BBASR PUBLISHERS

Biological and Agricultural Sciences Research Journal
eISSN: 2959-653X; pISSN: 2959-6521
www.basrj.com
DOI: https://doi.org/10.54112/basrj.v2023i1.21
Biol. Agri. Sci. Res. J., Volume, ***2****: 21*

BASRJ

Original Research Artilce

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EXPLORING MORPHOLOGICAL TRAITS VARIATION IN *GOMPHRENA GLOBOSA*: A MULTIVARIATE ANALYSIS

HAIDER MZ[1], SAMI A[1], MAZHAR HSUD[1], AKRAM J[2], NISA BU[2], UMAR M[1], MEERAN MW[1*]

[1]*Department of Plant Breeding and Genetics,* Faculty of *Agricultural Sciences, University of the Punjab, P.O BOX. 54590, Lahore, Pakistan*
[2] *Lahore College for Women University, Jail Road, Lahore, Lahore, Pakistan*
**Correspondence author email address: zeech280@gmail.com*

(Received, 17th January 2023, Revised 8st August 2023, Published 10th August 2023)

Abstract *Gomphrena globosa L. is a weed threatening important crops like wheat, maize, rice, sugarcane, and cotton. It competes with these crops for resources such as water, minerals, and nutrients, reducing crop yield. To address this problem, a study was conducted to examine the characteristics of Gomphrena globosa in three environments. The findings showed a positive relationship between traits studied, including height, weight (dry and fresh), leaf area, leaf length, width, and root length. Interestingly, the plant leaves' width stood out as the factor contributing to its overall height. Location two was identified as favorable for the growth and development of Gomphrena globosa plants. To minimize losses in crop yield caused by this weed species, removing or controlling Gomphrena globosa populations is recommended while emphasizing effective population management techniques.*

[*Citation: Haider, M.Z., Sami, A., Mazhar, H.S.U.D., Akram, J., NISA, B.U., Umar, M., Meeran, M.W. (2023). Exploring morphological traits variation in Gomphrena globosa: A multivariate analysis. Biol. Agri. Sci. Res. J.,* ***2023****: 21. doi: https://doi.org/10.54112/basrj.v2023i1.21*]

Keywords: *Gomphrena globosa, Nettle-leaved, morphological, weed, correlation, regression, PCA*

Introduction

Globe amaranth, scientifically known as *Gomphrena globosa* is a type of plant that can withstand high temperatures. It originated in Panama and Guatemala. Although these plants can handle drought conditions well when mature, they tend to grow when provided with moisture and full sunlight(Kugler et al., 2007). G. Globosa can adapt, allowing it to thrive in poor soil or colder climates. This adaptability has led to its spread across continents, including Europe (Cai et al., 2003). It is worth noting that globe amaranth is considered a weed in parts such as Australia, Africa, Asia, and Europe. Its prolific seed production and ability to survive in conditions contribute to its weed status in these areas.

The globe amaranth plant is typically short in height growing around 10 - 30 cm. Its stems are covered in hairs and can sprawl or stand upright (Council, 1989). The leaves are shaped like ovals or lances. Are positioned opposite each other along the stems. While the flowers may be small and unimpressive; they are surrounded by eye-catching bracts (Kumar et al., 2022) in colors like white, pink, red, purple, or orange (Kulakow, 2018). One of the challenges with globe amaranth is its tendency to produce an abundance of seeds quickly, making it a troublesome weed. It can withstand drought, heat, and poor soil quality allowing it to thrive and outcompete other plants. Additionally, it can spread further through its creeping stems that propagate vegetatively (Grodzinski et al., 1983). Several methods have been used to control the growth and spread of globe amaranth as a weed. These methods include removing by hand pulling, mowing the plants down, applying herbicides selectively, regularly rotating crops, and implementing biological control strategies. The appropriate control method will depend on the circumstances and severity of the infestation. Taking action to manage this plant is essential, in order to prevent it from becoming a significant weed issue (Wang et al., 2009).

Major crops experience a variety of problems that cause losses. Insects, fungi, bacteria, viruses, rusts, blights, aphids, locusts, and nematodes are a few examples of pests and illnesses that can be harmful (Sherf and MacNab, 1986). This harm includes decreased crop yields and decreased crop quality. Additionally, adverse effects from extreme weather might result from the destruction of fields and interruption of agricultural production during droughts, floods, hurricanes, and storms. Seeds make the issue worse by competing with crops for resources like sunlight, water, and nutrients (Monteiro and Santos, 2022). Productivity declines due to this competition. Complicates crop management and harvesting. Soil deterioration caused by erosive, depletive, and salinizing processes degrades soil quality, impacting crop development and yields. (Abd-ElGawad et al., 2020).

