CHAPTER ONE

INTRODUCTION

Pearl millet (*Pennisetumglaucum*) is a crop grown in the semi-arid and dry lands of Africa and Southeast Asia (Baltensperger, 2002). It is a short-day crop that flowers, or flowers earlier, when day lengths are short (Billiard and Pernes, 1985; Clerget et al., 2007) and long photoperiod delays floral initiation (Uzoma et al., 2010). Pearl millet grain is the staple diet for rural households in the world poorest countries (Basavaraj et al.,2010) and provides food to about five hundred million people in the arid and semiarid tropics particularly in Southeast Asia (Yayock et al., 1988; National Research Council (NRC), 1996). Pearl millet stover is a valuable livestock feed in India and Africa (Basavaraj et al., 2010). In countries like the United States of America pearl millet is grown as a summer forage crop, seed for the bird feed industry and wildlife (Obeng et al., 2012)

Millet is one of the oldest cultivated foods known to humans. As with many cereals, the history of the grain is diverse and difficult to track, but it seems to have originated in China and Africa (*Oelke1, etal, 1990*). Pearl millet probably originated from western tropical Africa more than 3000 years ago and from there spread across Africa and South Asia (*Oelke1 etal*, *1990*). However, there is thought that it may have originated in the Abyssinia region (present-day Ethiopia). Millet has been a staple in these areas since early times, but was replaced by rice as the main staple in Southeast Asia and India (*Oelke1 et al*, *1990*). Some records from China indicate that millet was grown as early as 4500 BCE, or possibly earlier, while other records indicate that several varieties arrived in China from Africa. Still others report it was grown by the

lake dwellers of Switzerland during the Stone Age .Millet was introduced to the U.S. in 1875, but was not well accepted for human consumption. Like pearl millet, finger millet is thought to have originated in Africa and imported to Asia, where it assumed greater importance than it had in Africa (*Oelke1*, *1990*)
Pearl millet (*Pennisetumglaucum*(L) R. Br.] is an important tropical food cereal grown on approximately26 million ha in semi-arid regions, including West and South Africa and India (*Andrews et al.,1993; Andrews and Bramel-Cox 1994*). In Niger, pearl millet is the main staple food and is the dominant crop in the agricultural production systems, contributing about 0.75 of the national total cereal production (*Amadou et al. 1999*). Pearl millet productivity is usually low (300–550kg/ha) (*GraefandHaigis 2001*) and variable(*Rockstrom et al.*, *1999*), in part because of natural causes, including a short rainy season that is spatially and temporally variable (*Graef and Haigis 2001*) and poor soil quality. In Niger, the length of the growing period is mainly a function of the date of the first rains (*Sivakumar, 1988*) and varies widely from year to year. However, due to the erratic rainfall pattern in the Sahelian regions, the first rain suitable for planting is often followed by several dry days that cause the planting to fail and require the farmers to replant. According to (*Bationo et al., (1990*) and (*Bationo and Ntare 2000*), during normal or above normal rainfall years, grain yield for pearl millet could be improved by increasing the plant population and N fertilizer applications; but yield could slightly decrease during drought years. However, (*Maman et al, 2000*) and (*Kathju et al., 2001*) found that even in drier years, a high plant population and fertilizer applications were necessary to obtain higher yields.

Pearl millet locally known as "Dukhun", is one of the important cereal crops of the Sudan, coming as the second most-important cereal crop, after sorghum , in both area and total production. It is the preferred staple food crop for the majority of the inhabitants of western Sudan (Kordofan and Darfur States). The average total area annually planted in the country is about 6 million feddans (2.5 million ha). About 95% of this area is found in Western Sudan. (*Abuelgasim, 1989, 1992, 1997*)

Since pearl millet is a drought and heat tolerant crop capable of producing grain in regions of low soil fertility and limited moisture, where other summer cereals like sorghum and maize, may fail, it occupies the marginal low-rainfall areas of western Sudan. This is mainly due to its extensive and more efficient root system, as well as its high ability to produce tillers. Although the crop is grown in areas where rainfall ranges between 200 mm to more than 1000 mm, most of it occurs in areas receiving 250-700 mm (*Abuelgasim, 1989, 1992, 1997*)

In Western Sudan Region, most of the pearl millet production is centered in the extensive sandy soils “Goz” occupying the northern parts of the region. These are marginal areas with less than 400mm rainfall. In these areas, pearl millet is the most extensively grown crop, and therefore, a millet-based farming system prevails. However, the cultivation of the crop extends further south into the clay soils where rainfall goes up to 700 mm. Within these southern areas, usually locations of lighter and more sandy soils are used for pearl millet. The average total pearl millet area annually planted in the Sudan ranges from 5 to 7 million feddans (2.1 to 2.9 million ha) (*Abuelgasim, 1989, 1992, 1997*). The crop is almost exclusively grown under rain-fed conditions, with about 98% of it being produced under traditional farming practices, mostly using local varieties.

Being an indigenous crop that has been growing for centuries in Western Sudan area, pearl millet has a wide diversity of local types. This diversity has been encouraged by the fact that pearl millet is a highly cross-pollinated crop (with 80% or more cross -pollination) (*Abuelgasim, 1989, 1992, 1997*). Farmers continued to grow local varieties that are usually heterogeneous populations with broadly based genetic composition. Within the same farmer's field, usually many different plant types can be seen. In spite of this within population variability, a number of local varieties or landraces could be identified and named by farmers in Western Sudan

Agriculture in Sudan is composed of three main farming systems, namely traditional rain-fed sector, mechanized rain-fed sector, and irrigated sector. The traditional rain-fed sector has occupied an average of 60% of the total cultivated land and employed about 65% of the agricultural population during the last ten years. Nevertheless, this sector is characterized by low crop productivity that is mainly driven by lower technical efficiency that has led to its average contribution to the total agricultural GDP being only about 16% during the last ten years (Siddig, 2009).

