BINDURA UNIVERSITY OF SCIENCE EDUCATION
FACULTY OF AGRICULTURE AND ENVIRONMENTAL SCIENCES

DEPARTMENT OF CROP SCIENCE

THE EFFECTS OF DROUGHT ON EARLY GROWTH AND DRY MATTER ACCUMULATION OF VARIOUS FINGER MILLET (*Eleusine coracana)* CULTIVARS.

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A dissertation submitted to the Bindura University of Science Education in partial fulfilment of the requirement for the award of Bachelor of Agricultural Science Honors' Degree in Crop Science

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ABSTRACT

Finger millet (Eleusine coracana) is a C4 crop that originated in the tropics and has thrived in harsh environments. Its drought tolerance and diverse applications have increased its production. However, finger millet is susceptible to drought during early growth stages, thus necessitating an assessment of its physiological and metabolic tolerance to drought and high temperatures. In this study, the drought resistance of three finger millet cultivars, FMV1, FMV2, and FMV3, was evaluated using a pot experiment with different water levels (600mm, 450mm, 300mm, and 150mm). The experiment was designed using a randomized complete block design (RCBD), and changes in plant height, biomass accumulation, and chlorophyll content were measured at various water levels. The results showed that FMV1 was more drought-resistant than the other two cultivars, and drought levels significantly impacted biomass accumulation (p = 0.001). FMV3 had reduced biomass accumulation, while FMV2 had decreased chlorophyll accumulation under drought conditions. FMV1 performed relatively better than the other cultivars under drought conditions. Therefore, farmers in drought-prone areas are encouraged to use FMV1 to promote growth and ultimately survival of the crop.

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I Muchemwa Persistence S, registration B1954033 declare that this research project is my own work and has not been raised or copied from any source without acknowledgement of source.

DEDICATION

Firstly, I thank the Almighty for revealing me with better ideas and power. This research project is a dedication to my family, I am grateful for all the motivations you raised towards me and for the financial support you rendered during my studies.

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LIST OF ABBREVIATIONS AND ACRONYMS

ANOVA	Analysis of Variance
ºC	Degrees Celsius
Ml	Millilitres
CB	Crop Biomass
CRBD	Completely Randomised Block Design

CHAPTER 1 : INTRODUCTION

1.1 BACKGROUND OF THE STUDY

Finger millet (Eleusine coracana) is an annual herbaceous plant that is commonly farmed as a cereal crop in Africa and Asia's dry and semi-arid regions. Finger millet is a very nutritious grain that is important in both human and animal diets. It is utilized for food, feed, thatching, and weaving. When compared to other minor millets, pseudo-cereals, and cereal grains, finger millet has a high nutritious content. Finger millet is rich in calcium, protein, dietary fiber, carbs, minerals, phytates (0.48%), tannins (0.61%), phenolic compounds (0.3-3%), and trypsin inhibitory factors (Devi, 2014).

It has been shown that finger millet is a subsistence crop, and as a food crop, it can lower instances of food insecurity. It also plays an essential part in the economy of subsistence farmers, since many farmers' livelihoods have altered as a result of cultivation of this crop (Verma and Patel, 2013). Millet has the ability to alleviate chronic food insecurity in semi-arid places due to drought, according to global study (Esilaba, A.O.et al., 2021).

Finger millet is subsistence crop that, when grown as a food crop, can help to minimize food insecurity (Verma and Patel, 2013). It is a drought-tolerant crop, which fits well into farmers' risk-aversion techniques in drought-prone areas.

According to some researchers (Gyawali et al., 2007; Mekbib, 2006), involving farmers in the breeding of crop varieties is essential to ensure local adaptation and preference in low-resource settings. In Ethiopia, finger millet yields are low due to several production problems, including a shortage of improved varieties, insufficient research focus on the crop, poor adoption of improved technologies, negative attitudes towards the crop, as well as diseases such as blast, lodging, moisture stress in dry areas, and threshing and milling difficulties (Tsehaye and Kebebew, 2002; Degu et al., 2009). The frequency of seasonal and inter-seasonal droughts caused by climate change is exacerbating the challenges in the agricultural sector (Bang and Sitango, 2003).

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It has been documented that average precipitation patterns have shifted, resulting in seasonal droughts IPCC (2013).

Studies have demonstrated that drought stress can hinder several aspects of plant physiology, such as cell division and expansion, nutrient absorption and transport, phyto-hormone metabolism and signaling, and overall metabolism (Soroushi et al., 2011). The severity of drought stress can significantly affect plant growth, as noted in studies by Galmes et al. (2007) and Kim et al. (2012).

