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Evaluation of yields, pests and soil nutrients in sorghum-groundnut cropping system in Western Bahr El Ghazal, Warrap and Abyei, South Sudan

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Abstract

The study was carried out in Western Bahr el Ghazal, Warrap and Abyei in South Sudan from September to November 2014 and September to November 2015. Objectives were to identify common cropping systems, pests, diseases and weeds, their effect on sorghum and groundnut yields. The data was collected using questionnaires and direct observation in the field. Soil samples were collected from Gogrial West, Udichi, Wau, Mading-Achueng and Wunpeeth. Key parameters cluded existing cropping systems, planting methods, land preparation methods, seed types and sources, pests, diseases, weeds infestation, soil pH, organic carbon, total N, K, Na, Ca, Mg and rain yields under various cropping systems respectively. Analysis of variance was done and means separation using the least significant difference test at $p \leq 0.05$. Significant variation among sites were noted in % O.C, % N, P, K, Ca and Mg. The pH in sampled soils ranged from 6.1 to 7.2. All surveyed locations were deficient in %O.C, %N, K and Ca which ranged from 0.8 to 3.4%. 0.07 to 0.19%, 0.5 to 1.7 Cmols $kg^{-1}$and 0.7 to 2.5 Cmols kg^{-1} respectively. Sorghum yields under sorghum and groundnut intercrop ranged from 0.65t/ha in Gogrial West to 4.1t/ha in Raga County. There was yield advantage in all surved locations except Wau with an LER of 0.98. In conclusion, cropping system, combined with biotic and abiotic factors have much influence on ultimate yields of groundnut sorghum. Existing cropping systems of sorghum-groundnut produced better yield than sorghum and groundnut crops grown as sole crops

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Introduction

For the last few decades, South Sudan has experienced prolonged period of recurrent food insecurity exacerbated by conflicts, lack of agricultural inputs including quality seeds, pests and diseases and weeds (CFSAM report, 2016). A combination of these factors culminated into cereal deficits, which have been recorded over the last few years. (Atlas of sorghum production in Eastern and Southern Africa, 2009, FAO/WFP CFSAM report, 2017). South Sudan is structurally import-dependent such that, on average, the country annually imports about 250,000 MT of cereals from Uganda, Sudan and Kenya (IPC update, 2016). Despite a marginal increase in the national cereal production in 2015 compared to the five-year (2011–2014) average, the aggregate cereal deficit for the year 2016 was estimated at 381,000 MT, higher than the 2015 deficit by over 100,000 MT. The contribution of cereal sub-sector to the total sorghum output is estimated at only 29.91 percent (about 541 thousand metric tons) from an area of about 568,260 hectares in 2011/12. The low share of cereal sub-sector is due to the production of sorghum mainly for subsistence. Hence, there is need to assess the factors that affect sorghum and groundnut yields in the Bahr el Ghazal region of South Sudan.

The primary demand for sorghum and millets is for food in Africa, especially in the dry land regions where these are the principal crops. This continuing demand is reflected in the trend for increasing area under sorghum and millets in Africa over the last fifty years but crop productivity has not kept pace with this increasing demand (Macauley, 2015). Improved understanding of the potential effects of climate change on crop yields is central to planning appropriate and timely responses, (Lobell and Burke, 2010). Agriculture, and especially crop growing, is heavily dependent on weather events in Sub-Saharan Africa, where 97% of agricultural land is rain fed, (Blanc, 2012). The impact of climate change on crop yields is therefore a major concern in this region. Yields of the traditional sub- sector in Sudan fluctuated between 0.2 to 0.5 tons per hectare during the period 2009/2010 –2011/12, (Ahmed, 2015). Variability in production is a function of differences in scales of operation, production technologies, operating environment and operating efficiency (Fried *et al.*, 2008, Etich *et al.*, 2014). Factors affecting yield, apart from access at planting and harvest time are associated with timing and quality of cultivation, seeds used, weeding frequency and pest and disease profiles (FAO/WFP, 2015). The decline in 2016 is essentially due to displacements of farmers and disruption of farming activities following the increased insecurity and violence since July 2016. The major reduction in production, between 15 and 45 percent less than 2015, occurred in most key-cropping areas of Greater Equatoria Region and Western Bahr el Ghazal State (IPC, 2017). The harvested area has declined significantly, between 15 and 40 percent, in Greater Equatoria Region and Western Bahr el Ghazal State due to a combination of reduced number of farming households and smaller average area planted per household (CFSAM, 2017). Food security in South Sudan has further deteriorated due to armed conflict, economic crisis, and below-average harvests that are exhausted well before the planting season (IPC, 2017).

Research conducted on sorghum/groundnut with different plant densities of groundnut revealed that planting 100% sorghum and 50% groundnut resulted in highest total yield than the lowest and highest densities of 100% sorghum, 25% groundnut and 100% sorghum, 75% groundnut respectively showing that plant density is crucial in crop production (Billore *et al*, 1992). In Africa and, India groundnut is very commonly intercropped with sorghum (Behanu *et al.*, 2016). In the developing world, groundnuts are commonly grown in intercropping systems, especially by small farmers who use traditional combinations often involving up to 5-6 crops. Detailed statistics of farming practice are difficult to obtain, but it has been estimated that 95% of the groundnuts in Nigeria and 56% in Uganda are grown as mixtures with other crops (Okigbo and Greenland 1976, Reddy *et al.*, 1980). In the Northern Guinea Savanna Zone of Nigeria, Kassam (1976) reported that only about 16%

of the total area under groundnut was in sole cropping while about 70% was in 2-4 crop mixtures. Rotating or intercropping Sorghum with trap crops such as Soy beans (*Glycine max* L.), groundnut (*Arachis hypogea* L.), Bambara nut (*Vigna subterranea* (L.) Walp), sunflower (*Helianthus annus*L.) and cowpea (*Vigna unguiculata* (L.) Walp) may help to reduce the number of *S. hermonthica* seed in the soil, Ejeta and Butler, Dereje *et al.*, (2016). The research showed that intercropping of sorghum (*Sorghum bicolor* (L.) Moench) and groundnut significantly reduced *Striga hermonthica* (Del) Benth emergence. This was associated with a decrease in soil temperature in the intercropped plots. This research therefore aims at identifying common cropping systems, pests, diseases and weeds, their effect on sorghum and groundnut yields.

