EFFECTS OF TILLAGE PRACTICES AND CROP RESIDUE MANAGEMENT ON GROWTH AND YIELD OF SORGHUM (*Sorghum bicolor* L. Moench) VARIETIES IN SUDAN AND SAHEL SAVANNAS OF NIGERIA

BY

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A DISSERTATION SUBMITTED TO THE DEPARTMENT OF AGRONOMY, FACULTY OF AGRICULTURE, BAYERO UNIVERSITY KANO, IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF SCIENCE IN AGRONOMY

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JANUARY, 2020

DECLARATION

I hereby declare that this work is the original product of my work and has not been presented anywhere for the award of a Degree. References made to published literature are duly acknowledged.

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CERTIFICATION

This is to certify that this research work titled "Effects of Tillage Practices and Crop Residue Management on Growth and Yield of Sorghum (*Sorghum Bicolor* L. Moench) Varieties in Sudan and Sahel Savannas of Nigeria" was conducted by SALIM IBRAHIM ISA (SPS/16/MAG/00019) under my supervision.

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APPROVAL

This dissertation titled "Effects of Tillage Practices and Crop Residue Management on Yield of Sorghum (*Sorghum Bicolor* L. Moench) Varieties in Sudan and Sahel Savannas of Nigeria" by SALIM IBRAHIM ISA (SPS/16/MAG/00019) submitted to the Department of Agronomy, School of Postgraduate Studies, Bayero University, Kano has been examined and approved for the award of the Degree of Master of Science in Agronomy.

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DEDICATION

This research work is dedicated to my father, Alh. Ibrahim Isa Wada, my mother Malama Rabi'atu Hassan Muhammad, my entire family and all those with whom we unite in the love of the Prophet Muhammad, peace and blessings of Allah be upon Him.

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ABSTRACT

Field trials were conducted during the 2018 rainy season at the Research Farms of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Minjibir, Kano and that of Usman Dan Fodio University, Dabagi, Sokoto located at the Sudan and Sahel Savannas Ecological Zones of Nigeria respectively, to evaluate the performance of Sorghum under different tillage conditions and to assess the effect of different levels of residue removal on growth and yield of Sorghum (*Sorghum bicolor* L. Moench) varieties. The treatments consisted of two tillage practices (minimum tillage and conventional tillage), three residue management levels (0%, 50% and 100% residue removals) and two Sorghum varieties (Local Kaura and Improved Deko). The treatments were arranged in Split-split plot design with four replications. Tillage practices, residue removals and varieties were assigned to the main, sub and sub-sub plots respectively. The gross plot size was 3.75m x 6m (22.5m^2), consisting of 5 ridges of 6m length each. Data on growth and yield characters were collected and subjected to analysis of variance (ANOVA) using Genstat 17th Edition. Treatment means were separated using Student-Newman Keuls Test. The results showed that tillage practices and residue removal had no significant effect on chlorophyll content, Leaf Area Index (LAI), Days to maturity, plant height, number of stands at harvest and yield ha^{-1}. Tillage practices significantly affected soil moisture content (MC), and stalk weight and had no significant effect on 1000 grain weight at Minjibir only. Residue management had significant effect on 1000 grain weight. Chlorophyll content, LAI, days to 50% flowering, days to maturity, number of stands at harvest, plant height, yield ha^{-1} and stalk weight ha^{-1} were significantly affected by varieties. Significantly higher yields were obtained from Improved Deko at Minjibir. Further research is recommended on the treatments at the study locations over the next years to arrive at optimum combinations for high sorghum yield.

CHAPTER ONE

1.0 INTRODUCTION

1.1 BACKGROUND OF THE STUDY

Sorghum (*Sorghum bicolor* (L) Moench) belongs to the family Poaceae and is known as guinea corn in West Africa and locally called Okababa, Dawa and Okili in three major languages of Nigeria (Adegbola *et al*., 2013). Sorghum originated from North Eastern Africa where it was domesticated about 5,000 years ago (Mann *et al.*, 1983) and spread to West Africa at an early date across Sudan to the upper Niger River. The early domestication of the crop resulted in its distribution through the major trading and migratory path of the early Africans and Asians (Dahlberg *et al.*, 2011). Sorghum is the fifth most important cereal in the world after Corn, Rice, Wheat, and Barley. It is considered as source of diet to over 500 million people in about 30 countries (Reddy *et al.,* 2010; Dahlberg *et al.,* 2011). Global sorghum production stood at 63.9 million tonnes in 2016. Nigeria being the world second largest producer accounted for 12% of global production with 6.9 million tonnes (FAOSTAT, 2017). The bulk of Sorghum produced in Nigeria is from Kaduna, Kano, Jigawa, Katsina, Borno, Plateau, Niger, Zamfara, Yobe, Kebbi, Bauchi, Adamawa and Gombe (Aba *et al.*, 2005; NAERLS, 2007).

1.2 SOIL AND CLIMATIC REQUIREMENTS

Sorghum is a warm-season crop that has a C_4 photosynthetic pathway (Newman *et al.*, 2013). The plant grows under relatively high temperatures of between 20^0C to 30^0C on a deep, well drained, fertile soil. It also requires a rainfall of between 400mm to 800mm distributed across the growing period. The crop can tolerate alkaline salt condition and thus able to grow on soils with a pH of 5.5 to 8.5 and is one of the hardiest cereals (Adegbola *et al.*, 2013). It is cultivated on marginal, fragile drought prone environment in the semi-arid tropics of Africa and Asia. This crop is genetically suited to hot and dry agro-ecologies where it is difficult to grow other grains (ICRISAT, 2004).

1.3 USES AND NUTRITIONAL VALUE OF SORGHUM

The ability of Sorghum to grow in areas where Maize may not grow gives it the advantage of reducing local food and livestock feed shortage (Legodimo and Madibela, 2013). Sorghum flour is also incorporated into wheat flour at various percentages to produce cakes, cookies and bread (Abdelghafoor *et al.*, 2011). It is considered as a principal source of energy, protein, vitamins and minerals for millions of poor people in Africa and Asia. About 33 % of the Sorghum grain is used in the production of livestock feed mostly in the Americas and other developed countries (Reddy *et al.*, 2010; Mason, 2010). The grains are also used in the production of alcoholic and non-alcoholic beverages such as beer ("burkutu") and malts (Adegbola *et al.*, 2013; Momoh, 2012; Eleke, 2011). The stalks are used as building material and fencing (Rooney and Waniska, 2000). Sorghum can also be utilized in the production of bio-industrial products such as bio-plastics (McLaren *et al.*, 2003). Sorghum is composed of starch (63 – 68%), moisture (9 – 13%), protein (9 – 11%), fats and oils (1 - 1.5%), crude fibre (1.5 – 2%), ash (1 – 2%) and other organics (8 – 12%) according to Sheorain *et al.* (2000).

1.4 PROBLEM STATEMENT

Soil degradation is a widespread issue around the globe and has long lasting implications on soil productivity and future food security. Intensive tillage and residue removal are widespread agricultural practices that can accelerate soil degradation by reducing soil biological activity, soil organic matter and aggregation, as well as increasing the susceptibly of soil to erosion, ultimately leading to a decline of soil productivity (Reicosky *et al.*, 2011). Today there are major problems facing the modernization of African Agriculture. Food production must necessarily keep pace with population growth. Many countries will soon have limited new land for agricultural development leaving no alternative other than intensifying yield per unit area. Tillage and residue management which have direct influence on soil and water conservation are two important components of soil management in Africa, especially in the semi-arid tropics. Soil management and conservation must play a major role in increasing crop yields and soil productivity on a sustainable basis (Ofori, 2018).

