards of *Grewia optiva*.

#### Correlation and Principal component analysis Studies

The correlation analysis revealed strong positive associations among growth and biomass-related traits (Fig. 3). Plant height (PH) was positively correlated with leaf length (LL), leaf width (LW), leaf area (LA), and biomass parameters such as fresh weight (FW) and dry weight (DW), indicating that increased plant stature is associated with enhanced leaf development and biomass accumulation. Leaf traits (LL, LW, and LA) were also highly intercorrelated, reflecting their combined contribution to canopy growth. Fresh and dry weights, both at leaf and whole-plant levels, exhibited significant positive correlations, suggesting consistency in biomass production. In contrast, traits such as peitole length (PL) and certain structural parameters showed weak to negative correlations with major growth traits, indicating independent or inverse relationships. The results are in accordance with the studies of Singh *et al.*, (2012) who observed that, early selection criteria in tree improvement programs are strongly influenced by genetic correlations, indicating that enhancing one trait will positively impact others. Principal component analysis (PCA) effectively summarized the multivariate variation among the studied traits into two principal components, with PC1 accounting for the largest proportion of total

**Table 5: Interaction effects in Fruit characteristics between diameter classes and population sites**

Parameter Diameter Population sites	Fruit length (mm)			Fruit width (mm)			Fruit thickness (mm)			Fresh wt (100 g)			Dry wt (100 g)		
	D1	D2	D3	D1	D2	D3	D1	D2	D3	D1	D2	D3	D1	D2	D3
Patiari	3.42	3.68	3.94	2.83	3.08	3.33	3.02	3.44	3.86	19.82	20.04	20.26	12.61	12.76	12.91
Janauri	3.79	4.22	4.65	3.00	3.34	3.68	3.76	3.92	4.08	20.74	20.82	20.90	12.63	12.82	13.01
Dholwaha	4.07	4.46	4.85	3.14	3.56	3.98	3.85	3.98	4.11	21.29	21.58	21.87	12.86	13.02	13.18
Bhaddi	3.56	3.82	4.08	3.03	3.24	3.45	3.78	3.96	4.14	21.31	21.58	21.85	12.93	13.26	13.59
Tibba Nangal	3.87	4.18	4.49	3.03	3.38	3.73	3.80	3.86	3.92	21.19	21.42	21.65	10.70	11.76	12.82
Ballowal Saunkri	4.01	4.40	4.79	3.21	3.66	4.11	2.88	3.22	3.56	19.75	20.30	20.85	12.66	12.86	13.06
Bangana	3.95	4.52	5.09	3.16	3.72	4.28	3.22	3.68	4.14	19.86	20.36	20.86	11.50	12.56	13.62
Badwar	4.81	4.96	5.11	3.78	4.16	4.54	3.71	3.94	4.17	20.84	20.88	20.93	12.77	13.32	13.87
Lambalahri	4.63	4.82	5.01	3.85	4.14	4.43	4.00	4.20	4.40	21.80	21.88	21.96	12.80	13.00	13.20
Gaura	4.64	4.86	5.08	3.57	3.96	4.35	3.57	3.98	4.39	21.19	21.52	21.85	12.72	13.12	13.52
Nauni	4.95	5.06	5.17	4.05	4.30	4.55	3.51	4.02	4.53	21.78	21.84	21.90	13.18	13.54	13.90
Kaitar	4.88	4.94	5.00	3.83	3.94	4.05	3.39	3.76	4.13	20.19	20.54	20.89	12.56	13.08	13.60
CD (P=0.05)			0.35			0.29			0.32			0.82			0.61