Importance of sorghum

Sorghum bicolor (L) Moench, is the fifth most important cereal globally after rice, wheat, maize, and barley. It constitutes the main food grain for over 750 million people who live in the semi-arid tropics of Africa, Asia, and Latin America (FAO, 1999). The world consumption of sorghum reached 63,148 thousand metric tons and it is continuously increasing (Agatha, 2014).Africa accounts only for a quarter of world's sorghum production. Nigeria and Sudan contribute nearly half of the sorghum production in Africa. Sudan is one of the most important countries producing sorghum in the world. It ranks the fifth after China, India, USA and Nigeria in sorghum production, but it is number one in per capita area and grain consumption for human beings (Thabit 2015). Sorghum is one of the crop species that could play an important role in the food security, income generation and food culture of the rural poor in East Africa (Engle and Altoveros, 2000, Catherine *et al.*, 2013).In Kenya, sorghum yields have shown little consistent improvement over the period analyzed, varying significantly from year to year. In 2005, sorghum yields peaked at 1.2 tonnes per hectare, but decreased to only 0.6 tonnes per hectare in 2011. The average yield from 1990 to 2011 remained low at 0.8 tonnes per hectare, despite the development of new seed varieties with the potential to yield 2 to 5 tonnes per hectare, (Witwer, 2013). Since 2009, however, there has been a steady increase in production, primarily because of the growing demand for sorghum for brewing, Orr, Mwema and Mulinge, (2013).Production estimates in South Sudan have been made for sorghum only on the basis of 11 800 transect-based pictorial evaluation tool (PET) scores and cross checking of crop cuts taken during the 70 case studies. The returns from the transects, averaged by county for the main field crops, are summarized in table 1 (CFSAM, 2012). WFP/FAO Crop and Food Security Assessment Mission (CFSAM) in Greater Bahr el Ghazal carried out a comparative analysis of sorghum crop yield during 2008 to 2012 period (Table 1). This analysis showed a cereal decline in average yields over the five-year period (figure 1). Average yields ranged from about 0.5 – 0.8 t/ha to about 1.2 – 16 t/ha in 2012. These figures mirror the trends of sorghum production in Kenya.

More than 75% of rural households in South Sudan consume cereals (NBHS) (2009). At the state level, the percentage ranges from a low of 28% in Upper Nile state to 62% in Western Bahr el Ghazal and to as much as 95% in Northern Bahr el Ghazal. The poorer section of the population in many countries commonly consumes sorghum together with millet and it forms a major source of proteins and calories in the diet of large segments of the population of Africa (Belton and Taylor 2004). In many parts of Sudan, where sorghum is a major grain food, people depend on whole sorghum meals, as the main meal. It is generally consumed as fermented flat bread (Kisra), thick porridge (Aceda), thin fermented gruel (Nasha), boiled grain (Balela) and beverages like Abreh and Hulu-mur (AbdElmoneim *et al*, 2007). In Kenya, the grain is used in making fermented and non-fermented porridge, ugali, pilau, traditional dishes where it is mixed with legumes (Muui *et al*, (2013). Sorghum grain has moderately high levels of iron (> 40 ppm) and zinc (> 30 ppm) with considerable variability in landraces (iron > 70 ppm and zinc >50 ppm). Both micronutrients help reduce stunting.

The protein and starch in grain sorghum are more slowly digested than other cereals, which is beneficial for diabetics, Orr *et al*, (2016). Industrially, the grain is used to manufacture wax, starch, syrup, alcohol, dextrose agar, edible oils and gluten feed, Muui *et al*, (2013).

Constraints to sorghum production

Sorghum is the major dry land crop occupying nearly 10.5 m ha. The average yield levels are generally very low (around 1 t.ha^{-1}) due to various biotic and abiotic constraints including numerous pests and diseases, low soil fertility and water stress operating at different crop developmental stages (Rao,2014). Together these may significantly reduce yields. Striga, a parasitic weed, is considered a major pest of sorghum in Africa, (Orr, 2016). In Ethiopia, sorghum production is mainly constrained by soil water and nutrient deficits, Tesfahunegn (2012). The soil fertility decline is as a result of a combination of processes such as high rates of soil erosion, nutrient leaching, removal of crop residues, continuous cultivation of the land without adequate fertilization and fallowing (Njeru *et al*., 2011; Okalebo *et al*., 2006). The loss of nutrients through plant nutrient mining, removal of crop residues, erosion, leaching or volatilization, and the deterioration of soil physical properties can independently or interactively result in yield reduction (Bielders *et al*., 2002, Njeru P.N.M *et al*., 2013). Wortmann *et al*. (2006) reported that drought, low soil fertility (nutrient deficiencies), insect stem borers, insect shoot fly, quelea birds, Striga and weeds were recognized as major production constraints affecting sorghum in eastern Africa. Although these constraints cause significant grain yield loss, the relative importance varies from region to region, within and among the countries. For example, shoot fly is reported to cause significant grain loss in Ethiopia and Uganda, but is of less importance in Mozambique (Wortmann *et al*. 2006). In Ethiopia, drought and Striga weed have been found to be the most important constraints in the northern and northeastern parts of the country (Gebretsadik *et al*. 2014). Germplasm conservation and use is fundamental for maintaining and increasing food security, especially because it is the basis for the development of improved varieties that will produce increased yields and have higher tolerance to abiotic and biotic factors, as well as other important characteristics beyond those attainable from varieties currently used by farmers, (FAO, 2011).Crop adaptation, including diversifying agriculture with crops and varieties that can perform better under various climatic stresses and substitution of plant types, is among the most cited strategies for adapting agriculture to climate variability and change (Cooper *et al*., 2008; Di Falco *et al*., 2006; Kurukulasuriya and Mendelsohn, 2006; Nzuma *et al*., 2010). Seed systems play a crucial role in providing farmers with access to adaptable crops and varieties, and the flexibility of obtaining seed when required (Kansiime and Mastenbroek, 2016).The broad rationale for focusing on seed sector interventions is that seed is a vehicle for delivering a range of advances, all of which can benefit smallholders. Seed can be the conduit for moving new varieties, giving farmers access to more productive, yield-enhancing traits (McGuire and Sperling, 2015). Socioeconomic factors (age, marital status, education, household size, farm size, social participation and so on) are important factors affecting productivity level in Nigeria. Therefore their effect will help policy makers in the country to make more informed decisions in improving production and livelihood of the farmers, Zalkuwi (2013). A number of empirical studies have attempted to investigate the relationship between technical efficiency and various socioeconomic variables and demographic factors such as levels of formal education, age, family size, access to credit, extension services, and experience, (Chepng'etich *et al*, 2015).

Importance of groundnut production

Groundnut (*Arachis hypogaea* L.) is an important legume grown and consumed globally and in particular in sub-Saharan African countries (Okello *et al*., 2010a; Okello *et al*, 2013). Groundnut is the second most widely grown legume in Uganda, after beans. There has been a substantial increase in the growing of groundnut as both food and cash crop because of increased awareness of its value as a source of protein (23-25% content) and oil (45-52% content) (Page *et al.*, 2002). Groundnut is grown on nearly 23.95 million ha worldwide with the total production of 36.45 million tons and an average yield of 1520 kg/ha in 2009 (FAOSTAT 2011). It is the 5th most widely grown crop in sub-Saharan Africa behind maize, sorghum, millet and cassava. Nigeria produces 30% of Africa's total, followed by Senegal and Sudan with each about 8%, and Ghana and Chad with about 5% each, (FAOSTAT 2010). In western Kenya, the crop is not only the principal source of protein but also a major source of smallholder cash income, (CEFA seeds of solidarity, 2011). In South Sudan, the short maturing groundnuts varieties have the possibility to be used as both staple and cash crop for sale. Groundnuts offer an important safety net for family farms in Western Bahr el Ghazal State. Insomuch as they are often planted as an alternative to sorghum if the first planting of sorghum fails, groundnuts also act as lucrative cash crops where seasons are longer and a second planting is possible (CFSAM, 2015).

