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Yield Performance Of Some Sorghum (*Sorghum Bicolor* (L.) Moench) Varieties and Land Races in Winter and Summer Seasons In South Darfur State

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Abstract: *Two field experiments were carried out during 2016 through 2018 in both summer and winter seasons in Nyala, South Darfur State, Sudan. Five sorghum cultivars were grown during the period July to October in summer season and October to January in winter season. The objective of this study was to evaluate the performance of two local genotypes; Abu-Ragaba and Abu-Kunjara under southern Darfur environments in summer and winter seasons for grain yield and forage production. The land races (Barbarei) in winter season gave the highest grain yield 1049.9 kg/ha and 1037 kg/ha for Abu-Ragba and Abu-Kunjara, respectively, compared to Wad Ahmed 294.4 kg/ha, Tabat 600.8 kg/ha and Butana 499.8 kg/ha, respectively. Similarly, in winter season the land races Abu-Ragaba and Abu- Kunjara out yielded the other tested cultivars in forage production, producing 1003 kg/ha and 956.8 kg/ha, respectively, compared to 861.9 kg/ha, 743.4 kg/ha and 597.8 kg/ha for Butana, Wad Ahmed and Tabat, respectively. In summer season the land races Abu-Ragaba and Abu-Kunjara failed to produce grain yield, but out yielded the other tested cultivars in forage production, giving 1115.5 kg/ha and 1060.8 kg/ha, respectively, compared to 630.5 kg/ha, 599.6 kg/ha and 501.0 kg/ha for Wad Ahmed, Butana and Tabat, respectively, Abu-Kunjara and Abu-Ragaba excelled the other tested cultivars in protein content recording 13.0% and 12.9% compared to 9.8%, 9.5% and 9.4% reordered for Tabat, Wad Ahmed and Butana, respectively.*

Chapter One
Introduction

Sorghum (*Sorghum bicolor*) is an important cereal crop, ranks fifth worldwide after wheat (*Triticum* spp.), rice (*Oryza spp*), maize (*Zea mays*) and barley (*Hordeum vulgdre*) (FAO, 1995). It is grown over 42 countries, developing countries growing 90% of the world sorghum area and producing 70% of the total sorghum production (Belum V.S. Reddy *et al*. 2004). Semi-arid tropical Sub-Saharan Africa and semi-arid tropical Asia grow about 60% of the world area (ICRISAT and FAO, 1996). Sorghum is grown mainly in the semi-arid areas of the tropics and sub tropics. Some zones where, the crop is grown may have a high rain fall during the actual growing season. Many of the types grown traditionally are photoperiod sensitive: these have been selected to flower at the end of the wet period, so that the grains ripen under dry conditions.

Sorghum is known under a variety of names; guinea corn in west Africa, Kaffircorn in south Africa, durra in Sudan and mtama in eastern Africa. In India, the crop is known as jowar (juar), in the north, and cholam in the south. There are many other names for the crop in the local languages of both continents. Indian publications prior to 1950 often referred to sorghum as the great millet. Much of the Chinese crop is known as kaoliang, while in America, the term milo–maize may be used.

Sudan grows about 24% of Africa area and produces 17% of its production. In Sudan sorghum is the main staple food especially in rural areas of the country used in different forms. It is grown under both irrigated and rain-fed conditions 90% or more of which is under rain-fed conditions while the rest under irrigation. Sorghum plays a significant role for both small and large scale farmers; it is the leading cereal crop by production, consumption as well as area cultivated. It is the chief source of food and income for majority of farmers and used in different forms however, the cultivated area varied from year to year due to many factors such as biotic and a biotic stress factors. The area cultivated annually is estimated as 7-8m/ha but sorghum production is still very low and crop management practices are lacking. The national average sorghum yield is estimated to be approximately 0.6 t/ha. The Agricultural Research Corporation has released different sorghum varieties for both irrigated and rain-fed areas; such as Fetarita Wad Ahmed (FW), Ingaz (Osman and Mahmud 1992), Tabat (Osman *et al*. 1996, Butana, Bashayer (Ibrahim N. *et al* 2007) and AG-8 (Mohammed *et. al.* 2009). Sorghum [*Sorghum bicolor* (L.) Moench] is the principal cereal grown for food, fodder, fuel around the world in over 45.8 m ha, with production and productivity of 59.6 m t and yield of 1.30 t /ha (FAO, 1995). In India, it is cultivated over 9.50 m ha with a production of 7.73 m t and productivity of 0.77 t/ ha. The major production constraints that reduce sorghum productivity are a biotic (nutrient and drought stresses, excess water, temperature extremes, etc.), biotic (shoot fly, stem borer, striga, head bugs, grain mold, foliar diseases, smut, charcoal rot, etc.). Sorghum in southern Darfur state is grown under dry land farming rain-fed conditions and considered as the major agricultural activity. Millet and sorghum are the main staple cereals. Annual rainfall in South Darfur state progressively increases more or less from north to south and on the bases of records, ranging from 300-400 mm in the North to 700-800 mm in the south. The length of growing season similarly increases from less than 3 months in the north to 4-5 months in the south and therefore, South Darfur state is characterized by different agro-ecological zones with erratic rainfall that contributes much to the problem of crop production.