1.5 JUSTIFICATION

In dry land areas, moisture and soil characteristics are major production limiting factors. Since crop residues have the potential to reduce soil degradation and improve water infiltration, they can be used as a strategic intervention to improve land productivity through effective soil and water conservation practices. Considerable work on tillage has been carried out during the past two decades in Africa, considering the limited number of research institutions. However, more intensive work is required on the different soil types, climatic conditions and cropping systems. The use of crop residue for soil management purposes must be given serious consideration (Ofori, 2018). Hence to improve production practices for both the Sudan and Sahel regions of the country, an understanding of the effects of different tillage systems and different levels of crop residue removal on the yield of important dryland crops such as sorghum is essential. There is also a need to test the adaptability of various Sorghum varieties in different agro-ecological zones if recommendations are to be made for specific locations. This research is aimed to evaluate the effect of tillage practices and crop residue concurrently on the productivity and long-term farm sustainably of two sorghum varieties in the study areas.

1.6 OBJECTIVES OF THE STUDY

This study was carried out to:

1. Evaluate the performance of Sorghum under different tillage conditions.
2. Assess the effect of different levels of residue removal on growth and yield of Sorghum.
3. Determine the best variety of Sorghum for the study location

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 TILLAGE

Tillage has been an important aspect of technological development in the evolution of agriculture, in particular in food production. The objectives of tilling the soil include seedbed preparation, water and soil conservation and weed control. Soil tillage is probably as old as settled agriculture. It has been therefore an integral part of traditional and/or conventional agriculture. Tillage of agricultural soils is defined as the manipulation, generally mechanical, of soil properties to modify soil conditions for crop production (Soil Science Society of America, 1987). Specific reasons for tilling a soil include weed control, incorporation of soil amendments, crop residues and pesticides, and modification of soil physical properties, thereby improving soil conditions for crop establishment, growth and yield (Cassel, 1983). There are various tillage systems that can be used but each of them has advantages and disadvantages to be considered. The two extremes are, however, conventional and minimum tillage.

2.1.1 Conventional Tillage

Conventional tillage can be defined as moldboard plowing followed by disking one or more times to obtain a loose, friable seedbed (Phillips *et al.*, 1980). This intensive operations not only kills weeds competing with crop plants for water and nutrients, but also modifies the circulation of water and air within the soil which enhances organic matter decomposition and hence the release of nutrients like nitrogen for crop growth (Reijntjes *et al.*, 1992).

2.1.2 Minimum Tillage

According to Phillips *et al.* (1980) minimum tillage can be defined as a system in which the crop is planted with just sufficient tillage to allow placement and coverage of the seed for germination and emergence. Usually no further cultivation is done before harvesting. Weeds and other competing vegetation are controlled by chemical herbicides. Soil amendments, such as fertilizers are applied to the soil surface.

Several other terms, such as zero tillage, reduced tillage, mulch tillage, direct seeding, sod planting and stubble planting are sometimes used to describe systems similar to what is defined as minimum tillage (Phillips *et al.*, 1980). Minimum tillage is also synonymous with conservation tillage (Willis and Amemiya, 1973) and implies retention of more than 30% of the crop residues on the soil surface. It is not surprising therefore that Lal (1989) stated that minimum tillage was developed to alleviate soil related constraints for crop production and meet the need for the conservation of soil, water and energy resources.

Many studies showed that minimum tillage is very beneficial for the conservation of soil and water (Phillips *et al.*, 1980). In essence it involves minimum disturbance of soil and good soil cover with residues. The crop residues remaining on the soil surface with minimum tillage provide not only essential physical protection to the soil particularly against erosion, but also make available decomposable biomass to the organic matter pool of soil which will improve fertility (Bruce *et al.*, 1991) .

Minimum tillage has been shown to have several advantages over conventional tillage. Some of these were discussed by Triplett and Van Doren (1977) and others by

Phillips *et al.* (1980). They included reduced erosion by wind and water, ability to grow crops on sloping land, increased productivity of farm workers, improved timing of planting and harvesting, more efficient use of soil water, lower machinery requirement, reduced soil compaction, standing residues provided shelter for wildlife and food for livestock where applicable.

2.2 EFFECTS OF TILLAGE SYSTEMS ON SOIL AND CROP YIELD

Tillage has various physical, chemical and biological effects on the soil both beneficial and degrading, depending on the appropriateness or otherwise of the methods used. The physical effects such as aggregate-stability, infiltration rate, soil and water conservation, in particular, have direct influence on soil productivity and sustainability (Ofori, 2018). Tillage affects soil physical, chemical and biological properties. Research results have been widely reported on the effects of tillage on soil aggregation, temperature, water infiltration and retention as the main physical parameters affected. It affects aeration and thus the rate of organic matter decomposition. Biological activities in the soil are vital to soil productivity through the activities of earthworms, termites and the many other living creatures in the soil. These influence water infiltration rates by their burrowing in the soil and their mucilage promotes soil aggregation.

A large volume of experimental data has been published on tillage effects on crop yields under various climates, agro-ecological conditions, soils, crops and residue management systems. Under some of these conditions, the tillage effect is either closely linked to soil aggregation, hence water infiltration rate and water storage capacity, or indirectly related to soil and water conservation. Moisture conservation is particularly important in semi-arid conditions (Ofori, 2018). The effect of tillage systems on crop yield is not uniform with all crop species, in the same manner as various soils may react differently to the same tillage practice. A research conducted by Nicou and Charreau (1985) showed the effect of tillage on yields of various crops in the West African semi-arid tropics.

2.3 EFFECTS OF RESIDUE MANAGEMENT STRATEGIES ON SOIL AND CROP YIELD

Crop residues are extremely important to soils to improve its chemical and physical characteristics. They enhance soil structure, reduce soil erosion and improve water availability to plants (Tittonell *et al.*, 2008). The work done by Hartkamp *et al.* (2004) revealed that retention of small amount of crop residues (1.5t ha^{-1}) doubled maize yield even at low rain fall areas.

Crop residues are also nutrient sources for soil fertility improvement. Crop residues represent about half of the nutrients exported through the main commodity production (Latham, 1997). Therefore, substantial amounts of crop residue retention increase soil fertility. Furthermore a study by Aggarwal *et al.* (1997) showed higher mineral fertilizer use efficiency for crop residue applied plots. From these findings, one can appreciate the role of crop residues in sustaining soil fertility and productivity. Effective soil and water conservation practices are possible when crop residues are adequately available (Unger *et al.*, 1997).

Other benefits of retaining crop residues on the soil surface include an increase of organic matter and nutrient levels, moderation of soil temperature and increased soil biological activity, all of which are important for sustaining crop production (Powell and Unger, 1997). However, the frequently-observed initial yield suppression which follows residue application to soil is attributed to N immobilization as mentioned above (Ocio *et al.*, 1991). It is generally reported that crop residues with a C:N ratio of greater than 35 or N content of less than 1.6%, usually decompose slowly, and cause immobilization (Nandwa *et al*., 1995).