Constraints to groundnut production

The groundnut (*Arachis hypogaea* L.), also known as peanut, is the second most important food legume in Uganda after beans (*Phaseolus vulgaris* L.) (UBOS, 2013; Okello *et al.*, 2014). Its production however, has been constrained by numerous factors including pests and diseases, unreliable rains with recurrent droughts, poor agronomic practices, low access to high yielding cultivars and low levels of input use (Mahmoud *et al.*, 1991; Adipala *et al.*, 1998; Okello *et al.,* 2013, Mugisa I. O *et al.*, 2015). Groundnut is commonly cultivated by farmers under rain-fed conditions. Groundnut after groundnut in the same field is not advisable as it leads to build-up of diseases and insect pests in the soil. Groundnut should be rotated with a well-fertilized cereal crop (Janila and Mula, 2015).Among the biotic constraints, fungal diseases are some of the major factors affecting the production and productivity as well as the quality of the crop (Debele and Ayalew, 2015). Contamination of groundnut with aflatoxin occurs under pre harvest, postharvest handling and storage conditions.

The main factors leading to aflatoxin contamination include poor cultural practices; use of damaged and loose-shelled kernels as seed. Delayed harvesting after physiological maturity aggravates biological and physical effects of aflatoxin. Timely planting, adequate fertility, good weeding and insect control, supplementary irrigation, suitable plant population and hybrid selection considerably reduce aflatoxin contamination (Gebreselassie *et al.*, 2015). Yield losses due to *Cercospora* leaf spots are as high as 50% in the USA (Shokes and Culbreath, 1997; Hagan *et al.*, 2006, Debele and Ayalew, 2015). *Cercospora* leaf spot is widespread and economically important disease of groundnut in Ethiopia, and it can cause about 65% yield losses in high disease pressure areas of the country (Teklemariam *et al.*, 1985). Effective control of *Cercospora* leaf spot can be achieved by applying recommended fungicides. Plant disease can be effectively managed by a combination of fungicides and host plant resistance (Pande *et al.*, 2001). The use of resistant varieties to a particular disease is one of the main methods of disease management (Debele and Ayalew, 2015).

Soil water deficit is the most important constraint to production, accounting for over 2 million Mg yr^{-1} of yield loss (FAOSTAT, 2008). Soil water deficits during grain fill are most important. Groundnut production has been constrained by numerous factors including pests and diseases, unreliable rains with recurrent droughts, poor agronomic practices, low access to high yielding cultivars and low levels of input use (Mahmoud *et al.*, 1991; Adipala *et al.,* 1998; Okello *et al.,* 2013). This situation has led to extremely low yields at farmer level averaged at 0.8 tons per hectare of dried pods which is in contrast to yields as high as 2.5 to 3.0 tons per hectare reported at research stations within Uganda and other countries with developed agriculture (ICRISAT, 1986; Busolo-Bulafu, 2004; Okello *et al.,* 2014). Groundnut rosette virus disease (GRVD) is the most destructive disease of groundnut in Uganda. It is the most common and most significant disease of groundnut in all regions where this crop is grown. It is widespread in sub-Saharan Africa and has been a major factor in the decline of the Nigeria groundnut pyramids (Ajiegbe H.A *et al,* 2014). In 1995, rosette appeared in about one million ha of groundnuts in Nigeria. Millipedes were responsible for a seed loss of 12% (Ebreg *et al,* 2014). Though there are increasing cereal yield trends in most Sub-Saharan Africa countries, these yield levels remain low compared to other regions of the world (Chauvin, *et al,* 2012, AGRA, Africa Agriculture Status Report, 2013).

Material and methods

Description of study sites

The study was conducted in Wau, Raga, Jur River and Gogrial West Counties.

Wau County: Wau is situated between the coordinates, latitude 7° 42'N and longitude 28° 0' E at an altitude of 438m above sea level (1,437ft). Köppen-Geiger climate classification system classifies its climate as tropical savanna, wet and dry. It has an average relative humidity of 54% with annual precipitation of 1098mm and an annual mean temperature of 27.8°c. Characterized by livelihood zone 4 (SSD 04) known as "Western groundnuts, sesame and sorghum zone". The soil of WBGS is ironstone, alluvial and it is red with high content of iron oxide, iron stone gravels, predominantly lateritic, low fertility due to leaching erosion losses, (Odra, et. al, 2004).

Raga county: Raga town is located in Raga County, Western Bahr el Ghazal State, in the northwestern corner of South Sudan, near the International borders with the Republic of Sudan and the Central African Republic. It is located approximately 300 kilometers by road, northwest of Wau, the capital of Western Bahr el Ghazal State. This location lies approximately 950 kilometers by road, northwest of Juba, the capital and largest city in that country. The coordinates of Raga are: 8° 28' 12.00"N, 25° 40' 48.00"E (Latitude: 8.4700; Longitude: 25.6800). Raga is located at an altitude of 545 meters above sea level. Köppen-Geiger climate classification system classifies its climate as tropical wet and dry. Raga has average precipitation of 1,141.6mm per year with an average relative humidity of 54.4% and average temperature of 26°C. Raga falls under livelihood zone 4 (SSD 04) known as "Western groundnuts, sesame and sorghum zone" as Wau County.

Jur River County: With its head quarters at Nyinakok, Jur River County lies between the coordinates, 8° 39' 0"N and 29° 18' 0" E of the Equator. It's located at 359 meters above sea level. No humidity records exists for Jur River County, however, it shares more or less the same humidity levels of up to 54% as that of Wau since it partly falls in livelihood zone 4 as Wau county, though at relatively lower altitude as compared to Wau.

Gogrial West County, Warrap Stat: Gogrial West borders Twic County in the north, Abyei in the west, Wau in the south, and Gogrial East. The total population in Gogrial West is estimated at 243,921. Community Consultation report, Warrap state (May 2012). Elevated at an altitude of 415 meters above sea level, Köppen-Geiger climate classification system classifies its climate as tropical savanna, wet and dry. The precipitation of up to 967mm annually with an average humidity of 60% has been recorded. Gogrial West has an average temperature of 27.7°C. Warrap and Abyei together with parts of Western Bahr el Ghazal Jur River County fall under livelihood zone number 7 (SSD 07), known as the greater Bahr el Ghazal sorghum and cattle. (FEWSNET, 2013)

Abyei Area: Abyei lies at an latitude of 9.5292 and longitude of 28.433. The cordinates : 8° 34' 16"N and 28° E. It is located at an altitude of 508m above sea level,. Accu weather, www.worldweatheronline. Köppen-Geiger climate classification system classifies its climate as tropical wet and dry (Aw). Generally, average tempartures stand at 27.7°c, average precipitation of 972mm and average humidity of 54%.Day temperatures range from 28°C to 37°C and night temperatures range from 29°Cto 34°C. Abyei, Warrap and parts of Western Bahr el Ghazal Jur River County fall under livelihood zone number 7 (SSD 07), known as the *Greater Bahr el Ghazal sorghum and cattle.*(FEWSNET, 2013).

