Screening for Drought Tolerance and Nutrient Foraging Ability of Some Local Varieties of Cowpea (Vigna Unguiculata L. Walp)

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DOI: https://doi.org/10.51584/IJRIAS.2025.100600139

Received: 13 June 2025; Accepted: 18 June 2025; Published: 23 July 2025

ABSTRACT

Drought stress is one of the greatest threats to crop productivity, including cowpea (Vigna unguiculata L. Walp) globally. Nutrient foraging is the ability of plants to efficiently explore and exploit the soil environment to acquire essential nutrients for their growth and development. The study was carried out at the Screen-house of the Department of Biological Sciences at Yelwa Campus of Abubakar Tafawa Balewa University; Bauchi State, Nigeria between August-September, 2024. The study was conducted as a complete randomized design into five varieties with three replicates. A regimental watering schedule was employed, with watering every 5 days.

Growth and yield parameters were assessed throughout the crop cycle, from planting to harvest. Weekly measurements of growth parameters included leaf length, plant height, and number of leaves per plant. Following harvest, yield parameters were recorded, encompassing the number of seeds per plant, number of pods per plant, number of seeds per pod, and root morphology study. Also, mass weighing was conducted to determine both dry and wet yield weights. Soil and seed analyses were conducted to determine elemental composition. Soil analysis involved assessing total nitrogen, phosphorus, and heavy metals (potassium, sodium, calcium, copper, manganese, iron, and zinc) using Aqua regia digestion and Atomic Absorption Spectroscopy (AAS) detection. Similarly, seed analyses were performed to evaluate elemental composition, including nitrogen, phosphorus, potassium, sodium, calcium, copper, manganese, iron, and zinc, employing the same Aqua regia digestion and AAS detection methods. In conclusion, the variations in drought tolerance among the selected local cowpea varieties revealed that Yaro da Kokari had high drought potential tolerance. However, nutrient foraging ability remains inconclusive due to the incomplete growth cycle. Based on the findings of this study, the Yaro da Kokari variety is recommended for water-limited regions due to its potential drought tolerance. Similarly, the result of nutrient analysis revealed that the Yar Niger variety is recommended for cultivation in areas with nutrient-poor soils due to its exceptionally high iron (Fe) and manganese (Mn) concentrations. Finally, breeding programs should prioritize selecting cowpea varieties with enhanced micro-nutrient content, such as Yar Niger, to improve nutritional quality.

Keywords; Nutrients, Foraging, Cowpea, Drought Stress

INTRODUCTION

Drought stress is one of the greatest threats to crop productivity, including cowpea (Vigna unguiculata L. Walp) globally (Ajayi, 2022). Understanding the impacts of drought on crop productivity is crucial to ensuring food security in a global context (Leng and Hall, 2019). Drought stress refers to a condition of sustained moisture deficit in soil capable of hindering crop growth and development with a significant reduction in yield (Ajayi et al., 2018; Ajayi, 2022). Drought is one of the main implications of climate change (Santos et al., 2020; Choudhary et al., 2021; Cirillo et al., 2021; Onyemaobi et al., 2021; Shanmugam et al., 2021; Ajayi, 2022). It is significant to agricultural production, with a disastrous effect projected for many plant species worldwide (Tebeje et al., 2017; Cirillo et al., 2021; Wasae, 2021; Ajayi, 2022).

Previous investigations have revealed that under drought stress, there is a reduction in nutrient uptake by the roots partially due to the reduction in soil moisture, which causes a decreased rate of nutrient diffusion from the soil matrix to the absorbing root surface (Hu et al., 2007, Silva et al., 2011). Moreover, under conditions of drought stress, roots are unable to take up many nutrients from the soil due to a lack of root activity as well as slow ion diffusion and water movement rates (Dubey and Pessarakli, 2001; Silva et al., 2011). More so, the mineralization process depends on microorganisms and enzyme activity, which may be affected by drought.

Increases in drought with global climate change will decrease plant growth, thereby decreasing food production in both natural ecosystems and agricultural systems. As plants are the main sources of food for most humans (UN-FAO, 2017; Bista et al., 2018), increases in drought will increase human hunger, and this will be exacerbated by population growth (Millenium Ecosystem Assessment, 2017). In addition, drought, heat stress and high CO_2 all tend to decrease the concentration of most nutrients in plant tissue (including in seeds) (Jablonski et al., 2002; Heckathorn et al., 2014; He and Dijkstra, 2014; Myers et al., 2014).

Globally, more than two billion people already suffer from iron and zinc deficiency (UN-FAO, 2017; Schroder et al., 2013), since most plant tissue has low concentrations of these and many other nutrients, including the cereal grains that provide most of the calories for humanity (UN-FAO, 2017). Hence, the proportion of humanity suffering from malnutrition, which is caused by insufficient quantity or quality of food (especially protein, vitamins and mineral nutrients) (Myers et al., 2014), is likely to increase in the coming decades due to climate change (Bista et al., 2018).