Efficiency literature in the Sudanese context reveals that technical efficiency in the overall Sudanese agriculture is low especially in the traditional sector that provides staple food for the majority of the subsistence farmers and other domestic consumers besides its contribution to the export sector. Siddig*et.al* (2011)

A major problem of rain- fed agriculture in semi- arid regions with short rainy seasons is how to determine the optimum sowing date for individual crops, a decision tied to a proper definition of onset of the rains. Managing planting date influence crop growth and development as the interaction between growth, development and stressful periods (*Abd-El-Lattif, 2011*). A decline in both temperature and length of photoperiod over successive sowing dates from July to September had a drastic effect on phonology and yield potentials of the pearl millet cultivars (*Maiti and Soto, 1999*). Meanwhile, (*Mass et al,2007*) found that planting dates was significant for yield and height. In view of this, the current study aimed at exploring and investigating on the effect of sowing dates on growth and yield under rainfall with following objectives: To see the growth and yield of three cultivars of millet under normal rainfall as well as to determine the production of millet crop under rainfall conditions

CHAPTER TWO
LITERATURE REVIEW

2.1 Agriculture in Sudan

Sudan is a vast country endowed with sizable land and natural resources. Agriculture occupies a pivotal position in Sudan's economy because of its sizable contribution to the national income. It generated an average of 40% of the gross domestic product GDP during the period between 1998 and 2003, over 90% of the national food requirements and accounted for almost 50% of the employment opportunities, and supplied about 60% of raw material needed by the manufacturing sector (*Mubarak etal, 2011*). The contribution of agriculture to the GDP remains at about31% in 2009 and 2010 (*CBoS, 2011*).

Agriculture remains an important sector in the Sudanese economy. It contributed an annual average of 45 % to total GDP during the last ten years in addition to its employment of about 80% of the total labor force including agricultural-related activities (*Siddig, 2009*). Moreover, agriculture contributes to other activities such as transportation, agro-industries, and commerce, in the industrial, trade, and service sectors which account for a large share of the GDP.

Nonetheless, the agricultural contribution to the GDP started to deteriorate in recent years. For instance, it has fallen from 48% in 1997 to 31% in 2009 (*CBOS, Annual Reports*).

Agriculture in Sudan is composed of three main farming systems, namely traditional rain-fed sector, mechanized rain-fed sector, and irrigated sector. The traditional rain-fed sector has occupied an average of 60% of the total cultivated land and employed about 65% of the agricultural population during the last ten years. Nevertheless, this sector is characterized by low crop productivity that is mainly driven by lower technical efficiency that has led to its average contribution to the total agricultural GDP being only about 16% during the last ten years (*Siddig, 2009*).

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Sudan is one of the driest but also the most variable countries in Africa in terms of rainfall. Extreme years (either good or bad) are more common than average years (*Zakieldeen, 2007*). Rainfall, on which the overwhelming majority of the country's agricultural activity depends, is erratic and varies significantly from the north to the south of the country. The unreliable nature of the rainfall, together with its concentration into short growing seasons, heightens the vulnerability of Sudan's rain fed agricultural systems. Drought threatens approximately 12 million hectares of rainfed land, particularly in the northern Kordofan and Darfur states. (*Zakieldeen, 2007*).

Climate change is expected to affect Sudan's water resources through reduced groundwater recharge brought about by decreased precipitation and/or increased temperatures and evaporation. (*SFNC, 2002; NAPA, 2007*).

Least developed countries (LDCs) like Sudan are particularly vulnerable to climate change because of the overwhelming dependence of their economies on natural resources, and their low adaptive capacity. Most land in Sudan is quite sensitive to changes in temperature and precipitation. Food security is mainly determined by rainfall, with more than 70% of Sudan's people directly dependent on climate sensitive resources for their livelihoods.

2.2 West Darfur:

In Darfur, after almost 10 years of conflict, the population remain displaced in the camps, with very little access to their normal livelihoods activities, while farming subsistence in rural areas is hampered by environment degradation and crop destruction, which is inextricably linked to the ongoing conflict, as attempts to control or gain access to scarce natural resources has resulted in heightened competition over resources and eventually proliferation of local level conflicts. Crop farming mainly Millet production is the main income activity for more than 80% of Darfur's population. The rural economy of West Darfur State is a typical peasantry type, dependents on production of millet and sorghum for both household consumption and local sales, sales of livestock and cash crops to other part of the country, collection and sales of forest products and export of labor (seasonal migration for labour). The livelihood strategies of West Darfur communities are subject to a number of shocks and risks after the famous famines of 1984 and 1991.

Historically, West Darfur has suffered from several droughts over the last 50 years making it a chronically food insecure area. Natural resources within West Darfur are meager due to declining rainfall, excessive use of forest and pasture for firewood and as a source of income for many households. Crop yields have remained low and unpredictable due to erratic rainfall, pest infestation and lack of access to agricultural inputs. Accumulation of 2-3 poor rainy years in West Darfur could easily develop into acute limitations of natural resources, acute food insecurity problems (production failure) and more risk of conflicts between sedentary farmers and pastoralists.

West Darfur State has been divided into three broad livelihood patterns, these are; pastoral, agro-pastoral and resident farmers all of them are mainly

cultivating Millet in addition to Groundnuts and Sorghum in some areas along the Wadi, Millet is considered to be the main food source in West Darfur.
West Darfur covers an area of approximately 17,619,470 acres and arable area of approximately 8,965,000 acres about 2.5 million acres are used for agriculture while the natural grasslands and forests cover is about 8,650,000 acres (*SMoHELGeneina data base*). The population is of about 1,308,225 inhabitants, with about 65% of the rural and nomadic about 18% according to the Census Bureau of statistics in 2008.

West Darfur State is located in the far western part of Sudan at latitude of (10 ˚- 38 ˚) North and Longitude (21 ˚-48 ˚) East. It isconsidered a remote region in comparison to other parts of Sudan. It covers about 75000 km^2. The climate of the state is ranging from semi-desert in the north, poor savannah and rich savannah in the south. Annual rainfall precipitation ranges between 200mm in the North and 800mm in the South. West Darfur state has been divided into three broad livelihoods patterns, these are; pastoral, agro-pastoral and resident farmers all of them are mainly cultivating Millet in addition to Groundnuts and Sorghum in some areas along the Wadi, Millet is considered to be the main food source in West Darfur. It is particularly adapted to nutrient poor soil and low rainfall conditions (Ali, 2010) In these areas rainfall is around 400 mm per annum, which is too little to sustain the production of other cereals. This allows millet to be the best alternative cereal to be grown in these areas. Average millet acreage is around 5.4 million feddans, producing some 300,000 tons with low average yields of about 90 kg/fed (*ARC. 2011*).