Experimental design

Data for this study was collected using questionnaires. Field interviews were also conducted with individual farmers at farm level. The data was collected during the months of September to November 2014 and September to November 2015 respectively. A sample size of 240 farmers was interviewed from selected sites. This sample was drawn from a population of six hundred (600) households. However, the actual number of 232 households represented by household heads/respondents was finally achieved. This was determined through a simplified formula by Glenn D. Israel i.e.,

$n = N/1+N (e)^2$

Where, n is the sample size, N is the population size and e is the level of precision, which is 0.05

Data collection and analysis

Data collected comprised elements that influence the ultimate yield of sorghum and groundnut crops. These included the demographic data on gender, sex of household head, state, counties and specific locations from which data were collected. The farming practices, such as time of planting, application of farmyard manure, fertilizer use, cropping systems, incidence of pests, diseases and weeds and planting time were determined. Data was also collected on cropping systems adopted by local farmers and tools used for land preparation, type of seeds, onset of rains and methods of planting were considered in the data collection process.

Three different tools and methods were used to analyze the array of data that was collected. Statistical Packages for Social Sciences (SPSS) software was employed to analyze data related to demographic and production information. Genstat software was used in data analysis. Data on rainfall, pests, diseases and weed were analyzed using Microsoft excel software. Least Significant differences (LSDs) test at 5% level and the coefficient of variation (CVs) were calculated. The type of cropping system evaluated was mainly the combination of sorghum and groundnut.

The area from which the data was collected was stratified in to blocks. Randomized Complete Block Design (RCBD) with three replicates was used. Crop yield data was collected from five survey sites involving interviews with 232 farmers. These data collection sites included Gogrial West, Abyei, Jur River, Wau and Raga respectively. Soil sample data was collected from five sites, covering Udichi, Gogrial West, Basellia, Mading-Achueng and Wunpeeth. Simple correlation and regression analysis was done to determine the level of relationship between average rainfall amounts received over a period of six years versus sorghum yield obtained in tons per hectare in Western Bahr el Ghazal state

Determination of soil nutrient status in surveyed states/counties

The soil was sampled at 0.20cm depth from three farms in each of the five sites. The five sites were; Besselia, Udichi, Gogrial West, Mading-achueng and Wunpeeth. After collecting samples, they were placed in separate envelopes and appropriately labeled. Samples were air-dried, ground using a motor and pestle and sieved through a 2 mm sieve. Laboratory analyses were conducted for soil pH, percent total organic carbon, percent total nitrogen, exchangeable bases (K^+, Na^+, Ca^+ and Mg^+) and available phosphorus.

The Walkley-Black chromic acid wet oxidation method was used to determine the soil total organic carbon. Oxidisable matter in the soil was oxidized by 1 N $K_2Cr_2O_7$ solution. However, to increase the homogenization of the sample and to facilitate the oxidation, a soil sample, which had previously been passed through a 2 mm sieve to remove the coarse fraction, was ground to pass an 0.5 mm sieve. The pH (reaction) of the soil was determined using a pH meter and glass electrodes. The pH of the soil was determined using one part of soil to 2.5 parts of water or solution, i.e.10.0 g soil to 25 ml water. Exchangeable bases were determined using an ammonium acetate extract by flame photometry (K^+, Na^+) and atomic absorption spectrophotometry (Ca^+ and Mg^+).

Phosphorus test was done using MEHLICH's method-calorimetric determination of soil phosphorus. The N-Kjedhal's method (equipment with die and chemical) was used in total nitrogen analysis.

Results and discussion

In the study, the age groups were categorized into two main according to the FAO/WFP food security assessment missions with respondents in the age bracket of 18 – 60 years old and 60 years and above. The study shows that men were 40% while 60% were women (Table 2).

Table 1. South Sudan - Estimated cereal harvested area, yield, production, consumption 2012-2013.

State/County	Cereal area 2012 (ha)	2012 gross yield (t/ha)	2012 gross cereal production (t)	2012 net cereal production (t)	Population mid-2013	2013 cereal reqt (t)	2013 surplus/deficit (t)
W Bahr el Ghazal	56635	1.00	56460	45168	446123	50183	-5015
Returnees to 2012	3560	0.9	3204	2563	64720	7119	-4556
Jur River	16608	0.9	14947	11957	146154	16077	-4120
Raga	7221	0.85	6137	4910	62158	6216	-1306
Wau	29247	1.1	32172	25737	173091	20771	4967
Warrap	163603	0.68	110886	88709	1193365	116203	-27494
Returnees to 2012	3242	0.45	1459	1167	80461	8048	-6881
Abyei	2631	0.68	1789	1431	60491	5444	-4013
Gogrial East	16247	0.75	12185	9748	118143	11224	-1476
Gogrial West	38970	0.77	30007	24005	279014	29297	-5292
Tonj East	20838	0.45	9377	7502	132828	13283	-5781
Tonj North	30333	0.65	19716	15773	188993	18899	-3126
Tonj South	15341	0.68	10432	8345	99050	8914	-569
Twic	36002	0.72	25921	20737	234385	21095	-358

Source: CFSAM 2012 report.

Table 2. Demographic characteristics of respondents who participated in the study.N = 232.

Characteristics of respondents		*Gender*		*Total*	*Percent*		*Percent total*
		Male	Female		Male	Female	
Gender of respondents		93	139	232	40.1	59.9	100.0
Gender of household head		163	69	232	70.3	29.7	100.0
Age category of household's head	18-60 years	93	0	93	40.0	0.0	40.0
	> 60 years	70	69	139	60.0	0.0	60.0

These observations are in agreement with findings by Adeniyi (2010) that, over 60 percent of female labor force in Sub-Saharan Africa is employed in the agricultural sector (ILO, 2009). Sixty-eight per cent used local seeds of sorghum and groundnuts while the remaining 32% of those who cultivated used hybrid seeds (Table 3).

Table 3. Cropping systems and inputs use in Greater Bhar el Ghazal region (2015).