To develop stress-tolerant plants, different approaches have been tested, including traditional genetic techniques and improved plant breeding methods. One such approach involves selecting genotypes or varieties that exhibit improved early growth stages and mechanisms to enhance yield in dry environments, as recommended by Ghannoum (2009), to improve plant resistance and crop performance in water-limited conditions.

It has been experimented that due to drought stress finger millet is facing challenges so on this research there is a task to prove if we have the best finger millet variety which can withstand during drought stress. Hasegawa *et al*., (2007).

The country is experiencing several seasonal shifts. Drought, which is the result of a combination of stress effects induced by high temperatures and a lack of water, is creating early season moisture stress in finger millet production, limiting plant developmental potential as some seeds die. Unpredictable rainfall and dryness have significantly decreased seedling stand, causing seeds to wilt at an early stage, lowering plant population, and leading in plant mortality, resulting in production loss.

It is critical to screen for drought-tolerant finger millet cultivars that will withstand the early season droughts. All plants are not equally capable of withstanding water stress, and their responses to stress differ as well. Even in highly tolerant plant species, tolerance is achieved by changes in the molecular and physiological pathways that allow plants to adjust morphologically to water deficiencies. Ghannoum, Ghannoum.

1.2 PROBLEM STATEMENT

The country is seeing a number of seasonal shifts. Drought, which is the result of a combination of stress effects induced by high temperatures and a lack of water, is creating early season moisture stress in finger millet production, limiting plant developmental potential as some seeds die. Unpredictable rainfall and dryness have significantly impacted germination and seedling stand, causing seeds to wilt at an early stage, limiting plant population. Plants die as a result of the interaction, resulting in yield loss.

1.3 JUSTIFICATION

This research is crucial as it will show the best variety of finger millet which can give better results and it is critical to screen for drought-tolerant finger millet cultivars that will be able to tolerate these early season droughts .In order to increase finger millet yield during climatic change disorders being encountered there should be a strong variety which can withstand during drought period on its early stage and have better yield results.

1.4 OBJECTIVES

1.4.1 Main objective

To determine the effects of drought on early growth and dry matter accumulation of three various finger millet cultivars.

1.4.2 Specific objectives

1. To evaluate the effects of drought stress on plant height, biomass and accumulation of chlorophyll on three different finger millet varieties.
2. To assess the variety which is tolerant to drought at early stage of development.

1.5 HYPOTHESIS

Drought had no influence on plant height, crop biomass, or chlorophyll accumulation in three distinct finger millet cultivars at an early stage of development. At this early stage of growth, drought level and variety have little influence on dry matter partitioning.

CHAPTER 2: LITERATURE REVIEW

2. 1 Origin and Domestication of finger millet

E. coracana, the cultivated form of finger millet, is a tetraploid that bears a morphological resemblance to both E. indica and E. africana. It is believed that E. coracana evolved from E. indica, which is widely distributed from Africa to Java. Cytological evidence suggests that one of the genomes of the allotetraploid E. coracana was derived from E. indica. E. coracana and E. africana share many morphological features, indicating that the former may have evolved from the latter through selection and further mutation towards larger grains. Finger millet has been found in archaeological sites in Ethiopia dating back to the third millennium BC (Hillu et al., 1979). Two distinct races of finger millet are known: the African highlands race and the Afro-asiatic lowland race (Channaveeraiah MS and SC Hiremath, 1974; Hillu and de Wet, 1976).

According to research, the African highlands race of finger millet is believed to have originated from E. africana under cultivation. This race gave rise to the African lowland race, which eventually migrated to India and evolved into the Afro-Asiatic lowland race. Finger millet is thought to have arrived in the Indian subcontinent around 3000 BC. Studies comparing the diversity of African and Asian finger millet varieties have shown that African germplasm has a higher diversity than the collections from India, supporting the hypothesis that Africa is the primary origin of finger millet. Over time, the history of agriculture in the Indian subcontinent, combined with human selection, has led to the development of a wide range of landraces and local cultivars. These findings have been reported by Purseglove (1976) and Mehra (1962).

2.2 Importance of the crop

Finger millet is a versatile grain with several applications in both human nutrition and animal feed. Many communities in East and Southern Africa grind the little grains into flour and use it to make porridge. The flour may also be used to make bread and other baked goods. Finger millet sprouted seeds, also known as malt, are often manufactured as a meal in a few regions, and are especially suggested for newborns and the elderly due to their nutritional value and ease of digestion. Much of Africa's finger millet malt is used to manufacture traditional beer. When burst, finger millet grains are commonly consumed in a delicious form, particularly in India. Finger millet straw is superior to pearl millet, wheat, or sorghum fodder and is estimated to provide up to 61 percent total digestible nutrients (National Research Council, 1996).

