International Journal of Agriculture and Forestry 2023, 13(2): 37-47
DOI: 10.5923/j.ijaf.20231302.01

Effect of Sorghum-Cowpea Intercropping and Nitrogen Application on Growth and Yield of Sorghum (*Sorghum bicolor* (L.) Moench)

Peter E. Moi*, George N. Chemining'wa, Onesmus M. Kitonyo, Josiah M. Kinama

Department of Plant Science and Crop Protection, University of Nairobi, Nairobi, Kenya

Abstract Despite the development of improved varieties, the yield of sorghum has remained significantly low in dryland environments due to low soil fertility and inappropriate cropping practices. The integration of cowpea into sorghum-based crop systems and the application of fertilizer nitrogen (N) could increase yield. However, the effect sorghum-cowpea compatibility, crop response to N and their interaction on growth and yield of the companion crops is only partially understood. Two experiments were simultaneously conducted during 2018/2019 short rain season at the Kenya Agricultural and Livestock Research Organization fields in Katumani and Igoji to determine the effect of intercropping and fertilizer N rate on growth and yield of selected varieties of sorghum and cowpea. Sole crop and intercrop systems of two sorghum varieties (Gadam and Serena) and two cowpea varieties (M66 and K80), and three N rates (0, 40 and 80 kg N ha^{-1}) were evaluated in a randomized complete block design with split-plot arrangement and replicated three times. Factorial combinations of sorghum-cowpea intercrop or sole crop systems formed the main plots while N rates formed the sub-plots. Crop growth traits and yield data were subjected to analysis of variance by the use of GenStat statistical software at 5% probability level. Intercropping significantly reduced crop growth rate (CGR) of Serena by 54% compared with sole crop system but cropping system did not affect the growth rate of Gadam. Addition of N increased sorghum CGR by 30% but no differences were detected between 40 and 80 kg N ha^{-1}. Under sole crop system, Gadam out-yielded Serena by 1.3 t ha^{-1} in Igoji but there were no differences in yield between the two varieties in Katumani which was drier than the former. However, intercropping significantly reduced the grain yield of both sorghum varieties by about 50%, irrespective of the cowpea variety. Addition of N increased grain yield by at least 27% in both sites but yield differences between 40 and 80 kg N ha^{-1} were marginal under both sole crop and intercrop systems. Cropping system × N interaction effects on grain yield were significant in Igoji only, where N increased sorghum grain yield under sole crop system but higher N rates only marginally increased yield under intercrop. Sorghum grain yield was positively correlated with leaf area index, the number of fertile tillers, panicle weight, harvest index and CGR under sole crop system. The total land equivalent ratio in both sites was greater than unity, with 1.4 in Igoji and 1.6 in Katumani. Although intercropping reduced sorghum yield, present results show that there is potential to exploit cropping system x N interactions to increase yield, especially in wetter environments than in areas with low rainfall. Lack of significant differences in grain yield between the application of 40 and 80 kg N ha^{-1} suggests that sorghum yield could be maximized at lower N rates. However, further studies are needed to establish the economically optimal N rate in sorghum production.

Keywords Cropping system, Crop growth rate, Land equivalent ratio, Drylands, Interactions

1. Introduction

Sorghum (*Sorghum bicolo*r (L.) Moench) is an essential cereal as a food security crop and a raw material for making malt thus, increasing its productivity could end severe food insecurity and increase incomes of smallholder farmers in the dryland environments due to its unique traits of tolerating moisture stress and high yielding ability in a wide range of soils (Mwadalu & Mwangi, 2013). Sorghum annual production in Africa is estimated at 20 million metric tonnes representing about 41% of total global sorghum production (ICRISAT, 2013; Mundia et al., 2019). However, Kenya is among the least sorghum producing countries in Africa where its overall annual production is only 0.6% of Africa's total annual production (Mitaru et al., 2006). Of the total sorghum annually produced in Kenya, 53% is consumed as food in the form of grain or flour, 24% is processed to make other commodities (e.g. beer), 11% goes to waste, 10% goes

* Corresponding author:
moipeter799@gmail.com (Peter E. Moi)
Received: May 28, 2021; Accepted: Jun. 29, 2021; Published: Dec. 16, 2023
Published online at http://journal.sapub.org/ijaf

to the animal feed industry and 2% is used as seed for planting (Kilambya & Witwer, 2013). Common varieties of sorghum in Kenya mostly developed by Kenyan Agricultural and Livestock Research Organisation (KALRO) include, "Serena", "Seredo", "KARI/Mtama1" KARI/Mtama2", "Gadam", "E 1291", "E 6518", "BJ28" which have been recommended for various ecological zones to increase the scale of sorghum production as a second food security crop after maize (Mwadalu & Mwangi, 2013). However, despite the development of these improved varieties, the yield of sorghum has remained significantly low in the dryland environments (0.8 t ha^{-1}) in comparison to expected grain yield of 2 – 5 t ha^{-1} due to low soil fertility resulting from continuous mining of soil nutrients (N) without replenishment, inappropriate cropping practices and weeds such as striga with capacity to cause 40% to 100% loss in the Sub-Saharan region (Kilambya & Witwer, 2013; Mwadalu & Mwangi, 2013). Additionally, in the dry environments, sorghum yield losses are high resulting from moisture stress due to predictably low rainfall (Kassahun et al., 2010). As a result of the low sorghum yields ha^{-1}, most farmers only produce enough sorghum to meet their domestic requirements, with little surplus to sell making Kenya a net importer of sorghum to meet increased market demand (Ochieng, 2011). Therefore, in order to increase sorghum productivity to offset the current sorghum deficit, and enhance food and income security of rural farmers, its critical to address the challenge of soil infertility in the dryland environments due to N deficiency which is a main limiting factor in sorghum production and a root cause of low sorghum grain yield. Thus, sustainable cropping systems in sorghum production such as integration of legumes like cowpea into sorghum-based cropping systems with capacity to fix up to 150 kg N ha^{-1} in a cowpea-rhizobium symbiosis and application of variable rate of nitrogen fertilizer could improve soil fertility, sorghum yields, fertilizer use efficiency, profitability as well as reduce negative environmental consequences to achieve sustainability of the agriculture systems (Alghali, 1993; Karanja et al., 2014; Shamme & Raghavaiah, 2016; Layek et al., 2018).