Residues of cereal crops comprise 60 to 75 % of the total biomass production and have lower nutrient concentrations than the grain (Van Duivenbooden, 1992). However, these residues contain about half of the nutrients exported from the soil through crop production (Unger, 1990). Therefore, returning of them to the soil in systems particularly, where no or low inputs are used, is essential in slowing down nutrient losses. However, crop residues by themselves are not enough to offset nutrient mining in sub-Saharan Africa (Woomer and Swift, 1994)

Crop residue management influences the availability of nutrients especially N. When crop residues with a wide ratio of C:N are incorporated into soil the residual inorganic N remaining in the soil after harvesting is immobilized. After maximum immobilization, mineralization of the previously immobilized N occurs, resulting in a net release of N (Allison and Klein, 1962). In such conditions even a portion of fertilizer N added to soil is immobilized, but the mineralization rate of the recently immobilized fertilizer N is greater than that of indigenous organic N for the same period (Freney and Simpson, 1969).

2.4 INTERACTIONS BETWEEN TILLAGE PRACTICES AND RESIDUE MANAGEMENT ON CROP PERFORMANCE

Crop residues are important to the accumulation or loss of soil organic matter (Barber, 1979). Unfortunately, addition of crop residues on conventionally tilled soils does not increase soil organic matter content (Beale *et al*., 1955), while minimum tillage coupled with crop residue addition has been reported to increase soil organic matter content of the surface horizon (Bruce *et al*., 1991). On the other hand, as far as placement is concerned, retention of crop residues on the soil surface with minimum tillage decreases the rate of decomposition (Parker, 1962) while with conventional tillage where crop residues are incorporated in the soil there is greater mechanical disruption and subsequently more intimate contact with decomposer organisms increases the rate of decomposition (Ambus and Jensen, 2001).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 EXPERIMENTAL SITES

The experiment was conducted during the 2018 rainy season at two different locations; the International Crop Research Institute for the Semi Arid Tropics (ICRISAT) Research Farm ($12^0$10'N $8^0$39"E), Wasai Village, Minjibir Local Government Area, Kano, in the Sudan Savanna and Teaching and Research Farm of the Faculty of Agriculture, Usmanu Danfodio University, Sokoto (8°13'N 3°6"E) at Dabagi Village in Dange-Shuni Local Government Area, in the Sahel Savanna ecological zone of Nigeria.

3.2 METEOROGICAL DATA

Meteorological data of the experimental sites were collected from the ICRISAT weather stations at Minjibir, Kano and Dabagi, Sokoto.

3.3 SOIL SAMPLING AND ANALYSIS

Soil samples of the experimental sites were randomly collected using soil auger, at the depth of 0-30cm prior to sowing. The samples collected were bulked, dried, ground, sieved and analysed for physico-chemical properties as described by Black (1965).

3.4 TREATMENTS AND EXPERIMENTAL DESIGN

The treatments consisted of two tillage practices (minimum and conventional), three levels of residue management (0%, 50% and 100% residue removals) and two sorghum varieties (Local Kaura and Improved Deko (Samsorg 45)). These were laid out in split-split plot design, with tillage practices assigned to the main plot, residue management assigned to the sub-plot and Sorghum varieties assigned to the sub-sub plot. The treatments were assigned to 12 plots which were replicated four times to give a total of 48 plots for each location.

Conventional tillage was achieved by clearing the land, ploughing, harrowing and ridging while minimum tillage was achieved by carrying out only the necessary soil disturbance during sowing, fertilizer application and weed control. Also, 0%, 50% and 100% residue removals were achieved by leaving all, half and none of the residues, respectively from the previous cropping season.

Main Plot: Tillage Practice; Conventional and Minimum tillage

Sub-Plot: Residue Management; 0%, 50% and 100% residue removals

Sub-sub Plot: Sorghum Varieties; Improved DEKO (SAMSORG 45) and Local Kaura

3.4.1 **Plot Sizes**

The plots were marked as follows:

Main plot: 66 ridges (49.5m x 5m) = 247.5m^2

Sub-plot: 33 ridges (24.75m x 5m) = 123.75m^2

Sub-sub plot: 5 ridges (3.75m x 5m) = 18.75m^2

Total Area = 55.5m x 28m = 1554m^2

3.4.2 Description of Varieties

S/No	Variety	Variety Details
1.	Local Kaura	Early – Medium Season, Medium Maturing (100 – 110 days), Tall height (2-2.5m), potential yield (2.5 t ha^{-1}).
2.	Improved DEKO (SAMSORG 45)	Early-Medium season, Early maturing (90 - 95 days), medium height (1-1.5m), potential yield (3.0 – 3.5 t ha^{-1}).

3.5 CULTURAL PRACTICES

3.5.1 Land Preparation

Conventional tillage was achieved by clearing the land, ploughing, harrowing and ridging while minimum tillage was achieved by carrying out only the necessary soil disturbance during sowing, fertilizer application and weed control.The experimental plots were then laid as per number of treatments.

3.5.2 Field Layout

The field was laid out as per the experimental design as shown in Appendix 1.

3.5.3 Source of Seeds and Sowing

The seeds were obtained from the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). Sowing was done at a spacing of 0.75m x 0.25m inter- and intra-row spacings respectively. Five seeds were sown at 3-5cm depth and later thinned to two plants per stand.

3.5.4 Fertilizer Application

Fertilizer was applied at sowing and three weeks after the first application in the form of NPK 15:15:15 at the recommended rate of 120kg N, 60kg P_2O_5, 60kg K_2O ha^{-1}. Farm yard manure was applied at the rate of 6 tha^{-1}.

3.5.5 Weed Control

Hoe weedings were done at 2, 4 and 6 weeks after sowing (WAS) to control weeds.

3.5.6 Pest Control

Pesticide (Cypermtrin + Dimetheote) at a concentration of 2l ha^{-1} a.i was used to control pests (army worm (*Spodoptera frugiperda*)) during occurrence at 6WAS.

3.5.7 Harvesting

The panicles were harvested at physiological maturity, detected by the formation of black spots beneath the seed capsule, and the turning of leaves from green to brown. Harvesting was done with sickle, and the panicles were packed and labeled for easy identification.

3.6 DATA COLLECTION

Four plants were randomly selected and tagged from each net plot and growth and yield data were collected from the plants as described below;

3.6.1 Chlorophyll Content (SPAD)

Chlorophyll content was taken using Konica-Minolta SPAD-502 Chlorophyll Meter; a hand-held, self-calibrating, convenient, and non-destructive lightweight device used to detect the amount of chlorophyll present in plant leaves. This was taken at 6, 9 and 12 WAS.

3.6.2 Leaf Area Index (LAI)

The Leaf Area Index was calculated as leaf area per unit ground surface area covered. This was taken using AccuPAR Model LP-80 PAR/LAI Ceptometer (Decagon Device, Inc. Pullman, USA).

3.6.3 Stand Count

Number of stands at harvest from each plot was counted and recorded.

3.6.4 Days to 50% Flag Leaf

Number of days from sowing to the appearance of 50% flag leaves was recorded.

3.6.5 Days 50% Flowering

The number of days from sowing to when panicles have emerged on 50% of the plants in each plot was recorded.

