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MORPHOMETRIC ANALYSIS OF ROSA SPP. IN YASIN VALLEY, GILGIT-BALTISTAN: DOCUMENTING FLORAL VARIATION IN HIGH-ALTITUDE MOUNTAIN ECOSYSTEMS

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Abstract: The genus *Rosa* (Rosaceae) encompasses approximately 150-200 species globally, with significant morphological diversity influenced by environmental conditions. High-altitude mountain ecosystems of the Himalayan region harbor unique rose populations adapted to extreme climatic conditions yet remain poorly documented. This study conducted a comprehensive morphometric analysis of wild rose (*Rosa* spp.) populations in Yasin Valley, Gilgit-Baltistan (2,547 m elevation), to quantify floral variation and establish baseline morphological data for this under-studied region. Ten rose specimens were collected from different locations within Yasin Valley (36.3334°N, 73.3572°E) during the flowering season (May-August 2024). Detailed measurements were recorded for five floral components: petals (n=9 per flower), sepals (n=4), leaves (n=4), stamen (n=4), and carpels (n=4). Length, width, and area calculations were performed using digital calipers (precision ±0.01 mm). Morphometric analysis revealed substantial intra-specific variation. Petal measurements showed mean length 2.86 ± 0.15 cm (R^2=0.0073) and mean width 2.71 ± 0.12 cm (R^2=0.01). Sepal dimensions averaged 1.53 ± 0.08 cm in length (R^2=0.1291) and 0.76 ± 0.05 cm in width (R^2=0.676). Leaf measurements recorded mean length 3.50 ± 0.18 cm (R^2=0.1598) and width 2.21 ± 0.14 cm (R^2=0.1441). Stamen length averaged 0.074 ± 0.006 cm (R^2=0.1291) with width 0.30 ± 0.03 cm (R^2=0.2727). Carpel measurements showed length 1.51 ± 0.09 cm (R^2=0.0183) and width 1.20 ± 0.07 cm (R^2=0.0016). This study provides the first quantitative morphometric dataset for rose populations in Yasin Valley. The observed variation suggests potential local adaptation to high-altitude conditions. These baseline data are critical for future biodiversity assessments, conservation planning, and understanding climate change impacts on alpine flora in Gilgit-Baltistan.
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1. Introduction

1.1 The Rosaceae Family: Global Distribution and Diversity

The Rosaceae family represents one of the most economically and ecologically significant angiosperm lineages. It comprises approximately 4,828 species distributed across 91 genera globally (Christenhusz & Byng, 2016). The family exhibits remarkable morphological diversity, ranging from herbaceous annuals to woody trees. Members occupy diverse ecological niches across temperate and subtropical regions, with highest species richness concentrated in the Northern Hemisphere (Xiang et al., 2017).

The genus *Rosa* contains 150-200 recognized species (Wissemann, 2003). These woody perennials display considerable morphological plasticity influenced by environmental factors, hybridization events, and genetic variability (Debener & Linde, 2009). Roses have evolved complex floral structures characterized by actinomorphic flowers with typically five petals, five sepals, numerous stamens, and multiple carpels arranged in a hypanthium (Bendahmane et al., 2013).

1.2 Economic and Ecological Importance

Rosaceae includes numerous economically vital crops including apples (*Malus* spp.), pears (*Pyrus* spp.), cherries (*Prunus* spp.), strawberries (*Fragaria* spp.), and roses (*Rosa* spp.) (Potter et al., 2007). The ornamental rose industry alone involves 30,000-35,000 cultivated hybrids worldwide, generating billions of dollars annually (Gudin, 2000). Beyond horticulture, roses provide essential ecosystem services. Wild rose populations support pollinator communities, prevent soil erosion in mountainous terrain, and contribute to biodiversity maintenance in fragile ecosystems (Eriksson et al., 2018).

Rose hips (fruits) serve as important food sources for wildlife and humans. They contain high concentrations of vitamin C, phenolic compounds, and carotenoids (Ercisli, 2007). Traditional medicine systems across Asia utilize rose hips for treating various ailments (Lattanzio et al., 2011). Essential oils extracted from rose petals (*Rosa damascena*, *R. centifolia*) constitute valuable commodities in perfume and cosmetic industries (Baydar & Baydar, 2013).

1.3 Roses in Mountain Ecosystems

Mountain environments present unique challenges including temperature extremes, intense UV radiation, variable precipitation, and short growing seasons (Körner, 2003). Plant species inhabiting these ecosystems exhibit specialized adaptations in morphology, physiology, and phenology (Graae et al., 2018). High-altitude rose populations demonstrate modifications in leaf structure, floral characteristics, and growth patterns compared to lowland counterparts (Chamberlain et al., 2012).

