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Effect of Cropping System and Nitrogen on Maize and Soy Bean Yields in Western Kenya

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Abstract

Inherent low soil fertility in the highly weathered and degraded soils largely accounts for low and unsustainable crop yields in most African countries (Okalebo et al., 2006; Sanchez et. al., 1997). Productivity of maize and soybeans in Kenya, particularly in the western region is generally low. The high costs of inorganic fertilizers and the possibility of decreasing soil productivity in due to soil mining and environmental pollution demands a reassement of their use, vis-a-vis, other alternative technologies. The objective of this study was to assess the effect of selected cropping systems, N fertilizer and manure on maize and soy bean crop yields in western Kenya (Bungoma, Vihiga, and Teso). The experiment was a split plot design arranged and laid down in a randomized complete block design (RCBD) with three replications. Cropping systems (mono cropping, MBILI and conventional) were the main factor while fertility interventions (FYM and CAN) were the treatments. The cropping systems consisted of conventional (Maize and soy beans were planted as intercrop in 37.5 cm alternating rows), MBILI (Managing Beneficial Interactions in Legume Intercrops), maize and soybean monocrop. Five fertilizer treatments were used: calcium ammonium nitrate and farm yard manure, both applied at the rate of 30 kg N ha^{-1} and 75 kg N ha^{-1}, respectively, and absolute control that had no added treatment. Field experiments were planted during two cropping seasons of short rains season (August to December 2011) and one long rains season (April to August 2012) Generally, maize yields were found to be significantly higher in both the mono cropping system (mean yield: 2.00 t/ha) and MBILI system (mean yield: 1.77 t/ha) compared to conventional farming (mean yield: 1.27 t/ha). Soybean yields were found, overall, to be significantly higher in the mono cropping system (mean: 1.00t/ha) compared to both MBILI (mean: 0.75 t ha^{-1}) and conventional system (mean: 0.59 t ha^{-1}). For both maize and soy bean grain, application of CAN75N and planting with FYM75N were found to significantly increase yields, compared to either top dressing with CAN30N or planting with FYM30N. CAN generally produced higher yields with monocrop system whereas MBILI system did better when FYM is used, suggesting that an optimal system could consist of MBILI with organic fertilizers. The mean Land Equivalent Ratio (LER) values were always greater than 1.0 for intercropping and I.0 for mono cropping system. Manure was found to produce similar yields as those in fertilizer applications. This study recommends MBILI system and organic manure as a beneficial way of growing maize and soy beans

Keywords: conventional, maize, MBILI, mono cropping, soy beans, yields

1. Introduction

Productivity of maize (*Zea mays*) and soybeans (*Glycine max*) in Kenya, and particularly in western region is generally low. Food and Agriculture Organisation (FAO) statistics in 2009 indicates an average maize production of 1294 kg ha^{-1} in Kenya compared to 4964 kg ha^{-1} in South Africa and 2227 kg ha^{-1} in Zambia. Productivity of soybeans in the region is just 450 kg ha^{-1}, which is about seven times lower compared with Brazil (3.05 t ha^{-1}) and USA (2.92 t ha^{-1}). Ranum, (2014) estimated that 50 percent of the population in Sub-Saharan Africa (SSA) and 900 million people worldwide use maize as their preferred food source. In Kenya, more than 2.1 million ha of Kenya's 5.3 million ha of all crops harvested area was occupied by maize, with the crop accounting for more than 51% of all the staples grown in the country. On the other hand, soybean has become the most widely cultivated legume in the world because of its richness in protein and lactose (Zander, *et al* 2016). Whereas the demand of these crops is expected to increase two-fold, yields are expected to decline – leading to higher global prices, malnutrition, and poverty (Pagano and Miransari, 2016).