3.6.6 Days to Maturity

The number of days from sowing to when the plants reach physiological maturity was taken and recorded. This was identified by the formation of a black layer, visible by a dark spot on the kernel opposite the embryo.

3.6.7 Plant Height (m)

Plant height at harvest was measured using metre rule from the base of the plant to the tip of the panicle.

3.6.8 1000 Grain Weight (g)

One thousand grains from each plot were counted using Toledo Seed Counter (Model: CT471103) and weighed using Mettle Toledo sensitive weighing balance model: XP60025.

3.6.9 Grain Yield ha^{-1} (kg)

Grain yield $plot^{-1}$ was measured using weighing balance and converted to grain yield in kg ha^{-1}.

3.6.10 Stalk Weight kg ha^{-1}

Stalk weight from each plot was taken using hanging scale, recorded and converted to stalk weight in kg ha^{-1}

3.7 DATA ANALYSIS

Data obtained was subjected to analysis of variance (ANOVA) using Genstat statistical package (17th Edition), and treatment means were separated using Student-Newman Keuls Test. The structure of the analysis of variance (ANOVA) is shown in Appendix 2.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 RESULTS

4.1.1 Meteorological Properties of the Experimental Sites

Weather (Temperature and rainfall) data at both experimental sites over the growing periods was collected from June to October, 2018. Highest rainfall was received at Minjibir in the month of August (329.2mm) and at Dabagi in July (319.5mm), while the lowest rainfall (7.5mm and 54.9mm respectively) was received in October at both locations. Dabagi also received higher rainfall (830.1mm) than Minjibir (585.9mm) over the period in consideration. At both locations, highest mean temperatures (30.1℃) were recorded in June while the lowest mean temperatures (26.5℃) were experienced in August at both locations (Appendix 3).

4.1.2 Physico-chemical Properties of Soils at the Experimental Sites

Table 1 shows the results of soil analyses at the experimental sites. The physical properties of soil samples collected from 0 – 30cm showed that the textural classifications of the soils were sandy at both locations with each having 92% sand, 2% silt and 6% clay. However, chemical analyses indicated that pH(H_2O) was 5.78 for Minjibir and 5.23 for Dabagi. pH($CaCl_2$) was 5.74 for Minjibir and 5.02 for Dabagi. Organic carbon content was 0.120% and 0.182% for Minjibir and Dabagi respectively. Total available Nitrogen was 0.175% at Minjibir and 0.105% at Dabagi. Phosphorous was 32.609m/kg at Minjibir and 2.74m/kg at Dabagi. Soil samples from Minjibir generally had higher exchangeable bases (Ca, Mg and K) than that of Dabagi.

Table 1. Physico-chemical Properties of Soils (0-30cm) at Minjibir and Dabagi During the 2018 Rainy Season

Soil Properties	Minjibir	Dabagi
Physical Composition (g kg^{-1})		
Sand	920	920
Silt	20	20
Clay	60	60
Textural Class	Sand	Sand
Chemical Composition		
pH(H_2O)	5.78	5.23
pH($CaCl_2$)	5.74	5.02
Organic Carbon (g kg^{-1})	1.20	1.82
Total available Nitrogen (g kg^{-1})	1.75	1.10
Phosphorus (m kg^{-1})	5.663	2.740
Exchangeable Bases (cmol kg^{-1})		
Ca^{2+}	0.635	0.334
Mg^{2+}	0.595	0.249
K	0.470	0.113
CEC	1.901	1.179

Analysed at the Soil Science Laboratory, BUK.

4.1.3 Chlorophyll content

The effects of tillage practice, residue management and varieties on chlorophyll content of Sorghum during the 2018 rainy season at Minjibir and Dabagi are shown in Table 2. There were no significant differences statistically ($P>0.05$) between the different tillage practices on chlorophyll content at both locations. Similarly, there was no significant difference statistically ($P>0.05$) between the residue management on chlorophyll content of sorghum across the sampling periods in both locations. However, highly significant statistical differences ($P<0.001$) were observed between the varieties on chlorophyll content of sorghum only at 12WAS in Minjibir. Interactions between tillage and residue management on chlorophyll content were significant ($P = 0.041$) only at 9WAS in Minjibir and at 6WAS at Dabagi ($P = 0.035$), between residue management and varieties at 6WAS in Minjibir only and between tillage, residue management and varieties at 9WAS only in Dabagi.

Table 3 shows the interactions between residue management and variety on chlorophyll content of Sorghum at 6WAS in Minjibir during the 2018 rainy season. Highest SPAD values (36.39) were obtained from Improved Deko with 0% residue removal. This was statistically at par with the observations made for SPAD values in Local Kaura (35.77) with 50% residue removal and Improved Deko (37.09) with 100% residue removal.

Table 4 shows the interaction between tillage practices and residue management on chlorophyll content of Sorghum at 9WAS in Minjibir during the 2018 rainy season. The interaction between 0% residue removal and conventional tillage gave the highest

Table 2. Effects of Tillage Practice, Residue Management and Varieties on chlorophyll content (SPAD) of Sorghum at Minjibir and Dabagi during the 2018 rainy season.

	Minjibir (WAS)			Dabagi (WAS)		
Treatment	6	9	12	6	9	12
<u>Tillage Practice (T)</u>						
Conventional	35.12	39.11	39.05	41.57	40.16	43.20
Minimum	35.18	36.50	39.23	38.62	40.15	44.90
P of F	0.954	0.169	0.880	0.329	0.996	0.37
SE±	0.874	1.450	1.065	2.535	1.495	1.66
<u>Residue Mgt (R%)</u>						
0	35.08	38.70	38.75	40.96	40.00	43.9
50	34.92	36.74	39.36	39.42	40.05	43.7
100	35.45	37.98	39.31	39.89	40.41	44.5
P of F	0.878	0.400	0.909	0.707	0.981	0.938
SE±	1.049	1.411	1.551	1.867	2.289	2.41
<u>Variety (V)</u>						
Improved Deko	35.85	38.43	41.48a	41.37	41.09	45.4
Local Kaura	34.45	37.18	36.80b	38.82	39.22	42.7
P of F	0.080	0.377	<.001	0.094	0.164	0.204
SE±	0.751	1.381	0.760	1.440	1.291	2.10
<u>Interaction</u>						
T x R	0.314	0.041	0.338	0.035	0.425	0.678
T x V	0.198	0.327	0.940	0.649	0.460	0.835
R x V	0.029	0.206	0.200	0.349	0.353	0.795
T x R x V	0.550	0.423	0.977	0.482	0.025	0.821

Means followed by the same letter within the same column are not statistically significant at 5% level of probability using SNK.

Table 3. Interaction between residue management and variety on chlorophyll content (SPAD) of Sorghum at 6WAS in Minjibir during the 2018 rainy season

	Residue Management (%)		
Variety	0	50	100
Improved Deko	36.39a	34.08b	37.09a
Local Kaura	33.77b	35.77a	33.81b
SE±		1.62	

Table 4. Interaction between tillage practices and residue management on chlorophyll content (SPAD) of Sorghum at 9WAS in Minjibir during the 2018 rainy season

	Tillage Practice (T)	
Residue Management (%)	Conventional Tillage	Minimum Tillage
0	40.54a	36.86ab
50	39.77a	33.70b
100	37.03ab	38.92a
SE±	2.449	

Means within and across columns followed by the same letter are not significantly different at 5% level of probability using SNK

SPAD values (40.54), which was statistically similar to the values observed for conventional tillage with 50% residue removal (39.77) and minimum tillage with 100% residue removal (38.92).