The performance and distribution and well-being of plants species largely depend on their acquisition of water, nutrient foraging and carbon fixation as well as how these aspects are regulated (Silva et al., 2011). Among the different abiotic forms of stress, drought is a major limiting factor regarding crop yields, nutritional composition and productivity around the world (Valliyodan and Nguyen, 2006, Silva et al., 2011, Bista et al., 2018). It negatively impacts also their growth, development, and reproduction (Pereira et al., 2006; Bradford and Hsiao, 1982; Araus et al., 2002; Bista et al., 2018) and the impact of a drought depends on its intensity and duration, as well as on when it occurs during a plant's life cycle (Bradford and Hsiao, 1982; Bista et al., 2018).

Nutrient foraging is the ability of plant to efficiently explore and exploit the soil environment to acquire essential nutrients for their growth and development. Higher plants predominantly absorb mineral nutrients through the roots and uptake is determined by both supply and demand at the root surface (Bederedse et al., 2007; Silva et al., 2011). Nutrient uptake by plants is a very effective process due to the large surface area of the roots and their ability to absorb microelements ions at low concentrations in the soil solution. However, most nutrients are dependent on soil moisture to move through the soil matrix and be taken up by plants (Taiz and Zeiger, 2006; Silva et al., 2011).

Cowpea (Vigna unguiculata (L.) Walp) is one of the most important food legumes in the drier regions of the world where drought is a major production constraint due to low and erratic rainfall (Agbicodo et al., 2009; Sanogo et al., 2023).

Cowpea provides a cheap source of protein, vitamins and carbohydrates to small-scale farmers in Africa (Sariah et al., 2010; Sanogo et al., 2023). The relatively high protein content of cowpea makes it an essential supplement to the diet of many Africans (Bressani, 1985). Cowpea is being cultivated over an area of about 12.5 million hectares with an annual production of more than 3 million tons world over (Singh and Tarawali, 1997). There has been an increasing trend over five decades in the global cowpea cultivation region from 2.41 to 10.68 million ha (FAOSTAT, 2012). Nigeria is the world's largest producer, contributing about 61% and 58% of production in Africa and worldwide, respectively with a yearly production over 2 million tons on 5 million ha of land (FAOSTAT, 2012; Sanogo et al., 2023).

Furthermore, cowpea offers high yield potential even under low input crop production systems in arid and semi-arid agroecologies (Singh et al., 2003; Gerrano et al., 2022). The grain is composed of 15 to 25% protein content, 50 to 60% carbohydrate, and 1% fat (Lambat, 2000; Agbogifi and Egho, 2012; Gerrano et al., 2019). Although grain is the primary focus of cowpea production for human use, leaves, immature pods, and flowers are also consumed in some parts of the world, especially in Africa (Belane and Dakora, 2011; Gerrano et al., 2015). Several studies have investigated the yield potential and nutrient content of cowpea as a grain crop (Lambat, 2000; Agbogifi and Egho, 2012; Gerrano et al., 2019; Gerrano et al., 2015) and as a vegetable crop utilizing the leaves (Belane and Dakora, 2011; Gerrano et al., 2015; Angessa, 2006; Malidadi, 2006; Kabululu et al., 2013; Towett et al., 2003), as well as immature pods (Gerrano et al., 2017; Gerrano et al., 2022).

Drought is a potential major constraint to crop production. It can cause serious damage to plant growth and development at anytime, anywhere. Plants are most prone to damage due to limited water during some of their developmental stages (Bahar and Yildrim, 2010). Cowpea is sensitive to soil moisture stress during the vegetative and reproductive growth stages (Alidu et al., 2013; Mwale et al., 2017). Despite the fact that cowpea is considered to be more drought tolerant than many other crops, its productivity is negatively affected by prolonged droughts and high temperatures (Isma'ila et al., 2016; Hall, 2012; Sanogo et al., 2023) which are currently attributed to the effects of climate change.

Despite the inherent capacity of cowpeas to withstand drought, the erratic pattern of rainfall exposes the crop to drought (Singh and Matsui, 2002) which affects the nutrient foraging thereby leading to poor growth. Therefore, it has become necessary to identify drought-tolerant cowpea varieties with nutrient-foraging ability that will overcome such conditions. Thus, this study was conducted to assess the nutrient-foraging ability of some cowpea varieties under drought stress conditions, which aimed to confirm that cowpea varieties can efficiently forage nutrients under such harsh conditions. Hence overcome the drought effect. However, the main environmental factor that affects the growth of plants in most savanna regions is drought. The study, therefore, sought to identify varieties that can forage nutrients under drought conditions, to improve their growth that can be used for future breeding applications ensuring food security.

