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MULTIVARIATE ANALYSIS OF MORPHOLOGICAL TRAITS IN *MALVA SYLVESTRIS*

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Abstract *Malva sylvestris is a revered medicinal plant spread across the world, well-known for its versatile therapeutic properties. However, the environmental stressors, specifically water scarcity, cause a damaging threat to its global cultivation and metabolic representation, involving a deeper understanding of its morpho-physiological adaptive approaches. This study examines the morphological and physiological characters of Malva syivestris collected across the three different locations at the University of Punjab, Faculty of Agricultural Sciences, Lahore, Pakistan. Three replications of three plants per site were taken to calculate the vegetative characters, including fresh weight(FW), dry weight(DW), leaf area(LA), leaf length (LL), leaf width(LW), moisture content(MC), root length (RL), and shoot height(SH). Data were investigated by using the analysis of variance(ANOVA), correlation coefficients, multiple linear regression, and GGEbiplot analysis.ANOVA demonstrates that the collection site greatly impacted all studied characters, revealing a suitable coefficient of variation (CV) range of 10-15%. On the other hand, the correlation analysis indicates a strong positive association between FW and DW. In contrast, a strong negative correlation was noticed between MC and RL, indicating a key physiological adjustment where plants alter the distribution of resources to enhance the root and shoot length under drought stress conditions. These studies demonstrate the high phenotypic plasticity of Malva sylvestris and build up an extensive morpho-physiological profile. To maximize the cultivation of Malva sylvestris, the breeding program should focus on selecting genotypes with larger leaf area, root length, and dry weight, which will work as a key character for environmental adaptation and stress resistance.*

Keywords*:* *Morphological Trairs; Malva sylvestris; correlation analysis; locations; shoot length*

Introduction

The *Malva sylvestris* is know as medicinal plant and is an important plant for its multiple uses. Its consumption is reported to have been discovered as early as 3000 BC (Gasparetto et al., 2012). *Malva sylvestris* L.is a flowering plant related to the Malvaceae family. In Europe, it is also known as common mallow (Batiha et al., 2023). The genus Malva sylvestris consists of approximately 40 taxa distributed throughout the world. Malva sylvestris is an annual plant species with leaves that are shallowly lobed, and the plant bears purple flowers during late spring (Razavi et al., 2011). The leaves and flowers of *Malva sylvestris* are used in the treatment of inflammatory conditions of the mucous membranes, including cystitis and diarrhea. The plant's therapeutic properties are attributed to the presence of mucilage and flavonoids in its leaves and flowers (Mousavi et al., 2021). Malva is a widely distributed plant commonly found across Middle Eastern countries. Different species of Malva are used in various ways by the local population. Many people consume it as a vegetable. The extensive use of Malva species among Arabian populations highlights the need to investigate and identify the medicinal and chemical properties of *Malva sylvestris*. It contains tannins, vitamins A, C, and E, folic acid, niacin, polyphenols, scopoletin, and coumarins (Shadid et al., 2021).

Although central Asia is considered its origin, the plant is now found growing in many parts of the world. The medicinal family Malvaceae includes 10 species, of which 7 have been reported in Iran, and three of these are endemic. In Iran, it is commonly known as Panirak, Nun-kalaagh, khabaazi, and Tooleh. Genetic diversity plays a vital role in enabling species to adapt to environmental changes and ensure their long-term survival. Therefore, understanding both inter and intra-population for the conservation of natural resources (Pahlavan et al., 2021a). Water scarcity is a serious issue that significantly limits crop production across arable land worldwide. In medicinal plants, drought stress can alter the production of metabolites that are essential for their therapeutic properties. One effective approach to address this problem is the development of drought-resistant cultivars. Plants have evolved a range of strategies to cope with drought conditions, including morphological adaptations such as a deeper root system and reduced leaf area, as well as physiological responses like stomatal regulation and osmotic adjustment. These mechanisms collectively help to enhance the plant survival under water-deficient conditions (Zeinab et al., 2025)

Materials and methods

Three replicates of each sample were calculated from *Malva sylvestris* at the University of Punjab Faculty of Agriculture, Lahore, Pakistan. Samples were obtained from three different locations, and each sample consisted of three plants. The plants were carefully uprooted by excavating the soil around the weeds.

