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EXPLORING MORPHOLOGICAL TRAITS VARIATION IN *AMARANTHUS HYBRIDUS*: A COMPREHENSIVE MULTIVARIATE ANALYSIS

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Abstract *Amaranthus hybridus, a neglected leafy vegetable, threatens crop plants because it competes for vital resources like water, minerals, and nutrients. Crop yield decreases due to this competition. To handle this issue, an organized study was developed to examine the characteristics of Amaranthus hybridus in three different locations with distinct environments. The result proved a connection between the studied traits, dry weight, fresh weight, plant height, leaf area, leaf width, leaf length, and root length. Notably, there was an impact of plant leaf width on its plant height. Furthermore, the study showed that location was identified as an environment for the vigorous growth and development of Amaranthus hybridus. The study recommended removing or controlling the Amaranthus hybridus population in crop yield to reduce losses. Amaranthus hybridus describes the importance of population managing strategies.*

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Introduction

Amaranthus hybridus belongs to the Amaranthaceae family and is a leafy green vegetable (Adegbola et al., 2020). This family encompasses a diverse range of plants, including herbs, shrubs, vines, and trees, comprising over 800 species across 60 genera. It is broadly classified into two subfamilies: "Amaranthiodeae" and "Gompheniodeae." Commonly called Green *Amaranthus* or Smooth *amaranthus*, A. hybridus is an annual flowering plant native to North America, later introduced to Europe and Eurasia. Displaying a weedy nature, it can reach heights of up to 2.5m, growing from a short taproot with a clumping habit. The seeds and leaves of *Amaranthus hybridus* are edible, with the leaves and young seedlings often cooked as spinach or added to soups. They can also be consumed raw (Ahmad et al., 2021; Asif et al., 2020; Ghafoor et al., 2020; Suma et al., 2002). The seeds, measuring about 1mm in diameter, are typically ground into flour for various culinary applications, such as porridge and bread. Additionally, astringent tea made from the leaves finds application in traditional medicine, specifically for treating intestinal bleeding, diarrhea, and excessive menstruation. In Cameroonian traditional medicine, macerated leaves and seeds are a fertility stimulant (Iranshahy et al., 2017). The stems of *Amaranthus hybridus* exhibit longitudinal grooves and are adorned with hairy structures. The plant is monoecious, bearing both male and female flowers on the same individual, with wind as the primary pollinator. Self-fertile and thrives in well-drained soil, adapting to light sandy, medium loam, and heavy clay soils. The pH range for optimal growth encompasses mildly acidic, neutral, and basic conditions (Iqra et al., 2020; Naseem et al., 2020; Nawaz et al., 2020; Sarwar et al., 2022; Winch, 2021). Intolerant to shade, *Amaranthus hybridus* prefers moist soil. *Amaranthus* offers various health benefits, including aiding in preventing heart attacks, improving digestion, supporting hair care, and boosting the immune system. However, individuals with kidney diseases, rheumatoid arthritis, and gout are advised against consuming *Amaranthus* leaves. Despite its nutritional value, the plant is not highly competitive and can be easily controlled (Freedman and Barnouin, 2010; Sarwar et al., 2021; Shafique et al., 2020; Zubair et al., 2016). A detailed analysis of *Amaranthus hybridus* revealed phyto components such as alkaloids, anthocyanins, anthraquinones, flavonoids, phenols, saponins, steroids, tannins, and triterpenes. Studies have highlighted its antimicrobial, antidiabetic, anticancer, and antioxidant properties. The plant's ability to adapt to

adverse environmental conditions is attributed to its utilization of the C4 photosynthetic pathway(Iftikhar and Khan, 2019). The physiological characteristics of *Amaranthus hybridus* contribute to easy cultivation, resistance to pathogenic organisms, and enhanced phenotypic plasticity and genetic diversity. Scientific publications emphasize the nutraceutical values of *Amaranthus hybridus*, reporting a higher proximate composition than other crops like corn, buckwheat, rye, and rice (Venskutonis and Kraujalis, 2013). Traditionally, this plant has been used for food and medicinal purposes by various Native American groups and in traditional African medicine. Despite its historical uses, *Amaranthus hybridus* is recognized as a harmful weed affecting North American crops. It has the potential to influence the germination and growth characteristics of five commonly used cover crops, including two forbs, two legumes, and one grass species (Renne et al., 2006)

Material and Methods

Collection of plant material

Samples of *Amaranthus hybridus* were collected from three different locations at the backfield of the faculty of agriculture sciences, University of the Punjab, Lahore. The entire plant material was then subjected to shade-drying.

Leaf Length (cm)

Three leaves were randomly selected from each plant, and a cm scale recorded their length. Then, the average three values were calculated.

Leaf Width (cm)

Leaf width was measured at three points on each leaf: the base, center, and tip. Three leaves were randomly selected from each plant, and the width at each point was recorded. The average value of three measurements was then calculated.

Leaf Area (cm)

To measure leaf area, leaf length is multiplied by leaf width and a correction factor of 0.74cm. The formula used to calculate the leaf area was as follows:

Leaf area =leaf width × leaf length × 0.74

Plant Height (cm)

Plant height was measured from the point of attachment of the stem to the root (base of the stem), and the longest shoot on each plant.