2.2.1 West Darfur climate and rainfall:

The climate is semi desert north of the State, poor savannah in the middle, rich savannah in south and Mediterranean climate in the Jebel Marraarea. Ranging from sandy soil predominate in the North and mid mandate to light in the Center, mud heavy in the South. West Darfur State has experienced many droughts and desertification in the years of 1973-1983-2004. This has led to environmental change in plant atrophy, leading to accumulation of agricultural activity both animal and crop production in very limited geographical area, causing friction and fighting in turn resulted to competition for natural resources. (SMoAELGeneina data base)

The state receives rainfall ranging from 280 mm (mostly in northern localities) to 698 mm (in south-eastern part of the state) This is within average rainfall for the state. Rains run from July through to first of October (SMoAELGeneina rainfall data base)

2.3 Millet varieties:

1- Dembi

2- AishBernu

3- Hammer

4- Sharoba:

5- Bauda:

6- Abu Soof or Abu Shara:

2.4 Climatic Requirements for Pearl Millet:

Pearl millet can grow in a wide range of ecological conditions and can still yield well even under unfavorable conditions of drought stress and high temperatures. It is generally grown between 40^{o} North and 40^{o} south of the equator, in warm and hot countries characteristic of the semi-arid environment.

Pearl millet is a warm weather crop and grows best at 20 to 28 ^{o}. Pearl millet is more tolerant to higher temperatures than probably any other cultivated cereal. These useful characteristics mean that it is finding a new niche in some unexpected places. The best temperature for the germination of pearl millet seed is 23 to 320 C. Pearl millet seed does not germinate and grow well under cool soil conditions. Poor emergence and seedling growth may result if planted before soil temperatures reach 230 C. (*kiranYadav, 2012*)

2.5 Crop Improvement Efforts:

The crop improvement efforts on pearl millet in the Sudan, has been summarized by (*Abuelgasim,1989, 1992, 1997*), In spite of the importance of the pearl millet crop in the Sudan, it did not receive much attention to improve it prior to 1974 when a plant breeder was appointed for starting a pearl millet improvement program in Western Sudan. The breeder was stationed at Elobeid in North Kordofan Province, with the idea of initiating a research station there. He Started pearl millet breeding program by collection of the local millet germplasm from different millet growing areas in Kordofan and some parts of Darfur regions

The crop improvement program was initiated with the objectives of producing adapted improved varieties with high grain yield, early maturity, resistance to prevailing pests and diseases, in addition to having acceptable grain quality and taste. Improvement of the cultural practices was also taken in consideration. The millet improvement program was strengthen in 1977,by initiation of a joint cooperative improvement program with the International Crop Research Institute for Semi –Arid Tropics (ICRISTAT), in India.A plant breeder from ICRISAT was stationed at Elobied to supervise ICRISAT millet breeding program.

This joint program resulted in the release of the first improved millet variety,in, January, 1981,under the name of 'Ugandi' This is an improved composite variety, with early maturity, bristled heads and grey seeds color. The millet improvement program in the Sudan, also received help from the international Sorghum and millet Improvement program (INTSORMIL) of USA. The second improved millet variety, named 'Ashana',was released in the year 2000. It is an introduction, (SDMV 93032), from ICRISAT Millet program in Zimbabwi (SADIC program). The variety 'Ashana' is characterized by early maturity, resistance to downy mildew disease, and it has grey grain color. Presently, the millet improvement program is continuing at three main research stations, namely, Wad Medani, Elobied and Sennarstations.It has the same objectives as before, and it depends mainly on local funding of research activities.

The optimum rainfall requirement of pearl millet ranges between 35 to 50 cm. But, pearl millet can be grown in areas, which receive less than 35 cm of annual rainfall. Prolonged spells of warm, rainless weather may be detrimental and may lead to reduced crop yields. At harvest time, dry warm weather is most suitable. Although pearl millet can respond to good moisture supplies during its growth, it is nevertheless one of the toughest, drought tolerant crops available. Pearl millet maintains its popularity in the regions where the weather is very unpredictable. The ability of pearl millet to grow in drier environments is due to a number of physiological and morphological characteristics; rapid and deep root penetration (root depths of 3.6m have been recorded);has root system with well-developed and specialized cell walls that prevent desiccation, Tillering capacity of pearl millet compensates any reduction in yield contributing components such as number of heads, length of the head, grain weight etc. (*kiran, 2012)*

2.6 Soil requirements:

Like most plants, pearl millet also does best in light, well-drained loams. The crop tolerates poor, infertile soil better than the other crops. It performs poorly in clay soils and cannot tolerate water logging. It is tolerant of subsoil that are acidic (even those as low as pH 4–5) and high in aluminum content. (*Board on Science and Technology for Interval Development, 1996*)

2.7 Millet diseases:

Pearl millet is infected by a large number of diseases caused by fungal, bacterial and viral pathogens, and nematodes. However, only a few are considered economically important, namely downy mildew (Sclerosporagraminicola), blast (Pyriculariagrisea), rust(Pucciniasubstriata var. indica), ergot (Clavicepsfusiformis) andsmut (Moesiziomycespenicillariae).

2.8 Cultural Practices:

2.8.1 Pest control

Grain pearl millet is not difficult to grow as it hosts few insect pests. Theprincipal insect problems in millet production are chinch bug, stinkbug,nematode and birds. Normally insecticides are not needed on pearl millet. (*Board on Science and Technology for Interval Development, 1996*)

2.8.2 Weed control:

Good weed control is necessary for successful pearl millet production, and it is particularly important to control early emerging weeds. Preventive control options begin with planting clean, weed-free seed. In addition, producers should make sure that all equipment used to plant millet is free of weed seeds. (*Mike Moechnig, etal 2011*).Margins will also help prevent weed seed from entering the fields. Mechanical controls should be used to prepare the seedbed prior to planting millets and where millets are planted in rows for seed, they give producers a head start on weed control. Because pearl millet is planted relatively late, two pre plant tillage operations are recommended, first to stimulate germination of weed seeds, then, several days later, to kill off weed seedlings prior to planting. If planted in wide rows, row cultivation for weed control should be planned, especially if herbicide control is ineffective. (Board on Science and Technology for Interval Development. 1996

2.9 Consumption:

Millets are a large part of the basic diet for farm households in the world's poorest countries and among the poorest people top consuming countries are identified in four countries: India, Nigeria, Niger and China. However, just because a country is a top global consumer does not mean that millet is a significant source of calories for them. India and China are rank as the #1 and #4 consumers of millet, but due to their population size they rank 11th and 38th in per-capita consumption, accordingly.