It is, therefore, germane to discover new solutions that can increase yield to obtain the estimated attainable and potential harvests of these crops. One way of addressing these is the use of suitable cropping systems and optimim rates of fertilizer to be applied. The use of mineral fertilizers, for instance, DAP and CAN, have shown to improve crop yields due to their ability to supply crucial nutrients like nitrogen and phosphorus to crops (Odendo et al., 2007). For instance, in a field experiment in Sudan, Radma and Dagash (2013) showed that addition of nitrogen fertilizer significantly increased maize cob yield and number of seeds cob^{-1}. Increasing nitrogen fertilizer rates led to significant increase in ear length, number of kernels row^{-1}, ear weight and grain yield (Younas, 2002). However, their prohibitive costs and the possibility of decreasing soil productivity in the long run due to soil mining and environmental pollution demands a reassement of their use, *vis-a-vis*, other alternative technologies (Kiani et al., 2005; Billen et al., 2014). The use of organic manure, such as FYM, could ameliorate some of these deleterious effects. Manure application has been found to provide nitrogen, phosphorus, potassium etc., and increase soil organic matter and improve soil water holding capacity (Hati et al., 2006; Barbazan, 2004). Maize and soybean yields that could be obtained when using artificial nitrogen (CAN) relative to organic manure and the precise levels of these ingredients has specifically not been investigated in the Western region of Kenya.

The type of cropping system has also been found to be pertinent in determining crop yields. Crops may be planted all alone (mono-cropping) or together with others (intercropping). The major advantage of intercropping is increased profitability, owing to growing more crops on limited land (Brintha and Seran, 2008), which could be crucial in providing food security in the developing world. Yields of Intercropping are often higher than in sole cropping systems (Lithourgidis, 2006) as resources such as water, light and nutrients can be utilized more efficiently (Li et al., 2006). Other benefits of intercropping include better soil cover, suppress weeds by increasing soil cover, and reduce erosion and nutrient leaching (Bilalisa et al., 2010; Seran and Brintha, 2010). It was found that maize-French bean gave high maize equivalent yield over sole maize yield by Hugar and Palled (2008) and kernel yield of maize was unaffected in maize-French bean intercropping according to Pandita (2001). Studies by Akinnifesi et al (2006) revealed that without nitrogen fertilizer application, gliricidia-maize intercropping system gave high maize yield. MBILI (acronym for ‘‘Managing Beneficial Interactions in Legume Intercrops) system, developed by a non-governmental organisation (NGO) called SACRED Africa in Bungoma, involves planting double rows of each intercrop. The system is touted to significantly improve the yield of legumes, while keeping the maize yield constant, as the staggered row spacing allows for greater light penetration through the maize canopy without changing the plant densities (Tungani et al., 2002). However, the effect of the interplay between various crop systems, different fertilizer, and manure applications on the yield of maize and soy beans has not been investigated in the Western region of Kenya. The objective of this study was to evaluate the effect of selected cropping systems, nitrogen (N) fertilizer, farm yard manure and interactions on maize and soy bean crop yields in western Kenya.

2. Materials and Methods

2.1 Study Area

2.1.1 Bungoma County is Located in Western Kenya

The altitude ranges from 2000 m above sea level around Mount Elgon to 1100 m at the minor valleys around the Nzoia river, which drains the major part of the county. The county has a bimodal rainfall pattern, with the first growing season (long rains) extending from March to August, and the second (short rains) from October to January. The county has generally abundant and well-distributed annual average rainfall of 1000-1800 mm. The temperature in the county ranges from about 20-22 ℃ in the southern part of Bungoma to about 15-18 ℃ on the slopes of Mount Elgon in the northern part of the county. Bungoma County falls under two major agro-ecological zones: the transitional upper midland zone UM_4 (referred to as the maize-sunflower zone) and the Lower Midland zones which cover a greater proportion of the county (LM1-LM3). The soils are developed from volcanic materials mainly the basalt; the soils are well drained, deep to very deep and vary from dark red Nitisols (alfisols) and Ferralsols (oxisols) to dark brown Acrisols (ultisols) (Jaetzold and Schmidt, 1983).

