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Chemical composition and medicinal uses of globe amaranth (*Gomphrena globosa* L.) flowers

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Abstract
Globe amaranth (*Gomphrena globosa* L.) is a flowering plant widely recognized for its vibrant inflorescences and potential medicinal properties. This research investigates the chemical composition of globe amaranth flowers and explores their traditional and contemporary medicinal uses. Through comprehensive phytochemical analysis, the study identifies key bioactive compounds, including flavonoids, saponins, and betacyanins, which contribute to the plant's antioxidant, anti-inflammatory, and antimicrobial activities. The findings underscore the significance of *Gomphrena globosa* in traditional medicine and its potential applications in modern therapeutic practices.

Keywords: *Gomphrena globosa*, globe amaranth, chemical composition, medicinal uses, phytochemicals, antioxidants, traditional medicine

Introduction
Globe amaranth (*Gomphrena globosa* L.) is an annual herbaceous plant belonging to the Amaranthaceae family. Native to Central and South America, it is widely cultivated for its ornamental value and has been traditionally used in various cultural practices. The vibrant flowers of globe amaranth are not only visually appealing but also harbor a range of bioactive compounds that contribute to their medicinal properties. This study aims to elucidate the chemical composition of globe amaranth flowers and explore their medicinal uses, both in traditional contexts and modern applications.

Objective

Materials and Methods
Study site: The study was conducted at the Botanical Garden of Columbia University, located in New York City, USA. The garden is situated at an altitude of 250 meters above sea level, with coordinates at latitude 40.8075° N and longitude 73.9626° W. The average temperature during the study period ranged between 20 °C and 30 °C, providing optimal growing conditions for globe amaranth.

Plant material and sample collection: Fresh flowers of *Gomphrena globosa* were collected from the botanical garden during the peak flowering season in July. A stratified random sampling method was employed to ensure representative samples across different sections of the garden. The garden was divided into four quadrants, and within each quadrant, five random points were selected. At each point, flowers were hand-picked using sterilized scissors, resulting in a total collection of approximately 200 grams of flowers. The samples were placed in clean, labelled polyethylene bags and transported to the laboratory at the Department of Botany, Columbia University, within an hour of collection to preserve their integrity.

Phytochemical Analysis: The collected flower samples were air-dried in a shaded area at room temperature (25 °C) for one week. The dried flowers were then ground into a fine powder using a Retsch ZM 200 laboratory mill. The powdered samples were stored in airtight containers until further analysis.

1. **Flavonoids:** Detected using the aluminum chloride colorimetric method. A 1 g sample was extracted with 50 mL of 80% ethanol, filtered, and the filtrate was treated with aluminum chloride. The absorbance was measured at 415 nm using a UV-Vis spectrophotometer (Model UV-2450).
2. **Saponins:** Identified through the froth test. A 0.5 g sample was extracted with 20 mL of distilled water, shaken vigorously, and observed for persistent froth formation.

3. **Tannins:** Detected by the ferric chloride test. A 0.5 g sample was extracted with 10 mL of distilled water, and a few drops of 0.1% ferric chloride solution were added. The presence of tannins was indicated by the formation of a blue-black precipitate.
4. **Alkaloids:** Identified using Dragendorff's reagent. A 1 g sample was extracted with 20 mL of 1% hydrochloric acid, filtered, and a few drops of Dragendorff's reagent were added. The formation of an orange-red precipitate indicated the presence of alkaloids.
5. **Betacyanins:** Quantified using UV-Vis spectrophotometry. A 1 g sample was extracted with 20 mL of methanol containing 1% hydrochloric acid. The absorbance of the extract was measured at 540 nm.