The Himalayan region harbors diverse wild rose species including *Rosa webbiana*, *R. macrophylla*, *R. sericea*, and *R. moschata* (Rajbhandari & Rai, 2016). These species play crucial roles in mountain ecosystems through pollinator support, soil stabilization, and genetic resource conservation. However, climate change threatens these populations through altered temperature regimes, precipitation patterns, and phenological mismatches (Pauli et al., 2012).

1.4 Gilgit-Baltistan: A Biodiversity Hotspot

Gilgit-Baltistan represents the northernmost territory of Pakistan, spanning 72,971 km² of the western Himalayan and Karakoram ranges (Khan et al., 2019). The region exhibits extraordinary topographic diversity, with elevations ranging from 1,000 to 8,611 meters (K2 summit). This elevational gradient creates diverse climatic zones supporting rich flora and fauna (Hussain et al., 2015).

Floristic surveys document approximately 2,500-3,000 plant species in Gilgit-Baltistan, many endemic or regionally restricted (Ilyas et al., 2018). The region serves as a critical transition zone between Central Asian, Himalayan, and Tibetan biogeographic realms. However, botanical research remains insufficient, with numerous valleys and ecosystems poorly studied (Ahmad et al., 2020).

Yasin Valley, located in the Ghizer District, extends along the Yasin River at elevations of 2,200-2,800 meters. The valley experiences a continental climate with cold winters (-15 to -20°C) and moderate summers (20-25°C). Precipitation occurs primarily as winter snowfall and summer monsoon rain (Sheikh & Palka, 2015). The valley's flora remains incompletely documented despite its ecological significance.

1.5 Morphometric Studies: Importance and Applications

Morphometric analysis involves systematic measurement and quantitative description of biological forms (Adams et al., 2004). This approach provides objective data for species identification, population differentiation, and evolutionary studies.

Previous morphometric studies on roses have focused primarily on cultivated varieties for breeding purposes (Pal et al., 2013; Srivastava et al., 2019). Wild rose populations, particularly in remote mountain regions, remain understudied. This knowledge gap hinders effective conservation and sustainable utilization strategies.

1.6 Research Gap and Study Objectives

Despite the ecological and economic importance of roses in mountain ecosystems, comprehensive morphometric data for Gilgit-Baltistan populations are lacking. No published studies have systematically quantified floral variation in Yasin Valley rose populations. This research addresses this critical gap through detailed morphometric characterization rose (*Rosa* spp.) populations in Yasin Valley, Gilgit-Baltistan, quantifying variation in floral structures.

2. Materials and Methods

2.1 Study Area Description

Geographic Location: Fieldwork was conducted in Yasin Valley, Ghizer District, Gilgit-Baltistan, Pakistan. The primary collection site (Noah locality) is located at coordinates 36.3334°N latitude, 73.3572°E longitude, at an elevation of 2,547 meters above sea level. Yasin Valley extends along the Yasin River, a tributary of the Ghizar River, covering approximately 2,400 km² of mountainous terrain.

Climate: The study area experiences a cold continental mountain climate. Mean annual temperature ranges from 4-8°C. Winter temperatures frequently drop below -15°C, while summer maxima reach 25°C. Annual precipitation averages 400-600 mm, occurring primarily as winter snowfall (60%) and summer rainfall (40%). The growing season extends approximately 150-180 days from late April to early October.

Figure 1 showing measurements and Rosa specimen treatments (pictures by the first author)

Vegetation: The valley supports diverse vegetation communities across elevational gradients. Dominant species include *Juniperus* spp., *Betula utilis*, *Salix* spp., and various Rosaceae members. Agricultural lands occupy valley bottoms, while natural vegetation covers slopes and higher elevations. Wild roses occur along watercourses, forest edges, and disturbed habitats.

2.2 Sample Collection

Sampling Design: Ten individual rose plants (*Rosa* spp.) were selected using purposive sampling to represent variation across the study area. Plants were chosen based on accessibility, flowering status, and spatial distribution to capture local diversity.

Collection Procedure: Samples were collected during peak flowering period (May-August 2024) to ensure complete floral development. For each selected plant:

1. One fully opened; undamaged flower was harvested using sterilized pruning scissors
2. Collection occurred during morning hours (0800-1000 hrs) under dry conditions
3. GPS coordinates and elevation were recorded for each collection point
4. Voucher specimens were prepared following standard herbarium protocols
5. Field photographs documented plant habit and habitat

2.3 Specimen Preparation

Pressing and Preservation: Collected flowers were immediately placed between absorbent paper sheets in a portable plant press. Pressure was applied using tightening straps to ensure flat, uniform pressing. Specimens were changed to fresh paper daily for the first three days to prevent fungal growth. Complete drying required 7-10 days.

