CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the study

Climate anomalies such as biotic and abiotic stresses due to global warming adversely affects the yield and growth of agricultural crops (Atkinson, 2013). Different abiotic stress conditions such as heat, cold, salinity and drought indirectly affect the crop plants by favoring the spread of insects, pathogens and weeds (McDonald, 2009). These stresses also directly affect the crop plants by decreasing photosynthesis and whole plant growth, stomatal closure and wilting (Sanchez et al., 2002). Additionally, abiotic stresses such as drought boost the weeds competition with crops as numerous weedy plants show enhanced water use efficiency than crop plants (Valerio et al., 2013).

Among these abiotic stresses, drought stress is one of the most damaging factors that causes significant loss of crop yield (Amelework et al., 2015). Drought is the most edaphic stress that damages cellular homeostasis and hinders the plant growth (Dai, 2015). Water demand for irrigation is continuously increasing while there was a drastic reduction in the availability of water, this condition is more critical in semi-arid and arid conditions (Rostamza et al., 2011).

Drought is the state of water shortage due to abnormal rainfall for a prolonged period of time. Agriculture drought is the lack of sufficient moisture essential for normal crop growth and development to complete life cycle. In general, drought stress at any growth stage showed detrimental and negative effects on development and growth of crop, depending upon the crop growth stage and severity of drought stress. Drought affects the biochemical, morphological and physiological processes in crop plants. Significant consequences of drought on crop include a reduction in cell expansion and division rate, impaired germination, reduction in leaf size, disturbed stomata oscillation, decreased chlorophyll contents. The Earth is a water-scarce planet; feeding more people by using less water is the major goal (Foley et al., 2011). To cop this drought challenge, crops having high adaptability in drier regions should be used. Among these, sorghum is one of the best choices grown for feed, food, fuel and fiber (Qadir et al., 2015).

Sorghum (Sorghum bicolor L. Moench), a cereal grain, has its origins in Africa, is the fourth most important cereal crop after wheat (Triticum aestivum L.), rice (Oryza sativa L.), and maize (Zea mays L.) and is now grown throughout the semiarid regions of the world. Archeological evidence suggests that hunter-gatherers consumed sorghum as early as 8000 BC (Smith and Frederiksen, 2000). Sorghum is believed to have been domesticated in Ethiopia and surrounding countries, commencing around 4000 – 3000 BC. Numerous varieties of sorghum were developed through the practice of selection, whereby selection for more than one level of a particular character within a population occurs (Doggett, 1970).

The genus Sorghum is very diverse and all cultivated sorghums belong to Sorghum bicolor ssp. bicolor which is divided, based on morphology, into five races (bicolor, caudatum, guinea, durra, and kafir), along with the ten intermediate races resulting from all possible interracial crosses (Harlan, 1972). The race bicolor is found nearly everywhere sorghum 2 is grown and is characterized by very loose, open panicles similar to wild sorghum. Caudatum race originated mostly from the region around Lake Chad to the Ethiopian border. The guinea race has its origins in West Africa and India and is grown in areas with higher rainfall. The Kafir race is primarily from southern Africa. Durra race has its origins around the edges of the Sahara and in India.

Sorghum is grown predominantly in low-rainfall, arid to semi-arid environments. Drought is perhaps the most important abiotic stress limiting crop productivity around the world and is certainly of great significance in the semi-arid tropics, where rainfall is generally low and its distribution is erratic. There are two forms of drought stress that have been identified in sorghum: pre-anthesis drought stress where plants experience moisture stress during panicle differentiation prior to flowering; and post-anthesis drought stress when moisture stress occurs during the grain filling stage (Rosenow and Clark, 1995).

The identification of varieties and lines with naturally high levels of pre-anthesis drought tolerance and the selection of these lines for higher yields has resulted in sorghum varieties with stable and high yields (Ellis et al., 1997). Post-anthesis drought stress can result in significant yield reduction. There are genotypes that show some post-flowering drought tolerance, a characteristic often referred to as stay-green. These genotypes maintain green leaf area and hence photosynthetic capability and/or improved translocation of carbohydrates under late season moisture stress, and produce higher grain yields compared with senescent genotypes (Borrell and Douglas, 1997; Borrell et al., 1999).

1.2 importance of sorghum in Agriculture

According to the 2007 United States Grains Council (Building Global Markets for America‟s Grains), grain sorghum is the third most important cereal crop in the US. Due to its adaptation to a wide variety of environmental conditions, sorghum has continued to be a major crop in Kansas. The state produces about 40% of the total sorghum grown in the nation and in 2005 production was 4.95 million metric tons out of the national production of 7.72 million metric tons. Even though grain sorghum is mainly produced as grain for the livestock industry, there is an expansion of its market to ethanol production and human consumption. The fact that grain sorghum is gluten free has resulted in research aimed at including it in diets for people who have gluten intolerance or celiac disease.