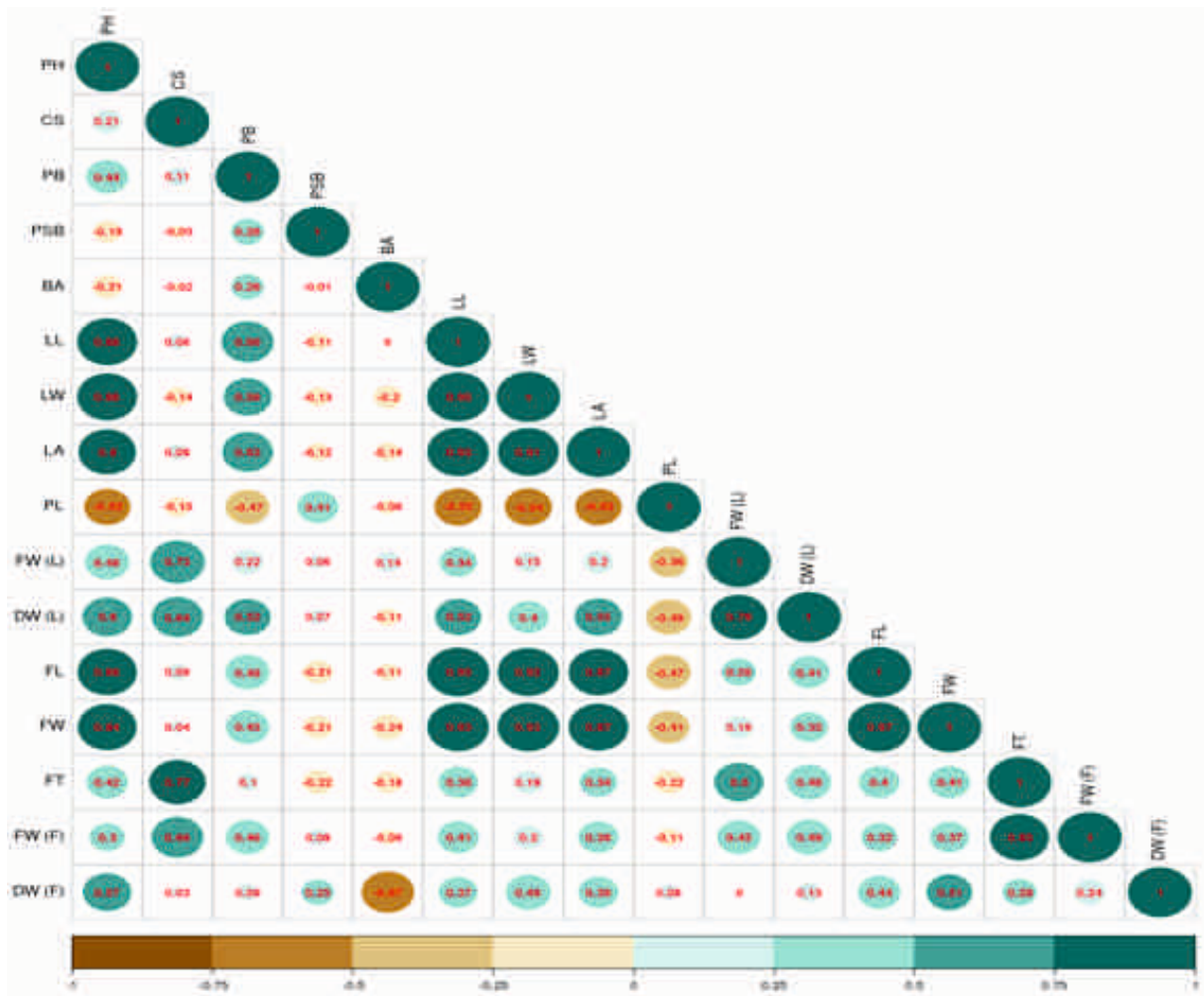


Fig.3 Correlation matrix (Pearson's r) showing relationships among tree growth, leaf and fruit traits,

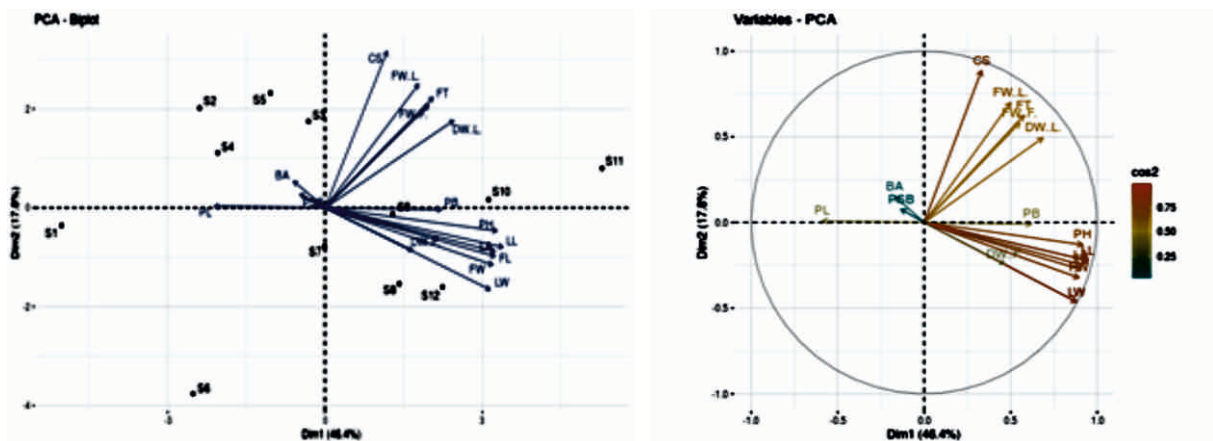


Fig 4. Principal Component Analysis (PCA) showing relationships among tree growth, leaf, and fruit traits