Fresh Weight (g)

Fresh weight was calculated immediately after the weed sample was removed from the field to prevent the sample from drying out. An electronic weight balance was used to measure the weight of the sample.

Dry Weight (g)

The sample was dried in oven to measure the dry weight. Each sample was packed separately in envelopes and left to dry for 8 -13 hours. After the sample was dried, it was weighed on an electron balance.

Moisture Percentage (%)

The total moisture percentage, both with and without the inflorescence, was recorded using the following formula:

Moisture Percentage = (fresh weight – dry weight)/ fresh weight*100

Results and Discussions

The results presented in the given Table 1 demonstrate statistically indicated outcomes between the studied locations of *Amaranthus* hybridus. The average plant height was recorded as (14.444±2.9565cm), leaf width (8.1733±0.8139cm), leaf length (8.0556±1.7093cm), leaf area (56.024±19.31cm), Root length (7.4444±1.3459cm), Fresh weight (16.894±3.1377g) Dry weight (3.5556±1.168g), Moisture percentage (78.711±4.4611%), for *Amaranthus hybridus* plant gathered from three different locations. The greater the plant's fresh weight, the more vigorous Amaranthus hybridus grows under varying environmental conditions. The higher moisture percentage indicates it can bear the harsh, hot, and dry climate. Additionally, the species can hold on to underwater logging conditions and eat up beneficial resources such as food, minerals, water, and space. So, removing these plants from crop fields is important due to their competitive nature (Aerts, 1999; Ali et al., 2013; Ali et al., 2016).

Table 1. Analysis of variance for morphological traits of *Amaranthus* hybridus

	Height	Leaf Width	Leaf Length	Leaf Area	Root Length	Fresh Weight	Dry Weight	Moisture
Locations	74.7778*	42.018*	25.2094*	5426.78*	43.0411*	53.2836*	4.80031*	203.87*
Error	13.1111	1.9875	8.7654	117.07	5.4344	29.536	4.09301	59.704
Grand Mean	14.444	8.1733	8.0556	56.024	7.4444	16.894	3.5556	78.711
CV	25.07	17.25	36.75	19.31	31.31	32.17	56.9	9.82
Standard Error	2.9565	0.8139	1.7093	19.31	1.3459	3.1377	1.168	4.4611

*= Significant at 5% probability value

A correlation analysis checks out the relationship between various morphological traits of Table 2 presents for *Amaranthus* hybridus, releasing significant and positive correlations among all the studied traits. These values specify the plant's ability to survive in harsh and hot conditions. Both organic compounds and its higher photosynthetic rate contribute to their robust growth and development (Lambers and Poorter, 2004).

Furthermore, there were deviations in the correlation between inflorescence dry weight and inflorescence moisture, inflorescence dry weight, and overall moisture. These notable traits did not show a positive

correlation, and a more intricate relationship between them was recommended (Lander and Schork, 2006).

Table 2. Correlations among morphological traits of *Amaranthus* hybridus

	Dry Weight	Fresh Weight	Height	Leaf Area	Leaf Length	Leaf Width	Moisture
Fresh Weight	0.4504*						
Height	-0.0855	0.3073					
Leaf Area	-0.0069	0.6612*	0.8288*				
Leaf Length	0.1679	0.4984*	0.7258*	0.8746*			
Leaf Width	-0.0989	0.4236*	0.954*	0.8938*	0.6951*		
Moisture	-0.8337*	0.0947	0.2285	0.3345	0.0443	0.293	
Root Length	0.2799	0.858*	0.5322*	0.8155*	0.5746*	0.7054*	0.1632

*= significant at 5% probability level

Regression analysis released that a higher contribution for dry weight was recorded as (24.02), followed by leaf width (5.957), leaf length (5.676), and fresh weight (3.619), while contribution was found for Moisture (2.961), leaf area (1.565), and root length (1.409). The regression equation was predicted in Table (3). Regression analysis is helpful for researchers to recognize the key plant traits that positively determine crop yield. Furthermore, the analysis showed that location 3 is favorable for the growth and development of *Amaranthus hybridus*, which shows the highest productivity (Martín-Robles et al., 2018).

Table 3. Stepwise multiple linear regression for fresh weight of *Amaranthus hybridus*

	Coefficients	Standard Error	t stat	P-Value	Lower 95%	Upper 95%
Dry Weight	6.519	1.378	4.732	0.133	-10.987	24.026
Leaf Width	1.063	0.385	2.760	0.221	-3.831	5.957
Leaf Length	-0.831	0.512	-1.623	0.352	-7.339	5.677
Fresh Weight	-1.314	0.388	-3.3864	0.183	-6.249	3.619
Moisture	0.911	0.161	5.644	0.112	-1.139	2.961
Leaf Area	0.220	0.106	2.079	0.285	-1.125	1.566
Root Length	-1.163	0.203	-5.744	0.109	-3.737	1.409

Conclusion

Based on the findings, location 3 is favorable for the growth and development of *Amaranthus* hybridus. However, it is suggested that techniques be applied to control the growth and development of *Amaranthus hybridus* to reduce crop yield losses.

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Declarations

Data Availability statement

All data generated or analyzed during the study are included in the manuscript.

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable

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Conflict of Interest

Regarding conflicts of interest, the authors state that their research was carried out independently without any affiliations or financial ties that could raise concerns about biases.