MATERIALS AND METHODS

Description of the Study Area

The study was conducted at the Abubakar Tafawa Balewa University Screen-House in Bauchi State, Nigeria, which provides a controlled environment with adequate sunlight and protection from pests and diseases. Bauchi State is located in Northeastern Nigeria, geographically it lies between Latitude 10.31°N and Longitude 10.30°E, covering an area of approximately 45,837 square kilometers, and climatically it falls within the tropical savanna climate zone, characterized by two distinct seasons: a wet season from May to October and a dry season from November to April. The average annual rainfall ranges from 800mm to 1,200mm, while the temperature varies between 18°C and 35°C. The topography is relatively flat with an elevation of approximately 200-1,500 meters above sea level.

Sample Collection

Five cowpea varieties were collected from five different states in Nigeria (Bauchi, Sokoto, Niger, Kaduna, and Jos) based on their adaptability to the local environment and potential for drought tolerance and nutrient efficiency (Dan kamaru, Kanannado Dan Samunaka, Yar Niger, Kannando Mai farin bawo, and Yaro da Kokari).

Experimental Design

The study was conducted as a complete randomized design into five varieties with three replicates. A regimental watering schedule was employed, with watering every 5 days.

Method of Data Collection

Drought Tolerance Assessment

Growth and yield parameters were assessed throughout the crop cycle, from planting to harvest. Weekly measurements of growth parameters included leaf length, plant height and number of leaves per plant. Following

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume X Issue VI June 2025

harvest, yield parameters were recorded, encompassing the number of seeds per plant, number of pods per plant, number of seeds per pod and root morphology study. Also, mass weighing was conducted to determine both dry and wet yield weights.

Nutrient Analysis

Soil and seed analyses were conducted to determine elemental composition. Soil analysis involved assessing total nitrogen, phosphorus, and heavy metals (potassium, sodium, calcium, copper, manganese, iron, and zinc) using Aqua-regia digestion and Atomic Absorption Spectroscopy (AAS) detection (Burt et al., 2014). Similarly, pre- and post-planting seed analyses were performed to evaluate elemental composition, including nitrogen, phosphorus, potassium, sodium, calcium, copper, manganese, iron, and zinc, employing the same Aqua-regia digestion and AAS detection methods (Burt et al., 2014).

Method of Data Analysis

Data analysis was conducted using IBM SPSS Statistics. Means and standard errors were calculated, and significant differences between treatments were determined using ANOVA followed by Duncan's Multiple Range Test ($p< 0.05$).

RESULTS AND DISCUSSION

Growth parameters of five local cowpea varieties under drought conditions

The growth parameters of five local cowpea varieties were evaluated under drought conditions to assess their tolerance and adaptability and nutrient foraging ability. The table 1 below shows the means of plant height (cm), leaves number, and leaf length (cm) for each variety, with their standard errors.

The growth parameters of the five local cowpea varieties under drought conditions revealed significant variations. This finding aligns with previous research indicating genetic variation in cowpea growth parameters under drought stress (Kumar et al., 2010). Notably, the Yaro da Kokari variety demonstrated superior growth, with the tallest plants and longest leaves, suggesting potential drought tolerance (Singh et al., 2016; Boukar et al., 2018). Research has shown that drought-tolerant cowpea varieties often exhibit enhanced water-use efficiency and deep root growth (Singh et al., 2016). This may be the case for the Yaro da Kokari variety, which could possess adaptive traits enabling it to perform well under water stress conditions. Conversely, the Dan kamaru and Kanannado mai farin bawo varieties exhibited shorter stature and fewer leaves, indicating adaptation to drought conditions through reduced growth and water conservation (Hall et al., 2017). The significant differences among varieties in leaves number and leaf length underscore the need for selective breeding programs to enhance drought tolerance and yield. By identifying and utilizing drought-tolerant varieties like Yaro da Kokari, farmers can improve cowpea productivity in water-limited regions (Singh et al., 2016; Boukar et al., 2018).

Table 1: Growth parameters of five local Cowpea varieties under drought conditions.

Varieties	Plant Height (cm)	Parameters Leaf Number	Leaf Length (cm)
Dan kamaru	$7.56±1.57^{a}$	$7±0.60^{b}$	$6.17±0.44^{b}$
Kanannado Dan Samunaka	$23.83±1.75^{bc}$	$3±0.72^{a}$	$2.55±0.58^{a}$
Yar Niger	$20.35±2.39^{b}$	$6±0.77^{b}$	$6.29±0.71^{b}$
Kanannado Mai Farin Bawo	$12.85±2.29^{a}$	$4±0.64^{a}$	$3.44±0.57^{a}$
Yaro da Kokari	$26.26±1.38^{c}$	$7±0.47^{b}$	$6.84±0.30^{b}$

Note: Means in the same column with different superscripts are significantly difference ($p< 0.05$).