In South Darfur sorghum is the second food staple crop after millet. It is mainly cultivated on clay soils and on the banks of valleys. The sorghum areas under cultivation increased from 750,000 feddans in 2000 to 1,135,750 feddans in 2013 while production increased from 116,400 metric tons in 2000 to 315,800 metric tons in 2013. Yield trends were down world from 250 kg/ fed in 2000 to 180 kg/fed in 2013. The decline of rain-fed sorghum yields, are partially due at least to uneven distribution of rainfall, unavailability of suitable cultural practices and planting of low yielding traditional varieties. The low yield problems compound by high cost of crop production are the main constrains of sorghum production in South Darfur. The ARC released varieties grown in south Darfur are: Yarwasha, Arfa- gdamak, Butana, Wad Ahmed and Tabat. There are unique land races of Sorghum named (Barbarei) which is wildly grown in south and west Darfur states. These genotypes cover wide genetic diversity with different local names such as; Abu-Ragaba and Abu-kunjara (Abdul Montalb *et al*. 2013). They have different phenotypes with different seed colors; the Barbarei phenotypes seem to have different morphological characteristics compared to other cultivated species. It flowers and sets seeds only when the weather gets cooler October to February (Abdul Montalb *et al*. 2013). The genetic variability, and chemical properties of the grains of these local genotypes in addition to varying soil types, different climate and water sources may add a new crop for the farmers for income and food security. Bearing in mind there is no winter sorghum variety released for such conditions. It worth testing these local land races under South Darfur environments in summer and winter seasons to identify the high yielding and adaptable genotype for commercial production in the region. Therefore, this study aims to evaluate the performance of the two local genotypes; Abu-Ragaba and Abu-kunjara under south Darfur environments for grain yield and Forage production.

Chapter two
Literature review

There are three main seasons in Dar Fur: Kharif, or rainy season which normally begins in May and extends to October, but sometimes starts as early as April but more. Temperature at first fall after the hot dry summer and then clime again as the rains tapper off, this is the time of harvest, called "Darat". The cool dry winter season, the "shita", starts in December to February. After that, the main summer dry season, the "sayf". Characterize with higher temperatures. Rain-fall distribution is crucial. A low annual rain fall spread over a whole year would be of little use. At high temperatures the balance between precipitation and evaporation is always negative and no crop can survive. If, however, the same total rain fall is concentrated a few months it become possible to grow crops. The difference between a good year and bad one in Dar fur often depends on how much of the rain falls in early or late month and how much in the crop season. The season is shorter in the north and a greater proportion of the total of the total rain (Ibrahim, 1984).

Sorghum is a warm-weather crop, which requires high temperatures for good germination and growth. The minimum temperature for germination varies from 7 to 10 °C. At a temperature of 15 °C, 80 % of seeds germinate within 10 to 12 days. The best time to plant is when there is sufficient water in the soil and the soil temperature is 15 °C or higher at a depth of 10 cm. Temperature plays an important role in growth and development after germination. A temperature of 27 to 30 °C is required for optimum growth and development. The temperature can, however, be as low as 21 °C, without a dramatic effect on growth and yield. Exceptionally high temperatures cause a decrease in yield. Flower initiation and the development of flower primordia are delayed with increased day and night temperatures. Plants with four to six mature leaves that are exposed to a cold treatment (temperatures less than 18 °C) will form lateral shoots. However, in plants in or beyond the eight-leaf stage, apical dominance will prevent the formation of lateral shoots. 7 Temperatures below freezing are detrimental to sorghum and may result in dying of the plant. At an age of 1 to 3 weeks, plants may recover if exposed to a temperature of 5 °C below freezing point, however, at 7 °C below freezing, plants die off. Plants older than 3 weeks are less tolerant to low temperatures and may die off at 0 °C.

Sorghum is mainly grown on low-potential, shallow soils with a high clay content, which usually are not suitable for the production of maize. Sorghum usually grows poorly on sandy soils, except where heavy textured subsoil is present. Sorghum is more tolerant of alkaline salts than other grain crops and can therefore be cultivated successfully on soils with a pH (KCl) between 5.5 and 8.5 Sorghum can better tolerate short periods of water logging compared to maize. Soils with a clay percentage of between 10 and 30 % are optimal for sorghum production.

Sorghum is grown mostly in an annual rainfall range of 300 to 750 mm. It is grown in areas which are too dry for maize. Early drought stops growth before floral initiation and the plant remains vegetative; it will resume leaf production and flower when conditions become favorable for growth. Late drought stops leaf development but not floral initiation. The crop has a relatively deep rooting system that can extract water from low sources.