2.3 Nutritional value of finger millet

The finger millet kernel comprises three main components, namely the seed coat (testa), embryo, and endosperm. While there are several varieties of finger millets available, including yellow, white, red, brown, or violet-colored, the red-colored variety is the most commonly cultivated worldwide. What makes finger millet unique compared to other millets, such as foxtail millet, pearl millet, kodo millet, and proso millet, is the presence of a five-layered testa (Chethan, 2007).

The existence of a five-layered testa, which is rich in micronutrients, might explain the increased dietary fiber content in finger millet. Finger millet contains a variety of critical elements, including calcium, carbohydrates, minerals, and fiber. The testa, endosperm, and embryo are the three primary sections of the finger millet kernel. Millet is typically ground with the seed coat to make flour, which is used in culinary preparation. The presence of tannins in the testa, on the other hand, might lead to astringency in the final product.

The carbohydrate content of finger millet is 81.5%, the crude fiber content is 4.3%, the mineral content is 2.7%, and the protein level is 9.8%. When compared to grains such as maize and wheat, finger millet has a greater crude fiber and mineral content. Finger millet has a well-balanced protein profile, with greater levels of lysine, valine, and threonine than other millets. Calcium (220mg-450mgs) and iron (3-20%) are also abundant in finger millet. It provides amino acids that other starchy meals lack, such as isoleucine (4.3 g), methionine (3.1 g), leucine (10.8 g), and phenylalanine (6.0 g). Millets include vitamin B and B6, as well as calcium, potassium, iron, magnesium, and zinc (National Nutrition and Food Commission, 2009).

2.4 Health-related benefits

Finger millet has significant quantities of polyphenols and dietary fiber, making it a potentially beneficial meal for lowering the risk of Diabetes Mellitus. Finger millet is very high in dietary fiber, which slows digestion and helps to manage blood sugar levels. This fiber level is far higher than that of rice and wheat. Furthermore, finger millet has a low glycemic index, which aids in keeping blood sugar levels within a healthy range. Finger millet is also high in iron, making it ideal for people who have low hemoglobin levels or a restricted supply of red blood cells. Patients who are anemic have low levels of red blood cells. Sprouting increases vitamin C levels, allowing iron (Fe) to enter the circulation more easily. Millet is naturally gluten-free, making it an excellent alternative for celiac disease sufferers who are continually irritated by the gluten content of other cereal grains. It is also useful for those with diabetic heart disease and atherosclerosis (Gélinas et al., 2008).

2.5 Drought as a major challenge to millet cultivation

Drought is a phenomenon defined by a brief decrease in the availability of moisture, during which the amount of water available is much lower than normal for a set period of time. Drought is categorized as meteorological, hydrological, or agricultural based on its influence on various industries. Drought is typically defined as a lack or absence of rainfall, which can result in losses for rain-fed agriculture (Bhatt, 2011).

When plants are subjected to progressively severe drought stress, their capacity to adapt may be compromised, resulting in major plant responses such as stomatal closure and considerable reductions in photosynthesis. According to research, these decreases in metabolism are followed with a fall in growth rate, which is thought to be a survival mechanism in reaction to the severity of the stress. This phenomena has been reported in a variety of plant species, and research by Kakumanu et al. (2012), Watkinson et al. (2003), Gong et al. (2010), Huang et al. (2008), and Li et al. (2012) supports it.

2.6 Impact of climate change on finger millet

Climate change may have a direct impact on finger millet output all around the world. Crop output can be reduced owing to a rise in the mean seasonal temperature, which reduces crop duration. (IPCC, 2007), warming will have an immediate impact on agricultural output in locations where temperatures are already close to physiological maxima. Global warming is also expected to reduce agricultural production by between 3 and 16%. (IPCC, 2007)

Finger millet production levels continue to be limited by environmental factors such as increasing temperatures and drought, which have been a challenge for decades. According to Lobell et al. (2011), climate change is expected to exacerbate the challenges related to crop growth and productivity, particularly in major food-producing countries. Drought is the most significant abiotic stress and a leading cause of crop losses, underscoring the importance of developing drought-tolerant cultivars to sustain food production. Drought tolerance is a complex trait that encompasses physiological, morphological, and molecular characteristics (Moussa et al., 2008). The adverse effects of drought stress on plants can result in social and economic problems, ecological damage, land desertification, and soil erosion. Therefore, drought stress is regarded as a pressing global and environmental problem.