Mounting: Dried specimens were affixed to standard herbarium sheets (42 × 29 cm) using archival-quality adhesive (pH-neutral PVA glue). Care was taken to position floral parts to maximize visibility for measurement. Mounting labels included collection date, location, GPS coordinates, elevation, and collector information.

2.4 Morphometric Measurements

Dissection Procedure: Each pressed flower was carefully dissected to separate individual floral components under a dissecting microscope (10× magnification). Components were organized systematically for measurement:

- **Petals:** All petals removed and individually measured (n=9 per flower)
- **Sepals:** Calyx dissected to separate individual sepals (n=4 per flower)
- **Leaves:** Compound leaves dissected to individual leaflets (n=4 per flower)
- **Stamens:** Representative stamens removed from different whorls (n=4 per flower)
- **Carpels:** Individual carpels extracted from the receptacle (n=4 per flower)

Measurement Protocol: Digital calipers (Mitutoyo CD-6"CSX, precision ±0.01 mm) were used for all measurements. Each component was measured for:

1. **Length:** Maximum distance from base to apex along the midline
2. **Width:** Maximum perpendicular distance at the widest point
3. **Size:** Length and width by multiplication, size was calculated
4. **Thickness:** (where applicable) measured at midpoint

Measurements were recorded in centimeters to two decimal places. Each component was measured three times, and mean values were calculated to minimize observer error.

Table 1: Petal Morphometry

Measurement	Mean ± SD (cm)	Range (cm)	Coefficient of Variation	R^2
Length	2.86 ± 0.15	2.40 - 3.25	5.2%	0.0073
Width	2.71 ± 0.12	2.30 - 3.10	4.4%	0.01
Area	6.08 ± 0.65 cm²	4.32 - 7.91 cm²	-	-

Table 2: Sepal Morphometry

Measurement	Mean ± SD (cm)	Range (cm)	Coefficient of Variation	R^2
Length	1.53 ± 0.08	1.25 - 1.75	5.2%	0.1291
Width	0.76 ± 0.05	0.60 - 0.90	6.6%	0.676
Area	0.91 ± 0.12 cm²	0.59 - 1.24 cm²	-	-

Area Calculation: For components with irregular shapes (petals, leaves), surface area was estimated using the ellipse formula:

$$\mathbf{Area = \pi \times (Length/2) \times (Width/2)}$$

This approximation provides reasonable estimates for comparison purposes, acknowledging limitations for highly irregular shapes.

Table 4: Stamen Morphometry

Measurement	Mean ± SD (cm)	Range (cm)	Coefficient of Variation	R^2
Length	0.074 ± 0.006	0.050 - 0.095	8.1%	0.1291
Width	0.30 ± 0.03	0.20 - 0.38	10.0%	0.2727
Area	0.017 ± 0.003 cm²	0.008 - 0.028 cm²	-	-

Table 3: Leaf Morphometry

Measurement	Mean ± SD (cm)	Range (cm)	Coefficient of Variation	R^2
Length	3.50 ± 0.18	2.80 - 4.10	5.1%	0.1598
Width	2.21 ± 0.14	1.70 - 2.65	6.3%	0.1441
Area	6.06 ± 0.78 cm²	3.74 - 8.53 cm²	-	-

2.5 Data Management

Table 5: Carpel Morphometry

Measurement	Mean ± SD (cm)	Range (cm)	Coefficient of Variation	R^2
Length	1.51 ± 0.09	1.20 - 1.75	6.0%	0.0183
Width	1.20 ± 0.07	0.95 - 1.40	5.8%	0.0016
Area	1.42 ± 0.17 cm²	0.89 - 1.93 cm²	-	-

All measurements were recorded in standardized data sheets and subsequently entered into Microsoft Excel 365 spreadsheets. For each floral component type, the following parameters were calculated using the Mean (arithmetic average), Standard deviation (SD), Range (minimum to maximum values), and Coefficient of variation (CV = SD/Mean × 100%)**.** Linear regression models were fitted to examine relationships between length and width for each component type. The coefficient of determination (R^2) was calculated to assess the proportion of variance explained.

3. Results

3.1 Overview of Morphometric Measurements

Morphometric analysis of ten rose specimens from Yasin Valley revealed quantifiable variation across all five measured floral components. Measurements encompassed 90 petals, 40 sepals, 40 leaves, 40 stamens, and 40 carpels, totaling 250 individual component measurements. The following sections present detailed results for each component type.