Millet is an excellent dietary source of calcium, iron, manganese, and methionine -- an amino acid lacking in the diets of hundreds of millions of the poor who live on starchy foods such as cassava, plantain, polished rice, and maize meal. Millet use is diverse, including in cereals (including porridge and kasha), soups, breads and stuffing's, fermented beverages, and baby food FAOSTAT data (2005) (*http://faostat3.fao.org*)

2.10 The effect of irrigation on growth and yield of millet:

The grain yield as a result of supplementary irrigation in addition to rainfall. Water applied ranged from 573.3 to 821.3 mm. The highest water consumption was recorded in the treatment that had multiple irrigations while the lowest was in the rain fed. More grain yield gave the highest water use efficiency with addition of only 14.65% more water to the total useful rainfall. This confirms the findings of (*Seghatoleetal, 2008*) and Powell and Fussell (1993) which reported that drought created by low rain, reduced harvest index, thus water stress had more effects on reproductive structures than vegetative one. Provision of supplemental irrigation of 84mm during booting and grain filling stages showed significant effect on the number of panicle, panicle length, chaff weight, grain weight and Stover weight indicating that supplemental irrigation is highly beneficial for pearl millet. The improved yield at that as a result of supplemental irrigation during booting and grain filling stages is similar with report by (*M'mboyi et al,2010*) which suggested that complete crop failure or reduced yield may result if drought occurs at the flowering or grain filling stages. Pearl millet growth responds to climate (temperature, rainfall, radiation), soil water supply. The treatment had the highest water use efficiency as compared with others. This study points out clearly that if adequate moisture can be supplied during critical stages of growth, the yield reduction will be minimized. The mid-season stage was the most sensitive to water stress. The need to supply adequate moisture at this stage is very important. However, it was reported by Yenesew and Tilahun (2009) that the crop water use efficiency was the lowest at optimum irrigation water application and the highest at stress of 75% deficit throughout the growth season. Although they pointed out that at individual farmer's level, maximum yield was obtained when the entire crop water requirement was fulfilled but water use efficiency was very low. Practicing deficit irrigation could increase the irrigated area since that lesser water is always used per unit area thereby resulting in of high water use efficiency.

2.11 The effect of rainfall on Millet:

In the drier farming regions of the world, mainly with arid and semi-arid environments, crop production is heavily dependent on rain fed practice. Agricultural production is facing increased competition for limited water resources and it is expected to increase with the number of water deficit countries, population pressure and intensification tending towards desertification of most land. The efficiency of utilization of irrigation water is often low and around 50% of the increase in demand for water could be met by increasing the effectiveness of irrigation (*Seckler et al., 1998*). It is, therefore, important to improve the efficiency of water use and this can be done by approaching the economic maximum of plant material that will ensures high water use efficiency. Water use efficiency nowadays is less improved hence, (*Mintesinot et al, 2004*) viewed that promoting its efficiency demands an urgent attention for improving productivity in dry environment. One of the methods for increasing water use efficiency is the adoption of cultural practices that will enhance production per unit of water. This can be achieved by crop-environment matching and by supplementing the cultural practice with irrigation. Water use efficiency is highly dependent on plant nutrient and, supply therefore any plant input factor that increases economic yield will improve the water use efficiency (*Davis, 1994*). Moreover, (*Tesfaye2004*) viewed that water shortage for crop production is not only the result of water scarcity but also of mismatches between the resources availability and demand. Water use efficiency is a major factor for identifying the best irrigation scheduling strategies for supplemental irrigation (*Pereira, et al.; 2002*). Hence, irrigation if well targeted might solve part of food security problem, which is the main goal for improving water use efficiency.

Agriculture in the areas where is heavily reliant on rainfall the productivity and production are strongly influenced by climatic and hydrological variability that are reflected as dry spells, droughts and floods. Droughts destroy watersheds, farmlands, and pastures, contributing to land degradation and causing crops to fail and livestock to perish. Dry spells during the rainy season is a common phenomenon in dry sub-humid and semi-arid climates, thus, resulting in low yields or sometimes to complete failure of staple food crops. Bridging the dry spells through supplemental irrigation of rain-fed crops can be an interesting option to increase water productivity at production system level (*Oweis and Hachum 2004*).

CHAPTER THREE

MATERIALS AND METHODS

3-1 **Site description:**
One experiments carried out at horticulture nursery in ELGeneina town West Darfur State The site of experimental was latitude 13 25 41.0 North and longitude 022 27 17.6 East

3.2 Experiment design:

The experiment was conducted for two consecutive seasons 2011/12 – 2012/13, to study the effect of sowing dates on growth and yield of three pearl millet cultivars under rainfall in West Darfur State ELGeneina, the main plots were the three local millet cultivars. While the sub-plots consist of four sowing dates. The treatments were arranged in split plot design with four replicates. The plot area was 4x4m and the space between rows was 75 cm.

Sowing was carried out in four dates as follows:

S1 = first sowing date in July 19th in the first season and July 5th in the second season

S2 = second sowing date in July 25th in the first season and July 10th in the second season

S3 = third sowing date in July 31st in the first season and July 16th in the second season

S4 = fourth sowing date in August 6 in the first season one and July 22nd in the second season

The three varieties of millet were selected as follows:

Dembi = V1

Bauoda = V2

Hariri (Baladi) = V3 is local Millet grown mainly the clay soils.

3.4 Soil:

The soil of area is sandy clay soil (loamy soil pushed by the Kajawadi during the rainy season floods

3.5 Climate

The climate is generally characterized by cold dry winter and hot rainy summers. The beginning of the rainy season is typical of the semi-arid savannah which is marked by great irregularity. The average temperature does not vary significantly between months especially during the rainy seasons, where the relative humidity is high. The potential evapotranspiration is about 180 cm/annum, with maximum of 20.1 cm in May and minimum of 4.2 in September. The annual mean temperature ranges from 25C to 27C. The hottest month in the year is May while the coldest month is January (*Metrological Station reports -ELGeneina*)

The rainy season usually begins in late June and extends to September, with occasional limited showers in April, May and October. The annual rainfall during the last 10 years varied from 280mm to 703mm (*MoA 2011 post-harvest assessment report – ELGeneina*)

3.6 Land preparation:

Land preparation started in the two seasons in late May by cleaning land form the big shrubs then plowing using disc harrow plough followed with leveling.