The photoperiod:

The development of sorghum plant is influenced by genes that control sensitivity to photoperiod, and their interaction with photoperiod and temperature. While temperature influences development throughout the life cycle of plants, photoperiod influences the vegetative stage (from seedling emergence to panicle initiation). Alagarswamy *et al*., 1998 reported that photoperiod sensitivity in some sorghum cultivars ends shortly before or at the panicle initiation (PI stage).

Barbarei sorghum type which is post-rainy season sorghum, is a short day durra sorghum race commonly grown with residual moisture on Vertisols during the dry season in the Tullus, Rihead, Elberdi and Um Dafug localities of South Darfur State. In Tullus Locality of South Darfur State of Sudan, the production practices and cultivars used are basically traditional. A field survey was conducted in October 2017 to document the production practices, identify opportunities, constraints among the farmers in areas where the crop is commonly grown. The crop is grown in soils with high clay content and classified in Tullus area as: Buta (heavy clay flooded soils), turtura (low clay content) and Naga'a dry soils with low water percolation). Two most common cultivars: Abu ragaba (white seeded), Abu Kunjara (yellow seeded). The shape of the head of the cultivar was characterized as (oval and compact) Abu Kunjara, (semi-loose) Abu ragaba (elliptical and compact). Abu ragaba is preferred for food, Abu Kunjara for cash are relatively early maturing. However, grain yields of Abu ragaba and Abu-kunjara were considered greater than the other cultivars. The production practice starts with land clearing during the dry season, allowing the Vertisol soil fields to flood and fallow during rainy season. Seedlings are in upland nursery between August and September. Field preparation follows after flood recession by burning the weed in October and transplanting of seedlings is done in October/November followed by manual hoe weeding in November/December and harvesting in January/February. No irrigation or fertilizer is used in the main field. Simple hand tools: axe and cutlass for land clearing and preparation, cups and buckets are used for applying small quantity of water during transplanting; and hoe or cutlass for weeding. The major constraints were low yield potential of the cultivars, moisture stress, persistent weeds, pests and disease infestation, low plant density, difficult soils and lack of research intervention and recommendations for the crop. The crop has high potential for enhancing livelihoods;

Two broad types of sorghum {*Sorghum bicolor* (L.) Moench} are cultivated along the Lake Chad Basin Area in Borno State: the rainy season and dry season types. The dry season sorghum is locally referred to as *masakwa* or postrainy season sorghum which is cultivated on heavy clay soils or Vertisols using residual moisture from the end of the rainy season to the end of the cool dry season known as *harmattan* (Ogunlela and Obilana, 1983; Dugje and Odo, 2011).

Blench (1991) reported that *masakwa* originated from Asia from where it spread to Nigeria from the Nile valley with Borno and Adamawa States forming the western limit of its diffusion. The major areas of cultivation in Borno State Nigeria are between Lake Chad in the north and part of Mandara hills in the south.

The specific areas in Borno State have opportunity for growing the sorghum cultivars at a time when it is impossible to grow other grain crops without irrigation. Thus *Masakwa* sorghum production is more appealing to farmers in the dry regions due to its drought tolerance. The crop is also grown and known as *Muskwari* in northern Cameroon and *Berbere* in The Republic of Chad (Djonnewa and Dangi, 1988). *Masakwa* provides supplementary supply of grains to the harvest obtained from rain- fed sorghum. The cultivar being dry season crop cushions the effect of poor yield realized from rain fed sorghum.

Chapter three
Material and methods

The experiment consisted of three improved varieties namely; Butana, Tabat and Wad Ahmed and two land races Abu-Kunjara with yellow grains and Abu –Ragaba with white grains. Butana, Wad Ahmed and Tabat seeds were from the Nyala Research station. Barbarei yellow Barbarei white seeds were provided by farmers.

The design used was a randomized complete block design with four replicates. In winter the entries were sown to six rows, 7 m length 6 m width, 50 cm intra row spacing, 50 cm between plants and thinned to three seedlings per hill. In summer the entries were also sown to six rows 7 m length, 6 m width, 50 cm intra row spacing, 50 cm between plants and thinned to three seedlings per hill. The net harvested area at each season was four rows x 5 m length x4 m width x 50 cm for grain yield and 5m length x1m for forage. Sowing was done within the first week of October in winter and the first to the third week of July in summer depending on the rainfall. All other cultural practices were followed as recommended by the (ARC). Supplementary irrigation was practiced from the first week after shoots showing for all cultivars and land races in order to establish the seedlings. Three weeks later the cultivars; Tabat, Wad Ahmed and Butana received supplementary irrigation every 7-10 days till maturity.

The data collected were; grain yield, forage yield, days to 50% flowering, plant height, panicle length, 100 grain weight and chemical analysis. Chemical analysis and Kisra quality tests, grain Samples of cultivars were sent to the Food Research Centre (FRC) to perform proximate chemical analyses Data was analyzed by Geinstat (2013) for separate seasons. The combined analyses were carried for both winter and rain fed environments.