Climate change and its potential long-term impacts on crop production are of significant global concern, with particular emphasis on Sub-Saharan Africa. This region is highly vulnerable to the consequences of climate change, which pose substantial threats to food security and environmental sustainability. The uncertainty surrounding the potential effects on agriculture presents a major challenge. Changes in climate can have profound effects on weather patterns and soil quality, both of which are critical factors influencing crop production. In Africa, agricultural practices heavily rely on rain-fed systems, primarily at subsistence levels with limited use of external inputs. As a result, any degradation in weather patterns, especially in terms of rainfall amounts and distribution, could have severe implications for food production, as noted by Breman et al. (2008).

As noted by Aggarwal et al. (2002), developing countries are expected to witness a decline in crop yields ranging from 10 to 25% due to rising temperatures, which are already nearing or surpassing the limits of crop tolerance. The increasing temperatures are anticipated to accelerate soil microbial processes, particularly those associated with the Carbon and Nitrogen cycles, potentially altering the decomposition patterns of crop residues.

Additionally, elevated soil temperatures can contribute to autotrophic carbon losses from the soil through mechanisms such as root respiration, root exudates, and turnover of fine roots. Regions with high levels of precipitation are likely to experience an upsurge in fungal and bacterial pathogens, leading to reduced cereal yields as a result of pest and disease outbreaks in warm and humid conditions.

Symptoms of moisture stress, including leaf rolling and stunted plant growth, may become evident, while drought conditions can also induce nutrient deficiencies in plants (Aggarwal et al., 2002).

2.7 Drought avoidance

Drought avoidance is the ability of a plant to maintain a favorable water balance to prevent water deficit in plant tissue during moisture stress. There are two types of drought avoidance strategies. The first type involves minimizing water loss through transpiration by reducing stomata conductance and leaf area. The second type involves sustaining water uptake during a drought by developing drought-resistant cultivars with enhanced drought-resistance mechanisms. These strategies have been described in the literature (Blum, 2017; Farooq et al., 2009).

CHAPTER THREE MATERIALS AND METHODS

3.1 Description of the study site.

The experiment was done in Gutu in Masvingo Province. The station is in natural region four and receives low amounts of rainfall ranging from about 650mm to 800mm of rain per annum. The temperatures ranges from 14.75 degrees celcius to 30.21 degrees celcius.

3.2 Experimental design

The study employed a randomized complete block design (RCBD) with a 4 x 3 factorial arrangement. The first factor (A) comprised three different finger millet varieties: FMV1, FMV2, and FMV3. The second factor (B) included three distinct watering regimes, with 450mm, 300mm, and 150mm serving as experimental treatments, and 600mm serving as the control. To ensure accuracy and reliability of the findings, the entire experiment was replicated three times.

3.3 Experimental procedure

For this experiment, finger millet was grown in plastic pots over a 30-day period. Seeds were sourced from the Klein Karoo, and a loamy sand soil was filled into 36 plastic pots and moistened to facilitate germination. The soil's water requirement was determined by weighing the dry soil before and after being irrigated, and then allowing it to drain for 12 hours. The difference between the weights was used to calculate the soil water requirement. Five seeds were planted per pot at a depth of 3cm, and a compound D fertilizer (NPK) was applied at a rate of 10 grams per pot during planting. The plants were watered until germination and thinned to one seedling per pot one week after emergence. To prepare for inducing different water regimes, the plants were left without water for five days after thinning.

3.4 Data collection

To assess the growth of finger millet plants, their height was measured using a ruler, from the root crown to the final leaf's tip. Plant biomass accumulation was calculated by subtracting the fresh weight of the entire plant from its dried weight. The fresh weight was measured using a balance scale shortly after harvesting the plants, while the dry weight was determined by weighing the plants again after drying them. The chlorophyll concentration in the leaves was measured using a SPAD-meter reading from the top two leaves of each plant before harvesting. Additionally, visual Inspections were conducted to detect any other stress-related effects that may have impacted growth, such as curled leaves caused by extreme water stress.

To induce drought conditions, the finger millet plants were left without water for seven days until they began showing visible signs of water stress. Before administering the first watering, plant height was measured, and germinating weeds were removed to prevent water competition. The first watering was given after height measurements were taken, but severe water stress and wilting were observed seven days after the initial watering. On the tenth day after the first watering, the plants were measured again and then harvested. Prior to harvesting, the chlorophyll content of each plant was measured. After harvesting, the leaves and roots were weighed, and their dry weights were determined by drying them separately for seven days before taking measurements**.**

3.5 Data Analysis

Analysis of variance (ANOVA) was carried out using Genstart version 18.