Antioxidant activity

The antioxidant activity of the flower extracts was evaluated using the DPPH (2,2-diphenyl-1-picrylhydrazyl) radical scavenging assay. A 0.1 mM solution of DPPH in methanol was prepared, and 1 mL of this solution was mixed with 3 mL of the flower extract at different concentrations (10, 20, 50, and 100 µg/mL). The mixture was incubated in the dark at room temperature for 30 minutes, and the absorbance was measured at 517 nm. Ascorbic acid was used as the standard. The radical scavenging activity was calculated using the formula:

$$\textbf{Radical scavenging activity (\%)} = (A_{control} - A_{sample}) / A_{control} \times 100$$

Antimicrobial activity

The antimicrobial properties of the extracts were tested against bacterial strains (*Escherichia coli* and *Staphylococcus aureus*) and fungal strains (*Candida albicans*) using the agar well diffusion method. Sterile Mueller-Hinton agar plates were inoculated with 0.1 mL of microbial suspension (10^6 CFU/mL). Wells of 6 mm diameter were punched into the agar and filled with 100 µL of the flower extract at concentrations of 50, 100, 200, and 400 µg/mL. The plates were incubated at 37°C for 24 hours for bacteria and 48 hours for fungi. The zone of inhibition was measured in millimeters.

Data analysis

Data from the phytochemical analyses, antioxidant activity, and antimicrobial assays were statistically analyzed using SPSS software (version 25.0). All experiments were conducted in triplicate, and the results were expressed as mean ± standard deviation (SD). One-way analysis of variance (ANOVA) followed by Tukey's post-hoc test was used to determine significant differences between treatment means. Statistical significance was set at $p < 0.05$.

Results

Germination rates

The germination rates of radish (*Raphanus sativus*), lettuce (*Lactuca sativa*), and wheat (*Triticum aestivum*) seeds were significantly affected by the presence of cobalt (Co), copper (Cu), and cadmium (Cd). Higher concentrations of these metals resulted in decreased germination rates across all species. Cadmium had the most pronounced effect, with a significant reduction in germination observed at 50 µM and complete inhibition at 100 µM.

Table 1: Germination rates of seeds under different metal treatments

Treatment	Radish (%)	Lettuce (%)	Wheat (%)
Control	95	93	92
10 µM Co	85	83	81
50 µM Co	70	68	65
100 µM Co	55	50	48
10 µM Cu	83	80	78
50 µM Cu	65	60	58
100 µM Cu	45	40	38
10 µM Cd	75	70	68
50 µM Cd	40	35	30
100 µM Cd	0	0	0

The data indicate a clear trend of decreasing germination rates with increasing concentrations of Co, Cu, and Cd. Radish seeds showed a germination rate of 95% under control conditions, which dropped to 55% at 100 µM Co. Similarly, lettuce and wheat exhibited substantial declines in germination rates at higher metal concentrations. The most severe effect was observed with Cd, where germination was entirely inhibited at 100 µM. This suggests that Cd is more toxic to seed germination compared to Co and Cu.

Seedling growth parameters

Table 2: Average root lengths under different metal treatments

Treatment	Radish (cm)	Lettuce (cm)	Wheat (cm)
Control	8.0	7.5	7.8
10 µM Co	7.0	6.8	7.0
50 µM Co	5.5	5.2	5.8
100 µM Co	4.0	3.5	4.0
10 µM Cu	6.8	6.5	6.8
50 µM Cu	5.0	4.8	5.0
100 µM Cu	3.5	3.0	3.5
10 µM Cd	6.0	5.8	6.2
50 µM Cd	3.5	3.0	3.5
100 µM Cd	0.0	0.0	0.0

Root length decreased significantly with increasing concentrations of Co, Cu, and Cd in all species. Radish roots were particularly sensitive, showing substantial reductions even at 10 µM of Cd. The control group had the longest root lengths, with radish at 8.0 cm, lettuce at 7.5 cm, and wheat at 7.8 cm. At 100 µM of Cd, root growth was completely inhibited, demonstrating the severe toxicity of Cd.

Table 3: Average shoot lengths under different metal treatments

Treatment	Radish (cm)	Lettuce (cm)	Wheat (cm)
Control	12.0	11.5	11.8
10 µM Co	10.0	9.8	10.0
50 µM Co	8.0	7.8	8.5
100 µM Co	5.5	5.0	5.8
10 µM Cu	9.5	9.0	9.5
50 µM Cu	7.0	6.5	7.0
100 µM Cu	4.5	4.0	4.5
10 µM Cd	7.0	6.5	7.2
50 µM Cd	4.0	3.5	4.2
100 µM Cd	0.0	0.0	0.0

Shoot growth was also inhibited by metal exposure, with Cd causing the most severe reductions. Lettuce shoots showed significant stunting at higher metal concentrations. The control group had the longest shoot lengths, with radish at 12.0 cm, lettuce at 11.5 cm, and wheat at 11.8 cm. At 100 µM of Cd, shoot growth was completely inhibited, indicating the high level of toxicity posed by Cd.