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Chapter four

Results

The analysis of variance for grain yield kg/ha of the five sorghum genotypes grown in seasons 2016/2017 and 2017/2018 revealed that the main effect of genotypes was significant (*P* >0.01) (Table 1). Seasons and season × genotypes mean squares were not significant, indicating that the genotypes performed similarly at both seasons. Mean grain yield kg/ha ranged between 1049.9 for (Abu-Kunjara) to 294.4 for Wad Ahmed (Table 2). This indicates that Abu-Kunjara had the heights mean grain yield kg/ha in the two winter seasons of testing. Whereas, Wad Ahmed had the lowest grain yield kg/ha mean. Whereas, the mean grain yield of sorghum cultivars grown in summer season ranged between 901.6 for Wad Ahmed, to 0.0 for Abu-Ragaba and Abu-Kunjara (Table 2), Indicating that during the two summer seasons, Abu-Ragaba and Abu-Kunjara failed to produce a grain yield in the two summer seasons of testing. That could be due to photoperiod sensitivity.

The analysis of variance of heads weight of five sorghum genotypes grown in winter and summer seasons 2016/2017 and 2017/2018 revealed that the main effect of genotypes was highly significant (P>0.01) (Table 3). Seasons and season ×genotypes mean squares were not significant, indicating that none of the genotypes had a specific performance at a specific season and no seasonal effect. Mean weight of heads (g) ranged between 59.3for Abu-Kunjara to 19.2 for Butana (Table 4). This indicates that Abu-Kunjara had the heights mean weight of head in the two seasons of testing. Whereas, Butana had the lowest weight of head mean, Mean head weight grown in summer season ranged between 35.419 for Butana, to 0.0 for Abu-Ragaba and Abu-Kunjara (Table 4). This indicates that Abu-Ragaba and Abu-Kunjara did not produce heads in the two seasons of testing, which could be due to photoperiod sensitivity.

The ANOVA table for 100 seed weight (g) of the five sorghum genotypes grown in summer and winter seasons 2016/2017 and 2017/2018 revealed that the main effect of genotypes was highly significant (P>0.01) (Table 5). Seasons and season × genotypes mean squares were not significant, indicating that none of the genotypes had a specific performance at a specific season and no seasonal variation. The combine mean of 100 seed weight grown in winter season ranged between 3.0125 for BW to 2.49 for Tabat (Table 6). This indicates that Abu-Ragaba had the heights mean The combine mean 100 seed in the two seasons of testing. Whereas, Tabat had the lowest 100 seed weight mean of 100 seed weight (g) grown in summer season ranged from2.5 for Wad Ahmed, to 0.0 for Abu-Ragaba and Abu-Kunjara (Table6). This indicates that Abu-Ragaba and Abu-Kunjara had not produce seeds in the two seasons of testing, which might be due to photo period sensitivity.

The combined analysis of variance of the head length of the five sorghum genotypes grown in winter and summer seasons 2016/2017 and 2017/2018 revealed that the main effect of genotypes was highly significant (P>0.01) (Table 7). Seasons and season × genotypes mean squares were not significant, indicating that none of the genotypes had a specific performance at a specific season and no seasonal effect. Mean head length grown in winter ranged between 25.31 for Abu-Ragaba to 12.58 for Abu-Kunjara (Table 8). This indicates that Abu-Ragaba had the longest mean head length in the two seasons of testing. Whereas, Abu-Kunjara had the shortest head length mean. Whereas the mean head length grown in summer ranged between 27.04 for Butana, to 0.0 for Abu-Ragaba and Abu-Kunjara (Table 8) which did not produce any heads in the two seasons of testing which could be due to photo period sensitivity and high temperature.

Analysis of variance of plant height of the five sorghum genotypes grown in winter seasons 2016/2017 and 2017L2018 showed that the main effect of genotypes was significant (P<0.01) (Table 9). Seasons and season × genotypes mean squares were highly significant, indicating that the genotypes performed similarly. Mean plant height ranged between 115.93 for Abu-Ragaba to 81.72 for Tabat (Table 10). This indicates that Abu-Ragaba was the tallest cultivars in the two seasons of testing. Whereas Tabat was shortest cultivar, the analysis of variance for plant height (cm) of five sorghum genotypes grown in seasons summer 2016/2017 and 2017/2018 revealed that the main effect of genotypes was highly significant (P>0.01) (Table 9). Seasons and season × genotypes mean squares were significant indicating that the genotypes had all most similar plant height. Mean plant height (cm) ranged between 130.23 for Abu-Ragaba, to 82.40 for Tabat (Table 10). This indicates that Abu-Ragaba had taller plant height in the two seasons of testing.

The analysis of variance for forage yield kg/ha of the five sorghum genotypes grown in seasons 2016/2017 and 2017 /2018revealed that the main effect of genotypes was significant (P>0.01) table13. Seasons and season × genotypes mean squares were not significant, indicating that the genotypes performed similarly at both seasons. Mean forge yield kg/ha ranged between 1003.5 for Abu-Kunjara to 597 for Tabat (Table 14). This indicates that Abu-Kunjara had the heights mean forage yield kg/ha in the two winter seasons of testing. Whereas, Tabat had the lowest forage yield kg/ha mean. Whereas, the mean forage yield of sorghum cultivars grown in summer was significant, the forage yield mean ranged between 1115.5 for Abu-Kunjara to 500.55 for Tabat (Table 14).