CHAPTER 4

RESULTS

The objectives of the experiment was to determine the effect of varieties and watering regimes on growth and productivity of millets on early growth stages. The results indicated that

4.1 Stem height

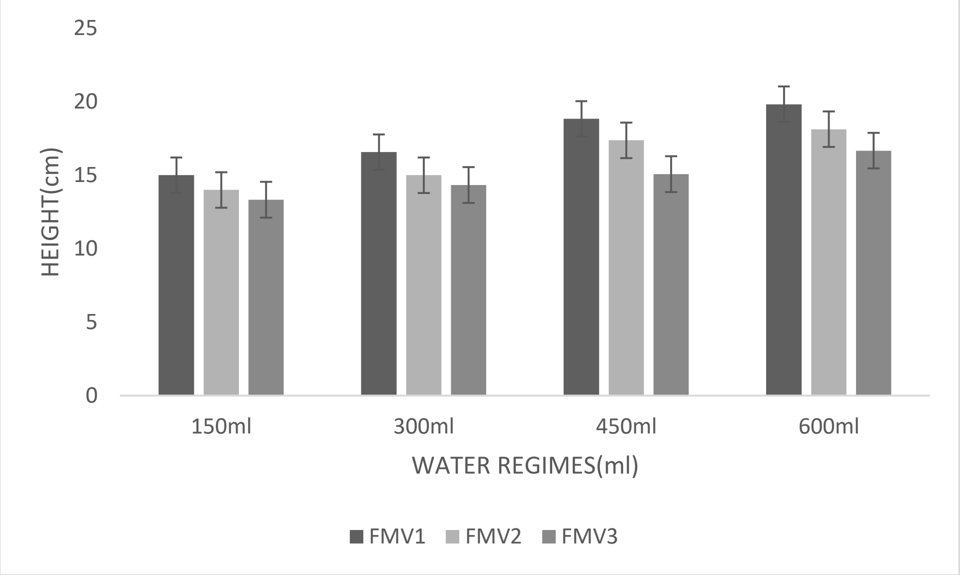

Figure4.1: Shows stem heights

The results indicated that for the drought-tolerant level of 150mls and 300mls there is no significant difference on FMV1, FMV2 and FMV3. In 450mls and 600mls, FMV1 and FMV3 had a significance difference and FMV2 and FMV3 had a slight difference, plant height was affected by varietal differences (p=0.001). There were interactions between plant variety and drought affected plant height (p=0.001). Plant height increased as a result of irrigation (p=0.001). FMV1 had the maximum height (15cm), followed by FMV2 (14cm), and FMV1 (13.33cm), for the drought-tolerant level of 150 ml. FMV1 (16.57cm) had the maximum height, followed by FMV2 (15cm) and FMV3 (14.33cm), for the drought-tolerant level of 300mls. FMV1 (18.83cm) had the maximum height, followed byFMV2 (17.37cm) and FMV3

(15.07cm), for the drought-tolerant level of 450mls. FMV1 (19.83) had the maximum height, followed by FMV2 (18.13cm) and FMV3 (16.67), for the drought-tolerant level of 600mls.