Table 5 shows the interaction between tillage practices and residue management on chlorophyll content (SPAD) of Sorghum at 6WAS in Dabagi during the 2018 rainy season. Highest chlorophyll content (43.82) was obtained from conventional tillage with 50% residue removal. All this was statistically similar to all other except that for minimum tillage with 50% residue removal which gave the lowest SPAD value (35.02).

The interaction between tillage practices, residue management and variety on chlorophyll content of Sorghum at 9WAS in Dabagi during the 2018 rainy season is shown in Table 6. The interaction between conventional tillage, Improved Deko and 100% residue removal gave the highest SPAD value (45.68) which was statistically at par with all other observations except with that between conventional tillage, Local Kaura and 100% residue removal was gave the lowest SPAD value (34.93).

4.1.4 Leaf Area Index (LAI)

Table 7 shows the effects of tillage practice, residue management and varieties on Leaf Area Index (LAI) of sorghum at Minjibir and Dabagi during the 2018 rainy season. There was no significant difference statistically in LAI for tillage practice across sampling periods in both locations. Similarly, there were no significant differences statistically ($P>0.05$) in residue management for LAI in both locations over the sampling period.

Table 5. Interaction between tillage practices and residue management on chlorophyll content (SPAD) of Sorghum at 6WAS in Dabagi during the 2018 rainy season

	Tillage Practice (T)	
Residue Mgt (R%)	Conventional Tillage	Minimum Tillage
0	39.79ab	42.14ab
50	43.82b	35.02a
100	41.09ab	38.69ab
SE±	2.662	

Table 6. Interaction between tillage practices, residue management and variety on chlorophyll content (SPAD) of Sorghum at 9WAS in Dabagi during the 2018 rainy season

	Tillage Practice (T)			
	Conventional Tillage		Minimum Tillage	
Variety (V)	Improved Deko	Local Kaura	Improved Deko	Local Kaura
Residue Management (R %)				
0	38.90ab	38.13ab	42.02ab	40.95ab
50	40.18ab	43.15ab	40.08ab	36.8ab
100	45.68a	34.93b	39.70ab	41.35ab
SE±	3.682			

Means within and across column followed by the same letter(s) are not significantly different at 5% level of probability using SNK.

Table 7. Effects of Tillage Practice, Residue Management and Varieties on Leaf Area Index (LAI) of Sorghum at Minjibir and Dabagi during the 2018 rainy season.

	Minjibir (WAS)			Dabagi (WAS)		
Treatment	6	9	12	6	9	12
Tillage Practice (T)						
Conventional	0.49	1.00	1.43	1.74	2.83	1.50
Minimum	0.59	1.01	1.46	1.76	2.90	1.42
P of F	0.652	0.659	0.574	0.962	0.862	0.731
SE±	0.198	0.171	0.062	0.363	0.378	0.202
Residue Mgt (R%)						
0	0.60	1.01	1.52	1.62	3.00	1.43
50	0.59	1.01	1.49	1.82	2.75	1.45
100	0.44	0.97	1.32	1.80	2.83	1.50
P of F	0.081	0.578	0.271	0.832	0.804	0.916
SE±	0.069	0.116	0.125	0.353	0.375	0.186
Variety (V)						
Improved Deko	0.42b	0.94b	1.35	1.79	2.94	1.66a
Local Kaura	0.67a	1.14a	1.54	1.71	2.78	1.27b
P of F	<.001	0.007	0.052	0.573	0.470	0.011
SE±	0.058	0.067	0.091	0.148	0.210	0.139
Interaction						
T x R	0.516	0.416	0.964	0.184	0.713	0.836
T x V	0.677	0.807	0.657	0.120	0.346	0.698
R x V	0.399	0.699	0.953	0.836	0.893	0.885
T x R x V	0.387	0.803	0.455	0.287	0.355	0.220

Means followed by the same letter within the same column are not statistically significant at 5% level of probability using SNK.

Highly significant difference ($P<0.001$) was observed between varieties at 6WAS only in Minjibir, with Local Kaura having higher LAI values than Improved Deko. Also Local Kaura had statistically significant higher LAI values at 9WAS at the same location. However, Improved Deko had statistically significant higher means ($P = 0.011$) at 12WAS only at Dabagi. All interactions between treatments were not statistically significant across sampling periods in both locations.

4.1.5 Soil Moisture Content (%)

The effects of tillage practice, residue management and varieties on soil moisture content of Sorghum during the 2018 rainy season at Minjibir and Dabagi are shown in Table 8. Highly significant differences ($P<0.01$) were observed in soil moisture at 9WAS and 12WAS in Minjibir with higher means recorded from minimum tillage. No significant difference statistically ($P>0.05$) was observed for soil moisture content between residue management at both locations throughout the sampling period. Similarly, no significant difference statistically ($P>0.05$) was observed for soil moisture content between varieties across the sampling periods at both locations. Interactions between tillage practice, residue management and varieties were not significant ($P>0.05$) at both locations throughout the sampling periods.

4.1.6 Days to 50% Flowering

The effects of tillage practices, residue management and varieties on days to 50% flowering of Sorghum during the 2018 rainy season at Minjibir and Dabagi are shown in Table 9. Significant difference statistically ($P = 0.049$) was observed in number of days to 50% flowering between tillage practices at Minjibir with minimum tillage having less

Table 8. Effects of Tillage Practice, Residue Management and Varieties on Soil Moisture Content (MC) of Sorghum at Minjibir and Dabagi during the 2018 rainy season.

	Minjibir (WAS)			Dabagi (WAS)		
Treatment	6	9	12	6	9	12
Tillage Practice (T)						
Conventional	5.95	8.20b	13.17b	15.45	13.16	5.55
Minimum	6.15	9.32a	17.80a	15.42	11.63	6.70
P of F	0.421	0.039	0.040	0.982	0.298	0.489
SE±	0.215	0.317	1.329	1.356	1.218	1.461
Residue Mgt (R%)						
0	6.07	8.62	15.38	16.84	13.47	5.79
50	6.19	8.86	15.15	15.42	11.56	6.30
100	5.90	8.81	15.93	14.02	12.16	6.27
P of F	0.831	0.852	0.688	0.233	0.331	0.813
SE±	0.481	0.426	0.914	1.552	1.256	0.875
Variety (V)						
Improved Deko	5.90	8.94	15.35	15.52	12.54	6.63
Local Kaura	6.21	8.58	15.62	15.33	12.25	5.61
P of F	0.420	0.268	0.686	0.751	0.703	0.054
SE±	0.374	0.314	0.649	0.594	0.743	0.498
Interaction						
T x R	0.620	0.156	0.275	0.223	0.499	0.460
T x V	0.280	0.532	0.869	0.178	0.770	0.767
R x V	0.248	0.410	0.573	0.269	0.834	0.171
T x R x V	0.267	0.283	0.184	0.981	0.383	0.226

Means followed by the same letter(s) within the same column are not statistically significant at 5% level of probability using SNK.

Table 9. Effects of Tillage Practice, Residue Management and Varieties on Days to 50% Flowering and Days to Maturity of Sorghum at Minjibir and Dabagi during the 2018 rainy season.