Table 15 shows the chemical composition of the five tested cultivars and land races produced in winter seasons of 2016/2017 and 2017/2018. Protein content ranged from 13.0 % for Abu-Kunjara to 9.4 % for Butana. Tabat recorded the highest starch content (75.8) % compared to Abu- kunjara which recorded the lowest (69.8) %.

Kisra quality

Results of questionnaire of Kisra and Asida quality indicated that Abu-Ragaba has white color, excellent in taste, with soft texture and good keeping quality for the next day. Abu-Kunjara has yellow color, soft texture, excellent taste, and good keeping quality for the next day. The results showed that most people preferred Abu-Ragaba because of its white color.

Table 1

Analysis of variance of the sorghum grain yield of the five sorghum cultivars and land races grown in winter and summer season 2016/2017 and 2017/2018 at Nyala.

		Winter			Summer		
Source of variation	**DF**	**SS**	**MS**	**FPR**	**SS**	**MS**	**FPR**
Season	1	102.28	102.28	0.228	5.7	5.7	0.013
Treatment	4	3593977.78	898494.44	0.001	6.566	1.641	0.001
Treatment x Season	4	369.24	92.31	0.269	4.42	1.107	0.172
Error	30	2026.66	67.56	8.721	8.721	2.907	
Total	39	3596475.96			6.566		

Table 2

Combined analysis of mean grain yield (kg/ha) of the five sorghum cultivars and land races grown in winter and summer seasons 2016/2017 and 2017/2018 at Nyala.

	Winter			Summer		
Treatment	**2016**	**2017**	**Combine**	**2016**	**2017**	**Combine**
Butana	507.54	492.20	499.87	691.3	696.0	692.15
Tabat	601.9	598.3	600.8	850.5	900.0	875.25
Wad Ahmed	295.2	295.0	294.4	900.0	903.3	901.6
BW	1038.2	1036.1	1037.1	0.0	0.0	0.0
BY	1051.6	1048.2	1049.9	0.0	0.0	0.0
CV	0.8	1.5	1.2	0.4	0.4	0.3
LSD	8.9	15.9	8.39	3.496	3.907	1.741

- In each column: Means followed by the same letter (s) are not significantly different at (P<0.05) level of significance.
- BW (Abu-Ragaba); BY (Abu-Kunjara)

Table 3

Analysis of variance of head weight (g) of the five sorghum cultivars and land races grown in winter and summer season 2016/2017 and 2017/2018 at Nyala.

		Winter			Summer		
Source of variation	**DF**	**SS**	**MS**	**FPR**	**SS**	**MS**	**FPR**
Season	1	12.544	12.544	0.252	0.252	3.133	0.012
Treatment	4	9548.728	2387.182	0.001	0.001	1.199	0.001
Treatment x season	4	27.339	6.835	0.57	0.57	2.438	0.001
Error	30	276.005	6.835			4.754	
Total	39	9864.616			1.199		

Table 4

Combined mean heads weight (g) of the five sorghum cultivars and land races grown in winter and summer season 2016/2017 and 2017/2018 at Nyala.

	Winter			Summer		
Treatment	**2016**	**2017**	**Combine**	**2016**	**2017**	**Combine**
Butana	18.80	19.50	19.15	30.737	31.183	31.178
Tabat	27.57	28.00	27.79	29.525	29.225	29.375
Wad Ahmed	29.95	29.57	29.85	35.362	35.650	35.419
BW	50.38	54.75	52.56	0.0	0.0	0.0
BY	59.20	59.50	59.35	0.0	0.0	0.0
CV	0.7	7.0	8.0	1.9	1.2	0.6
LSD	6.664	0.631	3.629	0.582	0.401	0.129

- In each column: Means followed by the same letter (s) are not significantly different at (P<0.05) level of significance.
- BW (Abu-Ragaba); BY (Abu-Kunjara)

Table 5

Analysis of variance of 100 seed (g) weight of the five sorghum cultivars and land races grown in winter and summer season 2016/2017 and 2017/2018 at Nyala.

		Winter			Summer		
Source of variation	**DF**	**SS**	**MS**	**FPR**	**SS**	**MS**	**FPR**
Season	1	0.004	0.004	0.227	0.0002	0.0003	0.009
Treatment	4	1.734	0.434	0.001	56.892	14.223	0.001
Treatment x season	4	0.011	0.003	0.150	0.024	0.006	0.677
Error	30	0.055	0.002		0.043	0.001	
Total	39	1.804			56.958		

Table 6

The combined mean of 100 seed (g) weight of the five sorghum cultivars and land races grown in winter and summer season 2016/2017 and 2017/2018 at Nyala.