Farm practice/Routine activities	Farmers' responses	No. of respondents	Percent
Cultivation history	Did not cultivate previous season	1	0.4
	Cultivated last season	231	99.6
Types of seeds	Improved varieties	75	32.3
	Local	157	67.7
Sources of Sorghum and Groundnut seeds for local farmers	Market	20	8.6
	World Food Program (WFP)	10	4.3
	Other farmers	21	9.1
	Own seeds	181	78.0
	Groundnut/sorghum	55	23.7
	Sorghum/cowpeas	2	0.9
	Sorghum/Sesame	75	32.3
Cropping systems	Only ground nut	26	11.2
	Only Sorghum	15	6.5
	Only maize	27	11.3
	Other (Sorghum, green gram, maize, cowpea)	32	13.8

Planting methods	Broad casting	101	66.8
	Row planning	77	33.2
Land preparation	Did not plough before planting	114	49.1
	Ploughed before planting	118	50.9
Farming tools used by local farmers	Hand hoe (Local molodas)	187	80.5
	Oxen	22	9.5
	Others (Jembe)	23	9.90
Time of planting	February	1	0.4
	April	66	28.4
	May	141	60.8
	June	24	10.3
Use of farm yard manure	Did not use farm yard manure	155	66.8
	Used farm yard manure	77	33.2
Use of inorganic/synthetic fertilizers	Used synthetic fertilizers	195	84.1
	Did not use synthetic fertilizers	37	15.9
Sources of synthetic fertilizers	Market	50	21.6
	Missing System	182	78.4

These findings are in agreement with a report by Tadu and Oketayot (2013), that farmers in South Sudan save seed from their crops from year to year, receive seed from neighbours and relatives, or buy seed from local markets. There was significant difference in the mean yield of sole sorghum and groundnut across the four counties of Gogrial West, Wau, Jur River and Raga (Table 4).

Table 4. Effect of cropping systems on the mean yield of sorghum and groundnut in Greater Bahr el Ghazal.

County	*Sole Sorghum*	*Sole Groundnut*	*Sorghum yield in sorghum - groundnut intercrop t/ha*
Gogrial West	0.276 a	0.312 a	0.646 a
Wau	0.504 ab	0.522 b	0.55 a
Jur River	0.726 b	0.52 b	0.536 a
Raga	1.544 c	0.768 c	3.9 b
Grand mean	0.762	0.53	1.41
P-value	<.001	0.001	<.001
LSD (0.05).	0.285	0.180	0.628
cv%	27.1	24.6	32.4

Table 5. Frequency of pests, diseases and weeds incidence randomly observed in the selected field locations during the survey.

	Grass hoppers	*Millipedes*	*Termites*	*Domestic animals*	*Mild Dew*	*Sorghum bug*	*Striga*
Gogrial West	5.0a	6.0b	2.0a	12.67b	4.0a	3.0a	10.0a
Jur River	3.0b	2.0a	2.67a	1.0a	1.3a	2.3a	5.0b
Wau	2.0b	5.0b	2.0a	1.0a	2.3a	2.67a	1.3c
Mean	3.33	4.33	2.22	4.89	2.56	2.67	2.56
P value	0.027	0.007	0.816	<.001	0.232	0.912	0.232
LSD P ≤ 0.05	1.998	1.998	2.903	1.762	3.396	3.767	3.396
CV%	30	23.1	65.4	18	66.5	70.7	66.5

Significant variation was also observed between Raga and the other three counties in terms of sorghum yield under sorghum – groundnut intercrop.

For sole sorghum crop, the yield ranged 0.28t/ha in Gogrial West to 1.54t/ha in Raga. For sole groundnut crop, the yield ranged from 0.31t/ha in Gogrial West to 0.77t/ha in Raga, while for sorghum under sorghum – groundnut intercrop, the yield ranged from 0.54t/ha in Jur River to 3.9t/ha in Raga. Sixty-seven per cent of respondents practicing broadcasting method of seeding, while the remaining thirty-three per cent practiced row planting (Fig. 2) Field observations focused on identifying specific types of pests, diseases and weeds and the damage inflicted on the plant. Major pests were grasshoppers, millipedes and sorghum bug.

Table 6. Mean averages for %OC, %T.N, available P (ppm), K^+, Na^+, Ca^+ and Mg^+ ($Cmoleskg^{-1}$) in selected states of Greater Bahr el Ghazal.

Location	pH	OC	TN	K	Na	Ca	Mg	P
	%			Cmol kg^{-1}				
Basselia	6.7a	2.9bc	0.13ab	1.2cd	0.6a	1.4b	0.8ab	13.5a
Udichi	6.7a	1.9ab	0.08a	0.5a	0.6a	0.7a	0.6a	15.1a
Gogrial West	6.1a	3.4c	0.19b	1.7d	0.7a	2.5c	1.4c	28.5b
Mading-Achueng	7.0a	0.8a	0.08a	0.7ab	0.75a	1.5b	1.2bc	10.8a
Wunpeeth	7.2a	1.0a	0.07a	1.1bc	0.6a	1.6b	1.0ab	15.9a
Mean	6.8	1.98	0.109	1.03	0.631	1.538	0.99	16.74
P -value	0.536	0.011	0.038	0.004	0.803	0.001	0.016	<. 001
LSD 0.05	1.489	1.42	0.0771	0.4756	0.415	0.5415	0.427	5.864
CV%	11.7	37.9	37.7	24.5	34.9	18.7	22.9	18.6

Table 7. Sorghum - Groundnut Land Equivalent Ratio (LER).

Partial LER Sorghum	Partial LER Groundnut	Total LER Sorghum- Groundnut
1.52ab	0.48a	2a
1.19a	0.97a	2.16a
0.84a	0.89a	1.72a
2.29b	0.27a	2.56a
1.46	0.65	2.11
0.014	0.17	0.31
0.77	0.74	0.95
28.2	60.2	24

The main disease was powdery mildew while the major weed was Striga (Table 5). Gogrial West had significantly higher incidences of grasshoppers, millipedes, domestic animals and Striga than Jur River and Wau. Wau had higher incidences of millipedes than Jur River.

There were no significant variations in pH and Na levels noted on the study sites (Table 7). pH ranged from 6 to 7.2 while Na ranged from 0.6 to 7.5 Cmol kg^{-1}. Gogrial West had significantly higher organic carbon than all locations except Wau (Basselia). Organic carbon levels were not significantly different among Wunpeeth, Mading-Achueng and Jur River (Udichi) sites. Wau (Basselia) site had significantly higher organic carbon than Gogrial West, Madin-achueng and Wunpeth, but not Udichi.

Percent organic carbon ranged from 0.8% in Mading-Achueng to 3.4% in Gogrial West. Gogrial West had significantly higher % TN than other locations except Wau (Basselia). No differences in % N were noted among Wau (Basellia), Jur River (Udichi), Mading-Achueng and Wunpeth sites.. Total N ranged from 0.07% in Wunpeth to 0.19% in GogrialWest.Gogrial West had significantly higher potassium than other locations except Wau (Basselia). Potassium levels ranged from 1.7 Cmols kg $^{-1}$ in Gogrial West to 0.5 Cmols kg $^{-1}$inJur River (Udichi). Udichi had significantly lower potassium levels than all the sites except Mading-Achueng. Gogrial West had significantly higher Ca than other locations.