4.2 Chlorophyll accumulation

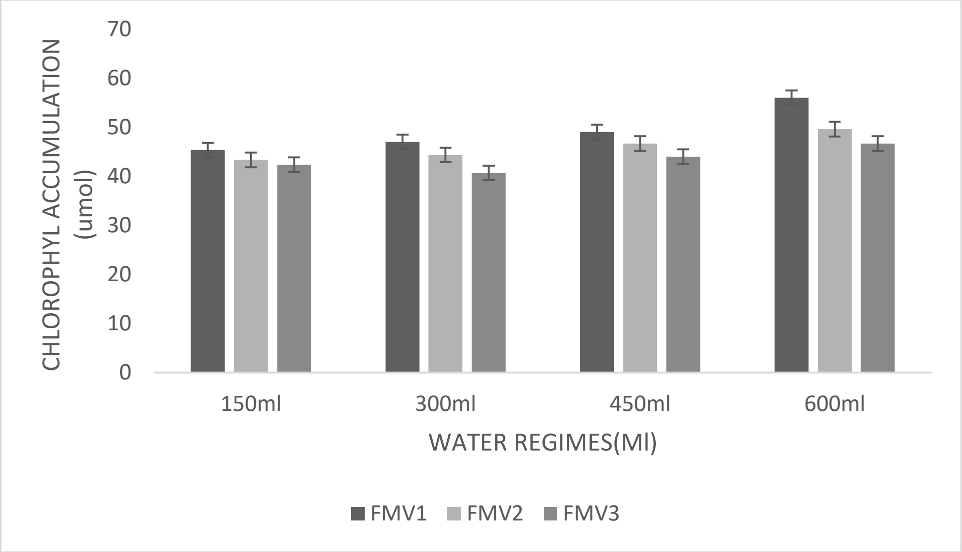

Figure 4.2 shows the effect of watering on chlorophyll accumulation

The results indicated that for the drought-tolerant level of 300mls, 450ml and 600mls had a significant difference, Drought levels had a statistically significant effect on chlorophyll accumulation (p=0.001). Furthermore, there was a significant difference in chlorophyll accumulation between FMV1, FMV2, and FMV3, demonstrating that the type of finger millet had an influence on chlorophyll accumulation (p=0.001). In terms of chlorophyll accumulation, however, there was no significant interaction between variety and drought level (p=0.127).FMV1 had the maximum chlorophyll accumulation (45.33umols), followed by FMV2 (43.33umols), and FMV1 (42.33umols), for the drought-tolerant level of 150 ml. FMV1 (47.00umols) had the maximum chlorophyll accumulation, followed by FMV2 (44.33umols) and FMV3 (40.67umols), for the drought-tolerant level of 300mls. FMV1 (49.00umols) had the maximum chlorophyll accumulation, followed byFMV2 (46.67umols) and FMV3 (44.00umols), for the drought-tolerant level of 450mls. FMV1 (56.00umols) had the maximum chlorophyll accumulation, followed by FMV2 (49.60umols) and FMV3 (46.67umols), for the drought-tolerant level of 600mls.

4.3 Biomass accumulation

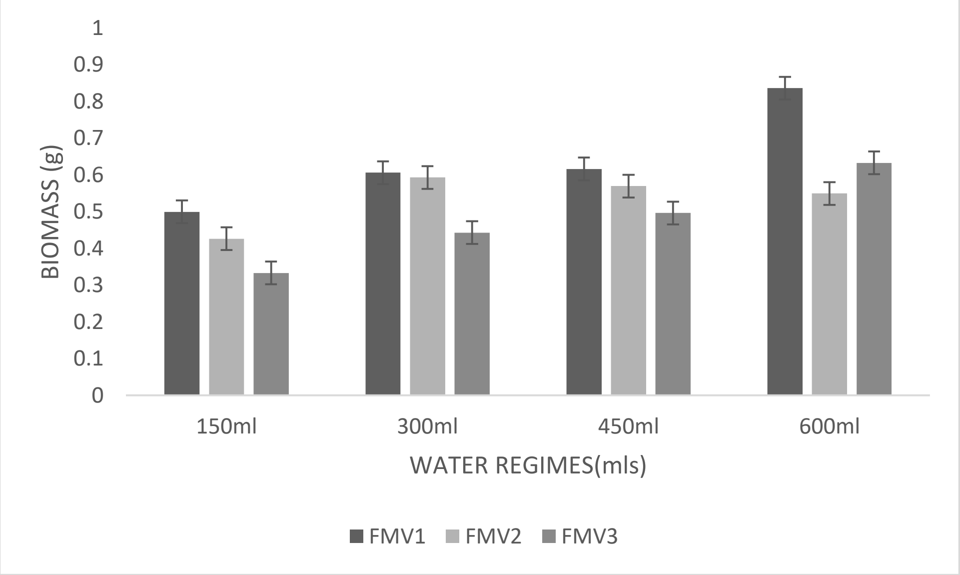

Figure 4.3 Effects of drought on biomass accumulation of finger millet

The results indicated that for the drought-tolerant levels of 150mls, 300mls, 450ml and 600mls had a significant difference on biomass accumulation (p=0.001), with 600 mm of0irrigation producing the maximum biomass accumulation and 150 mm producing the lowest. Variety and degree of drought had an effect on biomass accumulation (p=0.001). Between 450mm and 300mm, there were variances. On the buildup of biomass, there were varietal impacts (p=0.001).