	Winter			Summer		
Treatment	**2016**	**2017**	**Combined**	**2016**	**2017**	**Combine**
Butana	2.5	2.5	2.51	2.3	2.5	2.4
Tabat	2.47	2.5	2.49	2.5	2.5	2.4
Wad Ahmed	2.52	2.5	2.52	2.5	2.5	2.5
BW	3.02	3.0	3.01	0.0	0.0	0.0
BY	2.76	2.8	2.81	0.0	0.0	0.0
CV	1.6	1.7	1.6	3.8	2.5	2.0
LSD	0.064	0.070	0.082	0.087	0.056	0.03

- In each column: Means followed by the same letter (s) are not significantly different at (P<0.05) level of significance.
- BW (Abu-Ragaba); BY (Abu-Kunjara)

Table 7

Analysis of variance of head length (cm) of the five sorghum cultivars and land races grown in winter and summer season 2016/2017and 2017/2018 at Nyala.

		Winter			Summer		
Source of variation	**DF**	**SS**	**Ms**	**FPR**	**SS**	**Ms**	**FPR**
Season	1	0.035	0.0348	0.977	10.620	10.620	0.116
Treatment	4	751.651	187.9	0.001	6047.797	1511.949	0.001
Treatment x season	4	0.425	0.106	0.849	10.377	2.594	0.007
Error	30	28.491	0.95		38.471	1.282	
Total	39	780.6			6107.265		

Table 8

Combined mean head length (cm) of the five sorghum cultivars and land races grown in winter and summer season 2016/2017 and 2017/2018 at Nyala.

	Winter			Summer		
Treatment	**2016**	**2017**	**Combine**	**2016**	**2017**	**Combine**
Butana	17.71	17.58	17.64	27.4	26.17	27.04
Tabat	22.0	22.04	22.02	27.9	26.71	26.75
Wad Ahmed	17.50	17.60	17.61	20.95	18.92	19.84
BW	25.08	25.54	25.31	0.0	0.0	0.0
CV	5.1	5.0	5.1	7.5	7.6	7.7
LSD	1.499	1.473	0.995	1.756	1.672	1.156

- In each column: Means followed by the same letter (s) are not significantly different at (P<0.05) level of significance.
- BW (Abu-Ragaba); BY (Abu-Kunjara)

Table 9

Combined analysis of variance of the plant height (cm) of the five sorghum cultivars and land races grown in winter and summer season 2016/2017 and 2017/2018 at Nyala.

		Winter			Summer		
Source of variation	**DF**	**SS**	**Ms**	**FPR**	**SS**	**Ms**	**FPR**
Season	1	130.32	130.32	0.01	5.04	5.04	0.38
Treatment	4	7911.85	19227.96	0.001	16890.14	4222.54	0.001
Treatment x season	4	130.46	32.62	0.001	193.21	4.79	0.57
Error	30	269.81	8.99		17107.56	6.44	
Total	39	8442.44					

Table 10

Combined mean plant height (cm) of the five sorghum cultivars and land races grown in winter and summer season 2016/2017 and 2017/2018 at Nyala.

	Winter			Summer		
Treatment	**2016**	**2017**	**Combine**	**2016**	**2017**	**Combine**
Butana	85.40	83.08	84.24	89.70	90.5	90.10
Tabat	85.55	77.9	81.72	82.28	82.5	82.40
Wad Ahmed	90.55	90.73	90.64	90.40	89.5	89.95
BW	120.0	111.85	115.93	130.45	130.0	130.23
BY	111.0	110.90	110.95	129.40	126.17	127.79
CV	4.7	1.1	3.1	1.8	0.5	1.5
LSD	6.863	1.693	3.062	2.887	0.758	2.591

- In each column: Means followed by the same letter (s) are not significantly different at (P<0.05) level of significance.
- BW (Abu-Ragaba); BY (Abu-Kunjara)

Table 13

Analyses of variance for forge yield (kg/ha) of the five sorghum cultivars and land races grown in winter and summer season 2016/2017 and 2017/2018 at Nyala.

		Winter			Summer		
Source of variation	**DF**	**SS**	**Ms**	**FPR**	**SS**	**Ms**	**FPR**
Season	1	2299.8	2299.8	0.001	0.0003	0.0003	1.00
Treatment	4	869077.0	217269.2	0.001	56.892	14.223	0.001
Treatment x season	4	7772.2	1943.1	0.016	0.024	0.006	0.001
Error	30	10650.0	355.0		0.043	0.001	
Total	39	889799.0					

Table 14

Combined mean of forge yields (kg/ha) of the five sorghum cultivars and land races grown in winter and summer season 2016/2017and 2017/2018 at Nyala.

	Winter			Summer		
Treatment	**2016**	**2017**	**Combine**	**2016**	**2017**	**Combine**
Butana	850.0	873.5	861.9	599.3	600.0	599.6
Tabat	850.0	590.0	597.8	500.1	501.0	500.55
Wad Ahmed	774.8	712.0	743.4	631.9	629.1	630.5
BW	965.5	948.0	956.8	1060.8	1060.3	1060.6
BY	1005.0	1002.0	1003.6	1103.0	1127.5	1115.5
CV	1.5	2.5	2.3	0.3	0.3	0.3
LSD	22.027	35.363	19.24	4.001	3.085	2.697

- In each column: Means followed by the same letter (s) are not significantly different at (0.05) level of significance.
- BW (Abu-Ragaba) ; BY (Abu-Kunjara)

Table 15

Protein, nitrogen and starch (%) for five sorghum cultivars and land races grown in winter season, 2016/2017 and 2017/2018.