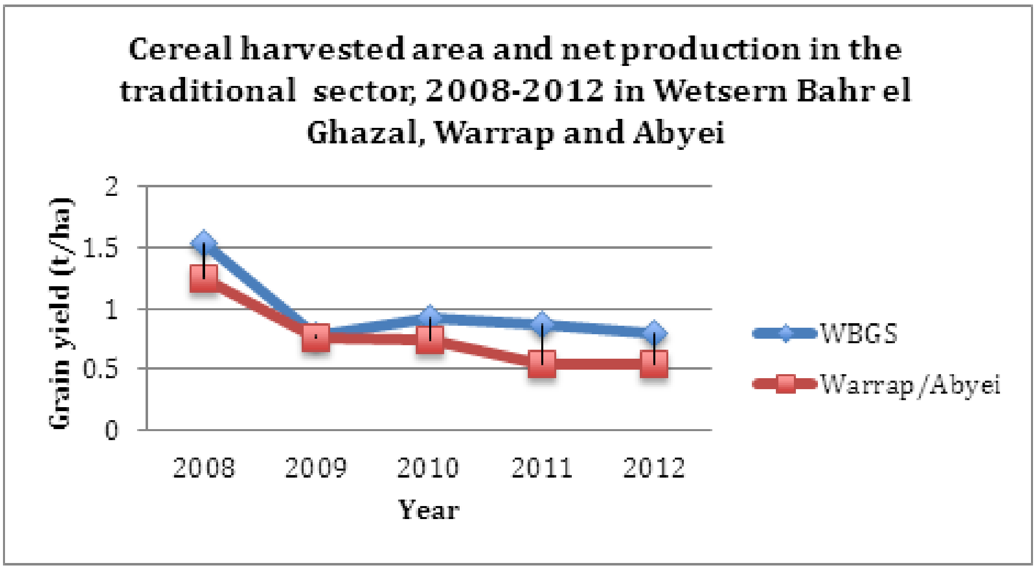

Fig. 1. Comparison of sorghum grain yield over a period of five years in South Sudan.

While Jur River (Udichi) had significantly the lowest Ca content, there were no significant differences in Ca content in Mading-Achueng, Basellia and Wunpeth sites. Ca content ranged from 0.7 Cmol kg $^{-1}$ in Jur River (Udichi) to 2.5 Cmol kg $^{-1}$ in Gogrial West. Gogrial West had significantly higher P than all other locations. Phosphorous levels ranged from 10.8Ppm to 28.5 Ppm.In terms of Land Equivalent Ratio (LER), there is yield advantage for sorghum and groundnut intercrops in all the locations (Table 7). The LER ranged from 2.34 to 5.04.

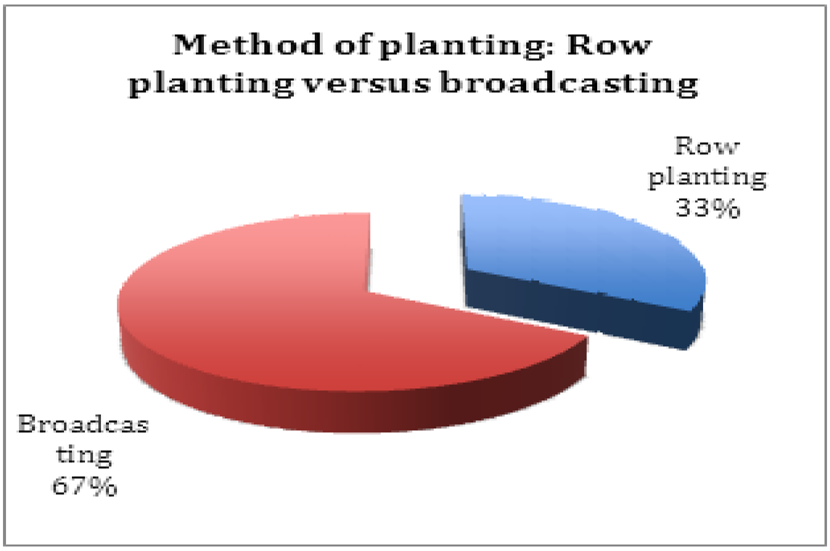

Fig. 2. Planting methods adopted by local farmers in South Sudan.

Conclusion

In this study, the sorghum – groundnut cropping system, coupled with biotic and abiotic factors have much influence on ultimate yields of groundnut and sorghum crops and thus, existing cropping systems of sorghum-groundnut produced better yield than sorghum and groundnut crops grown as sole crops.

Recommendations

Based on results of this study, local farmers need to be sensitized on importance of intercropping systems in yield improvement and soil fertility management. The government must prioritize further research on soil fertility management as well as environmental friendly pests, diseases and weeds management practices. Good agricultural practices must also be adopted by local farmers and incorporated in to agricultural extension policies of the government of the republic of South Sudan for sustained food production at farm level.

References

Ajeigbe HA, Singh BB, Ezeaku IE, Adeosun J. O.2010. On-farm evaluation of improved cowpea-cereals cropping systems for crop-livestock farmers: Cereals- cowpea systems in Sudan savanna zone of Nigeria. African Journal of Agricultural Research **5(17),** 2297–2304. Retrieved from www.academicjournals.org/AJAR

Ambang Z, Ndongo B, Essono G, Ngoh JP, Kosma P, Chewachong GM, Asanga A.2011. Control of leaf spot disease caused by *Cercospora* sp on groundnut (*Arachis hypogaea*) using methanolic extracts of yellow oleander (*Thevetia peruviana*) seeds. Australian Journal of Crop Science **5(3),** 227–232.

Assar AHA, Ahmadi AB, El Abdalla EGA, Mustafa ESA, ElEleasir MHA, Hussein AA. 2008. Bunting, a new large-seeded Virginia groundnut variety for the irrigated clays in **6,** 5–6.

Balya C.2005. Supporting Smallholder Farmers to Grow in Uganda : The Story of Eagle Lager, 33.

Blanc E.2012. The Impact of Climate Change on Crop Yields in Sub-Saharan Africa. American Journal of Climate Change **1(1),** 1–13. https://doi.org/10.4236/ajcc.2012.11001

Bucheyeki TL, Shenkalwa EM, Mapunda TX, Matata LW.2010. Yield performance and adaptation of four sorghum cultivars in Igunga and Nzega districts of Tanzania. Communications in Biometry and Crop Science **5(1),** 4–10.

Cefa.2011. Good agronomic practices for Groundnut in Western Kenya Good agronomic practices for Groundnut in Western Kenya Training manual for Trainers, Au.

Charleston K. 2013. Maize insect pest management Northern grains region.

Chepng'etich E, Bett EK, Nyamwaro SO, KizitoK.2014. Analysis of Technical Efficiency of Sorghum Production in Lower Eastern Kenya : A Data Envelopment Analysis (DEA) approach . Journal of Economics and Sustainable Development **5(4),** 58–65.