2.1.2 Busia County (Teso Sub-County)

Teso of Busia County is located in Western province of Kenya and is bordered by the Republic of Uganda to the west. The county lies between latitude 0^o 29 ´ and 0^o 32 ´ North and longitudes 34^o 01 ´ and 34^o 07 ´ East. The county’s altitude ranges from 1,300 m to 1500 m above sea level. Most parts of the county receive between 1,270 mm and 2000 mm of annual rainfall whose distribution is bimodal. Temperatures for the whole county are more or less homogenous with annual mean maximum temperature ranging between 26 and 30^oC while the mean minimum temperature ranges between 14 and 22^oC (Jaetzold and Schmidt, 1983, Jaetzold et al., 2006).

Soils are well drained acrisols and ferallsols mainly and are of a sandier texture than the Bungoma soils (Republic of Kenya, 1997).

2.1.3 Vihiga County (Vihiga Sub County)

Vihiga sub county, located in western Kenya, is a high agricultural potential area predominantly (95%) in the upper midland one (UM1) agro-ecological zone; has high human population density According to 2009 National Census Vihiga County has a population of 554,622 comprising of 262,716 males and 291,906 females. The population density is 1,051 persons per km ^{2}, which makes it one of the highly populated counties in Kenya (GoK, 2009). It has an altitude ranging between 1300 and 1800 meters above sea level and well-drained soils that comprise dystric acrisols and humic nitosols with low inherent fertility due to heavy leaching, erosion and poor management (Jaetzold et al., 2006). The area receives bimodal rainfall that ranges from 1,800 - 2,000 mm per year and average temperature of 24 Degrees C.

2.2 Experimental Design and Treatment

The experiment was set up in a split plot design, and arranged in a randomized complete block design (RCBD).

The treatments comprised of farm yard manure (FYM), Calcium Ammonium Nitrate (CAN) and a control

2.3 Methodology

Field trials were set up to test the effect of cropping system and fertilizer treatments on the yield of the crops. Cropping systems were the main factors while fertilizer treatments were sub factors. The cropping systems consisted of maize and soybean monocrop, conventional (Maize and soy beans were planted as intercrop in 37.5 cm alternating rows), and MBIL`I (Managing Beneficial Interactions in Legume Intercrops). In the MBILI system the crop was sowed at 0.50m between two locally-recommended IR maize hybrid rows and 1m in between the maize was intercropped with two soy bean rows 33.3cm apart. In the monocrop, IR (Imazapyr resistant) maize or soybean was planted at 75 cm row spacing and 30 cm plant spacing. IR- maize is resistant to a weed, *Striga hermonthica*, endemic in the study area. The MBILI system consisted of two rows (33.3 cm apart) of soybean crops planted between two rows (50 cm apart) of maize plants. The distance between the inner rows of maize and soya beans was 50 cm. In the conventional system, IR-maize was planted at 75 cm row spacing and 30 cm in-row spacing with soy bean seed planted between the maize at 10 cm spacing. Each experimental farm in each county measured 1428 m^2 (68 m by 21 m). The farm was divided into 12 main plots, each measuring 22 m by 4.5 m, and separated from the next plot by a distance of one metre. Each plot was then divided into five subplots, each measuring 4.5 m by 4 m, and separated from the nearest subplot by 0.5 m. The cropping systems, MBILI, maize mono crop, soya bean mono crop and conventional were randomly assigned to the 12 main plots, with each crop system replicated three times. Within each main plot, fertilizer treatments, calcium ammonium nitrate and farm yard manure, both applied at the rate of 30 kg N ha^{-1}, and hereafter referred to as CAN30N and FYM30N, respectively. In addition, CAN and FYM both applied at the rate of 75 kg N ha^{-1}, and hereafter referred to as CAN75N and FYM75N, respectively and control. This were randomly assigned to the subplots. During the short rains 2011, FYM (0.965% N) was sourced from the University of Eldoret farm. An application of 75kg N/Ha led to 7.8tons /ha of manure. In the long rains and short rains 2012, FYM from the farmers with N content of 0.39%, 0.73% and 0.85% in Teso, Vihiga and Bungoma counties was applied respectively. An application of 19.2, 10.27 and 8.82 ton/ha of FYM led to a realization of 75kg N/ha Lastly, there was a control, with neither fertilizer nor manure application.