3.7 Growth attributes:

3.7.1 Plant height:

To determine the average plant height, five plants were randomly marked in each treatment for measuring plant height; which was taken from thefirst node to the apical bud of the main stem axis. Then the mean of thefive plants was obtained in cm.

3.7.2 Leaf area LA:

Leaf area index was taken from the same five plants and was calculated by taking the leaf length multiplied by leaf width multiplied by 0.75.

3.7.3 Stem diameter:

From the same five plants stem diameter was determined usingVernia Clipper. Means of stem diameter was then calculated.

3.8 Yield attributes:

3.8.1 Panicle height:

From theselected five plants in the beginning of the process panicle height was determined. Means of panicle height were measured in cm.

3.8.2 Panicle diameter:

From the selected five plants, panicle diameter was determined using Vernia Clipper. Meansof panicle diameter were measured in cm.

3.8.3 Yield:

One square meter in each plot was specified and all the panicles in the selected areawere harvested then the yield weighted with a digital scale in grammes then this was transferred into kg feddan.

3.8.4 Straw yield:

The same areaof one meter, straw yield was roped and left for at least for 15 days to dry then was weightedand means were taken in Kg per feddan.

3.8.5 Weight of 1000 seeds (g):

From the yield of each plot 1000 seeds were counted and weighted ina digital scale.

3.8.6 Number of days to 50% flowering:

The time (days) from sowing until 50% plants flowered in each plot was recorded

3.8.7 Nutritional value:

Sample of millet grain from each plot wastaken to the chemistry laboratory and nutritional elements were determined for the two seasons

3.9 Soil Analysis:

Pre soil analysis was done before sowing to assess the nutrients and salinity levels. Four soil samples representing different locations inside the experimental site were taken for nitrogen and salinity analysis

3.10 Statistical analysis:

The data collected in the two seasons were analyzed using statistical analysis for split design according to Gomez and Gomez (1986). The means were compared to Least Significance Test (LSD) at P=0.05.

CHAPTER FOUR

4. RESULTS

4. Plant height at 30 days (cm):

The plant height at 30 daysispresented in Tables 4.1a.The results revealed non-significant difference in the first season, on the other hand the second season gave significant difference for all treatments, sowing dates, cultivars and their interaction. However, V2 in the secondseason recorded the highest plant height and S1 gavethe highest plant height during the two seasons and V1S1had the highest values of plant height in thefirst season (124.2 cm), and V2S1 gave the highest values in season two (135.5 cm).

Table 4.1a. Effect of sowing dates on plant height (cm) for three cultivars at30 days in season 2011/12 -2012/13

Sowing dates	Plant height at 30 days 2011/12				Plant height at 30 days 2012/13			
	V1	V2	V3	X	V1	V2	V3	X
S1	124.2	110.1	121.8	118.7	126.6	135.3	130.0	130.6
S2	121.2	103.1	114.9	113.1	123.1	126.3	119.2	122.9
S3	96.3	80.2	95.8	90.8	105.5	100	100.5	102.0
S4	85.2	98.1	94.4	92.6	94.9	99.3	100.6	98.3
Mean	106.7	97.9	106.7		112.5	115.2	112.6	
Cv%				6.7				5.5
LSD(v)				21.12ns				20.06ns
LSD(s)				16.11ns				13.89*
LSD(VXS)				29.92ns				26.86*

S_1 = first sowing date, S_2 = second sowing date, S_3 = third sowing date, S_4 = fourth sowing date. V_1 =Dembi, V_2= Bauoda, V_3=Hariri.

*, ** Significance at P< 0.05 and P< 0.01, respectively, ns not significant

4.1Plant height of flowering stage:

The effect of sowing dates of plant height at flowering stage presented in Table 4.2a the results showed significant differencesin plant height between the millet cultivars and sowing dates for the two seasons, V2 cultivar recorded the highest plant height in the two seasons (231.8cm) and S1 produced the highest plant height during the second season, while V3 showed the shortest plant height in the in season one and two respectively.

Table 4.2a. Effect of sowing dates on plant height (cm) for three cultivars at 80 days in season 2011/12 – 2012/13

Sowing date	Plant height at 60 days 2011/12				Plant height at 60 days 2012/13			
	V1	V2	V3	X	V1	V2	V3	X
S1	220.7	217.2	183.4	207.1	237.1	244.0	218.8	233.3
S2	220.5	232.2	180.6	211.1	203.7	230.6	210.3	214.9
S3	210.2	220.0	172.8	201.0	220	230.3	219.5	223.3
S4	188.3	214.1	167.1	189.8	220	222.1	196.7	212.9
Mean	209.9	220.9	176.0		220.2	231.8	211.3	
Cv%				1.3				4.8
LSD(v)				15.67**				13.06*
LSD(s)				15.39**				10.30*
LSD(VXS)				26.37*				18.89*

4.1.1 Plant Height at120 days:

The effect of sowing date on plant height at maturity stage is presented in Table 4.3a.The results showed significant differences for the cultivars and highly significant differences for sowing dates and the interaction in the first season.However, the result in the second season indicted that no significant differences on plant height between the cultivars nor sowing dates, Moreover, V2 reported the highest plant height in the two seasons. V2 S1 had the highest plant height interaction in the first season (235.cm), while V1 S1 reported the highest plant height interaction in season two (250.5cm). At the same time, the interaction of V1 S3 in season one reported the lowest plant height in the two seasons (22.6cm).

Table 4.3a. Effect of sowing dates on plant height for three cultivars (cm) at 90 days in season 2011/12 – 2012/13

Sowing date	Plant height at 90 days 2011/12				Plant height at 90 days 2012/13			
	V1	V2	V3	X	V1	V2	V3	X
S1	234.1	235.8	207.6	225.8	250.5	247.6	224.2	240.8
S2	219.3	212.2	199.9	210.5	215.2	240.5	215.3	223.7
S3	22.6	227.5	218.2	156.1	234.3	233.7	221.0	229.7
S4	231.9	231.9	189.7	217.8	233.2	327.4	200.1	253.6
Mean	177.0	226.9	203.9		233.3	262.3	215.2	
Cv%				6.4				7.8
LSD(v)				46.8*				51.31ns
LSD(s)				44.9**				47.87ns
LSD(VXS)				79.5**				83.14ns

4.2 Leaf Area (LA) at 30 days:

The effects of sowing date on Leaf Area at 40 days is presented in table 4.4aResults showed significant differences among the cultivars in the first season and highly significant differences in the cultivars and sowing dates in the second season, S1 reported the largest LAI in the two season, and V2 S1 reported the highest LAI interaction inthe first season (235.8cm) and the second season(296.8cm) respectively, while V1 in the first season indicated the lowest value among the three cultivars.