CHAPTER 5: DISCUSSION

5.1. Water stress effects on stem height

The study showed that height was affected by different water levels. FMV1 has the maximum stem height as compared to other two varieties FMV2 and FMV3. This could be linked to the fact that during the early stages of growth in finger millet plant stem height is impacted by water controls as water stress reduces the plant cell's water potential and turgor, which increase the solute concentrations in the cytosol and extracellular matrices. Different levels of drought can lead to stomatal closure, which lower gaseous exchange, decrease transpiration, and hinders photosynthesis by slowing down carbon assimilation rates. As a result, a partial change in water availability can lead to differences in the height of finger millet stems.

5.2 Effects of water stress on the synthesis of chlorophyll

The results showed that chlorophyll was significantly affected by water levels. The FMV1 cultivar showed the highest percentages of chlorophyll accumulation among FMV2 and FMV3. The difference in chlorophyll might have been triggered by low nutrient uptake impacted by water stress. Lack of nitrogen can result in a reduction in leaf chlorophyll levels Water is essential for optimum metabolic reactions during chlorophyll synthesis. Lack of photosynthesis can diminish chlorophyll accumulation in plants under water constraint. Anjumet et al. (2011), a common indication of pigment photo-oxidation and chlorophyll degradation in plants under drought stress is the reduction in chlorophyll content. This finding is consistent with the results reported by Maag et al. (1980).

5.3 Amount of biomass in relation to the availability of water

Finger millet varieties were significantly affected by different moisture levels FMV1 had more biomass as compared to the other varieties. With a reduction in moisture availability, biomass fell (Leport et al., 2006). (Komor, 2000).Drought impairs photosynthesis, which in turn lowers the sucrose concentration and, eventually, lowers the rate of export from source to sink. Water limitations will also affect how effectively the sink can use the incoming assimilates. Due to the fact that the activity of acid inverse is negatively impacted during moisture stress, the process of phloem loading and unloading is severely impaired. According to Brisson et al. (2003) and Hammer et al. (2010), the efficiency of turning collected light into biomass is determined by the rate of leaf photosynthesis. Due to decreased cell division and elongation under drought stress, biomass accumulation will be reduced.

CHAPTER6: CONCLUSIONS AND RECOMMENDATIONS

6. 1 Conclusions

According to the study, water stress impacts how well seedlings establish, thus careful management is required to lower the chance of crop failure. The evaluated kinds of finger millet reacted differentially to drought stress. The watering schedule had an impact on plant growth, and the FMV1 variety outperformed the FMV2 and FMV3 types in terms of biomass accumulation. FMV1 variety outperformed FMV2 variety in terms of chlorophyll accumulation, and FMV3 variety had the lowest proportion. Plant height fell as a result of the drop in water level, with FMV1 variety measuring higher FMV2 coming in second, and FMV3 coming in last. The plants could withstand 150mls drought, and their fastest growth occurred between 300mls and 600mls.

6.2 Recommendations

Basing on the information generated from this study, the recommendations below can be made;

1. To avoid early crop loss due to drought, farmers may plant the FMV1 variety.
2. To create types that are resistant to early drought, more plant breeding work should be done.

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APPENDICES

Analysis of variance

```
Variate: Height

Source of variation            d.f.        s.s.        m.s.      v.r.   F pr.

Block stratum                     2       1.467       0.734      0.33

Block.*Units* stratum
Milt                              2      44.061      22.030      9.99   <.001
treatment                         3      90.056      30.019     13.62   <.001
Milt.treatment                    6       4.746       0.791      0.36   0.897
Residual                         22      48.493       2.204

Total                            35     188.822
```

Information summary

```
All terms orthogonal, none aliased.
```

Message: the following units have large residuals.

```
Block 1 *units* 6                                        3.64       s.e.  1.16
Block 3 *units* 2                                        2.77       s.e.  1.16
Block 3 *units* 6                                       -2.56       s.e.  1.16
```

Tables of means

```
Variate: Height

Grand mean  16.18

      Milt          1        2        3
                17.56    16.12    14.85

 treatment          1        2        3        4
                14.11    15.30    17.09    18.21

      Milt  treatment        1        2        3        4
         1               15.00    16.57    18.83    19.83
         2               14.00    15.00    17.37    18.13
         3               13.33    14.33    15.07    16.67
```

Standard errors of means

```
Table                      Milt    treatment        Milt
                                               treatment
rep.                         12            9           3
d.f.                         22           22          22
e.s.e.                    0.429        0.495       0.857
```

Standard errors of differences of means

Table	Milt	treatment	Milt treatment
rep.	12	9	3
d.f.	22	22	22
s.e.d.	0.606	0.700	1.212

Least significant differences of means (5% level)

Table	Milt	treatment	Milt treatment
rep.	12	9	3
d.f.	22	22	22
l.s.d.	1.257	1.451	2.514