Climate change poses another threat, as shifts in temperature and precipitation patterns negatively impact crop growth and distribution, causing heat stress, altered growing seasons, and unpredictable weather events, ultimately leading to lower yields and crop failures (Crossman et al., 2011). Post-harvest losses occur due to improper storage and handling practices, resulting in spoilage, pest infestations, or disease outbreaks. Limited access to quality seeds, fertilizers, pesticides, and agricultural machinery hampers crop productivity and overall production (Catarino et al., 2019). Market factors, such as price fluctuations and restricted market access, can influence the profitability of crops, leading to losses for farmers. Water scarcity exacerbates the situation, particularly in water-dependent regions, reducing crop yields due to insufficient or irregular water supply. Lastly, deforestation and land degradation contribute to the loss of arable land, further limiting the potential area available for crop cultivation. Addressing these challenges requires a comprehensive approach that emphasizes sustainable agricultural practices, improved pest and disease management, resilient crop varieties, efficient water management, and measures to mitigate climate change and market fluctuations. Weeding is an important cultural practice in crop management, and it is essential to control weeds in their early stages to prevent yield losses (Van Acker et al., 1993).

Farmers, in Pakistan employ various methods to tackle Globe amaranth weed. They utilize techniques like hand weeding, hoeing, and pulling to control small weeds, although these methods require significant labor (Khan et al., 2021). For farms, manual practices are often combined with approaches. On the hand, mechanical weed control involves using tools such as harrows, cultivators, and rotary tillers to uproot and bury weeds(Bana et al., 2022). While this method is more suitable for farms, it should be executed correctly to avoid soil compaction and crop damage. Chemical weed control is another approach farmers adopt in Pakistan, where herbicides like paraquat and 2, 4 D are used specifically for Globe amaranth control (SAMI et al., 2023).

Materials and Methods

For this study, samples of Globe amaranth were collected from three locations at the Faculty of Agricultural Sciences (FAS) in Lahore, Pakistan. We ensured nine replications by taking three specimens from each location.

Leaf Length (cm)

Measuring the length of leaves involved selecting three leaves from each plant and using a centimeter scale to record their lengths.

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 the three measurements was then calculated.

Leaf Area (cm^2)

The leaf area was calculated by multiplying the leaf length by the leaf width and a correction factor of 0.74 cm. The formula used to calculate the leaf area was as follows:

$$Leaf\ area = leaf\ width \times leaf\ length \times 0.74$$

Plant Height (cm)

To measure the height of the plant, measurement was taken from the point where the stem attaches to the root (base of the stem) up to shoot length.

Fresh Weight (g)

As soon as the weed sample was taken out of the field, they were weighed immediately to prevent drying out.

Dry Weight (g)

To obtain the weight each sample was dried in an oven. Each sample was placed in envelopes. Left to dry for 8 to13 hours. After removing them from the oven, each sample was weighted.

Moisture Percentage (%)

The total plant moisture percentage was recorded using the following formula:

$$Moisture\ percentage = \frac{fresh\ plant\ weight - dry\ plant\ weight}{fresh\ plant\ weight} \times 100$$

Results and Discussions

Globe amaranth varies according to the region and characteristics, according to the data in **Table 1.** The average height of the plants was determined to be (62.778 ±1.5575 cm), with an average leaf width of (6.1889± 0.1305 cm), a leaf length of (7.5 ± 0.1944 cm), and a leaf area of (34.411 ± 1.0407 cm^2). Additionally, it was discovered that the length of the roots was (135.12± 2.3864 cm), with average weights of (18.356 ± 0.8821g) and (4.4222 ± 0.4805g) for dry weight and moisture (76.044 ± 1.5486%) respectively. Compared to the other plants in this study, the Globe amaranth can survive difficult circumstances, as shown by its plant weight and moisture content (Salustriano et al., 2022). However, because of their nature, it is crucial to remove these plants from crop fields since they deplete resources such as food, minerals, water, and space, which can lower crop output by outcompeting cultivated plants and causing them to dry out (SAMI et al., 2023).

Table 1. Analysis of variance for morphological traits of Globe amaranth

Entries	Height	Leave Width	Leave Length	Leave Area	Root Length	Fresh Weight	Dry Weight	Moisture

Locations	88.4444*	0.16444*	1.60333*	65.6311*	14.9911*	3.55444*	0.62111*	5.45778*
Error	7.2778	0.05111	0.11333	3.2494	17.0844	2.33444	0.69278	7.19444
Grand Mean	62.778	6.1889	7.5	34.411	135.12	18.356	4.4222	76.044
CV	4.3	3.65	4.49	5.24	3.06	8.32	18.82	3.53
Standard Error	1.5575	0.1305	0.1944	1.0407	2.3864	0.8821	0.4805	1.5486

*=Significant at 5% probability level, CV = Coefficient of variance

A correlation study was performed to determine the relationships between several Globe amaranth physical traits (**Table 2**). The research revealed strong positive relationships between all of the attributes looked at. This indicates that the plant can endure hot weather. The rate of photosynthesis and the buildup of substances that encourage rapid growth and development in its body are likely responsible for this adaptability (Chamkhi et al., 2022).