Nutrient composition of five local Cowpea varieties and the planting soil (mg/L).

The results in table 2 provide a comparative overview of the nutrient profiles of the cowpea varieties and the planting soil, serving as a basis for understanding the nutrient requirements and potential limitations for cowpea growth. The nutrient composition of five local cowpea varieties (Dan kamaru, Kanannado Dan Samunaka, Yar Niger, Kanannado Mai farin Bawo, and Yaro da Kokari) and the planting soil was analyzed using Aqua-regia digestion and Atomic Absorption Spectroscopy (AAS) detection method. The concentrations of potassium (K), sodium (Na), calcium (Ca), copper (Cu), manganese (Mn), iron (Fe), and zinc (Zn) are presented in milligrams per liter (mg/L).

The nutrient analysis revealed significant variations in nutrient composition among the five local cowpea varieties. This supports Boukar et al., (2018) assertion that cowpea varieties exhibit diverse nutritional profiles. The variations in nutrient content among varieties highlight the importance of varietal selection for optimal nutrient uptake. Notably, the Yar Niger variety demonstrated exceptionally high iron (Fe) and manganese (Mn) concentrations. This is consistent with Adebowale et al., (2011) finding that cowpea varieties with enhanced micronutrient content can improve nutritional quality and tolerance to nutrient deficiencies. The disparities between soil and cowpea variety nutrient concentrations suggest potential nutrient deficiencies or imbalances, consistent with Kumar et al. (2020) findings on soil nutrient depletion impacting cowpea growth. Considering the high Fe and Mn levels in the Niger variety, and the potential for soil nutrient depletion (Kumar et al., 2020), integrated soil fertility management (ISFM) practices may be necessary to optimize cowpea yield and quality. The variations in nutrient composition among cowpea varieties may influence cowpea growth and development, supporting Hall et al. (2017) findings on soil degradation and cowpea production.

Therefore, understanding nutrient composition in cowpea varieties is crucial for enhancing nutritional quality and yield.

Table 2: Nutrient composition of five local Cowpea varieties and the planting soil (mg/L).

Elements	**Concentrations (mg/L)**					
	Dan kamaru	**Kanannado Dan Samunaka**	**Yar Niger**	**Kanannado Mai Farin Bawo**	**Yaro da kokari**	**Soil**
Potassium (K)	0.020	0.127	0.074	0.099	0.002	0.040
Sodium (Na)	0.002	0.105	0.019	0.018	0.031	0.046
Calcium (Ca)	0.451	0.333	1.106	1.048	0.665	0.228
Cupper (Cu)	0.471	0.313	0.427	0.331	0.484	0.094
Manganese (Mn)	0.220	0.365	0.417	0.398	0.119	3.578
Iron (Fe)	0.599	0. 548	4.668	0.576	0.497	4.792
Zinc (Zn)	0.153	0.202	0.293	0.239	0.062	0.303

CONCLUSION AND RECOMMENDATIONS

This study on variations in drought tolerance among the selected local cowpea varieties revealed that the Yaro da Kokari showed a high drought potential tolerance. However, the results on nutrient foraging ability remain inconclusive due to the incomplete growth cycle. Based on the findings of this study, the Yaro da Kokari variety is recommended for water-limited regions due to its potential drought tolerance. Similarly, based on the findings of the pre-planting nutrient analysis, the Yar Niger variety is recommended for cultivation in areas with nutrient-poor soils due to its exceptionally high iron (Fe) and manganese (Mn) concentrations. Moreover, breeding programs should prioritize selecting cowpea varieties with enhanced micro-nutrient content, such as Yar Niger, to improve nutritional quality, farmers in drought-prone areas should consider planting Yaro da Kokari or other drought-tolerant varieties to enhance productivity, **t**o address soil nutrient depletion, implement integrated soil fertility management (ISFM) practices, conduct further research on nutrient composition and drought tolerance in cowpea varieties to inform breeding programs and agricultural practices, develop selective breeding programs to enhance micro-nutrient content and drought tolerance in cowpea varieties and promote sustainable agricultural practices to mitigate soil degradation and improve cowpea productivity.

ACKNOWLEDGMENT

The authors are grateful to Abubakar Tafawa Balewa University, Bauchi for granting the Institutional Base Research (IBR) supported by TETFUND and also grateful to the Department of Biological Sciences for providing us with the work space and technical support.

Conflict of interest

The authors declared no conflict of interest.

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