Cereal-legume intercropping is a sustainable agricultural practice where more than two crops are grown simultaneously on the same land (Musa et al., 2012). In comparison with sole crop systems, intercropping improves crop diversification, increases crop yield and stability, especially under low-input conditions, improves soil fertility and conservation, as well as weed control (Dariush et al., 2006; Oseni, 2010; Layek et al., 2018). Despite the benefits of intercropping, the yield of cereals in these systems fluctuates, often depending on the environment. Higher cereal yield in intercrop systems are reported in medium potential environments (Egesa et al. 2016) while yield declines are frequently reported dry lands (Karanja et al., 2014; Sibhatu & Belete, 2015). Yield reduction in intercrop systems is attributed to interspecific competition for nutrients, radiation and moisture, among others. Biological N fixation by legumes is limited in drylands, hence supplementation with sufficient and timely application of fertilizer N can significantly increase sorghum yield (Das et al., 2014). However, other studies on sorghum-cowpea intercropping in dry environments have reported a decrease in grain yield of intercropped sorghum by between 31% and 38% at higher cowpea density attributed to incompatibility of the companion crops causing interspecific competition for growth (Oseni, 2010; Karanja et al., 2014; Sibhatu & Belete, 2015). Likewise, contrasting results of intercropping effect on legumes have been reported (Ibrahim, 1994; Sibhatu & Betele, 2015). The choice of companion crops in an intercrop system depends on growth habit, growth period, susceptibility to pests and diseases as well as other desirable attributes such as diversity in food supply (Yang & Udvardi, 2018). One of the most essential tools to evaluate the success and productivity of an intercrop system is the land equivalent ratio (LER) which expresses yields obtained in an intercrop system comparative to the sole crop yield of the dominant species where an LER greater 1 indicates that intercrop is more productive than the comparative sole crops (Sibhatu & Belete, 2015). Previous studies on sorghum-cowpea intercropping recorded LER greater than 1 (Hussain et al., 2002, Oseni 2010, Rathore et al., 2015).

Nitrogen (N) is among the most deficient nutrients in many agricultural soils for cereal production on a global basis but is essential in crop growth (Yagoub and Abdelsalam, 2010). Higher crop yields have been attained by increasing N addition and improving fertilizer N efficacy (Dobermann, 2007). Further, increased growth and yield of sorghum with addition of N in the form of urea has been reported (Ahmed & Tanki, 1997). Additionally, Uchino et al. (2013) observed that sorghum performed poorly in the dry environments without addition of N. However, increasing nitrogen use efficiency is challenging due to excessive use of nitrogen in the agricultural systems where, 30% – 50% of the applied nitrogen fertiliser continue being lost through leaching, denitrification and runoff (Dobermann, 2007; Shamme & Raghavaiah, 2016). Therefore, adoption of best management practices of establishing an equilibrium between plants nutrient supply and demand, and adoption of appropriate placement method at the correct rate and right time is required to increase productivity, efficient use of inputs and reduce negative environmental impact (Roberts, 2007; Shamme & Raghavaiah, 2016). Further, meeting sorghum N requirements through a combination of symbiotic N fixation by the legume in an intercrop system and minimal external synthetic N supply would help attain high yield at low cost and minimum environmental pollution from N losses. However, little information exists on the appropriate N rate for sorghum production in sorghum-legume intercrop system in dry and medium potential environments.

Therefore, the objective of the study was to determine the effect of cropping system and N rates on sorghum growth and yield, and the relationships between yield traits and grain yield. In this study, it was hypothesized that intercropping sorghum with cowpea and N-fertilizer application increases growth and yield of sorghum.

2. Materials and Methods

2.1. Sites

Two field experiments were concurrently conducted under rain-fed conditions at the KALRO research stations in Katumani and Igoji during the 2018/2019 short rain season. Katumani lies 1°34'58.5"S, 37°14'52.5"E and 1575 m above sea level (masl) while Igoji lies, 0°11'13" S, 37°40'10" E and 1770 masl. Annual mean temperature in Katumani and Igoji is 21.0°C and 19.7°C, respectively (Jaetzold & Schmidt, 1983). The soils of Katumani are classified as ferral chromic luvisols (Kinama et al., 2007). Soils in Igoji are deep well-drained volcanic dusky red to dark reddish brown (Jaetzold & Schmidt, 1983). Rainfall distribution in both sites is bimodal where long rains fall between March and May while short rains are received from October to December (Huho, 2017). In the short rain season, Katumani receives 288 mm compared with 370 mm in Igoji (Jaetzold & Schmidt, 1983).

2.2. Treatments and Experiment Design

Treatments consisted of two cropping systems (intercrop and sole), four crop varieties (two sorghum varieties and two cowpea varieties) and three fertilizer N rates (0, 40 and 80 kg N ha^{-1}). The sorghum varieties were Gadam and Serena while Machakos 66 (M66) and Katumani 80 (K80) formed the cowpeas. Under intercrop system, a row of cowpea was sown between two rows of sorghum. Fertilizer N was supplied from urea (46% N) and side banded to the planting rows of both crops where 1/3 was applied at sowing and 2/3at tillering stage. All plots received 60 kg P ha^{-1} at sowing from triple super phosphate. Experiments were laid out in a randomized complete block design with split-plot arrangement and replicated three times. Factorial combinations of sorghum-cowpea intercropping or sole crop formed the main plots while N rate formed the sub-plots. Main plots measured 24 m × 8 m and sub-plots were 12 m × 4 m.

2.3. Experiment Management

Land was prepared before the onset of the rains. Crops of sorghum and cowpea were sown manually in 5 cm deep holes. In the sole crop system, sorghum was sown at 0.75 m between rows and 0.20 m between plants. Cowpea was planted 0.6 m and 0.3 m between rows and from plant to plant, respectively. In the intercrop system, a row of cowpea was sown between two rows sorghum at a row spacing of 0.9 m. In both crops, three seeds were planted in each hole and later thinned to one plant per hole to achieve a sorghum density of 6.7 plants m^{-2} in sole crop system and 5.6 plants m^{-2} in intercrop system. Cowpea plant density was 5.6 plants m^{-2} in sole crop system and 3.7 plants m^{-2} in an intercrop system. Pre-emergence weed control was done using Roundup® (glyphosate) immediately after sowing. Experiments were kept weed free through hand weeding. Insect pests, mainly thrips and aphids in cowpea and stem borers in sorghum, were controlled with Thunder® (Imidacloprid 100 g /L + Betacyfluthrin 45 g/L) at 10 mL per 20L of water. Sorghum was guarded against birds feeding on the grains at grain filling until harvesting.

2.4. Data Collection

Initial soil analysis: Prior to sowing the experiments, soils were sampled at 0 - 30 cm depth and analyzed. A mehlich double acid method was used to analyze the soils for P, K, Na, Ca, Mg, Mn, Fe, Zn and Cu. The total organic carbon (C) % was analyzed using calorimetric method (Shamme & Raghavaiah, 2016), while the total nitrogen (N) % was determined using Kjeldahl method (Ghosh, 2004). A digital pH meter was used to measure the soil pH in a ratio of 1:1 soil-water suspension (w/v) (Shamme & Raghavaiah, 2016). Ammonium acetate method was used to analyze for cation exchange capacity (CEC) (Shamme & Raghavaiah, 2016).

Weather data: Daily rainfall and temperature data were obtained from weather stations within the research fields.