2.4 Crop Management

The land was prepared by hand digging, levelled and pegged. Triple Super Phosphate (TSP) (0-46-0) was applied at a rate of 26 kg P ha^{-1} during planting to all the plots except for the controls, to eliminate P deficiency (FURP, 1994) and evaluate the performance of the system under conditions where P was not limiting. For the FYM30N and FYM75N treatments, farmyard manure containing 30 kg N ha^{-1} and 75 kg N ha^{-1}, respectively, was applied to the specified plots during planting. These plots were not top dressed with any other form of N. For CAN30N treatment, the plots that received CAN at the rate of 30 kg N ha^{-1} at planting were not top dressed. On the other hand, for CAN75N treatment, CAN at the rate of 30 kg N ha^{-1} was applied at planting and later top dressed with CAN at the rate 45 kg N ha^{-1} at six weeks after planting.

2.5 Data Collection

Data for maize and soybean grain, maize stover and soybean haulm was collected for analysis.

2.6 Data Analysis

A mixed-design analysis of variance (ANOVA) was used to analyse the split-plot design, with fertilizer treatments and cropping system as sub plots and main plots, respectively, while block was the random factor. Maize and soy bean yields were the dependent variables.

The split-plot design for each crop in every study was represented explicitly in the form:

$$Y_{ijkl} = \mu + b_i + \alpha_j + (b\alpha)_{ij} + \beta_k + (\alpha\beta)_{jk} + \varepsilon_{ijk} \tag{1}$$

Where,

Y_{ijkl}= Crop yield on the l^{th} plant growing in the i^{th} block in the j^{th} cropping system and k^{th} fertilizer treatment.

μ = overall mean

b_i= effect of the i^{th} block, which was a random variable

α_j= effect of the j^{th} level cropping system

$(b\alpha)_{ij}$= interaction between the i^{th} block and the j^{th} level of cropping system.

β_k= effect of the k^{th} level of fertilizer treatment.

$(\alpha\beta)_{jk}$= interaction between the jth level of cropping system and the k^{th} level of fertilizer.

E_{ijk} = experimental error.

Land Equivalent Ratio (LER) was computed to determine yield advantages. The LER was calculated as by the procedure of Vandermeer (1989), in which the amount of the intercropped yield was divided by the amount of the mono cropped yield for each crop in the field as calculated as follws:

$$LER = (Yim/Ysm) + (Yic/Yss)$$

Partial LERs were added together to find the total LER. Where Yim and Ysm are the yields of intercropped and monocrop maize, and Yic and Yss are the yield intercropped and monocrop soy bean

All statistical tests were performed with the aid of SAS (version 9) statistical package (SAS Institute 2002) All the tests were two – tailed. Significant levels were measured at 95% confidence level with significant differences recorded at $p < .05$

3. Results

3.1 Maize and Soy Beans Yields in 2011 Short Rains Season

Table 1 gives maize yields (t/ha) in different crop systems and fertilizer treatments.