Although there were a few outliers, it's important to note that there were correlations between moisture, leaf length, and leaf area. These traits failed to exhibit a correlation, indicating a complicated relationship between them (Almas et al., 2023), (Chamkhi et al., 2022). Effective growth management of Globe amaranth plants is essential to preventing crop losses brought on by these plants. Farmers can accomplish this by eliminating them or by sparingly applying chemicals. To restrict the growth of these weeds, another alternative is to think about using modified crop plants that are glyphosate-resistant. Farmers can safeguard their harvests by putting these techniques into practice enhance agriculture output (Chamkhi et al., 2022).

Table 2. Correlation among morphological traits of Globe amaranth

Traits	Dry Weight	Fresh Weight	Height	Leave Area	Leave Length	Leave Width	Moisture
Fresh Weight	0.9449*						
Height	0.5048*	0.6622*					
Leave Area	0.5016*	0.6964*	0.9328*				
Leave Length	0.3505*	0.5534*	0.9284*	0.9746*			
Leave Width	0.8199*	0.9375*	0.6967*	0.7988*	0.6505*		
Moisture	-0.9699*	-0.8388*	-0.3556*	-0.3333	-0.1908	-0.679*	
Root Length	0.6039*	0.6836*	0.5297	0.443*	0.4158*	0.4688*	-0.4946*

*=Significant at 5% probability level

The analysis of regression showed that the height of the leaves had the impact, with leaf width having a contribution of 127.7853 followed by leaf length with 36.08159 moisture, with 25.9729 leaf area with 19.10816, and fresh weight, with 10.87457. Conversely, negative contributions were observed for leaf width (- 43.9139). Root length (- 1.07197). The regression equation was then predicted as follows; (**Table 3**),

Y (FW) = -9.995 -112.151 (Leaf Width) -21.4993 (Leave Length) + 6.935607 (Leave Area) -1.56089 (Root Length) + 0.469304 (Fresh Weight) + 76.94094 (Dry Weight) + 16.17899 (Moisture).

Regression analysis is a tool used by plant researchers to determine the plant characteristics that have a substantial impact, on crop yield. Through examining a range of traits, in a dataset, researchers can identify the key factors that contribute to achieving higher crop yields (Bajwa et al., 2019).

Table 3. Stepwise multiple linear regression for fresh weight of Globe amaranth

Traits	*Coefficients*	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Leave Width	-112.151	5.370366	-20.8833	0.030461	-180.388	-43.9139
Leave Length	-21.4993	4.531715	-4.74419	0.132253	-79.0802	36.08159
Leave Area	6.935607	0.958001	7.239667	0.087382	-5.23695	19.10816
Root Length	-1.56089	0.038479	-40.565	0.015691	-2.0498	-1.07197
Fresh Weight	0.469304	0.818912	0.573082	0.668708	-9.93596	10.87457
Dry Weight	76.94094	4.001535	19.22786	0.033079	26.09662	127.7853
Moisture	16.17899	0.770799	20.98991	0.030307	6.385065	25.97291

The Principal of Component Analysis (Figure 1) suggests that PC1 explains the majority, 72.7%, of the variations, in all the studied morphological traits. This means that most of the differences we see among these traits can be attributed to this factor captured by PC1(Chamkhi et al., 2022). On the hand, PC2 only accounts for 18.7% of the variation. Moreover our analysis highlights that location 2 is particularly suitable for plant growth and development as it exhibits the productivity of Globe amaranth. Considering these findings, it is advisable to implement measures to control the plant population's Globe amaranth at location 2. By doing so, we can minimize crop yield losses and ensure optimal growth conditions for Globe amaranth. This approach has the potential to enhance practices and improve crop productivity.

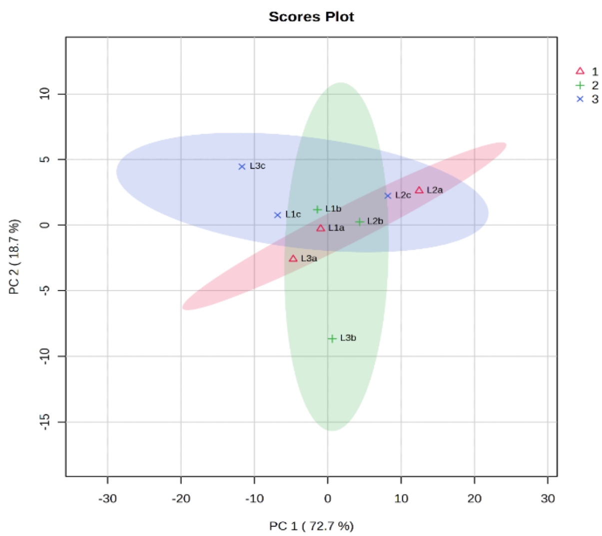

Figure 1: Scores Plot for Morphological Traits of Globe Amaranth across Three Different Locations

Conclusion

The study suggests controlling the Globe amaranth plant population is advisable to minimize crop yield losses.

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

Funding

Not applicable

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.

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