Sorghum biomass: Sorghum was sampled for shoot biomass m^{-2} at flowering and physiological maturity. Samples were dried in an oven at 70°C for a period of 3 days and dry weight measured using a weighing scale. Sorghum crop growth rate (CGR) (g m^{-2} day^{-1}), computed between the two stages.

Sorghum fertile productive tillers: The number of fertile tillers m^{-2} was counted and means determined $plot^{-1}$.

Sorghum grain yield: Sorghum panicles were harvested using a knife at physiological maturity in a net plot area of $16m^2$ and air-dried. The air-dried panicles were then threshed and cleaned. The moisture content of the grain was measured consistently during the air drying period using a grain moisture meter. The total grain weight for each plot was adjusted to 12.5% (Sibhatu & Belete, 2015). 1000 seeds in each plot were countered using a seed counter and weight measured using a digital weighing scale in grams.

Cowpea biomass: Cowpea was sampled for shoot biomass at branching and physiological maturity and samples were dried in an oven at 70°C for a period of 3 days and dry weight measured using a weighing scale. The dry mass was used to compute the cowpea CGR (g m^{-2} day^{-1}) between the two stages.

Cowpea grain yield: Cowpea pods $plot^{-1}$ at physiological maturity were manually harvested by hand picking from a net plot area of 16 m^{-2}, air-dried and counted. The air-dried pods $plot^{-1}$ were then threshed and cleaned. The moisture content was consistently measured during the air drying period using a grain moisture meter and grain weight was adjusted to 10.5% (Sibhatu & Belete, 2015).

Land equivalent ratio: The LER was used to determine the productivity of an intercrop system, and was computed following Mead and Willey (1981).

2.5. Data Analysis

All data were subjected to the analysis of variance using GenStat 14th Edition. A split plot design option in GenStat was used where the treatment structure composed of Cropping system + N rates. The means were separated using least significant difference (LSD) test at probability level of 5% (Gomez & Gomez, 1984). Relationships between grain yield and yield traits were examined by correlation analysis using SigmaPlot version 10.0 (Systat Software, Inc., San Jose California USA, www.systatsoftware.com).

3. Results

3.1. Weather Data and Initial Soil Fertility

Weather: Rainfall and temperature data during the growing season is shown in Figure 1. The conditions were typical of a normal growing season were rainfall tampers as the crop matures.

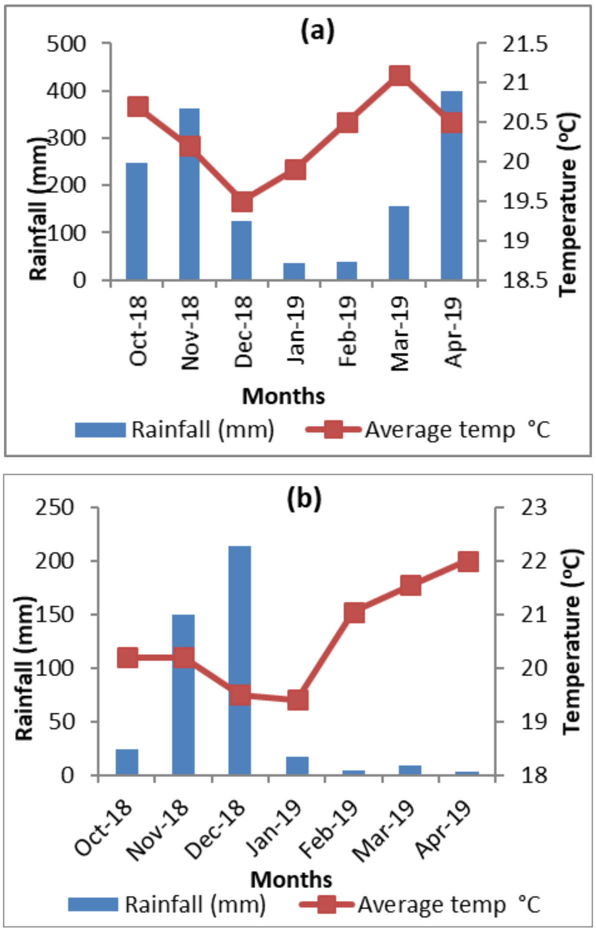

Figure 1. Weather conditions from sowing to physiological maturity of sorghum during 2018/2019 short rains at the KALRO in Igoji (a) and Katumani (b) research stations

Initial soil fertility: Total nitrogen (0.1% in both sites), organic carbon (Igoji: 0.93%, Katumani: 0.83%) and phosphorus (Igoji: 13.33 ppm, Katumani: 18.33 ppm) levels in both sites were low in both sites. However, potassium (Igoji: 0.26 me%, Katumani: 0.91 me%), calcium (Igoji: 1.07 me%, Katumani: 2.9 me%), magnesium (Igoji: 2.48 me%, Katumani: 2.35 me%), manganese (Igoji: 0.58 me%, Katumani: 0.5 me%), copper (Igoji: 0.55 ppm, Katumani: 1.26 ppm), iron (Igoji: 18.46 ppm, Katumani: 11.77 ppm), zinc (Igoji: 7.08 ppm, Katumani: 1.88 ppm) and sodium (Igoji: 0.15 me%, Katumani: 0.16 me%) were adequate for sorghum and cowpea production. Soil pH was 4.6 in Igoji and 5.9 in Katumani.

3.2. Sorghum Growth Parameters

Crop growth rate (CGR) did not significantly differ between Gadam and Serena in both sites but cropping system significantly affected sorghum growth rate in Igoji ($P = 0.002$) and Katumani ($P = 0.016$) (Table 1). In both sites, intercropping significantly reduced sorghum CGR by at least 2.2 g m^{-2} day^{-1} (58%), irrespective of the cowpea variety (Table 1). However, addition of N significantly increased sorghum growth rate only in Igoji ($P = 0.002$) where application of 80 kg N ha^{-1} increased overall CGR by 1.6 g m^{-2} day^{-1} (30%) compared with control plots but without significant differences between 40 and 80 kg N ha^{-1} (Table 1). Cropping system × N rate interaction effect on crop growth rate (CGR) was significant in Igoji ($P <.001$) and Katumani ($P = 0.042$) (Table 2). Under sole cropping system, CGR sorghum increased with N however marginal effects were observed under intercrop system (Table 2). Correlation analysis revealed CGR was positively and significantly correlated with sorghum grain yield under sole cropping system (Igoji: $R^2 = 0.95$, Katumani: $R^2 = 0.83$) but was weakly and insignificantly correlated with grain yield under intercrop system in both experimental sites (Table 3).