variability, followed by PC2 (Fig. 4). The biplot revealed that PC1 was primarily driven by growth and biomass-associated traits, including plant height (PH), leaf length (LL), leaf width (LW), fresh weight (FW), and dry weight (DW), which were strongly and positively loaded on the positive axis. The close clustering and acute angles among these vectors indicate a high degree of positive correlation,

suggesting that these traits collectively contribute to overall plant vigor and productivity.

Similarly, Bhagta and Sankhyan (2016) reported a strong genotypic (0.22) and phenotypic (0.17) correlation between 100 dry fruit weight and 100 seed weight in the seedling seed orchard of *Grewia optiva*. Mehta *et al.* (2022) also found strong positive correlations between collar diameter and fresh fodder

weight, as well as between diameter at breast height, collar diameter, fresh fodder weight, and fuelwood weight in *Grewia optiva* clones from the lower Shivalik Himalayas. Thakur *et al.* (2022) observed strong positive correlations between growth traits and fresh fruit weight, while dry fruit weight correlated positively with seed weight and negatively with leaf dry matter content.

#### 4. CONCLUSION

The study revealed significant variations in tree, leaf, and fruit traits of *Grewia optiva* across different locations, influenced by environmental conditions and genetic factors. Nauni exhibited the highest tree growth, leaf size, and fruit dimensions, while Ballawal Saunkhri and Patiari recorded the lowest values. Strong correlations were observed between plant height, diameter, leaf traits, and fruit characteristics, indicating their interconnected growth patterns. PCA identified key traits contributing to variability, with leaf and fruit dimensions being the most influential. This finding highlights substantial phenotypic variability and identifies Nauni, Kailar, and Gaura as superior populations for selection and genetic improvement programs, selection of superior genotypes, and sustainable plantation management.