	Minjibir		Dabagi	
Treatment	50% flowering	Maturity	50% flowering	Maturity
Tillage Practice (T)				
Conventional	90a	132	79	113
Minimum	89b	130	80	113
P of F	0.049	0.131	0.560	0.826
SE±	0.285	1.108	1.592	0.697
Residue Mgt (R%)				
0	89	132	79	113
50	89	129	81	113
100	89	132	79	114
P of F	0.295	0.244	0.243	0.395
SE±	0.390	1.552	1.257	0.661
Variety (V)				
Improved Deko	87b	125b	85a	116a
Local Kaura	91a	138a	74b	110b
P of F	<.001	<.001	<.001	<.001
SE±	0.365	1.574	0.598	0.685
Interaction				
T x R	0.728	0.533	0.733	0.959
T x V	0.373	0.163	0.202	0.343
R x V	0.845	0.084	0.040	0.361
T x R x V	0.109	0.502	0.154	0.674

Means followed by the same letter within the same column are not statistically significant at 5% level of probability using SNK.

number of days to flowering (89) than conventional tillage (90). No significant difference statistically (P = 0.56) was observed between tillage practices in Dabagi. Residue management had no statistically significant effect (P>0.05) on number of days to 50% flowering in both locations. There were highly significant differences statistically (P<0.001) in number of days to 50% flowering between varieties, with Local Kaura taking more days to flower (91) than Improved Deko (87) at Minjibir and Improved Deko taking longer to flower (85) than Local Kaura (74) at Dabagi. All interactions had no significant effect on number of days to 50% flowering at both locations except the interaction between residue management and varieties which was statistically significant (P<0.01) at Dabagi.

Table 10 shows the interactions between residue management and variety for days to 50% flowering of Sorghum in Dabagi during the 2018 rainy season. The highest number of days to 50% flowering (87.38) were observed on Improved Deko with 50% residue removal, followed by 100% residue removal (83.75) for the same variety.

4.1.7 Days to Maturity

The effects of tillage practices, residue management and varieties on days to maturity of Sorghum during the 2018 rainy season at Minjibir and Dabagi are shown in Table 9. There was no significant difference statistically (P>0.05) in number of days to maturity for tillage practice at both locations. Similarly, here was no significant difference statistically (P>0.05) in number of days to maturity between residue management at both locations. Highly significant differences statistically (P<0.001) were however observed between varieties at both locations with Local Kaura taking longer to

Table 10. Interaction between residue management and variety days to 50% flowering of Sorghum in Dabagi during the 2018 rainy season

Variety (V)	Residue Management (R %)		
	0	50	100
Improved Deko	83.75b	87.37b	83.75bc
Local Kaura	73.75a	74.38a	74.62a
SE±		1.58	

Means within and across column followed by the same letter(s)are not significantly different at 5% level of probability using SNK.

mature (138) than Improved Deko (125) at Minjibir and Improved Deko taking longer to mature (116) than Local Kaura (110) at Dabagi. The interactions between treatments had no statistically significant effects on the number of days to maturity of Sorghum at both locations.

4.1.8 Number of Stands at Harvest

The effects of tillage practice, residue management and varieties on number of stands at harvest of Sorghum at Minjibir and Dabagi during the 2018 rainy season are shown in Table 11. Tillage practice did not significantly (P>0.05) affect the number of stands of Sorghum at Minjibir and Dabagi. However, more stands at harvest were obtained with minimum tillage at Minjibir and with conventional tillage at Dabagi. Similarly, no statistically significant difference (P>0.05) was observed between residue management at both locations. There was highly significant difference (P<0.001) in number of stands at harvest between Local Kaura and Improved Deko at Minjibir while varieties did not have a statistically significant effect (P = 0.11) on number of stands at Dabagi. Interactions between treatments were not significant at both locations.

4.1.9 Plant Height (m)

From the results in Table 11, plant height was statistically similar for tillage practice and residue management at both locations. Highly significant difference (P<0.001) was however observed between Local Kaura and Improved Deko, with Local Kaura being taller than Improved Deko at both locations. There was no siginificant difference among interactions between treatments.

Table 11. Effects of Tillage Practice, Residue Management and Varieties on Number of Stands and Plant height (m) of Sorghum at Minjibir and Dabagi during the 2018 rainy season.

	Minjibir		Dabagi	
Treatments	Stand count	Plant Height (m)	Stand count	Plant Height (m)
Tillage Practice (T)				
Conventional	64	2.1	73	2.22
Minimum	71	2.2	60	2.07
P of F	0.525	0.624	0.678	0.311
SE±	9.65	0.1730	29.29	0.1205
Residue Mgt (R%)				
0	73	2.2	74	2.24
50	70	2.10	57	2.05
100	59	2.10	66	2.57
P of F	0.317	0.188	0.374	0.605
SE±	9.192	0.090	11.790	0.193
Variety (V)				
Improved Deko	56b	1.6b	62	1.72b
Local Kaura	79a	2.60a	70	2.57a
P of F	<.001	<.001	0.110	<.001
SE±	5.630	0.083	4.950	0.081
Interaction				
T x R	0.081	0.112	0.348	0.540
T x V	0.838	0.401	0.608	0.785
R x V	0.987	0.421	0.258	0.920
T x R x V	0.222	0.880	0.290	0.397

Means followed by the same letter(s) within the same column are not statistically significant at 5% level of probability using SNK.

4.1.10 Grain Yield (kgha^{-1})

The results in Table 12 show the effects of tillage practice, residue management and varieties on the yield of Sorghum in Minjibir and Dabagi during the 2018 rainy season. Tillage practice had no statistically significant effect (P = 0.751) on yield in both locations. However, minimum tillage gave higher means (2261.6 kgha^{-1}) than conventional tillage (2080.2 kg ha^{-1}) at Minjibir, while higher means were obtained with conventional tillage (1486.3 kg ha^{-1}) than minimum tillage (1383.6 kgha^{-1}) at Dabagi.

There were no significant differences (P>0.05) in yield for residue management at both locations. However, 0% residue removal gave the highest yields in both locations. Highly significant difference (P<0.001) was observed between varieties at Minjibir. Improved Deko gave higher yield (2728kg ha^{-1}) than Local Kaura (1613.7 kg ha^{-1}). However, Local Kaura gave higher yield (1501.4kg ha^{-1}) than Improved Deko (1368.5kg ha^{-1}) at Dabagi, though without significant difference (P = 0.44). The interactions between all treatments were not significant at both locations.

4.1.11 1000 Grain Weight (g)

The effects of tillage practice, residue management and varieties on 1000 seed weight of Sorghum in Minjibir and Dabagi during the 2018 rainy season are shown in Table 12. The differences between 1000 seed weight for tillage practice in both locations were not statistically significant (P>0.05). With respect to residue management, removal of 0% residue gave higher means in both locations, with the difference between means at being statistically significant (P = 0.038) at Dabagi only.

Table 12. Effects of Tillage Practice, Residue Management and Varieties on Yield ($kgha^{-1}$) and 1000 seed weight (g) of Sorghum at Minjibir and Dabagi during the 2018 rainy season.