3.3. Sorghum Yield and Yield Components

Sorghum grain yield was significantly affected by cropping system ($P <.001$) in both experimental sites, N rate in Igoji ($P <0.01$) and Katumani ($P = 0.013$) while cropping system × N rate interactions only occurred in Igoji ($P <0.01$) (Table 1). Under sole crop system, Gadam sorghum out-yielded Serena by 1.3 t ha^{-1} in Igoji but there were no differences in yield between the two varieties in Katumani. However, intercropping significantly reduced the grain yield of both sorghum varieties by about 50%, irrespective of the cowpea variety (Table 1). Addition of fertilizer increased grain yield by at least 27% in both sites but yield differences between 40 and 80 kg N ha^{-1} were marginal under both sole crop and intercrop systems (Table 1). Cropping system × N rate interaction effect on sorghum grain yield in Igoji ($P <0.01$) revealed that while sorghum grain yield increased with the addition of N under sole crop system, higher N rates only marginally increased yield under intercropping system (Table 2). Further, the study revealed positive and significant correlation between sorghum grain yield and LAI, number of fertile tillers, panicle weight, harvest index (HI) and growth rate under sole cropping system in both experimental sites however, these traits were weakly and insignificantly correlated with sorghum gran yield (Table 3).

Generally, Gadam seeds were heavier than those of Serena by about 3.6 g under sole cropping system in both experimental sites however the seed weight difference between the two sorghum varieties was marginal under intercrop system. In spite of some inconsistent results, intercropping sorghum with either cowpea variety significantly (P <.001) reduced 1000 seed weight mainly in Katumani (drier environment) by about 4.5 g under sole cropping system. Addition of N and cropping system × N rate interactions did not significantly affect 1000-seed weight in both sites (Table 1). Further, 1000 seed weight was weakly and insignificantly correlated with sorghum grain yield under sole and intercrop system (Table 3).

Table 1. Crop growth rate (CGR), grain yield, 1000 seed weight, productive fertile tillers and total LER of two sorghum varieties (Gadam and Serena) grown under sole and intercrop system with two varieties of cowpea (K80 and M66) and at three N rates (0, 40 and 80 kg N ha-1) at Igoji and Katumani KALRO research stations during 2018/2019 short rain season

Treatments	Igoji					Katumani				
	CGR (g m^{-2} day^{-1})	Grain yield (t ha^{-1})	1000 seed weight (g)	Number of fertile tillers m^{-2}	Total LER	CGR (g m^{-2} day^{-1})	Grain yield (t ha^{-1})	1000 seed weight (g)	Number of fertile tillers m^{-2}	Total LER
Cropping system										
Sole Gadam	5.32ab	3.15a	31.1a	6.9a		5.86ab	3.09a	33.6a	16.3a	
Gadam+K80	5.19ab	1.48bc	30.7a	0.7b	1.4a	3.74bc	0.89c	29.1b	8.1bc	1.131ab
Gadam+M66	6.17a	1.27bc	30.9a	0.5b	1.071a	7.69a	1.43b	32.9a	5.9bc	1.563a
Sole Serena	4.35b	1.82b	27.4b	2.2b		4.31bc	2.76a	30.1b	13.0ab	
Serena+K80	4.88ab	1.06bc	26.1b	2.6b	1.038a	3.44bc	1.10bc	26.3c	2.6c	0.883b
Serena+M66	1.97c	0.95c	31.0a	1.7b	1.221a	1.94c	1.27bc	30.7b	3.9c	1.167ab
P-value	0.002	<.001	0.002	0.044	0.347	0.011	<.001	<.001	0.016	0.014
$LSD_{p\leq0.05}$	1.54	0.75	2.3	4.1	ns	2.71	0.42	1.7	7.7	0.598
N rates										
0 kg N ha^{-1}	3.67b	1.46b	30.06a	1.9c	1.088a	3.60a	1.43b	30.33a	7.4a	1.018a
40 kg N ha^{-1}	5.00a	1.57b	29.50a	2.1b	1.227a	5.11a	1.96a	30.72a	8.1a	1.096a
80 kg N ha^{-1}	5.27a	1.84a	29.06a	3.0a	1.206a	4.77a	1.88a	30.28a	9.4a	1.444a
P-value	0.002	0.015	0.341	0.021	0.603	0.157	0.013	0.803	0.258	0.339
$LSD_{p\leq0.05}$	0.88	<.001	ns	0.8	ns	ns	0.37	ns	ns	ns
P-value CS x N	0.07	<.001	0.236	0.107	0.67	0.61	0.061	0.761	0.438	0.847
$LSD_{p\leq0.05}$	ns	0.86	ns	ns	ns	ns	ns	ns	ns	ns

Within a column, means followed by the same alphabets are not significantly different, CS x N is cropping system and N rate interactions, ns is not significant at 5% probability level

Table 2. Cropping Systems (sole and intercrop) × N rates (0, 40 and 80 kg N ha^{-1}) interaction effect on Leaf Area index and crop growth rate (CGR) of two sorghum varieties (Gadam and Serena) in Igoji and Katumani during 2018/2019 short rains

Treatments	Igoji						Katumani					
	CGR (g m^{-2} day^{-1})			Grain yield (t ha^{-1})			CGR (g m^{-2} day^{-1})			Grain yield (t ha^{-1})		
	0 kg N ha^{-1}	40 kg N ha^{-1}	80 kg N ha^{-1}	0 kg N ha^{-1}	40 kg N ha^{-1}	80 kg N ha^{-1}	0 kg N ha^{-1}	40 kg N ha^{-1}	80 kg N ha^{-1}	0 kg N ha^{-1}	40 kg N ha^{-1}	80 kg N ha^{-1}
Gadam	8.20	4.00	3.80	2.6	3.4	3.7	3.30	6.60	7.60	2.7	3.8	3.0
Gadam+K80	3.00	6.70	5.90	0.9	1.4	1.6	5.10	3.70	2.40	0.6	0.6	0.6
Gadam+M66	3.50	4.90	10.20	1.0	0.8	0.9	6.70	8.10	8.30	0.4	0.6	0.4
Serena	6.20	3.90	2.90	1.6	1.3	2.8	1.80	8.40	2.80	2.9	3.1	2.4
Serena+K80	7.40	2.20	5.10	1.2	1.0	0.4	2.10	2.20	6.10	0.4	0.4	0.6
Serena+M66	1.70	0.40	3.80	1.0	0.6	0.7	2.70	1.80	1.40	0.8	0.6	1.0
pvalue CS x N	<.001			<.001			0.042			0.061		
$LSD_{p\leq0.05}$ CS x N	2.233			0.9						ns		

CS × N is interaction between cropping system (CS) and N rate, ns is not significant

Table 3. Correlation coefficients of sorghum grain yield against yield components under sole and intercropping system in Igoji and Katumani experimental sites