#### References

- Al Jibouri, H.A., Miller, R.A., Robinson, H.F. 1958. Genotypic and environmental variances and Covariance's in an upland cotton across of interspecific origin. *Agronomy Journal*. 50:633-637.
- Bhagta S, Sankhyan HP, Sharma JP, Kumari R. Assessment of Variability in half-sib progenies of *Grewia optiva* Drummond for various qualitative and quantitative traits in North Western Himalayas. *Int J Curr Microbiol App Sci*. 2019;8(4):1661-9.
- Bhagta, S. 2015. *Progeny evaluation of open-pollinated seedling seed orchard of Grewia optiva Drummond*. Ph.D. Thesis, Dr. Y.S. Parmar University of Horticulture and Forestry, Solan (H.P.), India.
- Bhagta, S. and Sankhyan, H.P. 2016. Progeny evaluation of open-pollinated seedling seed orchard of *Grewia optiva* Drummond for seed germination attributes. *International Journal of Agricultural Sciences* 7: 1-3.
- Bhagta, S., Sankhyan, H.P., Thakur, S. and Sharma, S.S. 2015. Progeny evaluation of open-pollinated seedling seed orchard of *Grewia optiva* J.R. Drumm. ex Burrett for seed morphometric traits. *Indian Journal of Forestry* 38: 387-391.s
- Bhat, S.S. 2010. *Evaluation of established open-pollinated seedling seed orchard of Grewia optiva Drummond*. M.Sc. Thesis, Dr. Y.S. Parmar University of Horticulture and Forestry, Solan (H.P.), India.
- Chauhan RS, Jadeja DB, Thakur NS and Jha SK. Variability in stone characters and early progeny performance of selected *Melia dubia* genotypes from northern western ghats of India *Indian J of Ecol*. 2021;48(4):1032-8.
- Coleman, J.R. 1982. Chromosome numbers of angiosperms collected in the state of São Paulo. *Revista Brasileira de Genética* 5: 533-549.
- Dhiman, D. 2018. *Studies on variabilities and propagation techniques of Toona ciliata M. Roem under Punjab conditions*. M.Sc. Thesis, Punjab Agricultural University, Ludhiana, India.
- Gachuri, A.N., Carsan, S., Karanja, E., Makui, P. and Kuyah, S. 2017. Diversity and importance of local fodder tree and shrub resources in mixed farming systems of Central Kenya. *Forests, Trees and Livelihoods* 26: 143-155.
- Gomez, K.A. and Gomez, A.A. 1984. *Statistical Procedures for Agricultural Research*. John Wiley & Sons, New York, USA.
- Gopinath, P.P., Parsad, R., Joseph, B. and Adarsh, V.S. 2020. GRAPES: General Rshiny based analysis platform empowered by statistics. Available from <https://www.kaugrapes.com/home>, version 1.0.0 (2020).
- Heuze, V., Tran G., Hassoum P., Lebas F. 2019. Bhimal (*Grewia optiva*). Feedpedia, a programme by INRAE, CIRAD, AFZ and FAO. Last updated on July 15, 2019; 1: 15
- Isik, F. and Toplu, F. 2004. Variation in juvenile traits of natural black poplar (*Populus nigra* L.) clones in Turkey. *New Forests* 17: 175-187.
- Kar, S., Pant, K.S., Chandel, A., and Roshanzada, S.R. The trend of soil parameters under different spacings of *Grewia*-based agroforestry system in the mid hill zones of Himachal Pradesh. *Int J Chem Stud*. 2019;7(1):1904-7. 32.
- Katoch, R., Singh, S.K., Tripathi, A. and Kumar, N. 2017. Effect of seasonal variation in biochemical composition of leaves of fodder trees prevalent in the mid-hill region of Himachal Pradesh. *Range Management and Agroforestry* 38: 234-240.
- Khobragade, N.D., Prasad, H., Pradha, A.C.S. and Mandal, A.K. 2013. Parameters for selection of candidate plus trees of *Terminalia chebula* and *Terminalia bellerica*. *Indian Forester* 139: 833-835.
- Kumari, R. 2015. *Crop production and physico-chemical characteristics of soils under Toona ciliata M. Roem. trees in mid-hill conditions of Himachal Pradesh*. M.Sc. Thesis, Dr. Y.S. Parmar University of Horticulture and Forestry, Solan (H.P.), India.
- Leigh, A., Sevanto, S., Close, J.D. and Nicotra, A.B. 2017. The influence of leaf size and shape on leaf thermal dynamics: does the theory hold up under natural conditions. *Plant Cell and Environment* 40: 237-248.
- Luna, R.K. 1996. *Plantation Trees*. IBD Publisher, Dehradun, India. pp. 1-975.
- Mehta, H., Kumar, P., Rathore, A.C., Kaushal, R. and Gupta, A.K. 2022. Evaluation of *Grewia optiva* clones for fodder yield under North Western Himalayas conditions. *Journal of Sustainable Forestry* 1-12. <https://doi.org/10.1080/10549811.2022.2045502>
- Mukherjee, A., Modal, T., Bist, J.K. and Pattanayak, A. 2018. Farmer's preference of fodder trees in mid hills of Uttarakhand: A comprehensive ranking using analytical hierarchy process. *Range Management and Agroforestry* 39: 115-120.
- Murasing, K.K., Kumar, M. and Kumar, A. 2022. Effect of altitude on the mechanical strength of *Grewia optiva* fiber in Garhwal Himalaya India. *J. Nat. Fibers* 19(13):6638-6647
- Negi, S.V., Maikhuri, K.R., Rawat, S.L. and Phondani, C.P. 2010. Current status and future potential of fiber yielding crop *Hibiscus cannabinus* L. in mountain region of Central Himalaya. *Int J Sci Technol*. 5:87-96.
- Orwa, C., Mutua, A., Kindt, R., Jamnadass, R. and Simons, A. 2009. *Agroforestry Database: A Tree Reference and Selection Guide Version 4*. pp. 2-5.