Table 1. Maize yields (t ha^{-1}) in 2011 short rain seasons

Site	**Crop system**	**Treatments (each treatment replicated 3 times)**					**Total**
		CAN30N	CAN75N	FYM30N	FYM75N	Control	
Bungoma	Mono	3.66+0.03	4.55+0.29	3.06+0.98	3.57+0.35	1.03+0.59	3.17+1.30
	MBILI	3.24+0.98	3.86+1.20	2.53+0.65	2.65+0.99	1.26+0.56	2.71+1.18
	Conventional	1.63+0.49	2.14+0.31	1.49+0.13	2.23+0.59	0.99+0.25	1.69+0.57
	Total	2.85+1.07	3.52+1.25	2.36+0.91	2.82+0.85	1.09+0.44	2.53+1.21
Vihiga	Mono	2.17+0.18	2.47+1.05	1.41+0.17	2.23+0.51	0.66+0.39	1.79+0.84
	MBILI	0.53+0.07	2.14+0.11	1.92+0.80	2.50+0.07	0.94+0.73	1.60+0.87
	Conventional	1.16+0.47	1.36+0.15	1.65+0.47	2.38+0.04	0.41+0.12	1.39+0.69
	Total	1.29+0.72	1.99+0.72	1.67+0.47	2.37+0.29	0.67+0.48	1.59+0.81
Teso	Mono	1.45+0.22	1.51+0.06	1.52+0.08	1.59+0.08	0.69+0.02	1.35+0.36
	MBILI	1.51+0.26	1.64+0.12	1.61+0.39	2.60+0.13	0.54+0.29	1.58+0.71
	Conventional	1.05+0.65	1.69+0.28	1.29+0.43	1.55+0.09	0.45+0.10	1.20+0.55
	Total	1.34+0.42	1.61+0.18	1.47+0.33	1.91+0.52	0.56+0.18	1.38+0.57
Total	Mono	2.43+0.99	2.84+1.45	1.99+0.94	2.46+0.93	0.79+0.39	2.10+1.19
	MBILI	1.76+1.29	2.55+1.17	2.02+0.68	2.59+0.51	0.91+0.57	1.96+1.06
	Conventional	1.28+0.54	1.73+0.41	1.47+0.28	2.05+0.48	0.62+0.31	1.43+0.63
	Total	1.82+1.06	2.37+1.16	1.83+0.71	2.36+0.68	0.77+0.44	1.83+1.02

Key: CAN = calcium ammonium nitrate; FYM = Farmyard manure; SED = Standard errors of the Difference; Conv. = conventional. For every county, means with the same letter in a row (for crop system) or column (for fertilizer treatment) are not significantly different at $p<0.05$ by the Tukey HSD test. All yields are in t ha^{-1}.

3.1.1 Effect of Cropping System, Fertilizer Treatment and Interaction on Crop Yield

In Bungoma, significant main effects of cropping system, F (2, 6) = 5.01, p=0.037 and fertilizer treatments, F (4, 24) = 41.02, p<.0001 on the yield of maize were found. These were qualified by a significant interaction between cropping system and fertilizer levels, F (4, 24) = 4.04, p=0.004. Yields were significantly higher in both mono (3.2 t ha^{-1}) and MBILI (2.7 t/ha) compared to conventional farming (1.7 t ha^{-1}). Maize yields were found to be the highest when top-dressed with CAN75N (3.5 t ha^{-1}), followed by top dressing with CAN30N (2.9 t/ha), FYM30N (2.4 t/ha) and FYM75N (2.8 t ha^{-1}), while it was the lowest in the control (1.1 t ha^{-1}). In Vihiga, crop system had no significant effect on maize yield in 2011 short rains, F (2, 6) = 2.80, p=0.138. However, fertilizer treatment had a significant influence on maize yield, F (4, 24) = 18.67, p<.0001. A significant interaction between cropping system and fertilizer was also found F (4, 24) = 3.52, p=0.008. The highest maize yield (Table 6.1) was found with FYM75N (2.4 t ha^{-1}), followed by CAN75N (2.0 t/ha), and then, by both FYM30N (1.7 t ha^{-1}) and CAN30N (1.3 t ha^{-1}). The lowest yield was recorded in the control (0.7 t ha^{-1}). In Teso, both crop system and fertilizer treatments had significant effects on maize yield in 2011 short rains, F (2, 4) = 8.01, p=0.04 and F (4, 24) = 37.05, p<.0001, respectively. A significant interaction between cropping system and fertilizer was also found F (8, 24) = 3.47, p=0.009. The highest maize yield was found with FYM75N (1.9 t ha^{-1}), followed by CAN75N (1.6 t ha^{-1}), FYM30N (1.6 t ha^{-1}) and CAN30N (1.3 t ha^{-1}). Both MBILI and mono crop systems produced the highest maize yields (1.6 and 1.4 t ha^{-1}, respectively) compared with conventional farming (1.2 t ha^{-1}).