		Igoji		Katumani	
Cropping System	Traits*	r	P (0.05)	r	P (0.05)
Sole	Leaf area index	0.99	0.002	0.88	0.048
	Number of fertile tillers m^{-2}	0.84	0.035	0.89	0.016
	Panicle weight	0.83	0.040	0.89	0.019
	Harvest index	0.89	0.016	0.95	0.004
	1000 seed weight	0.51	0.299	0.32	0.531
	Crop growth rate (CGR)	0.95	0.004	0.83	0.043
Intercrop	Leaf Area Index	0.56	0.061	0.20	0.526
	Number of fertile tillers	0.70	0.011	0.02	0.940
	Panicle weight	0.04	0.910	0.24	0.443
	Harvest index	0.05	0.884	0.25	0.436
	1000 seed weight	0.12	0.707	0.31	0.335
	Crop growth rate (CGR)	0.07	0.823	0.01	0.979

r is correlation coefficients, Traits*: values used for the traits are averages of the 3 blocks in sole and intercrop and at 0, 40 and 80 kg N ha^{-1}

Table 4. Cowpea Crop growth rate (CGR) and grain yield of two cowpea varieties (K80 and M66) grown in sole and intercrop system with two varieties of sorghum (Gadam and Serena) and at three N rates (0, 40, 80 kg N ha-1) at Igoji and Katumani KALRO research stations during 2018/2019 short rain season

	Igoji		Katumani	
Treatment	CGR (g m-2 day-1)	Grain yield (t ha-1)	CGR (g m-2 day-1)	Grain yield (t ha-1)
		Cropping Systems		
K80	0.280a	0.95a	0.200a	1.09a
K80+Gadam	0.110c	0.94a	0.067d	0.72ab
K80+Serena	0.140b	0.44b	0181a	0.54b
M66	0.064de	0.90b	0.122b	0.81ab
M66+Gadam	0.086cd	0.44b	0.066d	0.60ab
M66+Serena	0.056e	0.69ab	0.092c	0.60ab
P-value	<.001	0.034	<.001	0.021
$LSD_{p\leq0.05}$	0.028	0.39	0.021	0.49
N rates				
0 kg N ha^{-1}	0.10c	0.70a	0.12c	0.73a
40 kg N ha^{-1}	0.18b	0.68a	0.72b	0.71a
80 kg N ha^{-1}	0.89a	0.80a	0.77a	0.74a
P-value	<.001	0.358	<.001	0.94
$LSD_{p\leq0.05}$	0.02	ns	0.02	ns
P-value CS x N	0.055	0.25	0.061	0.846
$LSD_{p\leq0.05}$	ns	ns	ns	ns

Means within a column followed by the same alphabets are statistically similar; CS × N is interaction between cropping system (CS) and N rate, ns is not significant

The number of productive fertile tillers m^{-2} significantly differed between Gadam and Serena only in Igoji whereby Gadam out-yielded Serena by 4.7 tillers m^{-2} under sole cropping system however, marginal difference was observed in an intercrop system (Table 1). The effect of cropping system on the fertile tillers m^{-2} was significant in Igoji (P = 0.044) and Katumani (0.016). Irrespective of the cowpea variety, intercropping reduced the number of fertile tillers m^{-2} of sorghum by 6.2 in Igoji and 8.2 tillers in Katumani, (Table 1). The effect of N was only significant in Igoji (P = 0.021) where addition of 80 kg N ha^{-1} significantly increased the mean number of fertile tillers m^{-2} by about 1 tiller compared with control plots while addition of 40 kg N ha^{-1} only marginally increased the number of fertile tillers (Table 1). Nonetheless, there were no significant effect of the cropping system × N rate interactions on the mean number of fertile tillers m^{-2} in both experimental sites (Table 1). Tillering was positively and significantly correlated with grain yield under sole (R^2 = 0.84) and intercrop (R^2 = 0.70) in Igoji while in Katumani, tillering was only positively and significantly correlated with grain yield under sole cropping system (R^2 = 0.89) (Table 3).

3.4. Cowpea Crop Growth and Yield

The CGR of K80 exceeded M66 by 0.216 g m^{-2} day^{-1} in Igoji and 0.078 g m^{-2} day^{-1} in Katumani (Table 4). Further, cropping system effect on the cowpea CGR was significant in Igoji (P <.001) and Katumani (P <.001) (Table 4). In Igoji, irrespective of the sorghum variety, intercropping significantly reduced the CGR of K80 by 0.14 g m^{-2} day^{-1} (50%) compared with sole crops however, intercropping marginally affected CGR of M66 (Table 4). In Katumani, intercropping significantly reduced the CGR of K80 by 0.133 g m^{-2} day^{-1} when intercropped with Gadam representing 67% reduction compared with sole crops while irrespective of the sorghum variety, intercropping significantly reduced the CGR of M66 0.03 g m^{-2} day^{-1} (24%) compared with sole crops (Table 4). Addition of N significantly affected cowpea CGR in Igoji and Katumani (P <.001) whereby application of 80 kg N ha^{-1} significantly increased CGR of cowpea by at least 0.65 g m^{-2} day^{-1} and addition of 40 kg N ha^{-1} increased cowpea CGR by 0.6 g m^{-2} day^{-1} compared with control plot in both sites (Table 4). Nonetheless, cropping system × N effect on CGR was insignificant (Table 4).

Cowpea grain yield did not significantly differ between K80 and M66 in both sites but was significantly affected by cropping system in Igoji (P = 0.034) and Katumani (P = 0.021). In Igoji, intercropping K80 with Serena significantly reduced grain yield by 0.51 t ha^{-1} (54%) compared with sole crops but grain yield of K80 was not significantly affected by intercropping with Gadam (Table 4). In Katumani, intercropping K80 with Serena significantly reduced grain yield by 0.55 t ha^{-1} (50%) compared with grain yield of sole crops but intercropping M66 with either Gadam or Serena had no significant effect on grain yield (Table 4). Nonetheless, addition of N and cropping system × N rate effect on grain yield was insignificant in both sites (Table 4).

4. Discussion

4.1. Effect of Intercropping and N Rate on Sorghum Growth and Yield

The CGR of sorghum grown under sole cropping system were higher than for intercropped sorghum by 54% while addition of N significantly increased sorghum CGR by 30% compared with control plots. This could be attributed to competition for growth resources (nutrients, moisture, light) in an intercrop system which reduced photosynthetic capacity hence negatively affected growth of vegetative and reproductive parts (steam, leaves, panicle) resulting into low biomass production and consequently reduced CGR of intercrop sorghum. On the other hand, presence of N could have enhanced the growth and development of plant reproductive and vegetative parts. Similar results were reported in previous studies where sorghum grown as sole had higher photosynthetic rates which increased crop growth rate compared with counterparts in mixed culture for sorghum/cowpea intercropping study (Makoi et al., 2010; Siddig et al., 2013; Karanja et al., 2014) and for maize/cowpea intercropping (Legwaila et al., 2012). Further, Sibhatu & Belete (2015) and Shamme & Raghavaiah (2016) reported that addition of N increased sorghum growth by 35% compared with control plots where no fertilizer was applied while Haghighi et al. (2010) and Yang et al. (2018) reported CGR of maize was increased by 11 to 19% with application of N fertilizer compared with control plots.