Fresh Weight Measurement

After collecting, the fresh weight of each sample was measured using a weighing machine.

Measurement of Morphological Characteristics

Morphological parameters, including shoot length, root length, leaf area, and leaf width, were measured using a scale.

Dry Weight Measurement

The plant samples were then placed in a dry environment for 5-6 days to remove all moisture, avoiding any exposure to humidity. After complete drying, the dry weight was recorded.

Calculations

After recording all measurements, the following calculations were performed:

Leaf Area=(Leaf length)(Leaf Width)(0.74)

Moisture Content(%)=(Fresh Weight-Dry Weight)/Fresh Weight(100) (Hayat et al., 2025)

Results and discussion

The result from table 1 consists of different morphological traits of *Malva sylvestris* under various environments, showing various adaptations that allow it to survive. These traits are considered to be significant at the probability level os 5% the traits are included: SOV(spread of vegetation), leaf area(LA), shoot height(SH), root length(RL), leaf width(LW), leaf length(LL),mioture content(MC), dry weight(DW), fresh weight(FW) these traits shows thrie responses in stress conditions such as drought condition, light and nutrient defficiency and ant kind of change in temperature will cause the variation in the trait responses. The characters like fresh and dry weight, root length, are not always measurable, as it depends upon the environmental conditions. THE results show that the geographical and environmental conditions had a significant effect on each character that is measured. The plant growth highly depends upon the location or site where it develops under certain conditions. In all cases, the MS value of location is significantly heigher then the MS value of error, so it has a significant effect on each character, which is measured. The CV values are below then 13%, so the variability within this range (10-15%) is acceptable. The low value of CV does not influence the traits as much as location causes the variation among the traits. This analysis concludes that the location is the primary factor which derives the physical variation in *Malva sylvestris.* The location factor has significantly influenced the trait at 95% of confidence level. The physical structure of *Malva sylvestris* is sensitive to soil type and the site where it grows (Kakaei and Chaghakaboodi, 2025).

Table 1. ANOVA for morphological traits of *Malva sylvestris*

SOV	LA	LW	LL	FW	DW	RL	MC	SH
Location	14.7678	1.33000	1.39000	0.85990	0.37634	24.5100	114.752	41.6133
Error	0.9178	0.03333	0.02500	0.06923	0.00964	0.2133	13.325	0.1483
Grand Mean	7.7444	1.9667	5.3333	3.5100	0.8711	7.6667	75.440	9.0000
Standard error	0.5531	0.1054	0.0913	0.1519	0.0567	0.2667	2.1076	0.2224
CV	12.37	9.28	2.96	7.50	11.27	6.02	4.84	4.28

The correlation analysis shows the significant interaction among the studied traits. Fresh weight (FW) indicates a strong positive correlation with dry weight(DW), demonstrating that plants have a direct relationship between FW and DW. Higher fresh weight plants also exhibit greater dry biomass. Leaf length also positively interacted with fresh weight, revealing that larger leaf size assists in higher fresh weight. Leaf area presents a strong positive interaction with leaf width (LW)(r=0.9217) and shoot height (SH)(r=0.6499*), revealing that larger leaves enhance the larger leaf area and plant growth. Similarly the root length(RL)also positively corresponds with leaf width (LW), and moisture content (MC) reveals that the plant with larger leaves and greater moisture content is inclined to develop longer roots. Shoot height (SH) also indicates a strong positive interaction with leaf width (LW), illustrating the significance of leaf expansion in promoting vegetative growth (Pahlavan et al., 2021b). On the other hand, the moisture content indicates a strong negative relation with leaf width(r=-0.8956*) and with leaf length (r=-0.9318*), showing that the increase in moisture content was linked with the decrease in dry mass aggregation and leaf length. Root length also shows a negative relation with dry weight (DW) (r=-0.7854*) and also shows a negative relation with leaf length (LL)(r=-0.7872), indicating that the increase in root length is interlinked with the reduction of dry weight and leaf area, so the leaves are shorter. Similarly, the shoot height (SH) was negatively related to dry weight(DW) (r=-0.7307*), FW(r=-0.6884*), and leaf length(r=-0.7291*). So it also shows an inverse relationship with each other; the enhancement of one trait leads to the reduction of another trait. That correlation analysis summarizes that traits linked to leaf extension, such as leaf area(LA) and leaf width(LW), were positively linked with plant growth standards. On the other hand, the moisture content(MC) and some root traits indicate a negative relation with biomass-linked traits. The significant analysis shows that mutual dependence between morphological and physiological characters may be helpful in breeding programs during the selfing of superior genotypes (Abbas et al., 2024; Afzal et al., 2016).