Table 4.4a. Effect of sowing dates on Leaf Area LA (cm) for three cultivars at 40 days in season 2011/12 – 2012/13

Sowing date	LA at 30 days 2011/12				LA at 30 days 2012/13			
	V1	V2	V3	X	V1	V2	V3	X
S1	234.1	235.8	207.6	225.8	275	296.8	216.4	262.7
S2	219.3	212.2	199.9	210.5	252.4	248.2	231.1	243.9
S3	022.6	227.5	218.2	156.1	233.4	254.2	226.7	238.1
S4	231.9	231.9	189.7	217.8	188.2	243.1	213	214.8
Mean	177.0	226.9	203.9		237.3	260.6	221.8	
Cv%				6.4				4.7
LSD(v)				46.8*				19.14**
LSD(s)				44.9**				15.67**
LSD(VXS)				79.5**				28.35**

4.2.1 Leaf Area (LA) at flowering stage:

The effect of sowing date on Leaf Area at flowering stageis presented in Table 4.5a. Results showed highly significant differences in the two seasons, S1 indicated the largest LA in the firstand second seasons respectively, however V2 S1 gave the highest LA (367.1cm), (366.2cm) in the two seasons respectively. V1 S4 reported the lowest LA interaction in the first season. V3 gave the lowest LA among the three cultivars.

Table 4.5a. Effect of sowing dates on Leaf Area LA (cm) for three cultivars at 60 days in season 2011/12 – 2012/13

Sowing date	LA at 00 days 2011/12				LA at 60 days 2012/13			
	V1	V2	V3	X	V1	V2	V3	X
S1	329.2	366.2	310.8	335.4	348.6	367.1	290.2	335.3
S2	327.6	353.3	273.1	318.0	271.9	297.3	270.7	280.0
S3	275.1	249.8	221.3	248.7	276.9	303.1	276.9	285.6
S4	213	268.4	217.5	233.0	284.5	309.5	257.5	283.8
Mean	286.2	309.4	255.7		295.5	319.3	273.8	
Cv%				2.9				5.5
LSD(v)				47.29**				31.07**
LSD(s)				29.68**				22.42**
LSD(VXS)				60.16**				42.58**

4.2.2Leaf Area (LI) at maturity stage:

Table4.6a showed effects of sowing date on LA at maturity stage. The results reflected highly significant differences among the cultivars, sowing dates and interactions. S1 indicated the highest LA in the first and second season respectively, while V2 S1 reported the highest LA interaction in the two season (227.8 cm) in season one and (163.9cm) in season two, moreover V3 reported the lowest LA value among the three cultivars in the two seasons

Table 4.6a. Effect of sowing dates on Leaf Area LA (cm) for three cultivars at 90 days in season 2011/12 – 2012/13

Sowing date	LA at 90 days 2011/12				LA at 90 days 2012/13			
	V1	V2	V3	X	V1	V2	V3	X
S1	154.8	163.9	116.3	145.0	221.2	227.8	125.5	191.5
S2	124.3	137.8	095.7	119.3	156.7	179	113.7	149.8
S3	093.8	081.6	081.7	085.7	155.4	181.3	104.3	147.0
S4	067.5	083.0	063.3	071.3	158.1	172.6	101.3	144.0
Mean	110.1	116.6	089.3		172.9	190.2	111.2	
Cv%				3.4				4.5
LSD(v)				22.15*				26.87**
LSD(s)				19.9**				14.11**
LSD(VXS)				34.94**				31.64**

4.3: Stem diameter at seedling stage:

Tables 4.7a showed that no significant differences on the stem diameterbetween the cultivars, sowing date and the interaction for the two season, S1 reported the thickest stem diameter in the firstseason while, S2 reported the thickest stem diameter in the secondseason. The means of V1, V2 and V3 gave the same values in season one (0.9cm), while among the three cultivars the mean of V3 indicated the thinnest stem diameter in season 2 (0.8cm), however V2 S2 produced the thickest stem diameter interaction for the two seasons at the same time V3 S4 in season one indicated the thinnest stem diameter interaction

Table 4.7a. Effect of sowing dates on stem diameter (cm) for three cultivars at 30 days in season 2011/12 – 2012/13

Sowing date	Stem diameter at 30 days 2011/12				Stem diameter at 30 day 2012/13		
	V1	V2	V3	X	V1	V2	V3
S1	1.1	1.2	1.0	1.2	1.0	0.9	0.9
S2	0.9	1.0	0.9	0.9	0.9	2.9	0.8
S3	0.9	0.8	0.8	0.8	0.9	0.9	0.8
S4	0.9	0.8	0.8	0.8	0.8	0.8	0.7
Mean	0.9	0.9	0.9		0.9	1.4	0.8
Cv%				5.7			
LSD(v)				0.18ns			
LSD(s)				0.13ns			
LSD(VXS)				0.25ns			

4.3.1: Stem diameter at flowering stage:

Tables 4.8a showed the effect of sowing date on stem diameter at flowering stage. The result indicated significant differences between the three cultivars and non-significant differences between sowing dates and the interaction in first season. However, the result obtained from second season clearly reported that no significant differences between cultivars, sowing datesnor the interaction.Moreover, sowing date S1 revealed the highest value of stem diameter in the two seasons, V1 S1 indicated the highest stem diameter (1.9cm) in the firstseason, while V2 S1 reported the highest stem diameter (1.4cm) in season two, in addition to that V1 reported the highest values among the cultivars at the same time V3 reported the lowest value among the cultivars.