Hence, the overall results suggest that sole cropping system and addition of N was efficient in biomass accumulation and increasing CGR where competition for growth resource might have been minimal compared with intercrop system. Further, grain yield of intercrop sorghum would be lower than for sole crops since CGR in this study was strongly and positively correlated with grain yield under sole cropping system which corroborates with results of Sankarapandian et al. (2013); however, further investigation across ecological zones is required.

Grain yield of intercropped Gadam and Serena were significantly reduced by about 50% compared with yields of sole crops. This could be attributed to competition for resources like soil nutrients, sunlight and water in the intercrop system by the companion crops (Oseni, 2010). Previous study on sorghum-cowpea intercropping in dry environment reported intercropping significantly reduced sorghum grain yield by 31.0% and 37% (Oseni, 2010; Karanja et al., 2014; Sibhatu & Belete, 2015). Since intercropping significantly reduced sorghum grain yield in both sites irrespective of the difference in agro-ecological conditions between Igoji and Katumani, this suggests that sole cropping system was effective in increasing the individual grain yields of sorghum since growth resources can be utilized without competition from companion crop compared with an intercrop system.

Further, sorghum grain yield in the present study was significantly increased by 27% with addition of 40 kg N ha^{-1} compared with control plots but without yield difference between addition of 40 and 80 kg N ha^{-1}. This could be attributed to the important role of N in increasing growth and development of plant reproductive parts due to increased photosynthetic capacity that resulted into higher grain yields. The results are in agreement with both the study hypothesis and previous studies. An earlier study reported the maximum grain yield of sorghum and barley was produced in N fertilized plots while the lowest grain yield was produced in control plots without fertilizer N addition (Gue´nae¨lle et al., 2006; Shamme & Raghavaiah, 2016). Therefore, lack of significant differences in grain yield between the application of 40 and 80 kg N ha^{-1} suggests that sorghum yield could be maximized at lower N rates. However, further studies are needed to establish the economically optimal N rate in sorghum production.

Tillering is an important agronomic trait that can compensate for poor plant stand to produce higher grain yield under favourable conditions (Kim et al., 2010).

However, intercropping sorghum with cowpea significantly reduced the number of fertile tillers m^{-2}. These findings could be justified by high population density in an intercrop system resulting into decreased tillering because there are more plants competing for available water and nutrients compared with sole cropping system (Kim et al., 2010). Related to these findings, Nawal (1997) reported that intercropping reduced the number of tillers in sorghum/cowpea/pigeon pea intercropping study in Sudan. Further, Dantata (2014) reported significantly high yield number of tillers in sugarcane was obtained in sole cropping in a sugar cane-cowpea intercropping. Nitrogen application increased the number of fertile tillers by 1.1 tillers m^{-2} compared with control plots. This could be attributed to effect of N on cytokinin synthesis which consequently increased the growth and development of the number of fertile tillers as reported by Shamme and Raghavaiah (2016) while Abebe (2016) reported addition of N increased wheat tillers by 28.6% compared with control plots.

The study results further showed the number of fertile tillers m^{-2} was positively and significantly correlated with grain yield in sole cropping system in both sites (Igoji: $R^2 = 0.84$, Katumani: $R^2 = 0.89$), and intercropping system only in Igoji ($R^2 = 0.70$). This could be due to the fact that fertile tillers produce grains under favourable conditions which contribute to the improvement of the overall harvest (Kim et al., 2010). Similar findings were reported by Sankarapandian et al. (2013) in sorghum, (Singh & Singh, 2016) in pearl millet who reported positive correlations between sorghum grain yield and tillers. Therefore, these results suggest that sorghum in sole cropping system and fertilised with N which have high tillering will likely produce high grain yield compared with counterparts in intercrop system and control plots. However, it should be noted that tillering could also be influenced by genetic and environmental (Kim et al., 2010), which were beyond the scope of the present study hence evaluation of more than two varieties across different environments in future studies is required.

4.2. Effect of Intercropping on Cowpea Growth and Yield

The CGR of cowpea under sole cropping system exceeded counterparts in an intercrop with sorghum by at least 50% for K80 and 25% for M66 compared with counterparts in intercrop with sorghum and addition of N significantly increased cowpea CGR. This was attributed to limited competition for growth resources in sole cropping system hence more dry matter was accumulated in the stem, branches and leaves in sole cropping system. Additionally, the presence of N could have increased photosynthetic capacity of cowpea resulting into increased biomass accumulation and consequently cowpea crop growth rate. The findings are in agreement with previous studies which reported intercropping significantly reduced the dry biomass (CGR) of forage legumes in maize-forage legume intercropping study (Getachew et al. 2013) and of cowpea in a sorghum-cowpea intercropping studies while addition of N increased cowpea CGR (Karanja et al. 2014; Sibhatu and Belete, 2015).

Grain yield of intercropped cowpea with Sorghum was significantly reduced by more than 50%. Likely reason was interspecies competition and shading effect of sorghum on cowpea (Oseni, 2010). The findings are in agreement with previous studies. Karanja et al. (2014) and Sibhatu and Belete (2015) revealed intercropping reduced cowpea grain yield by 58.34% to 64% in sorghum-cowpea intercropping which was attributed the interspecies competition for growth resources while Oseni, (2010) reported that intercropping not only reduced sorghum yield but equally reduced yields of cowpea in a sorghum-cowpea intercropping. Therefore, the results suggest that sole cropping is an appropriate cropping system for cowpea production.

4.3. Effects of Cropping System x N Rate Interaction of Growth and Yield of the Companion Crops

Cropping system × N rate interactions significantly affected sorghum CGR and grain yield while cowpea growth and yield traits were not affected by the main effects interactions. Under sole cropping system, addition of N increased these traits while the increase was marginal under intercrop system. This could be attributed to non-proportional sharing of soil N sources resulting from competition between sorghum and cowpea and limited fixation of N by the cowpea in an intercrop system resulting to low grain yield in an intercrop system as opposed to sole cropping system (Jensen et al., 2020). These findings are consistent with results of Abebe et al. (2013) and Mahmoud et al. (2013) who found that the interactions between N and cropping system in soybean-maize intercropping where N increased grain yield, biomass and growth rate of maize under sole cropping system. Similarly, the present results findings corroborated with findings of YAA, (2017) who reported that application of N increased total biomass yield in sole and intercropped sorghum.

Overall, the results show that although intercropping reduced sorghum yield, present results show that there is potential to exploit cropping system × N interactions to increase yields, more so in wet environments than in areas with low rainfall. However, future studies should consider evaluating sorghum yield performance across agro ecologies and N rates under sorghum-cowpea intercropping since significant variation in the cropping system × nitrogen interactions of the main effects were observed in the two experimental sites.

