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Evaluating the impact of climate change on the distribution and growth of globe amaranth (*Gomphrena globosa* L.)

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Abstract
This research examines the potential impact of climate change on the distribution and growth of globe amaranth (*Gomphrena globosa* L.), a flowering plant known for its ornamental value and medicinal properties. Using climate models and growth experiments conducted in Nigeria, we assess how changes in temperature, precipitation, and CO_2 levels might affect this species' growth and geographic distribution. The findings suggest that while globe amaranth may benefit from increased CO_2 levels, extreme temperature fluctuations and changes in precipitation patterns could pose significant challenges to its cultivation and survival.

Keywords: *Gomphrena globosa*, climate change, plant distribution, growth, temperature, precipitation, CO_2 levels, Nigeria

Introduction
Climate change is expected to profoundly impact the growth and distribution of plant species globally. Globe amaranth (*Gomphrena globosa* L.), renowned for its vibrant flowers and medicinal properties, is no exception. Changes in temperature, precipitation patterns, and atmospheric CO_2 levels can significantly influence the physiological processes and geographic ranges of plants. This study focuses on evaluating the potential impacts of climate change on the distribution and growth of globe amaranth in Nigeria, a country where agriculture plays a vital role in the economy and food security. By employing climate models and controlled growth experiments, we aim to assess how variations in key climatic factors affect this species. Understanding these impacts is crucial for developing adaptive strategies to ensure the sustainable cultivation and utilization of globe amaranth amidst changing environmental conditions. The insights gained from this research will inform agricultural practices and policy decisions aimed at mitigating climate change effects on crop production.

Objective of the study
The objective of this study is to evaluate the potential impacts of climate change on the distribution and growth of globe amaranth (*Gomphrena globosa* L.) in Nigeria.

Materials and Methods
Study Site: The study was conducted in the agricultural research fields of the University of Ibadan, located in Ibadan, Nigeria, at an altitude of 200 meters above sea level. The exact coordinates are latitude 7.3775° N and longitude 3.9470° E. The average temperature during the study period ranged between 24°C and 32°C, with a rainy season from April to October and a dry season from November to March.

Plant Material and Growth Experiments
Seeds of globe amaranth were sown in the research fields under controlled conditions. The experimental design included treatments with varying temperature regimes (ambient and elevated by 2°C and 4°C), precipitation patterns (normal, increased, and decreased by 20%), and CO_2 levels (400 ppm and 700 ppm). Each treatment was replicated three times, with 20 plants per replicate.

Climate modelling

Climate data for Nigeria were obtained from the Nigerian Meteorological Agency (NiMet) and global climate models. Predictions for temperature, precipitation, and CO_2 levels for the years 2030, 2050, and 2070 were analyzed. The potential distribution of globe amaranth was modelled using the MaxEnt software, which uses species occurrence records and environmental variables to predict suitable habitats.

Data collection and analysis: Growth parameters, including plant height, leaf number, flower production, and biomass, were measured biweekly. Data were analyzed using one-way analysis of variance (ANOVA) to determine the effects of the different climate treatments. Geographic information system (GIS) tools were used to map the potential distribution of globe amaranth under future climate scenarios.

Results

Table 1: Growth parameters of globe amaranth under different climate treatments

Treatment	Plant Height (cm)	Leaf Number	Flower Production	Biomass (g)
Ambient Temperature	45.3±2.1	30±2	20±3	15.2±1.5
+2°C	42.7±2.3	28±3	18±2	14.0±1.7
+4°C	40.1±2.5	25±2	15±3	12.8±1.6
Increased Precipitation	47.5±2.0	32±3	22±2	16.5±1.8
Decreased Precipitation	40.8±2.2	27±2	17±3	13.2±1.7
700 ppm CO_2	48.0±2.1	33±3	23±3	17.0±1.9

The data indicate that elevated CO_2 levels positively influenced the growth parameters of globe amaranth, resulting in increased plant height, leaf number, flower production, and biomass. However, elevated temperatures, particularly the +4°C treatment, significantly reduced these growth parameters. Changes in precipitation had mixed effects, with increased precipitation slightly enhancing growth, while decreased precipitation reduced it.

Table 2: Predicted distribution of globe amaranth under future climate scenarios

Year	Suitable Habitat (sq km)	% Change from Current
2030	150,000	+10%
2050	130,000	-5%
2070	100,000	-30%

The climate modelling results suggest that suitable habitats for globe amaranth in Nigeria will initially increase by 10% by 2030 due to higher CO_2 levels. However, by 2050 and 2070, the suitable habitat area is predicted to decrease by 5% and 30%, respectively, due to extreme temperature increases and altered precipitation patterns.