Table 4.8a. Effect of sowing dates on stem diameter (cm) for three cultivars at 60 days in season 2011/12 – 2012/13

Sowing date	Stem diameter at 60 days 2011/12				Stem diameter at 60 days 2012/13			
	V1	V2	V3	X	V1	V2	V3	
S1	1.9	1.8	1.7	1.8	1.3	1.4	1.3	
S2	2.1	1.8	1.5	1.8	1.2	1.3	1.1	
S3	1.8	1.6	1.4	1.6	1.2	1.1	1.1	
S4	1.8	1.7	1.5	1.6	1.2	1.2	1.1	
Mean	1.9	1.7	1.5		1.2	1.3	1.1	
Cv%				4.1				[illegible]
LSD(v)				0.26*				0
LSD(s)				0.28ns				0
LSD(VXS)				0.47ns				0

4.3.2: Stem diameter at maturity stage:

Tables 4.9a showed the effect of sowing date on stem diameter at maturity stage. Result showed no significant differences between the cultivars, sowing date and the interaction for the two seasons.However, sowing date S4 in season one reported the highest value in the two seasons (2.9cm) similarly V2 S4 in the first season indicated the highest value in stem diameter (7.1cm). Moreover, the highest mean value among the cultivars wasreported by V2 in the first season

Table 4.9a. Effect of sowing dates on stem diameter (cm) for three cultivars at 90 days in season 2011/12 – 2012/13

Sowing date	Stem diameter at 90 days 2011/12				Stem diameter at 90 days 2012/13			
	V1	V2	V3	X	V1	V2	V3	
S1	1.0	1.2	0.9	1.0	0.8	0.9	0.7	
S2	1.0	0.9	0.8	0.9	0.6	0.6	0.7	
S3	1.0	1.0	0.7	0.9	0.7	0.7	0.7	
S4	0.8	7.1	0.8	2.9	0.7	0.7	0.7	
Mean	0.9	2.6	0.8		0.7	0.7	0.7	
Cv%				71.3				
LSD(v)				3.03_{ns}				0
LSD(s)				2.96_{ns}				0
LSD(VXS)				5.08_{ns}				0

4.4: Panicle diameter during maturity 2011/12:

Data on effect of sowing dates on panicle diameter during maturity stage presented in the Table 4.10a indicated significant differences between cultivars, sowing dates and the interaction of cultivar and sowing dates, however S1 reported the highest value in panicle diameter in the two seasons, V2 S1 interaction indicated the thickest panicle diameter in the two seasons (2.80cm) while V3 S4 reported the thinnest panicle diameter in the two seasons (1.85cm), in addition to that the data on mean values clearly showed that V3 recorded the lowest value among the cultivars (1.94cm) and that was observed in season

Table 4.10a. Effect of sowing dates on panicle diameter for three cultivars of millet during maturity stage in season 2011/12 – 2012/13

Sowing date	Panicle diameter at 90 days 2011/12				Panicle diameter at 90 day 2012/13			
	V1	V2	V3	X	V1	V2	V3	
S1	2.42	2.25	2.05	2.24	2.55	2.80	2.55	[illegible]
S2	2.05	2.00	1.95	2.00	2.47	2.60	2.32	[illegible]
S3	2.07	1.95	1.90	1.98	2.40	2.50	2.25	[illegible]
S4	1.95	2.02	1.85	1.94	2.12	2.67	2.12	[illegible]
Mean	2.13	2.06	1.94		2.39	2.64	2.31	
Cv%				2.1				
LSD(v)				0.30*				0
LSD(s)				0.23*				0
LSD(VXS)				0.42*				0

4.4.1: Panicle length during maturity 2011/12 - 2012/13:

Data on effect of sowing dates on panicle height during maturity stage presented in the Table 4.11a indicated significant differences between cultivars, sowing date and the interaction between them in the first season, while the collected data reported significant differences between the cultivars and the interaction between cultivars ad sowing dates at the same time no significant differences between the sowing dates in the second season. However, S4 in the first season gave the shortest panicle length (22.65cm)for the tow season while S3 in the second season gave the tallest panicle length for thetwo season (26.87cm), moreover V1 S3 in the second season reported the tallest panicle interaction for the two season (28.75.cm) while V3 S4 reported the shortest panicle height interaction for the two season (19.45cm), in general V3 considered to be the shortest panicle height in the two seasons

Table 4.11a. Effect of sowing dates on panicle length for three cultivars of millet during maturity stage in season 2011/12 – 2012/13

Sowing date	Stem diameter at 90 days 2011/12				Stem diameter at 90 days 2012/13			
	V1	V2	V3	X	V1	V2	V3	
S1	22.19	23.95	19.77	21.97	26.05	25.82	22.62	2
S2	22.12	26.75	20.47	23.11	25.85	27.82	23.77	2
S3	23.97	25.95	19.45	23.12	28.75	27.45	24.40	2
S4	23.00	25.1	19.85	22.65	26.27	27.60	21.35	2
Mean	22.82	25.44	19.89		26.73	27.17	23.04	
Cv%				2.8				
LSD(v)				2.52*				2
LSD(s)				1.92*				2
LSD(VXS)				3.57*				3

4.5: Straw yield at maturity 2011/12:

Data on effect of sowing dates on straw yield during maturity stage presented in Table 4.12a indicated significant differences between cultivars, sowing dates as well as the interaction between them for the two seasons. However, S1 in the second season reported the highest value (1.81kg) while S3 in the second season reported the lowest value (0.94kg), V2 S1 in the second season indicated the highest value in straw yield for the two seasons (2.32kg) while V3 S3 reported the lowest value in straw yield for the two seasons.Among the three cultivars, V3 reported the lowest value in the first and second season respectively.

Table 4.12a. Effect of sowing dates on three cultivars of millet on Straw yieldduring maturity stage in season 2011/12

Sowing date	Straw yield at 90 days 2011/12				Straw yield at 90 days 2012/13			
	V1	V2	V3	X	V1	V2	V3	X
S1	1.55	1.22	1.00	1.26	1.72	2.32	1.37	1.81a
S2	1.47	1.27	0.97	1.24	1.47	1.97	0.90	1.45b
S3	1.45	0.70	0.67	0.94	1.57	1.22	0.92	1.24b
S4	1.10	1.07	1.12	1.10	1.10	1.27	1.25	1.21b
Mean	1.39	1.07	0.94		1.47	1.70	1.11	
Cv%				19.7				9.5
LSD(v)				0.56*				0.43*
LSD(s)				0.29*				0.24*
LSD(VXS)				0.66*				0.52*

4.5.1: Grain yield kg 2011/12 -2012/13:

Data on effect of sowing dates on grain yield is presented in Table 4.13a indicated significant differences in cultivars, sowing dates and interaction in the two seasons. However, S1 indicated the highest grain yield in the two seasons while S4 gave the lowest grain yield in the two seasons, V2 S1 in season two reported the highest grain yield for the two seasons (222.8kg), while V3 S4 in the first season reported the lowest grain yield for the two seasons.Moreover, V2 showed the highest value in grain yield for the two seasons (145.0 kg) while V3 reported the lowest value in grain yield for season one and two respectively.