Stratum standard errors and coefficients of variation

Variate: Ht

Stratum	d.f.	s.e.	cv%
Block	2	0.247	1.5
Block.*Units*	22	1.485	9.2

```
  71                                SET                    [IN=*]
  77          "Two-way      design      in      randomized      blocks"
  78                DELETE          [REDEFINE=yes]          _ibalance
  79             A2WAY        [PRINT=aovtable,information,means,%cv;
TREATMENTS=Milt,treatment;                             BLOCKS=Block;\
  80   FACTORIAL=2; FPROB=yes; PSE=diff,lsd,means,alllsd; LSDLEVEL=5;
PLOT=*;                                       COMBINATIONS=present;\
  81                   EXIT=_ibalance]       CHPL;       SAVE=_a2save
```

Analysis of variance

```
Variate: Chlorophyll accumulation

Source of variation          d.f.        s.s.        m.s.      v.r.   F pr.

Block stratum                   2      28.402      14.201      4.29

Block.*Units* stratum
Milt                            2     211.269     105.634     31.91   <.001
treatment                       3     289.164      96.388     29.12   <.001
Milt.treatment                  6      37.629       6.271      1.89   0.127
Residual                       22      72.824       3.310

Total                          35     639.289
```

Information summary

```
All terms orthogonal, none aliased.
```

Message: the following units have large residuals.

```
Block 1 *units* 7                                  3.74          s.e.   1.42
```

Tables of means

```
Variate: Chlorophyll accumulation

Grand mean  46.24

      Milt        1        2        3
              49.33    45.98    43.42

  treatment         1        2        3        4
                43.67    44.00    46.56    50.76

      Milt  treatment        1        2        3        4
         1               45.33    47.00    49.00    56.00
         2               43.33    44.33    46.67    49.60
         3               42.33    40.67    44.00    46.67
```

Standard errors of means

```
Table                      Milt    treatment         Milt
                                               treatment
rep.                         12            9            3
d.f.                         22           22           22
e.s.e.                    0.525        0.606        1.050
```

Standard errors of differences of means

Table	Milt	treatment	Milt treatment
rep.	12	9	3
d.f.	22	22	22
s.e.d.	0.743	0.858	1.486

Least significant differences of means (5% level)

Table	Milt	treatment	Milt treatment
rep.	12	9	3
d.f.	22	22	22
l.s.d.	1.540	1.779	3.081

Stratum standard errors and coefficients of variation

Variate: Chlorophyll accumulation

Stratum	d.f.	s.e.	cv%
Block	2	1.088	2.4
Block.*Units*	22	1.819	3.9

Analysis of variance

Variate: Crop biomas

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	0.019272	0.009636	6.68	
Block.*Units* stratum					
Milt	2	0.164422	0.082211	57.01	<.001
treatment	3	0.290144	0.096715	67.06	<.001
Milt.treatment	6	0.079222	0.013204	9.16	<.001
Residual	22	0.031728	0.001442		
Total	35	0.584789			

Information summary

All terms orthogonal, none aliased.

Message: the following units have large residuals.

Block 1 *units* 11	0.0614	s.e.	0.0297
Block 2 *units* 6	0.0672	s.e.	0.0297

Tables of means

Variate: Crop biomas

Grand mean 0.5506

```
        Milt         1          2          3
                0.6400     0.5350     0.4767

   treatment         1          2          3          4
                0.4200     0.5478     0.5611     0.6733

        Milt   treatment        1          2          3          4
           1               0.5000     0.6067     0.6167     0.8367
           2               0.4267     0.5933     0.5700     0.5500
           3               0.3333     0.4433     0.4967     0.6333
```

Standard errors of means

```
Table                          Milt     treatment          Milt
                                                      treatment
rep.                             12             9             3
d.f.                             22            22            22
e.s.e.                      0.01096       0.01266       0.02193
```

Standard errors of differences of means

```
Table                          Milt     treatment          Milt
                                                      treatment
rep.                             12             9             3
d.f.                             22            22            22
s.e.d.                      0.01550       0.01790       0.03101
```

Least significant differences of means (5% level)

```
Table                          Milt     treatment          Milt
                                                      treatment
rep.                             12             9             3
d.f.                             22            22            22
l.s.d.                      0.03215       0.03713       0.06431
```

Stratum standard errors and coefficients of variation

Variate: CB

```
Stratum                          d.f.          s.e.         cv%
Block                               2       0.02834         5.1
Block.*Units*                      22       0.03798         6.9
```