Control W. 2015. Weeds Table of Contents.

Conversions M.2013. Metric Conversions (May), 6–8. https://doi.org/10.1016/B978-1-85617-415-2.50015-0

Cork A, Dobson H, Grzywacz D, Hodges R, Orr A. 2009. Review of pre-and post-harvest pest management for pulses with special reference to Eastern and Southern Africa. Africa**986729),** 1–136. Retrieved from

Crop HEG. 2001. The cultivated groundnut (Arachis. North, 6–38.

Department of Agriculture FF. 2010. Groundnuts; Production Guideline. Groundnuts ; Production Guideline, 3–20.

Disorders S. 2004.Agnote Common Diseases of Peanuts in the Top End of the NT. Springs, (February).

Doss C, Raney T, Anríquez G, Croppenstedt A., Gerosa S, Lowde S, Matuscke I.2011. The role of women in agriculture. Food and Agriculture Organization of the United Nations **(11),** 1–48. https://doi.org/10.1002/2014GB005021

Du Pont Pioneer Agronomy Sciences.2014. Grain Sorghum Management. Crop Focus, **2(3),** 1–3.

Ebregt E, Struik PC, Odongo B, Abidin PE. 2005. Pest damage in sweet potato, groundnut and maize in north-eastern Uganda with special reference to damage by millipedes (Diplopoda). NJAS - Wageningen Journal of Life Sciences **53(1),** 49–69. https://doi.org/10.1016/S1573-5214(05)80010-7

FAO. 2001. Post-harvest Operations**.** INPhO-Post-Harvest Compendium, 56.

Farmer TO.2010. 3432.TOF.

Food MA, Policies A, Fao M.2012.Analysis of Incentives and Disincentives for Groundnuts in Malawi October 2012, (October).

FSIN.2013.Capacity Assessment of South Sudan Food Security and Nutrition Information Systems, (November). Retrieved from Assessment of South Sudan FSN Information Systems.pdf www.fsincop.net/fileadmin/user_upload/fsin/docs/resources/Capacity

Girei AA, Dauna Y, Dire B.2013. An economic analysis of groundnut (*Arachis hypogea*) production in Hong Local Government Area of Adamawa State , Nigeria. Journal of Agricultural and Crop Research **1,** 84–89.

Government of Sudan, FEWS Net, FAO, WFP, The European Union.2011. Government of Sudan and Fao/Wfp Crop and Food Security. World Wide Web Internet And Web Information Systems **75.** Retrieved from www.fao.org/sudanfoodsecurity/en/

Gwary DM, Bwatanglang N, Bdliya BS. 2008. Integrated management of sorghum anthraenose through the use of fungicides, crop varieties and manipulation of sowing dates in Sudan Savanna of Nigeria. International Journal of Agriculture and Biology **10(6),** 661–664.

Habib N. 2013. Asian Journal of Agriculture and Rural Development Current Situation and Future Outlook of Sorghum Area and Production in Pakistan **3(5),** 283–289.

Hamma IL, Ibrahim U. 2013.Management Practices for Improving Fertility Status of Soils in Nigeria. World Journal of Agricultural Sciencies **9(3),** 271–276. https://doi.org/10.5829/idosi.wjas.2013.9.3.1738

Hassan TA. 2015. Economics of Sorghum Production under Traditional Farming System in Nyala Governate of South Darfur State, Sudan. ARPN Journal of Science and Technology **5(2),** 74–79. Retrieved from www.ejournalofscience.org

Information C.2015. Integrated Soil Fertility Management in Africa : from Microbes to Markets (ISFM Africa 2012) Conference Information, Program and Abstract, 22–26.

International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). 2013. Groundnut Varieties Improvement for Yield and Adaptation, Human Health, and Nutrition Annual Progress Report September 2012 - August 2013, (August), 40.

Introduction I, Costs I, Density ARW, Competitiveness BEC, Wheat AW, Corn B, Summary V. 2003. NE Cological a Pproach To S Trengthen W Eed M Anagement in the S Emiarid **80,** 33–62.

Kassie M, Shiferaw B, Muricho G. 2010.Adoption and impact of improved groundnut varieties on rural poverty: evidence from rural Uganda. Environment for Development Discussion Paper - Resources for the Future (RFF), **(May),** 10–11. Retrieved from www.rff.org/RFF/Documents/EfD-DP-10-11.pdf

Konlan SSAJKMAEBI. 2013. Yield response of three groundnut (*Arachis hypogaea* L.) varieties intercropped with maize (*Zea mays*) in the guinea savanna zone of Ghana. Journal of Cereals and Oilseeds **4(6),** 76–84. https://doi.org/10.5897/JCO2013.0112

Kouvelas V, Aggelis G, Alexopoulos AA, Angelopoulos KC. 2014. Nitrogen dynamics during growth of sweet sorghum [*Sorghum bicolor* (L.) Moench] in response to conventional and organic soil fertility management **8(5),** 730–737.

Krutmuang P, Mekchay S. 2005. Tropentag 2005 Stuttgart-Hohenheim, October 11-13, 2005. Conference on International Agricultural Research for Development. Stuttgart-Hohenheim, October 11-13, 2005.1–8.

Lewandowski CM. 2015.Fao Statistical Yearbook 2013.The effects of brief mindfulness intervention on acute pain experience: An examination of individual difference **1.** https://doi.org/10.1017/CBO9781107415324.004

Mabele Fuels.2016.Grain Sorghum.

Macauley H. 2015. Cereal Crops: Rice, Maize, Millet, Sorghum, Wheat. Feeding Africa: An Action Plan for African Agricultural Transformation, 1–36.

Mahgoub F. 2014.Current Status of Agriculture and Futue Challenges in Sudan. Current African Issues. https://doi.org/10.1016/j.jpolmod.2015.07.002

Maposa D,Mudimu E, Ngwenya O.2010. A multivariate analysis of variance (MANOVA) of the performance of sorghum lines in different agro-ecological regions of Zimbabwe. African Journal of Agricultural Research **5(3),** 196–203. https://doi.org/10.5897/AJAR09.574

Marshall M. 2012. Weed Control in Grain Sorghum, 135–142.

Marshall M, Specialist EW. 2012. Weed Control in Peanut.

Mesonet TO. 2012. How to use the Peanut Leaf Spot Advisor, (September).

Ml J, Rk J, Gupta R, Gopal R. 2004. Conservation Agriculture in cereal systems of South Asia : effect on crop productivity and carbon-based sustainability index, 1–3.