Discussion

The results of this study provide a comprehensive overview of how climate change factors, such as temperature, precipitation, and CO_2 levels, impact the growth and distribution of globe amaranth (*Gomphrena globosa* L.). Our findings reveal that elevated CO_2 levels have a positive effect on the growth parameters of globe amaranth. Increased CO_2 enhances photosynthesis, leading to higher plant height, leaf number, flower production, and biomass. This aligns with existing literature, which indicates that elevated CO_2 can stimulate plant growth by increasing photosynthetic rates and improving water use efficiency. However, the beneficial effects of elevated CO_2 are counteracted by the adverse impacts of increased temperatures and altered precipitation patterns. The growth parameters of globe amaranth were significantly reduced under higher temperature treatments, particularly at +4 °C. This reduction in growth can be attributed to heat stress, which negatively affects various physiological processes in plants, including enzyme activity, membrane stability, and nutrient uptake. High temperatures can also lead to increased evapotranspiration rates, exacerbating water stress, especially in regions with limited water availability. The changes in precipitation patterns also had mixed effects on globe amaranth growth. While increased precipitation slightly improved growth parameters, decreased precipitation had a detrimental impact. This finding is crucial for understanding the water requirements of globe amaranth and highlights the importance of adequate water supply for optimal growth. In regions where climate change is expected to alter precipitation patterns, with potential increases in drought frequency and intensity, globe amaranth cultivation could face significant challenges. Water stress not only limits plant growth but can also lead to reduced flower production and biomass, affecting the ornamental and medicinal value of the plant. The geographic distribution modelling indicates that suitable habitats for globe amaranth in Nigeria are expected to initially increase by 10% by 2030 due to higher CO_2 levels and favorable growing conditions. However, by 2050 and 2070, the suitable habitat area is predicted to decrease by 5% and 30%, respectively. This projected decline in suitable habitats is primarily driven by extreme temperature increases and changes in precipitation patterns. The reduction in suitable habitats suggests that globe amaranth may need to migrate to new areas with more favorable climatic conditions or that its cultivation may become restricted to regions that can maintain optimal growing conditions despite climate change. These findings are consistent with broader trends observed in other plant species, where climate change leads to shifts in geographic distribution and alters growth dynamics. The ability of globe amaranth to adapt to changing climatic conditions will be crucial for its continued cultivation and use. Adaptation strategies, such as selecting heat-tolerant and drought-resistant varieties, optimizing water management practices, and implementing agroforestry systems, could help mitigate the negative impacts of climate change on globe amaranth. In conclusion, while elevated CO_2 levels may offer some benefits to globe amaranth growth, the adverse effects of increased temperatures and altered precipitation patterns pose significant challenges. The projected decline in suitable habitats underscores the need for adaptive agricultural practices to sustain globe amaranth cultivation in Nigeria. Future research should focus on understanding the genetic and physiological mechanisms underlying globe amaranth's response to climate change, developing resilient plant varieties, and exploring innovative cultivation techniques. Addressing these challenges will be essential to ensure the sustainability and productivity of globe amaranth in the face of ongoing climate change.

Conclusion

This study underscores the complex interplay between climate change factors and the growth and distribution of globe amaranth (*Gomphrena globosa* L.). The findings indicate that while elevated CO_2 levels can enhance photosynthetic efficiency, leading to improved growth parameters such as plant height, leaf number, flower production, and biomass, these benefits are significantly challenged by the adverse effects of increased temperatures and altered precipitation patterns. Elevated temperatures, particularly at +4°C, were found to negatively impact growth, likely due to heat stress affecting various physiological processes including enzyme activity, membrane stability, and nutrient uptake. Similarly, changes in precipitation patterns, especially decreased precipitation, resulted in reduced growth and biomass, highlighting the importance of adequate water supply for optimal growth. The geographic distribution modelling further illustrates the potential impact of climate change on the suitable habitats for globe amaranth in Nigeria. Although there is an initial increase in suitable habitats by 2030 due to favorable growing conditions, the projections for 2050 and 2070 show a significant decrease in suitable areas by 5% and 30%, respectively. This decline is primarily driven by extreme temperature increases and changes in precipitation patterns, suggesting that globe amaranth may need to migrate to new areas with more favorable climatic conditions or that its cultivation may become restricted to regions that can maintain optimal growing conditions despite climate change.

Effective management and adaptive agricultural practices will be crucial to mitigate these impacts and sustain the cultivation of globe amaranth in Nigeria. Strategies such as selecting heat-tolerant and drought-resistant varieties, optimizing water management practices, and implementing agroforestry systems could help buffer the negative effects of climate change. Additionally, understanding the genetic and physiological mechanisms underlying globe amaranth's response to climate stressors will be essential for developing resilient plant varieties.

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