Cultivars/land races	Protein	Nitrogen	Starch
BW	12.9	2.5	75.2
BY	13.0	2.5	69.8
Wad Ahmed	9.5	1.4	74.0
Butana	9.4	1.4	74.4
Tabat	9.8	1.4	75.8

- BW (Abu-Ragaba); BY (Abu-Kunjara)

Chapter five
Discussion:

The analysis of variance for grain yield kg/ha for five sorghum genotypes grown in winter seasons of 2016/2017 and 2017/2018 revealed that the main effect of genotypes was significant (P>0.01).Indicating that the genotypes performed similarly at both seasons. Mean grain yield kg/ha ranged between 1049.9 for Abu-kunjara to 294.4 for Wad Ahmed (Table 2). This indicates that Abu-kunjara had the heights mean grain yield kg/ha in the two winter seasons of testing. These results agreed with Dugje and Odo (2011) who reported grain yield of 1567 kg/ha for Adjagama cultivar (Barbarei type) in Sahel savanna. Also, Dugje et. al., (2014) reported grain yield of 800 -1500 kg/ha in Sudan Savanna and 500-1000 kg/ha in Sahel Savanna in some Barbarei cultivars. The yield of these cultivars could be higher if supplementary irrigation was adopted and fertilizers applied. Supplementary irrigation was practiced from the first week after sowing for all cultivars and land races in order to establish the seedlings. Three weeks later the cultivars Tabat, Wad Ahmed and Butana received supplementary irrigation every 7-10 days till maturity. The land races efficiently utilized the store moisture even without supplementary irrigation compared to the other cultivars. Grain yield was affected by the amount of rainfall received during the rainy season. In winter 2016/2017 total amount of rain was 903.1 mm compared to 624.5 mm in 2017/2018 that supported 1050 kg/ha and 1037 kg/ha respectively. This result implies that rain fall ranging between 600-900 mm can secure a reasonable grain yield from the land races Abu-kunjara and Abu-Ragaba in winter in such areas of Southern Dar Fur. Other factors like plant density, weeds, and temperature could be responsible for grain yield potential. Water harvesting technology seems to be of prime importance in supporting the crop all the season encouraging fertilizers application to enhance productivity.

Results showed that protein content ranged from 13.0 % for Abu-kunjara to 9.4 % for Butana. Abu-Ragaba recorded the same protein content (12.9). The results indicated that the land races Abu-kunjara and Abu-Ragaba had the highest protein content compared to the other cultivars tested. Khatir *et. al.*, stated that protein contents and composition varies due to genotypes and water availability moisture, temperature, soil fertility and environmental conditions during grain development. The protein contents of the tested cultivars and land races could be higher if adequate fertilizers and water requirements were supplied. The results of this study agreed with Khatir *et. al.* 2013 who reported 12.5 % for Abu-Ragaba and 12.16 % for Abu-kunjara .Tabat recorded the highest starch content (75.8)% compared to Abu-kunjara which recorded the lowest (69.8) % and the other tested cultivars and land races recorded similar starch content compared to Tabat.

Mean grain yield of sorghum cultivars grown in summer season ranged from 901 kg/ha for Wad Ahmed, to 0.0 kg/ha for Abu-Ragaba and Abu-kunjara (Table 7). This indicates that for two seasons Abu-Ragaba and Abu-Kunjara failed to produce grain yield in the two summer seasons of testing. This could be due to photoperiod sensitivity and high temperature. This result confirmed the finding of the research work done at Zalingy where, *Sorghum bicolor* (phenotype Barbarei) under rain fed (July to October) failed to produce seeds although small heads were seen on some plants (Ali H. Bahar et. al. 2015). They concluded that the crop was successfully cultivated in Western and southern Darfur during the cool season (September to January).

The analysis of variance of forage yield kg/ha of the five sorghum genotypes grown in seasons 2016/2017 and 2017/2018 revealed that the main effect of genotypes was significant. Abu-Kunjara land race was leading in forage production in winter and summer season and significantly higher even than Abu-Ragaba; produced 1003.6 kg/ha and 1115.5 kg/ha in winter and summer respectively. Tabat had the lowest forage yield kg/ha mean 597.8 kg/ha and 501.1 kg/ha in winter and summer respectively. The results of forage production in this study indicated that Abu-kunjara land race followed by Abu-Ragaba had the highest forage production in both winter and summer seasons. More research is needed to study the performance of Abu-kunjara and Abu-Ragaba in summer for forage production and in winter for both forage and grain yield in other states of the country.