4.4. Land Equivalent Ratio

The LER is an essential tool to evaluate the performance of an intercropping systems (Beets, 1982, Sibhatu and Belete, 2015). In the present study, apart from Serena + K80 intercropping combination, all the different intercropping combinations were greater than unity (>1). These findings suggest that sole sorghum or cowpea crops require more land to be planted by 40% in Igoji and 60% in Katumani to match the combined sorghum/cowpea yield in an intercropping system. These results are in conformity with findings of Oseni (2010) who reported the maximum total LER was attained when sorghum recorded 70% and cowpea 38% of their sole yields. Furthermore, Chaichi et al. (2007) reported high land equivalent ratio greater unity in a sorghum cowpea intercropping. Therefore, since LER was greater than 1, the results indicate intercropping was more productive than the comparative sole crops (Dantata, 2014).

5. Conclusions

Intercropping significantly reduced CGR and grain yield of sorghum and cowpea by about 50% while addition of N increased CGR of sorghum by about 30% and sorghum grain yield by 27% however, N had no effect on grain yield of cowpea. Therefore, the overall findings suggest that sole cropping system and application of N fertilizer was effective in increasing sorghum crop growth rate and yield hence recommended for commercial production of sorghum compared with intercropping system and no fertilizer application. Additionally, although intercropping reduced CGR and sorghum grain yield by about 50%, present results show that there is potential to exploit cropping system × N interactions to increase yield to improve food security, more so in wet environments than in areas with low rainfall. Intercropping also increased overall land productivity (LER>1) hence the practice is useful to ensure food security at household level however, screening and breeding of cowpea varieties compatible with sorghum in intercrop systems is desirable to reduce sorghum grain yield losses observed in the current study. Further, the lack of significant differences in grain yield between the application of 40 and 80 kg N ha^{-1} suggests that sorghum yield could be maximized at lower N rates, and further studies are needed to establish the economically optimal N rate. Gadam out-yielded Serena in the present system hence highly recommended to farmers in the study areas for commercial production under sole cropping system and with addition of 40 kg N ha^{-1} however, its evaluation across ecological conditions is required.

ACKNOWLEDGEMENTS

This material is based upon work supported by the United States Agency for International Development, as part of the Feed the Future initiative, under the CGIAR Fund, award number BFS-G-11-00002, and the predecessor fund the Food Security and Crisis Mitigation II grant, award number EEM-G-00-04-00013. The authors would like to thank the entire management of KALRO of Embu and Katumani stations for availing land for setting the experiments of this study and providing support during the data collection.

REFERENCES

[1] Abebe, B. (2016). Effect of the Time and Rate of N-Fertilizer Application on Growth and Yield of Wheat (Triticum aestivum L.) at Gamo-gofa Zone. *Journal of Natural Sciences Research*, *6*(11), 111–122.

[2] Abebe, Z., Sharma, J.J., Dechasa N., & Fred, K. (2013). The effect of integrated organic and inorganic fertilizer rates on performances of soybean and maize component crops of a soybean/maize mixture at Bako, Western Ethiopia. *African Journal of Agricultural Research, 8(29: 3921-3929.*

[3] Ahmed, N., & Tanki, M. (1997). Effect of nitrogen and phosphorus on growth and seed yield of okra. *Indian Journal of Horticulture*, *54*(2), 156–159.

[4] Alghali, A. M. (1993). Intercropping as a component in insect pest management for grain cowpea, Vigna unguiculata Walp production in Nigeria. International Journal of Tropical Insect Science, 14(1) 49-54. https://doi.org/10.1017/S17427584000 13382.

[5] Beets, W.C. (1982). Multiple Cropping and Tropical Farming Systems. Westview Press, Boulder.

[6] Chaichi, M. R., Daryaei, F., & Aqaalikhani, M. (2007). Forage Production of Sorghum and Alfalfa in Sole and Intercropping Systems. A*sian Journal of Plant Sciences*, *6*: 833-838.

[7] Dantata, I. J. (2014). Effect of Legume-Based Intercropping on Crop Yield: A Review. *Asian Journal of Agriculture and Food Sciences*, *2*(6), 507–522.

[8] Dariush, M., Ahad, M., & Meysam, O. (2006). Assessing the Land Equivalent Ratio (Ler) of Two Corn [Zea Mays L.] Varieties Intercropping At Various Nitrogen Levels in Karaj, Iran. *Journal of Central European Agriculture*, *7*(2), 359–364. https://doi.org/10.5513/jcea.v7i2.383.

[9] Dobermann, A. (2007). Nutrient use efficiency – measurement and management. In: Krauss, A., Isherwood, K., Heffer, P. (Eds.), Fertilizer Best Management Practices General Principles, Strategy for Their Adoption and Voluntary Initiatives vs Regulations. *International Fertilizer Industry Association, Paris, France,* 1–28.

[10] Ghosh, P. K. (2004). Growth, yield, competition and economics of groundnut/cereal fodder intercropping systems in the semi-arid tropics of India. Elsevier, 88(2–3), 227–237. https://doi.org/10.1016/j.fcr.2004.01.015.

[11] Gomez, A. A., & Gomez, K. A. (1984). Statistical procedures for agricultural research: second Edition. *A Wiley-Interscience Publication*, *6*, 690.

[12] Huho, J. M. (2017). An Analysis of Rainfall Characteristics in Machakos County, Kenya. *IOSR Journal of Environmental Science, Toxicology and Food Technology*, *11*(04), 64–72. https://doi.org/10.9790/2402-1104026472.

[13] Hussain, I., Jatoi, S. A., Sayal, O. and Baloch, M. S. (2002). Green fodder yield and land equivalent ratio of sorghum-legume association. Pakistan Journal of Biological Science, 3, 175-176.

[14] International Crops Research Institute for the Semi-Arid Tropic (ICRISAT), (2013). The value chain for sorghum beer in Kenya.

[15] Jaetzold, R., & Schmidt, H. (1983). Farm Management Handbook of Kenya Vol. II C East Kenya. Natural Conditions and Farm Management Information. Kenya Ministry of Agriculture, GAT, GTZ, Nairobi, Kenya.

[16] Karanja, S. M., Kibe, A. M., Karogo, P. N., & Mwangi, M. (2014). Effects of Intercrop Population Density and Row Orientation on Growth and Yields of Sorghum-Cowpea Cropping Systems in Semi Arid Rongai, Kenya. *Journal of Agricultural Science*, *6*(5). https://doi.org/10.5539/jas.v6n5p34.

[17] Kassahun, B., Bidinger, F. R., Hash, C. T., & Kuruvinashetti, M. S. (2010). Stay-green expression in early generation sorghum [Sorghum bicolor (L.) Moench] QTL introgression lines. *Euphytica*, *172*(3), 351–362. https://doi.org/10.1007/s10681-009-0108-0.

[18] Karanja, D. R., Githunguri, C. M., M'ragwa, L., Mulwa, D., & Mwiti, S. (2006). Variety Characteristics and Production Guidelines of Traditional Food Crops. KALRO Katumani and Eastern Province Horticulture and Traditional Food Crops Project, Kenya.