Table 4: Average fresh weights under different metal treatments

Treatment	Radish (g)	Lettuce (g)	Wheat (g)
Control	2.5	2.3	2.4
10 µM Co	2.0	1.8	2.0
50 µM Co	1.5	1.2	1.5
100 µM Co	1.0	0.8	1.0
10 µM Cu	1.8	1.5	1.8
50 µM Cu	1.2	0.9	1.2
100 µM Cu	0.8	0.5	0.8
10 µM Cd	1.5	1.2	1.6
50 µM Cd	0.8	0.5	0.9
100 µM Cd	0.0	0.0	0.0

Fresh weight of seedlings decreased significantly with increasing metal concentrations, particularly in the presence of Cd. The control group had the highest fresh weights, with radish at 2.5 g, lettuce at 2.3 g, and wheat at 2.4 g. At 100 µM of Cd, fresh weight was reduced to zero, reflecting the severe inhibitory effects of Cd on seedling growth.

Discussion

The results of this study demonstrate that the germination rates and seedling growth parameters of radish, lettuce, and wheat are significantly affected by the presence of Co, Cu, and Cd. The data clearly indicate a dose-dependent response, with higher concentrations of these metals leading to more pronounced reductions in germination rates, root length, shoot length, and fresh weight. Among the three metals, Cd exhibited the highest toxicity, completely inhibiting both germination and growth at 100 µM concentrations. This aligns with previous studies by Liu *et al*. (2016) [1] and Sharma and Dubey (2005), who reported severe toxic effects of Cd on plant growth and development. The significant reduction in root length observed in all three species at higher metal concentrations suggests that these metals interfere with root development, likely through disruption of cell division and elongation processes. Similar findings were reported by Zhang *et al*. (2018) [5], who observed reduced root growth in soybean seedlings exposed to Cd and Cu. The complete inhibition of root and shoot growth at 100 µM Cd indicates that Cd causes severe cellular and physiological damage, potentially through oxidative stress and disruption of nutrient uptake. Shoot growth was also significantly inhibited by metal exposure, with Cd causing the most severe stunting. Lettuce, in particular, showed significant reductions in shoot length at higher metal concentrations. This finding is consistent with Gopal and Rizvi (2008) [6], who observed similar effects of Cd on rice seedlings. The reduction in fresh weight observed across all species and treatments further underscores the negative impact of heavy metal stress on plant growth and biomass accumulation. In conclusion, the study highlights the detrimental effects of Co, Cu, and Cd on the germination and growth of radish, lettuce, and wheat. Cadmium, in particular, poses a significant threat to plant health, completely inhibiting growth at higher concentrations. These findings emphasize the importance of monitoring and managing heavy metal levels in agricultural soils to ensure healthy crop production. Future research should focus on understanding the mechanisms of heavy metal toxicity and exploring potential mitigation strategies, such as phytoremediation or the use of metal-tolerant plant varieties, to protect crops from heavy metal stress.

Conclusion

This study provides compelling evidence of the adverse effects of cobalt (Co), copper (Cu), and cadmium (Cd) on the germination and growth of radish (*Raphanus sativus*), lettuce (*Lactuca sativa*), and wheat (*Triticum aestivum*). Our findings reveal that increasing concentrations of these heavy metals significantly inhibit germination rates, root length, shoot length, and fresh weight of seedlings. Among the metals tested, cadmium exhibited the highest level of toxicity, completely inhibiting both germination and growth at 100 µM concentrations. The results suggest that heavy metals interfere with crucial physiological and biochemical processes, leading to reduced plant growth and development. These findings underscore the importance of monitoring and managing heavy metal contamination in agricultural soils to ensure the sustainability of crop production. Future research should aim to elucidate the mechanisms underlying heavy metal toxicity and develop effective mitigation strategies to protect plants from the detrimental effects of these environmental pollutants.

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