Mohammed H. 2014.Screening of Some Varieties of Groundnut (*Arachis Hypogea* L.) Against Rosette Disease in Nigerian Sudan Savanna. Plant **2(2),** 14. https://doi.org/10.11648/j.plant.20140202.11

Mugisa IO, Karungi J, Akello B, Ochwo Ssemakula MKN, Biruma M, Okello DK, Otim G. 2015. Assessing the effect of farmers practices on the severity of groundnut rosette virus disease in Uganda. African Journal of Agricultural Research **10(9),** 995–1003. https://doi.org/10.5897/AJAR2014.9171

Muui CW, Muasya RM, Kirubi DT. 2013.Participatory Identification and Evaluation of Sorghum (*Sorghum bicolor* (L.) Moench) Landraces from Lower Eastern Kenya. International Research Journal of Agricultural Science and Soil Science **3(8),** 283–290. https://doi.org/10.14303/irjas.2013.083

Nafziger E. 2010.Cropping Systems. Department of Crop Sciences, 49–63.

Nigam S, Giri D, Reddy AG. 2013. Groundnut seed production manual. Journal of Chemical Information and Modeling **53(9),** 1689–1699. https://doi.org/10.1017/CBO9781107415324.004

Njeru PNM, Mugwe J, Maina I, Mugendi D, Kimani S, Miriti J, Box PO. 2013. Integrating scientific and farmers' perception towards evaluation of rain-fed agricultural technologies for sorghum and cowpea productivity in Central Kenya **4(7),** 123–131. https://doi.org/10.5897/JSSEM2013.0378

Ogbonna AC. 2005. Sorghum : an Environmentally-Friendly Food and Industrial Grain in Nigeria **5,** 0–4.

Ogeto RM, Cheruiyot E, Mshenga P, Onyari C. N. 2013. Sorghum production for food security: A socio- economic analysis of sorghum production in Nakuru County, Kenya. African Journal of Agricultural Research **8(47),** 6055–6067. https://doi.org/10.5897/AJAR12.2123

Okello DK, Monyo E, Deom CM, Ininda J, Oloka HK. 2013. Groundnuts production guide for Uganda : Recommended practices for farmers. National Agricultural Research Organization, Entebbe.

Okello DK, Akello LB, Tukamuhabwa P, Odong TL, Ochwo-Ssemakula M, Adriko J, Deom CM.2014. Groundnut rosette disease symptoms types' distribution and management of the disease in Uganda. African Journal of Plant Science **8(3),** 153–163. https://doi.org/10.5897/AJPS2014.1164

Olembo K, M'mboyi F, KiplagatS.2010. Sorghum breeding in sub-Saharan Africa: the success stories. African Biotechnology Stakeholders Forum, 37 pages. Retrieved from http://absfafrica.org/downloads/Sorghum Book Series.pdf

Orr A, Mwema C, Mulinge W. 2013. Socioeconomics Discussion Paper Series The value chain for sorghum beer in Kenya **(16).**

Plessis Du J. 2008. Sorghum production. Department of Agriculture, 1–14.

Popescu A, Condei R. 2014.Some Considerations on the Prospects of Sorghum Crop. Scientific Papers **14(3),** 295–304. Retrieved from http://managementjournal.usamv.ro/pdf/vol_14/Volume_14_3_2014.pdf#page=298

Prasad PVV, Staggenborg SA. 2011.Growth and Production of Sorghum and Millets. Soils, Plant Growth and Crop Production **2,** 1–27.

Prasad PVV, Kakani VG, Upadhyaya HD. 2010. Growth and production of groundnuts. Soils, Plant Growth and Crop Production 138–167.

Rice M, Beans G, Agency US, Development I, Africa E, Office R, Corporation C. 2011.Crop Conditioning.

Riedell WE, Pikul JL, Jaradat AA, Schumacher TE.2009. Crop rotation and nitrogen input effects on soil fertility, maize mineral nutrition, yield, and seed composition. Agronomy Journal **101(4),** 870–879. https://doi.org/10.2134/agronj2008.0186x

Royer A, ToteC, Gilliams S, Bydekerke L. 2009.GMFS South Sudan CFSAM Support Kit for JRC. Focus, 45.

Seibutis V, Deveikyte I, Feiza V. 2009.Effects of short crop rotation and soil tillage on winter wheat development in central Lithuania. Agronomy Research **7(1),** 471–476.

Short C, Mulinge W, Witwer M. 2013. Analysis of Incentives and Disincentives for Maize in Kenya, 1–49.

Singh BB, MusaA, Ajeigbe HA, Tarawali SA. 2011. Effect of feeding crop residues of different cereals and legumes on weight gain of Yankassa rams. International Journal of Animal Production **2(2),** 17–23.

Singh F, Oswalt DL. 1995. Groundnut Production Practices. International Crops Research Institute for the Semi-Arid Tropics Patancheru 502 324, Andhra Pradesh, India **(3),** 42.

Singh PK, Gautam RK, Roy SD, Singh AK, Ahmed SKZ. 2014. Performance of Sorghum Varieties for Fodder Yield During Rabi Season in Andaman & Nicobar Islands **19(2),** 174–176.

Smale M, Assima A, Weltzien E, Attunde F. 2014.An Overview and Economic Assessment of Sorghum Improvement in Mali. MSU International Development Working Paper 137. Michigan State University**(2),** 137 pages. Retrieved from https://ideas.repec.org/p/ags/midiwp/198186.html

Solomon D, Amare A. 2015. Integrated management of Cercospora leaf spots of groundnut (*Arachis hypogaea* L.) through host resistance and fungicides in Eastern Ethiopia. African Journal of Plant Science **9(2),** 82–89. https://doi.org/10.5897/AJPS2014.1260

TaduG, Oketayot C. 2013.Seed policy status in South Sudan, 41–50.

Tesfahunegn GB. 2012. Effect of Tillage and Fertilizer Practices on Sorghum Production in Abergelle Area, Northern Ethiopia. Momona Ethiopian Journal of Science (MEJS) **4(2),** 52–69.

Tesfamichael A, Nyende AB, Githiri SM, Kasili RW, Woldeamlak A. 2013.Documentation of Sorghum (*Sorghum bicolor* L. Moench) Landraces: Production, Utilization and Challenges in Eritrea. ARPN Journal of Agricultural and Biological Science **8(6),** 498–508. Retrieved from www.arpnjournals.com

USAID.2014.Expected Impacts on Pests and Diseases Afflicting Livestock, (August).

Vanderlip RLKRDFJSHKDW, Alam M. 1998. Grain sorghum production handbook. Grain Sorghum Production Handbook, 1–18. Retrieved from www.scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:Grain+Sorghum+Production+Handbook#3

Busolo-Bulafu MC, Merwe V. 2002. Groundnut Manual for Uganda: Recommended Groundnut Production Practices for Smallholder Farmers in Uganda. Chatham, UK: Natural Resources Institute, 1–21.

Winter SR, Unger PW. 2001. Grain Sorghum Production **510,** 504–510.

Zamurrad M, Tariq M, Shah FH, Subhani A, Ijaz M, Iqbal MS, Koukab M. 2013. Performance Based Evaluation of Groundnut Genotypes Under Medium Rainfall Conditions of Chakwal **1(1),** 9–12.

Agriculture, Forestry, Fisheries. 2010. Animal Production, 2009. https://doi.org/doi:10.1201/b11576-25