Treatment	Minjibir		Dabagi	
	Grain Yield ($kgha^{-1}$)	1000 seed weight (g)	Grain Yield ($kgha^{-1}$)	1000 seed weight (g)
Tillage Practice (T)				
Conventional	2080.2	23.67	1486.3	22.46
Minimum	2261.6	23.83	1383.6	22.67
P of F	0.751	0.878	0.216	0.813
SE±	522.00	0.995	65.71	0.809
Residue Mgt (R%)				
0	2256.6	24.25	1722.1	23.81a
50	2241.7	23.56	1241.0	21.12b
100	2014.3	23.44	1341.9	22.75ab
P of F	0.293	0.808	0.264	0.038
SE±	164.60	1.327	293.86	0.917
Variety (V)				
Improved Deko	2728.0a	22.71b	1368.5	23.79a
Local Kaura	1613.7b	24.79a	1501.4	21.33b
P of F	<.001	0.017	0.440	0.001
SE±	202.96	0.792	168.14	0.637
Interaction				
T x R	0.316	0.796	0.326	0.861
T x V	0.457	0.188	0.701	0.406
R x V	0.616	0.903	0.575	0.115
T x R x V	0.263	0.150	0.333	0.185

Means followed by the same letter(s) within the same column are not statistically significant at 5% level of probability using SNK.

Local Kaura had a significantly higher (P = 0.017) mean (24.79g) than Improved Deko (22.71g) at Minjibir. Highly significant difference (P<0.001) was however observed between Improved Deko (23.79g) and Local Kaura (21.33g) at Dabagi. No significant difference was observed between interactions between treatments at both locations.

4.1.12 Stalk Weight (kg ha^{-1})

Table 13 presents the effects of tillage practice, residue management and varieties on stalk weight of Sorghum in Minjibir and Dabagi during the 2018 rainy season. Statistically significant difference (P = 0.049) was observed between tillage practices with conventional tillage giving higher stalk weight (7147.1kg ha^{-1}) than minimum tillage (5233.2kg ha^{-1}) at Dabagi. Contrarily, there was no significant difference statistically (P = 0.64) between tillage practices at Minjibir. However, minimum tillage gave higher means. There was no significant difference (P>0.05) between residue management practices in both locations However, 0% residue removal gave the highest mean (10608.1kgha^{-1}) followed by 50% residue removal (9489.8kgha^{-1}) at Minjibir. There was highly significant difference statistically (P<0.001) between varieties, with Local Kaura outperforming Improved Deko in both locations. The interactions between treatments at both locations had no significant effect on stalk weight.

Table 13. Effects of Tillage Practice, Residue Management and Varieties on stalk weight ($kgha^{-1}$) of Sorghum at Minjibir and Dabagi during the 2018 rainy season.

Treatment	Minjibir	Dabagi
Tillage Practice (T)		
Conventional	8462	7147a
Minimum	9955	5233b
P of F	0.638	0.049
SE±	2866.17	598.69
Residue Mgt (R%)		
0	10608	6468
50	9489.8	5517
100	7527	6585
P of F	0.241	0.502
SE±	1740.65	969.54
Variety (V)		
Improved Deko	5262.6b	5453.1b
Local Kaura	13153.2a	6927.2a
P of F	<.001	<.001
SE±	1143.66	373.58
Interaction		
T x R	0.242	0.334
T x V	0.645	0.513
R x V	0.357	0.404
T x R x V	0.589	0.176

Means followed by the same letter(s) within the same column are not statistically significant at 5% level of probability using SNK.

4.2 DISCUSSIONS

4.2.1 Response to Tillage Practices, Residue Management and Varieties on Growth of Sorghum

Chlorophyll content of plants was highly influenced by the availability of nitrogen and since the decomposition and subsequent release of nitrogen from the residues is gradual**,** it might take longer than a single growing season to affect the chlorophyll contents of the plants significantly. Improved Deko had higher chlorophyll content than Local Kaura at Minibir. This may be due to higher nitrogen uptake and photosynthetic efficiency as a result of variations in genetic composition of the varieties.

Both tillage practice and residue management did not significantly affect the LAI of sorghum at both locations. However, minimum tillage had generally higher LAI. This is a result of more availability of moisture in the plots were minimum tillage was practiced, which gave the plants of such plots more advantage in terms of growth. This is in contrast to the findings of Bisrat *et al.* (2015) who reported low LAI in minimum tillage in Maize. This might be as a result of differences in environmental and soil conditions as well as crop under consideration. Also the significantly higher LAI observed for Local Kaura at Minjibir at 6WAS and 9WAS was in line with relatively higher crop morphology of Local Kaura with longer and wider leaf size when compared to the Improved Deko. This means that Local Kaura exhibited higher growth activity and by extension, a denser canopy and more solar interception during early growth, which was in line with the findings of Pollo *et al.* (2018).

At Minjibir, the soil moisture content was significantly higher for minimum tillage at 6WAS and 9WAS, while all other interactions did not significantly affect soil moisture content. This shows that minimum tillage allows for better water retention in soils as observed by Thiefelder and Wall (2009).

Highly Significant differences were observed in number of days to 50% flowering and days to maturity among the sorghum varieties at Minjibir and Dabagi. Improved Deko performed better than Local Kaura at Minjibir by taking less number of days to flower and mature. In contrast, Local Kaura outperformed Improved Deko at Dabagi with less days to 50% flowering and days to maturity. This may be due to the response of the varieties to variations in weather conditions at the two locations. Though not significantly, minimum tillage gave higher number of stands at harvest at Minjibir while Conventional Tillage had a higher number of stands at Dabagi. Similarly, a research by Dabney *et al.* (1996) resulted in higher stands at harvest in sorghum. These variations may be due to differences in soil conditions at various sites of the experiments. The differences observed in plant height between the varieties could be due to varietal differences with Local Kaura being a tall variety and Improved Deko being a medium growing variety.

4.2.2 Response to Tillage Practices, Residue Management and Varieties on Yield of Sorghum

The non-significant difference statistically between conventional and minimum tillage on yield of sorghum supported the findings of Francis and Knight (2013), who observed no variable difference in grain yield between Minimum Tillage and

Conventional Tillage. However, evidences from extensive data published on tillage indicate that minimum and conventional tillage differed in crop yield with soil conditions and environment (Lal, 1986; Triplett, 1986; Arnon, 1992; Dao, 1993; Radford *et al.*, 1995). Also, 0% residue removal resulted in higher yields at both locations. This may be due to increase in soil organic matter content and enhanced soil water retention as observed by Linstrom *et al.* (1984) and Brown *et al.* (1989). Highly significant difference was observed between Local Kaura and Improved Deko at Minjibir where Improved Deko gave higher yield than Local Kaura. This may be attributed to the adaptability of the varieties to the environmental and soil conditions of the experimental locations. Tillage practice did not significantly affect 1000 seed weight at both locations. However Agbede *et al.* (2008) reported higher grain weight with minimum tillage in sorghum attributable to higher nutrient uptake at the study site. It was observed that Local Kaura had significantly higher grain weight than Improved Deko at Minjibir while the reverse is the case at Dabagi. This might be due to nutrient availability to the plants at the study sites. The Local Kaura had significantly higher stalk weight than Improved Deko at both locations. This was as a result of the longer plant height earlier observed with Local Kaura as a result of varietal differences.