3.2 Petal Morphometry

Petal measurements (n=9 petals per flower, 10 flowers, total n=90 petals) showed the following characteristics:

Petals exhibited relatively uniform dimensions across specimens, as indicated by low coefficients of variation (<6%). The very low R^2 values (0.0073 for length, 0.01 for width) indicate weak correlation between petal size and specimen number. This suggests minimal systematic variation in petal size across the sampled population. Petal length exceeded width by only 5.5%, indicating near-circular shape characteristic of many wild rose species. (see table 1).

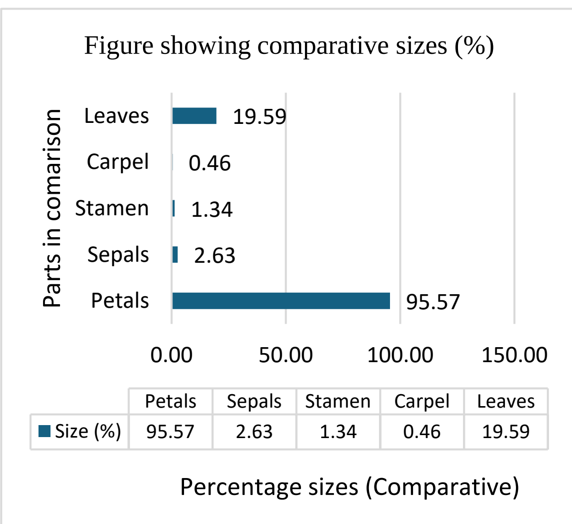
3.3 Sepal Morphometry

Sepal measurements (n=4 sepals per flower, 10 flowers, total n=40 sepals): Sepals demonstrated notably different patterns compared to petals. The higher R^2 value for width (0.676) suggests moderate correlation with specimen variation, while length showed weaker correlation (R^2=0.1291). Sepals exhibited a clear length-to-width ratio of 2:1, consistent with typical rose morphology. The relatively narrow width range indicates greater uniformity in this dimension across specimens. (see table 2).

3.4 Leaf Morphometry

Leaf measurements (n=4 leaves per flower, 10 flowers, total n=40 leaves):

Leaves were the largest measured components, showing intermediate levels of variation. The similar R^2 values for length and width (0.1598 and 0.1441 respectively) indicate comparable levels of specimen-related variation in both dimensions. The length-to-width ratio of 1.58:1 reflects typical elliptical leaf shape in roses. Higher coefficient of variation in width (6.3%) compared to length (5.1%) suggests width may be more responsive to environmental conditions.