The genotypes recorded significantly different 50% flowering in both winter and summer seasons of 2016/2017 and 2017/2018. Mean 50% flowering for the genotypes grown in winters ranged between 52.3 for Tabat to 75.4 for Butana, indicating that Tabat had the lowest mean 50% flowering in the two winter seasons of testing and hence earlier in maturity compared to Butana which flowered later. Mean 50% flowering in summer seasons showed that Tabat and Wad Ahmed were the latest genotypes recording 73.8 while the two land races Abu-Ragaba and Abu-kunjara had no flowers which could be due to photoperiod sensitivity.

The ANOVA table for 100 seed (g) of five sorghum genotypes grown in summers and winters, 2016/2017 and 2017/2018 revealed that the genotypes had significantly different 100 seed weight that ranged in winter between 3.01 g for Abu-Ragaba to 2.49 g for Tabat. indicating that Abu-Ragaba had the heights mean 100 seed weight in the two winter seasons of testing, compared to Tabat that recorded the lowest 100 seed mean weight. The 100 seed weight means in summer season ranged between 2.5 g for Wad Ahmed to 0.0 for Abu-Ragaba and Abu-kunjara. For all yield components there is no much data available or literature review since no too much research has been done in these land races for comparisons.

Panicle length for the five sorghum genotypes grown in winters and summers seasons of 2016/2017 and 2017/2018 revealed that genotypes had significantly different panicle length; in winters Panicle length ranged between 25.31 cm for Abu-Ragaba to 12.58 cm for Abu-Kunjara indicating that Abu-Ragaba had the heights mean of panicle in the two winter seasons of testing, compared to Abu-kunjara which had the lowest panicle length. In summer panicle length ranged from 27.04 cm for Butana, to 0.0 cm for Abu-

Ragaba and Abu-Kunjara this is because both Abu-Ragaba and Abu-kunjara did not developed any reproductive parts due to photoperiodic sensitivity and high temperature. Heads weight of the five sorghum genotypes grown in winters 2016/2017 and 2017/2018 revealed again significant differences between the genotypes. The head weight means ranged from 59.35 (g) for Abu-kunjara to 19.15 (g) to Butana. This indicates that Abu-Kunjara had the heights mean head weight in the two winter seasons of testing compared to Butana which had the lowest mean head weight. In summer seasons 2016/2017 and 2017/2018 head means weight of the genotypes were lower than the winters mean which ranged between 35.42 g for Butana, to 0.0 g for Abu-Ragaba and Abu-kunjara.

Plant height of the five sorghum genotypes grown in winter seasons 2016/2017 and 2017/2018 differed significantly ranging from 115.92 cm for Abu-Ragaba to 81.72 for Tabat. This indicates that Abu-Ragaba had the tallest plant height in the two winter seasons of testing, whereas, Tabat had the shortest plant height. Summer seasons of 2016/2017 and 2017/2018 resulted in taller plant than that of winter and Abu-Ragaba again had the tallest plant height (130.23) and Tabat ranked the least for plant height recording 82.39 cm. The results of this study indicated that Abu-Ragaba recorded the highest plant height in both winters and summers. Due to its taller plant and thick stem diameter characteristics the local people use Abu-Ragaba in their building.

Conclusion

In winter season the land races of Barbarei type gave the highest grain yield 1049.9 kg/ha and 1037 kg/ha for Abu-kunjara and Abu-Ragba, respectively compared to Wad Ahmed 294.4 kg/ha, Tabat 600.8 kg/ha and Butana499.8 kg/ha, respectively. Abu-Ragba and Abu-Kunjara, in winter season excelled the other tested cultivars in forage production, producing 1003 kg/ha and 956.8 kg/ha, respectively compared to 861.9 kg/ha, 743.4 kg/ha and 597.8 kg/ha for Butana, Wad Ahmed and Tabat, respectively. In summer season, the land races Abu-Ragaba and Abu-kunjara failed to produce grain yield, but gave high forage production (1115.5 kg/ha and 1060.8 kg/ha respectively), compared to 630.5 kg/ha, 599.6 kg/ha and 501.0 kg/ha for Wad Ahmed, Butana and Tabat respectively. Abu-Ragba and Abu-kunjara excelled the other tested cultivars in protein content recording 13.0% and 12.9% compared to 9.8%, 9.5% and 9.4% reordered for Tabat, Wad Ahmed and Butana, respectively.

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Means of total rains and temperatures, seasons 2016/2017 and 2017/2018

Season	Rain 2016-2017	Rain 2017 -2018	Max Temperature 2016	2017	Min Temperature 2016	2017
May	10.5	7.9	37.4	39.6	25.8	25.8
June	73.4	19.0	34	36.9	34.3	25.8
July	88.6	156.8	31.9	34.3	22.9	23.6
August	182.2	124.1	33.7	31.7	21.7	21.9
September	265.2	199.2	36.2	33.7	21.8	22.1
October	260.7	117.5	35.4	36.4	21.5	22.4
November	22.5	0.0	31.4	33.8	17.5	20.2
Total	903.1	624.5	34.28	35.2	23.6	23.11

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