Table 2. Soy bean grain yields (t/ha) in 2011 short rain seasons

Site	**Crop system**	**Treatments (each treatment replicated 3 times)**					**Mean**
		CAN30N	CAN75N	FYM30N	FYM75N	Control	
Bungoma	Mono	0.38+0.28	0.54+0.31	0.37+0.08	0.52+0.18	0.42+0.16	0.45a+0.20
	MBILI	0.19+0.03	0.29+0.08	0.10+0.04	0.16+0.05	0.14+0.05	0.18b+0.08
	Conventional	0.14+0.09	0.22+0.12	0.12+0.05	0.11+0.05	0.12+0.06	0.14b+0.08
	Mean	0.24k+0.18	0.35k+0.22	0.20k+0.13	0.27k+0.22	0.23k+0.16	0.26+0.19
Vihiga	Mono	1.75+0.35	1.74+0.16	1.72+0.28	1.47+0.45	1.15+0.14	1.56a+0.35
	MBILI	0.82+0.18	0.63+0.08	0.72+0.09	0.75+0.03	0.71+0.06	0.73b+0.10
	Conventional	0.70+0.20	0.50+0.15	0.81+0.28	1.12+0.99	0.70+0.67	0.77b+0.52
	Mean	1.09k+0.54	0.96k+0.60	1.08k+0.52	1.12k+0.62	0.85k+0.41	1.02+0.53
Teso	Mono	0.23+0.20	0.45+0.15	0.57+0.19	0.87+0.20	0.41+0.20	0.51a+0.27
	MBILI	0.34+0.17	0.25+0.10	0.47+0.10	0.35+0.08	0.09+0.06	0.30b+0.16
	Conventional	0.25+0.13	0.25+0.16	0.33+0.02	0.33+0.03	0.18+0.07	0.27b+0.10
	Mean	0.28k+0.15	0.32k+0.15	0.46l+0.15	0.52l+0.28	0.23k+0.18	0.36+0.22

Key: CAN = calcium ammonium nitrate; FYM = Farmyard manure; SED = Standard errors of the Difference; Conv. = conventional. For every county, means with the same letter in a row (for crop system) or column (for fertilizer treatment) are not significantly different at p<0.05 by the Tukey HSD test. All yields are in t/ha (tonnes/hectare)

3.1.2 Effect of Cropping System, Fertilizer Treatment and Interaction Crop Yield

In both Bungoma and Vihiga, an ANOVA revealed significant main effects of only the cropping system, F (2, 28) = 21.12, p<0.0001 and F (2, 6) = 11.56, p = 0.009, respectively, on the soy bean yields. Yields were significantly higher in the mono cropping system than in the other crop systems. However, soy bean yields in both MBILI and conventional system were found not to be significantly different. In Teso, an ANOVA revealed significant main effect of both crop system, F (4, 28) = 13.26, p<.0001 and fertilizer treatments, F (4, 28) = 7.20, p=0.0004 on the yield of soy beans. Soy bean yields were found to be significantly higher with both FYM75N (0.52 t/ha) and FYM30N (0.46 t/ha) compared with the fertilizer treatments. Interaction effects indicated that MBILI gave significantly higher yields when the crop was top dressed with CAN whereas mono cropping gave the highest yield with FYM.