Sorghum (Sorghum bicolor) is a significant cereal crop globally, especially valued for its ability to withstand drought, making it essential for food and fodder in arid and semi-arid regions. Ranking as the fifth most important cereal worldwide, it supports food security and economic stability for millions of people, particularly in Africa and Asia (Taylor et al., 2006). Sorghum's resilience enables it to thrive in conditions where other staple crops may struggle, making it a reliable agricultural resource in challenging environments (Doggett, 1988). Its ability to grow in low-fertility soils and with limited water access also makes sorghum a favored crop in regions susceptible to climate variability and water scarcity.

Nutritionally, sorghum is rich in carbohydrates, protein, and essential minerals, providing a highly nutritious food source for populations in drought-prone areas (Dicko et al., 2006). Unlike some other staple grains, sorghum is gluten-free, making it suitable for individuals with gluten sensitivities, which has contributed to its popularity as a health food in recent years (Ratnavathi et al., 2016). Sorghum's high fiber content and low glycemic index also make it beneficial for managing blood sugar levels, adding to its appeal as a staple food in both traditional and modern diets (Subramanian & Jambunathan, 1982).

Beyond human nutrition, sorghum is a vital source of feed in the livestock industry, providing a cost-effective alternative to maize, especially in regions with limited resources. The crop's stalks, leaves, and grains are widely used as animal fodder, supporting the livestock sector, which is an integral part of rural economies (Reddy et al., 2012). Additionally, sorghum's versatility extends to industrial uses, with varieties like sweet sorghum increasingly cultivated for biofuel production. This dual-purpose approach allows sorghum to contribute to renewable energy initiatives, further enhancing its economic importance and sustainability potential (Wu et al., 2010).

The adaptability and versatility of sorghum have also made it a focal point in breeding programs aimed at enhancing drought tolerance and disease resistance in crops. By identifying and cultivating varieties of sorghum with high resilience, agricultural researchers and farmers can improve yield stability and reduce crop losses, ensuring a steady food supply in the face of climate change (Blum, 2005). Such breeding efforts not only improve the crop's productivity but also contribute to sustainable agriculture by promoting crop diversity and reducing reliance on water-intensive crops.

1.3 Problem Statement

In regions prone to drought, crop yield and food security are significantly threatened by water scarcity. Sorghum, a drought-tolerant cereal crop, presents a viable solution for sustaining agriculture in such environments. However, not all sorghum varieties perform equally under drought stress, and the quality of sorghum seeds, essential for successful crop establishment is directly influenced by biochemical changes due to stress. Currently, there is limited information on the specific biochemical characteristics that influence seed quality across different sorghum varieties under drought conditions. Without clear insights into these characteristics, identifying and cultivating the most drought-resistant varieties remains challenging for farmers and breeders. This study, therefore, aims to investigate and characterize the biochemical markers of seed quality in various sorghum varieties under drought stress, with the goal of identifying those with the greatest resilience and potential for cultivation in drought-affected areas.

1.4 Objectives of the study

1. To Assess and compare key biochemical parameters, such as protein, carbohydrate, and lipid content, in different varieties of sorghum seeds subjected to drought stress.

2. To Analyze Antioxidant Activity: Measure the antioxidant activity and enzymatic responses of sorghum seeds under drought conditions to determine their role in mitigating oxidative stress.

3. To Identify Biochemical Markers for Seed Quality: Identify specific biochemical markers that correlate with seed quality and viability in sorghum varieties under drought stress.

4. To Compare Drought Resistance: Compare the drought resistance of various sorghum varieties based on their biochemical composition and physiological responses to water deficit.

5. To Provide Recommendations for Breeding Programs: Offer insights and recommendations for breeding programs aimed at developing drought-resistant sorghum varieties by identifying promising candidates based on their biochemical profiles.

1.5 Significance of the study

1. **Enhancing Food Security:** By identifying drought-resistant sorghum varieties with superior seed quality, the research contributes to improving crop yields in arid and semi-arid regions. This is crucial for ensuring food security, particularly in developing countries where sorghum serves as a staple food.

2. **Supporting Sustainable Agriculture:** Understanding the biochemical characteristics that confer drought resistance will aid in promoting sustainable agricultural practices. This research will support the development of crop varieties that require less water and are more resilient to changing climate conditions, thereby reducing the reliance on water resources.

3. **Guiding Breeding Programs:** The identification of specific biochemical markers associated with seed quality under drought stress will provide valuable insights for plant breeders. This information can be utilized to develop targeted breeding programs aimed at enhancing drought tolerance in sorghum, leading to the cultivation of varieties that can thrive in challenging environments.

4. **Contributing to Climate Adaptation Strategies:** As climate change leads to increased frequency and severity of droughts, this study contributes to broader climate adaptation strategies. By enhancing the resilience of sorghum—a vital crop in many regions—this research helps mitigate the impacts of climate variability on agriculture.

5. **Informing Policy and Agricultural Practices:** The findings from this study can inform agricultural policies and practices aimed at improving crop management under drought conditions. Policymakers can utilize the research outcomes to support initiatives that promote the cultivation of drought-resistant crops, thereby enhancing rural livelihoods and economic stability.