4.2.3 Interaction between Tillage Practices, Residue Management and Varieties on Growth and Yield of Sorghum

Significant responses to interactions between tillage practice and residue management were observed at 9WAS in Minjibir and 6WAS at Dabagi. This supports the findings of Ambus and Jensen (2001), who noted strong interactions between tillage practice and residue management. Also, the significant difference observed for days to 50% at Dabagi indicates varietal response to residue management.

CHAPTER FIVE

5.0 SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 SUMMARY

Field trials were conducted during the 2018 rainy season at the Research Farms of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Minjibir, Kano and that of Usman Dan Fodio University, Dabagi, Sokoto located at the Sudan and Sahel Savannas Ecological Zones of Nigeria respectively. The aim of the study was to evaluate the performance of Sorghum under different tillage conditions and to assess the effect of different levels of residue removal on growth and yield of Sorghum (*Sorghum bicolor* L. Moench) varieties. The treatments consisted of two tillage practices (minimum tillage and conventional tillage), three residue management level (0%, 50% and 100% residue removals) and two Sorghum varieties (Local Kaura and Improved Deko). The treatments were arranged in Split-split plot design with four replications. Tillage practices, residue management and varieties were assigned to the main, sub, and sub-sub plots respectively. Soil and meteorological data were collected. Growth and yield parameters such as chlorophyll content, leaf area index (LAI), plant height (m), days to 50% flowering, days to maturity, soil moisture content, 1000 grain weight (g) and grain yield ha^{-1} were collected, recorded and subjected to analysis of variance (ANOVA) using Genstat 17th Edition. Treatment means were separated using Student-Newman Keuls Test. The results showed that tillage and residue management did not significantly affect the yield of Sorghum at both locations. However, Improved Deko performed significantly better at Minjibir.

5.2 CONCLUSION

From the results of this study, it can be concluded that even though type of tillage practice and residue removal levels did not have significant effects on yield and some growth parameters of Sorghum, varietal difference resulted in significant yield difference where Improved Deko performed better than Local Kaura at Minjibir.

5.3 RECOMMENDATION

Further research should be carried out under various soil and climatic conditions over years to arrive at the optimum recommendations on the combined effects of tillage and residue removal on the growth and yield of Sorghum varieties.

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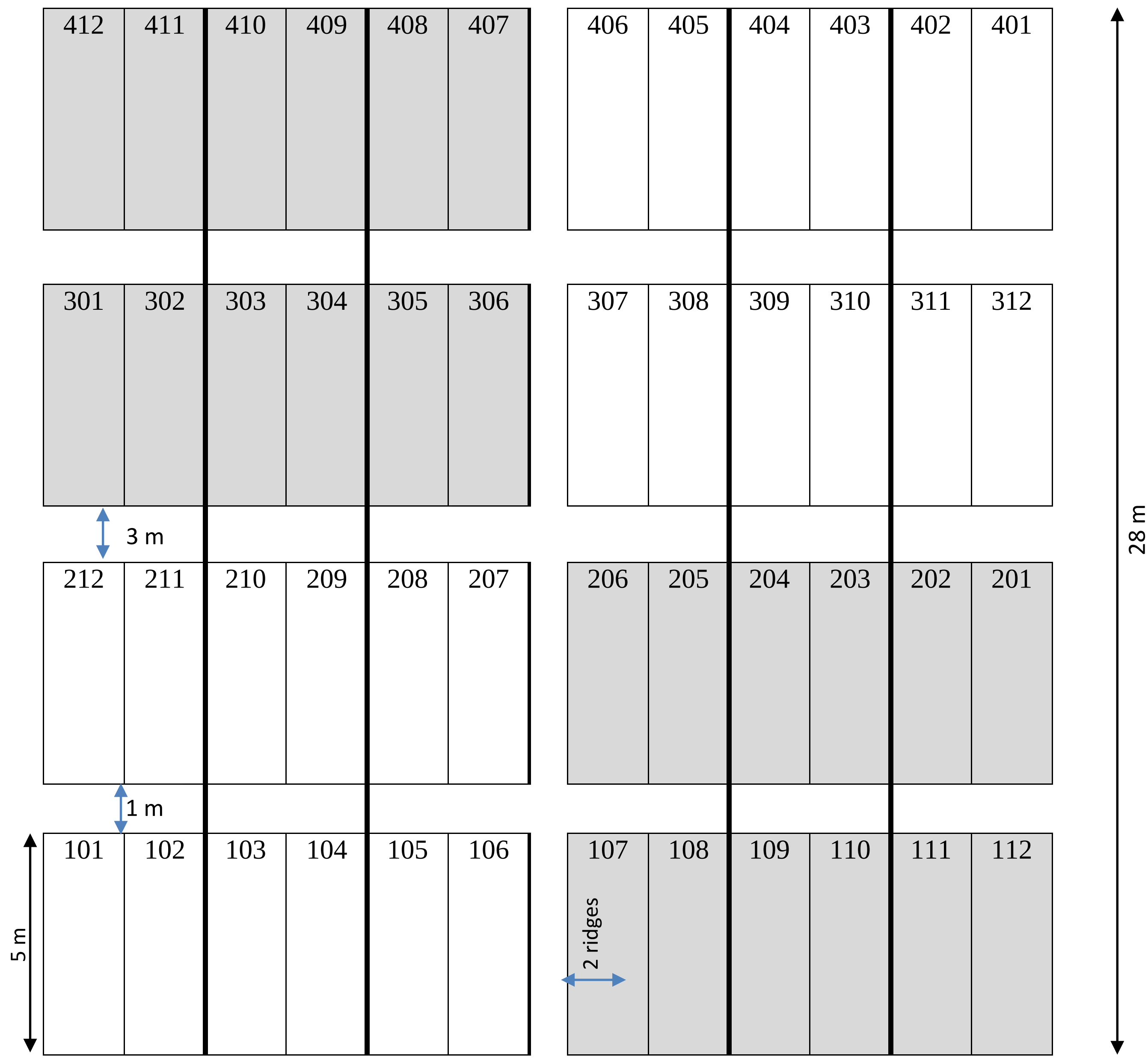
APPENDICES

Appendix 1. Field Layout for Effect of Tillage and Plant Residues on Sorghum Yield



Appendix 2. ANOVA Structure

Source of Variation	**df**	
Rep (r)	(r -1)	3
Main Plot (A)	(A-1)	1
Error (a)	(r -1) (A-1)	3
Sub plot (B)	(B - 1)	2
A x B	(A-1) (B - 1)	2
Error (b)	A (r - 1) (B - 1)	12
Sub sub plot (C)	(C - 1)	1
A x C	(A-1) (C - 1)	1
B x C	(B - 1) (C - 1)	2
A x B x C	(A-1) (B - 1) (C - 1)	2
Error (c)	AB (r - 1) (C - 1)	18
Total	(rABC – 1)	47

Appendix 3. Meteorological Data of Minjibir and Dabagi During 2018 Rainy Season.

Rainfall (mm)		
Month	**Minjibir**	**Dabagi**
June	65	89.9
July	111.9	319.5
August	329.2	199.9
September	72.3	165.9
October	7.5	54.9
Total	585.9	830.1
Mean Temperature (℃)		
June	30.1	30.1
July	27.2	26.89
August	26.5	26.5
September	27.8	27.5
October	28.7	29.0

Source: ICRISAT, Kano – Nigeria.