Table 4.13a. Effect of sowing dates on three cultivars of millet on Grain yield during maturity stage in season 2011/12 – 2012/13

Sowing date	Grain yield at 90 days 2011/12				Grain yield at 90 days 2012/13			
	V1	V2	V3	X	V1	V2	V3	X
S1	190.5	191.0	186.8	189.4 a	209.3	222.8	196.8	209.6a
S2	169.0	170.0	164.8	167.9 a	176.0	186.8	164.8	175.9b
S3	077.8	091.2	085.0	084.7 b	090.8	105.5	085.0	093.8c
S4	037.8	052.5	034.2	041.5 c	054.2	65.00	034.2	051.1d
Mean	118.8	126.2	117.7		132.6	145.0	120.2	
Cv%				9.2				8.5
LSD(v)				28.47*				28.36**
LSD(s)				26.67**				25.16**
LSD(VXS)				46.28**				44.35**

CHAPTER FIVE

DISSCUSSION

The effect of sowing dates on plant height of three millet cultivars during three growing stages were presented in Tables 4.1a. The results showed significant difference for most parameters through three stages for two seasons except for seedling stage of first season. The three cultivars had no clear variation in plant height, sometime V_2 was the tallest in plant height. The first sowing date S_1 gave the tallest plant height during three stages for two seasons (*Siddig A, etal 2013*). The interaction of cultivars with sowing dates produced the tallest plants, almost S_1V_2 in

Maturity stage of first season and three stages of second season. During first July (S_1) plants showed vigorous growth and this could be due to fact that at this time the rain was continues and well distributed to enable good germination of seeds and well-established of plants. (Siddig AMA, etal 2013) obtained the same results under similar area and condition in Sudan.

The data of LA showed in Tables 4.6a for two seasons. Among cultivars V_3 showed the lowest LAI in all readings with significant difference except in seeding stage of first season, in which V_1 gave the lowest values. Sowing date S_1 revealed the widest LAI compared with other sowing date with significant difference. The interaction between cultivars and sowing dates showed highly significant difference at p=.01 and V_1S_1 had the highest values for the two seasons. This was in line with (*Deshmukh LS, etal 2009*)but in contrast to (*Siddig AMA, etal 2013*) who found insignificant difference between sowing dates and varieties and attributed that may be due to the dry spills during the seasons.

There were no significant differences on stem diameter of three millet cultivars as affected by sowing dates for two seasons except on the cultivars of flowering stage of season two Tables 3a and 3b. Effect of sowing dates on three cultivars of pearl millet on plant density was presented in Tables 4a and 4b for two seasons. The cultivars had no significant variation, except in maturity stage at second season and V_1 had height plant density. Sowing date showed significant difference and S_1 had the highest plant density for all stages for two seasons, except in first season in seedling stage in which S_2 higher plant density. On the other hand, the interaction had significant difference and the following values had the biggest values respectively for two seasons for the three stages, V_2S_2, V_3S_2, V_3S_1, V_2S_1, V_3S_2 and V_1S_1. Effect of sowing dates on panicle diameter and panicle length was presented in Table 4.10a, 4.11a for two seasons. The result showed significant difference for both readings. V_1 and V_2 had the thickest panicle diameter for season one and two respectively. Among the sowing date S_1 produced plants with the biggest panicles for two seasons, interaction between V_1S_1 and V_2S_2 had the highest values for the two seasons. For panicle height cultivars V_2, and sowing dates S_3 were the best values for two seasons. V_2S_2 and V_1S_3 were the best values of interaction for two seasons respectively.

Yield of straw and grain yield in kg/ha of three millet cultivars for two seasons were presented in (above) Table 6 the results obtained significant difference for all the readings. Pearl millet productivity was low as it ranged from 222 kg/ha to 34 kg/ha during two seasons respectively. This results was in line with, (*Graef F, etal, 2001*) who reported that pearl millet productivity was usually low and variable, because of natural causes, including a short rainy season that is spatially and temporally variable and poor soil quality. For straw yield cultivars V_1 and V_2 was the highest value for season one and two, and S_1 was the best sowing date for two seasons. In interaction results the best values were obtained in V_1S_1 and V_2S_1. Grain yield data V_2 and S_1 and their interaction (V_2S_1) were reviled the highest values. In general, S_1 is the most ideal date for yield improvement. (*Uzoma AO, etal*)respond that to periods of reduced photoperiod, striga infection, temperature and adequate rainfall. Also (*Zarafi AB 200*) reported that early sowing gave lower disease incidence and higher grain yield than late sowing. (*Siddig AMA, etal 2013*) found that on most crop yield component whereas, results showed insignificant interaction between sowing dates and varieties.

Data on effect of sowing dates on grain yield is presented in Table 4.13a indicated significant differences in cultivars, sowing dates and interaction in the two seasons this is in line with (*Eshraghi, etal 2013*) who reported that the interaction effect due to sowing date on grain yield was significant. However, S1 indicated the highest grain yield in the two seasons while S4 gave the lowest grain yield in the two seasons, V2 S1 in season two reported the highest grain yield for the two seasons (222.8kg), while V3 S4 in the first season reported the lowest grain yield for the two seasons. Moreover, V2 showed the highest value in grain yield for the two seasons (145.0 kg) while V3 reported the lowest value in grain yield for season one and two respectively.

CONCLUSION

Based on current data and plant growth habits planting date of early July had resulted in significantly higher yields of grain and Stover. Dembi and Bauoda cultivars of millet were also of great productivity in two seasons, in spite of flocculation of rain fall. Research on sowing dates must lie heavily on the length of the growing period and the time of first rainfall put in consideration that the length of the growing period is mainly a function of the date of the first rains.

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