[19] Kilambya D., & Witwer, M. (2013). Analysis of incentives and disincentives for sorghum in Kenya. Technical notes series, MAFAP, FAO, Rome.

[20] Kim, H., Koo, O., Erik, Dingkuhn, Michael , Luquet, Delphine, Hammer, G. (2010). Regulation of tillering in sorghum: Environmental effects. *Annals of botany*. *106*. 57-67. 10.1093/aob/mcq079.

[21] Kinama, J., Stigter, C. J., Ong, C., Nganga, J., & Gichuki, F. (2007). Contour Hedgerows and Grass Strips in Erosion and Runoff Control on Sloping Land in Semi-Arid Kenya. *Arid Land Research and Management*. *21*, 1-19. https://doi.org/10.1080/15324980601074545.

[22] Layek, J., Das, A., Mitran, T., Nath, C., Meena, Ram S., Yadav, G., Shivakumar, B. G., Kumar, S., & Lal, R. (2018). Cereal+Legume Intercropping: An Option for Improving Productivity and Sustaining Soil Health. *Legumes for Soil Health and Sustainable Management* .*11*, 347-386. https://doi.org/10.1007/978-981-13-0253-4_11.

[23] Legwaila M., G., K. Marokane, T., & Mojeremane, W. (2012). Effects of Intercropping on the Performance of Maize and Cowpeas in Botswana. *International Journal of Agriculture and Forestry*, *2*(6), 307–310. https://doi.org/10.5923/j.ijaf.20120206.07.

[24] Mead, R., and Willey, R. W. (1980). The Concept of a 'Land Equivalent Ratio' and Advantages in Yields from Intercropping. *Experimental Agriculture*, *16*(3), 217–228. https://doi.org/10.1017/S0014479700010978.

[25] Mitaru, B. N., Mgonja, M. A., Rwomushana, I., & Opio, F. (2012). Integrated sorghum and millet sector for increased economic growth and improved livelihoods in Eastern and Central Africa. Proceedings of the ECARSAM Stakeholders Conference, 20–22 November 2006, Dar es Salaam, Tanzania. ASARECA (Association for Strengthening Agricultural Research in Eastern and Central Africa), Entebbe.

[26] Mundia, C. W., Secchi, S., Akamani, K., & Wang, G. (2019). A Regional Comparison of Factors Affecting Global Sorghum Production: The Case of North America, Asia and Africa's Sahel. *Sustainability*, *11*(7), 1–18.

[27] Musa, E. M., Elsheikh, E. A. E., Mohamed A. I. A., & Babiker, E. E. (2012). Intercropping Sorghum (Sorghum bicolor L.) and Cowpea (Vigna unguiculata L.): Effect of Bradyrhizobium Inoculation and Fertilization on Minerals Composition of Sorghum Seeds . *ISRN Agronomy*, *2012*, 1–9. https://doi.org/10.5402/2012/356183.

[28] Mwadalu, R., & Mwangi, M. (2013). The potential role of sorghum in enhancing food security in semi-arid eastern Kenya: A review. *Journal of Applied Biosciences*, *71*(1), 5786. https://doi.org/10.4314/jab.v71i1.98826.

[29] Nawal, M. & Tag, (1997). The effect of intercropping on growth and yield of sorghum (Sorghum bicolor (L. Moench). Research in Agriculture, ISSN 2740 -443.

[30] Ochieng J.A.W. et al. (2011). Report on the Review and Analysis of the Staple Crops Sub-sector and Product Value Chains. Vol 1: Staple Food Crops Sub-sector Review. KALRO.

[31] Oseni, T. O. (2010). Evaluation of Sorghum-Cowpea Intercrop Productivity in Savanna Agro-ecology using Competition Indices. *Journal of Agricultural Science*, *2*(3), 229. https://doi.org/10.5539/jas.v2n3p229.

[32] Roberts T. L. (2007). Right product, right rate, right time and right place the foundation of best management practices for fertilizer. *International Plant Nutrition Institute (IPNI), USA; troberts@ipni.net*. *4*, 14-15.

[33] Sankarapandian, R., Audilakshmi, S., Sharma, V., Ganesamurthy, K., Talwar, H. S., & Patil, J. V. (2013). Effect of morpho-physiological traits on grain yield of sorghum grown under stress at different growth stages, and stability analysis. *Journal of Agricultural Science*, *151*(5), 630–647. https://doi.org/10.1017/S002185961200072X.

[34] Shamme, S. K., & Raghavaiah, C. V. (2016). Sorghum (Sorghum bicolor L.) Growth, Productivity, Nitrogen Removal, N- Use Efficiencies and Economics in Relation to Genotypes and Nitrogen Nutrition in Kellem- Wollega Zone of Ethiopia, East Africa. *Advances in Crop Science and Technology*, *04*(03), 3–10. https://doi.org/10.4172/2329-8863.1000218.

[35] Sibhatu, Berhane, & Belete, K. (2015). Effect of cowpea density and nitrogen fertilizer on a sorghum-cowpea intercropping system in Kobo, northern Ethiopia. *International Journal of Agriculture and Forestry*, *5*(6), 305–317. https://doi.org/10.5923/j.ijaf.20150506.02.

[36] Siddig, A., Mohamed, A., Adam, A., Mohamed, A., Bahar, H., & Abdulmohsin, R. K. (2013). Effects of Sorghum (Sorghum Bicolor (l) Moench) and Groundnut (Arachis Hypogaea l) İntercropping on Some Soil Chemical Properties and Crop Yield Under Rain-Fed Conditions. *ARPN Journal of science and Technolology*. 3(1):69-74.

[37] Singh, O. V., & Singh, A. K. (2016). Analysis of genetic variability and correlation among traits in exoticgermplasm of pearl millet [Pennisetum glaucum (L.) R. Br.]. *Indian Journal of Agricultural Research*, *50*(1), 76–79. https://doi.org/10.18805/ijare.v50i1.8589.

[38] Uchino, H., Watanabe, T., Ramu, K., Sahrawat, K. L., Marimuthu, S., Wani, S. P., & Ito, O. (2013). Effects of nitrogen application on sweet sorghum (Sorghum bicolor (L.) Moench) in the semi-arid tropical zone of India. *Japan Agricultural Research Quarterly*, *47*(1), 65–73. https://doi.org/10.6090/jarq.47.65.

[39] YAA, M. (2017). Effect of Nitrogen Levels on Yield, Competitive, Economic indices and Efficiency of Sorghum

cultivars and Common Bean Intercropping. *Agricultural Research & Technology: Open Access Journal*, *3*(3). https://doi.org/10.19080/artoaj.2017.03.555614.

[40] Yagoub, S. O., & Abdelsalam, A. K. (2010). Effect of Nitrogen and Seed Rates on Growth and Yield of Forage Sorghum (Sorghum bicolor L Moench cv. Abusabien). *Journal of Science and Technology*, 11(2), 123 - 136.