Table 2. *Malva sylvestris* morphological traits correlation

Trait	DW	FW	LA	LL	LW	MC	RL
FW	0.795*						
LA	-0.0184	-0.3284					
LL	0.9776	0.7066*	0.0338				
LW	-0.3974	-0.5778	0.9217*	-0.3554			
MC	-0.8956*	-0.4447	-0.1887	-0.9318*	0.1896		
RL	-0.7854*	-0.7002	0.5643	-0.7872*	0.8311*	0.6646*	
SH	- 0.7307*	-0.6884*	0.6499*	-0.7291*	0.8899*	0.5979	0.9881

Dry weight (DW) indicates the positive regression coefficient (13.6858) with a T-statistic of 6.84, demonstrating a strong contribution towards the dependent variable. Likewise the leaf area (LA), moisture content (MC), and root length(RL) reveals possitive cofficient of 2.62553,0.55249, and 0.34601respectively shows that increases in these traits were linked with the enhancement of response variables. Likewise, the fresh weight (FW), leaf length(LL), and leaf width (LW) indicate negative regression coefficients of -3.41120,-4.95789, and -6.60586, respectively. These negative coefficients reveal the inverse interaction with dependent variables. The leaf length(LL) demonstrates that the larger negative T-statistic value shows a comparatively stronger negative effect. In the regression model, T-statistics showcased the relative impact of each variable. Root length(RL) had a strong positive influence of 8.96, while leaf length (LL) exerted the most significant negative effect. Further moisture content (MC) and dry weight (DW) indicate high positive T-statistics, revealing their substantial roles in the model. The P-values, including all variables, were larger than 0.05, showing that the regression coefficients were statistically non-significant at 5% probability level. The variables such as leaf length(LL), root length(RL), and dry weight (DW) were really closer to significance, proposing a moderate level of linkage between the dependent variables. So overall, that regression analysis shows that the dry weight, leaf area, moisture content, and root length positively impact the studied indicators of *Malva sylvestris;* on the other hand, the fresh weight(FW), leaf length (LL), and leaf width(LW) influence the negative effect. The relationships were not statistically significant at the standard 5% level; different variables show noticeable trends that may be biologically important (Afzal et al., 2016; Arshad et al., 2024; Rasheed and Malik, 2022).

Table 3. Stepwise multiple linear regression for fresh weight of *Malva sylvestris*

Variable	Cofficient	Standard error	T Stat	P-value
DW	13.6858	2.00014	6.84	0.0924
FW	-3.41120	0.64578	-5.28	0.1191
LA	2.62553	0.49813	5.27	0.1194
LL	-4.95789	0.50617	-9.79	0.0648
LW	-6.60586	1.84281	-3.58	0.1732
MC	0.55249	0.09035	6.11	0.1032
RL	0.34601	0.03860	8.96	0.0707

Conclusion

It is proposed that to maximize the cultivation and biomass yield of the *Malva sylvestris* breeding program should focus on selecting the genotypes with enhanced leaf area, root length, and dry weight, which function as key traits for environmental adaptation and drought resistance.

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Declaration

Data Availability statement

All authenticated data have been included in the manuscript.

Consent for publication

Not applicable

Declaration of Competing Interests

The authors declare that they have no conflict of interest.

Author Contribution Statement

ZB collected data and conducted research and wrote article. Final editing was carried out and approved for final publication.

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Informed Consent

Not applicable.

Ethical Statement

Not applicable