6. **Encouraging Research and Development:** Finally, this study lays the groundwork for further research into other stress factors affecting sorghum and similar crops. It emphasizes the importance of biochemical characterization in understanding plant responses to environmental challenges, fostering ongoing innovation in agricultural science.

1.6 Scope and limitation of the study

1. Geographical Focus: The study will focus on selected sorghum varieties cultivated in regions that experience significant drought stress, ensuring the relevance of the findings to areas most affected by water scarcity.

2. Variety Selection: A specific number of sorghum varieties will be chosen for analysis based on their known performance in drought conditions. This selection aims to provide a comparative understanding of the biochemical characteristics that influence seed quality across diverse genetic backgrounds.

3. Biochemical Analysis: The research will focus on several key biochemical parameters, including protein, carbohydrate, lipid content, antioxidant activity, and enzyme responses, to comprehensively assess seed quality and stress resilience.

4. Experimental Conditions: Controlled experiments will be conducted to simulate drought stress in a laboratory or greenhouse setting. This approach allows for a standardized evaluation of the sorghum varieties under controlled drought conditions, isolating the effects of water deficit on seed quality.

5. Data Analysis: The study will utilize various statistical methods to analyze the data collected from biochemical assays, enabling a robust comparison of the results across different sorghum varieties.

Limitations of the Study

1. Environmental Variability: Although the study aims to control experimental conditions, inherent variability in environmental factors (such as temperature and humidity) may affect the biochemical responses of sorghum seeds, potentially limiting the generalizability of the findings.

2. Number of Varieties: The study may be constrained by the number of sorghum varieties included in the analysis. While a diverse selection will provide valuable insights, it may not encompass all available varieties, potentially limiting the breadth of conclusions drawn.

3. Laboratory Conditions: Conducting the study in a controlled environment may not fully replicate field conditions where multiple stress factors (e.g., soil type, pests, and diseases) can interact with drought stress. Therefore, the findings may need validation under real-world agricultural scenarios.

4. Focus on Biochemical Parameters: While the biochemical characterization is crucial, other factors influencing seed quality, such as physical traits (germination rate, seed size) and genetic factors, may not be addressed in detail, which could provide a more comprehensive understanding of overall seed performance.5. Duration of Drought Stress: The duration and intensity of drought stress applied in the experiments may not reflect the variability of drought conditions

experienced in different geographical regions, which could impact the applicability of the results to real-world farming situations.

1.7 Research Question

1. What are the key biochemical parameters that influence seed quality in different varieties of sorghum when subjected to drought stress?

2. How do antioxidant activities vary among various sorghum varieties under conditions of drought stress, and what implications do these variations have on seed viability?

3. What specific biochemical markers correlate with improved seed quality in sorghum varieties when exposed to drought conditions?

4. How does the drought tolerance of different sorghum varieties manifest at the biochemical level, and what are the physiological consequences for seed development and germination?

5. What differences exist in the biochemical composition (e.g., protein, carbohydrate, lipid content) of sorghum seeds between drought-resistant and drought-sensitive varieties?

6. How does the duration and intensity of drought stress impact the biochemical responses of sorghum seeds, and which varieties demonstrate the most resilience?

7. What are the implications of biochemical characterization findings for breeding programs aimed at developing drought-resistant sorghum varieties?

1.8 Keywords

1. Sorghum: A cereal crop (Sorghum bicolor) widely cultivated for food, fodder, and biofuel.

2. **Drought Stress:** A condition that occurs when water availability is insufficient for optimal plant growth and development.

3. **Biochemical Characterization:** The process of analyzing the chemical compounds and biochemical processes within plants.

4. **Seed Quality**: Refers to the characteristics that determine the potential for germination, growth, and yield of a seed.

5. **Drought Resistance**: The ability of a plant to survive and thrive in conditions of low water availability.

6. **Antioxidant Activity**: The capacity of compounds within the plant to counteract oxidative stress caused by drought conditions.

7. **Physiological Responses:** The changes in plant behavior and processes in reaction to environmental stressors such as drought.

8. **Biochemical Markers:** Specific compounds or metabolites that indicate the physiological state of the plant, particularly under stress.

9. **Protein Content**: The amount of protein present in sorghum seeds, which is essential for the nutritional quality of the crop.

10. **Carbohydrate Content**: Refers to the sugars and starches present in sorghum seeds, which serve as energy sources for germination and growth.

11. **Lipid Content:** The amount of fats and oils in sorghum seeds, which can affect seed energy reserves and quality.

12. **Seed Viability**: The ability of seeds to germinate and grow into healthy plants.

13. **Environmental Stress:** Refers to the adverse conditions that affect plant growth, such as drought, salinity, and temperature extremes.

14. **Crop Resilience**: The capacity of crops to recover from or withstand environmental stresses while maintaining productivity.

15. **Agricultural Sustainability**: Practices that promote long-term agricultural productivity without degrading the environment.