- Özel, H.B., Ertekin, M. and Tunctaner, K. 2010. Genetic variation in growth traits and morphological characteristics of eastern cottonwood (*Populus deltoides* Bartr.) hybrids at nursery stage. *Scientific Research and Essays* 5: 962–969.
- Pandey, A. and Gupta, R. 2003. Fibre yielding plants of India, genetic resources, perspectives for 336 collection and utilization. *Nat. Prod. Radiance* 2(4):194–204.
- Paray, P.A., Bhat, S.J.A., Bhat, A. and Parrey, A.A. 2017. Candidate plus tree selection of *Salix alba* – A multipurpose tree species. *International Journal of Pure and Applied Bioscience* 5: 387–395.
- Poonam, I., Thakur, K., Sharma, J.P. and Gupta, T. 2012. Evaluation of plus tree progenies of *Bauhinia variegata* for morphometric and fodder characteristics. *Indian Journal of Forestry* 35: 331–338.
- Rana, K., Kumar, M. and Kumar, A. 2020. Assessment of annual shoot biomass and carbon storage potential of *Grewia optiva*: An approach to combat climate change in Garhwal Himalaya. *Water, Air, & Soil Pollution* 231: 450.
- Robinson, H.F., Comstock, R.E., Harvey P.H. 1951 Genotypic and phenotypic correlation in corn and their importance in selection. *Agronomy Journal* 43:282-287.
- Sahoo, B., Garg, A.K., Mohanta, R.K., Bhar, R., Thirumurgan, P., Sharma, A.K. and Pandey, A.B. 2016. Nutritional value and tannin profile of forest foliages in temperate sub-Himalayas. *Range Management and Agroforestry* 37: 228–232.
- Sankhyan, H.P. and Bhagta, S. 2016. Fodder quality analysis of open-pollinated seedling seed orchard of *Grewia optiva* Drummond. *The Bio Scan* 11: 709–713.
- Sankhyan, H.P., Bhagta, S. and Thakur, S. 2019. Evaluation of the half-sib progenies to identify prepotency of the mother clones of *Grewia optiva* Drummond. *Journal of Pharmacognosy and Phytochemistry* 8: 1265–1270.
- Sankhyan, H.P., Dhiman, J., Rana, N. and Chand, K. 2022. Genetic variability among different populations of *Grewia optiva* Drummond in low and mid-hill zones of Himachal Pradesh. *Indian Journal of Agroforestry* 24: 30–38.
- Sankhyan, H.P., Singh, N.B., Bawa, R. and Gupta, T. 2013. Variability in fodder quality traits of *Anogeissus latifolia* Wall. in Himachal Pradesh. *Indian Forester* 139: 1017–1023.
- Sankhyan, H.P., Thakur, S., Kumar, S., Karishma and Prachi. 2020. Variation in morphological descriptors among different populations of *Grewia optiva* Drummond (Beul) in Himachal Pradesh. *Journal of Pharmacognosy and Phytochemistry* 9: 249–254. <https://dx.doi.org/10.22271/phyto>.
- Sankhyan, H.P., Thakur, S., Kumar, S., Karishma, Prachi and Chand, K. 2020a. Morphological characteristics among different populations for screening of Beul trees (*Grewia optiva* Drummond). *International Journal of Chemical Studies* 8: 1845–1848. DOI: 10.22271/chemi.2020.v8.i4s.9896.
- Singh, B. and Todaria, N.P. 2012. Nutrient composition changes in leaves of *Quercus semecarpifolia* at different seasons and altitudes. *Annals of Forest Research* 55: 189–196.
- Singh, C., Singh, R. and Himshikha. 2018. *Grewia optiva* (Drumm. ex Burr) – A multi-purpose tree under agroforestry in sub-tropical region of Western Himalaya. *Journal of Tree Science* 37: 36–43.
- Singh, N., Gupta, T. and Sankhyan, H.P. 2021b. Variability and divergence in morphological traits of *Toona ciliata* in provenances. *International Journal of Botany Studies* 6: 84–88.
- Thakur, S. 2021. *Evaluation of clonal seed orchard of Grewia optiva Drummond for morphological and fodder quality parameters*. M.Sc. Thesis, Dr. Y. S. Parmar University of Horticulture and Forestry, Solan (H.P.).
- Thakur, S., Sankhyan, H.P. and Sharma, J.P. 2022. Evaluation of *Grewia optiva* Drummond clonal seed orchard for morphometric and fodder quality parameters. *Research square* DOI: <https://doi.org/10.21203/rs.3.rs-2308160/v1>
- Verma, A., Kaushal, R., Alam, N.M., Mehta, H., Chaturvedi, O.P., Mandal, D., Tomar, J.M.S., Rathore, A.C. and Singh, C. 2014. Predictive models for biomass and carbon stocks estimation in *Grewia optiva* on degraded lands in western Himalaya. *Agroforestry Systems* 88: 895–905.
- Verma, A., Singh, N.B., Suresh, N.V., Choudhary, P., Sankanur, M., Aggarwal, G. and Sharma. 2015. RAPD and ISSR markers for molecular characterization of *Grewia optiva*: an important fodder tree of north western Himalayas. *Range Management and Agroforestry* 36: 26-32.