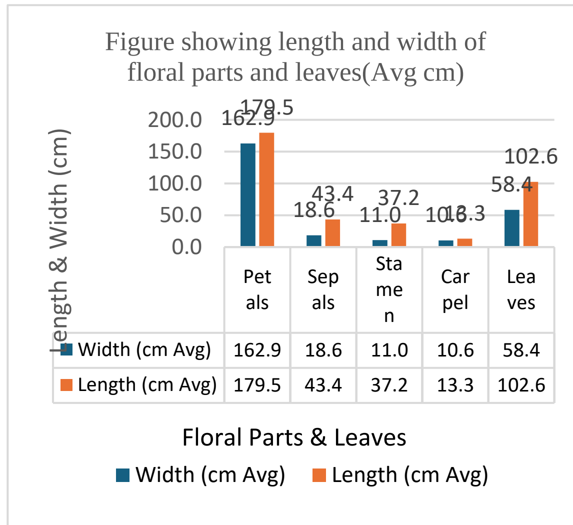


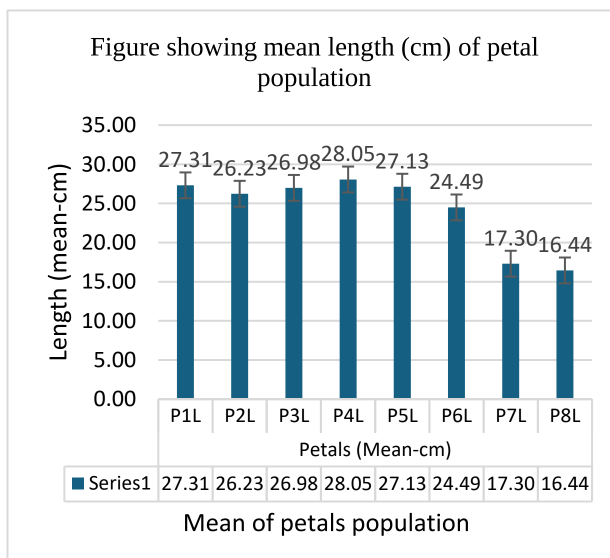
3.5 Stamen Morphometry

Stamen measurements (n=4 stamen per flower, 10 flowers, total n=40 stamens): Stamens represented the smallest measured components and exhibited highest variation (CV=8-10%). The R^2 value for width (0.2727) was notably higher than for other components, suggesting width variation may be influenced by specific specimen characteristics. The dramatic difference between length and width (width 4× length) reflects the typical anther morphology in roses. Higher variability in stamens may reflect functional adaptation to pollination efficiency.

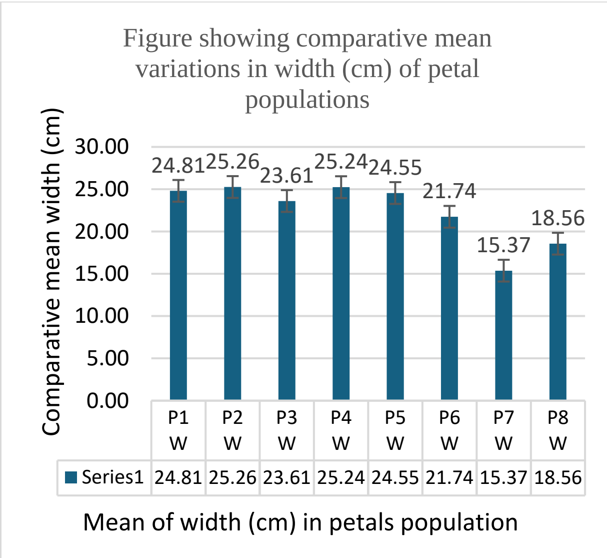
3.6 Carpel Morphometry

Carpel measurements (n=4 carpels per flower, 10 flowers, total n=40 carpels): Carpels showed remarkably uniform dimensions, with very low R^2 values (0.0183 for length, 0.0016 for width) indicating minimal correlation with specimen variation. The near-equal length and width (1.26:1 ratio) suggests approximately circular carpel cross-section. Low coefficients of variation (5-6%) indicate strong developmental constraint on carpel morphology, likely reflecting functional requirements for seed development.





3.7. Comparative Dimensions



4. Discussion

The morphometric analysis of high-altitude rose populations in Yasin Valley revealed moderate yet consistent variation across all floral components, with coefficients of variation ranging from 4.4% to 10.0%. This aligns with expected diversity for wild plant populations and suggests genetic diversity maintained through outcrossing. The observed petal dimensions, with a mean length of 2.86 cm and width of 2.71 cm, are comparable to other wild Himalayan species like *Rosa webbiana*. These high-altitude populations exhibit distinct, smaller morphology compared to larger lowland and cultivated varieties, a difference likely representing an adaptation to resource limitations and shorter growing seasons.

The morphological patterns reflect functional adaptations to the local pollination ecology. The moderate, near-circular petal shape provides an efficient visual display for attracting pollinators while conserving resources-a critical strategy in high-altitude environments with unpredictable pollinator activity. Notably, stamens showed the highest variation, which may optimize pollen transfer across different pollinator sizes. In contrast, carpel morphology was remarkably uniform, indicating strong developmental constraints on structures directly affecting reproductive fitness. Sepal dimensions showed the strongest correlation with specimen identity, suggesting this trait may be particularly responsive to environmental gradients or genetic differences, potentially related to microclimate regulation and bud protection. Leaf morphology also appears adapted to high-altitude stresses, exhibiting a smaller, more compact elliptical shape that balances light capture with protection from wind and radiation.

This study provides the first quantitative baseline for rose populations in this under-documented region. Establishing these morphometric references is critically important for detecting future climate-induced shifts, as the Himalayas are experiencing rapid warming. The data also contribute to taxonomic identification and conservation planning, suggesting the populations maintain viable genetic diversity. However, the small sample size and limited geographic coverage highlight the need for future, expanded studies. Integrating these morphological findings with molecular genetics and multi-year monitoring would greatly strengthen understanding of population structure, genetic health, and the potential for these unique alpine roses to adapt to ongoing environmental change.

5. Conclusion

This study provides the first comprehensive morphometric analysis of wild rose (*Rosa* spp.) populations in Yasin Valley, Gilgit-Baltistan, Pakistan. Analysis of ten specimens across five floral components (petals, sepals, leaves, stamens, carpels) revealed quantifiable variation characteristic of healthy wild populations.

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