3.2 Maize and Soy Beans Yields in 2012 Long Rains Season

Table 3. Maize yields (t ha-1) in 2012 long rain season

Site	**Crop system**	**Treatments (each treatment replicated 3 times)**					**Mean**
		CAN30N	CAN75N	FYM30N	FYM75N	Control	
Bungoma	Mono	2.81+0.0	4.27+0.01	4.03+0.01	5.02+0.01	2.66+0.01	3.76a+0.93
	MBILI	2.08+0.01	3.85+0.01	2.69+0.51	4.86+0.01	1.64+0.01	3.02b+1.23
	Conventional	1.24+0.01	3.36+0.01	2.38+0.01	2.94+0.01	1.21+0.01	2.29c+0.89
	Mean	2.14k+0.65	3.82l+0.39	3.03m+0.80	4.27n+0.99	1.83o+0.64	3.04+1.17
Vihiga	Mono	2.07+0.01	4.68+0.01	1.82+0.01	1.96+0.01	1.43+0.1	2.39a+1.20
	MBILI	1.35+0.01	1.44+0.01	1.16+0.01	1.84+0.01	0.62+0.01	1.28b+0.41
	Conventional	1.10+0.01	.95+0.01	1.30+0.10	1.54+0.01	0.64+0.01	1.11c+0.32
	Mean	1.51k+0.43	2.36l+1.75	1.43m+0.30	1.78n+0.18	0.90o+0.40	1.59+0.93
Teso	Mono	0.15+0.01	0.15+0.01	0.15+0.01	0.16+0.01	0.13+0.01	0.15a+0.01
	MBILI	0.14+0.01	0.19+0.01	0.16+0.01	0.13+0.01	0.13+0.01	0.15a+0.02
	Conventional	0.15+0.01	0.16+0.01	0.15+0.01	0.16+0.01	0.13+0.01	0.15a+0.02
	Mean	0.15k+0.01	0.17l+0.01	0.16k+0.01	0.16k+0.02	0.13m+0.01	0.15+0.02

Key: CAN = calcium ammonium nitrate; FYM = Farmyard manure; SED = Standard errors of the Difference; Conv. = conventional. For every county, means with the same letter in a row (for crop system) or column (for fertilizer treatment) are not significantly different at p<0.05 by the Tukey HSD test. All yields are in t/ha (tonnes/hectare)

3.2.1 Effect of Cropping System, Fertilizer Treatment and Interaction on Crop Yield

An ANOVA revealed significant main effects of cropping system, F (2, 30) = 504.01, p<0.0001 and fertilizer treatments, F (4, 30) = 589.23, p<.0001 on the yield of maize in Bungoma. Yields were highest in the mono crop (3.8 t/ha), followed by MBILI (3.0 t/ha), and were lowest in conventional farming (2.3 t/ha). Application of FYM at 75 kg/N per hectare produced the highest yield of maize (4.3 t/ha), followed by CAN75N (3.8 t/ha), which was unlike the 2011 season, where the highest yield was produced by The highest maize yield was found with CAN75N (0.17 t/ha). No significant differences in maize yield were found between CAN30N (0.15 t/ha), FYM30N and FYM75N (both had 0.16 t/ha). CAN75N. The significant interaction between crop system and fertilizer indicated that when FYM was very high (75N), maize yields in mono and MBILI systems were not significantly different from each other. In Vihiga, significant main effects of both the cropping system, F (2, 30) = 9724.51, p<.0001 and fertilizer treatments, F (4, 30) = 3399.01, p<.0001 were found on the yield of maize. Yields were highest in mono (2.4 t/ha), followed by MBILI (1.3 t/ha), and were lowest in conventional farming (1.1 t/ha). The highest yield produced by fertilizer treatments was in CAN75N (2.4 t/ha), followed by FYM75N (1.8 t/ha), CAN30N (1.5 t/ha), FYM30N (1.4 t/ha), while it was the lowest in the control (0.90 t/ha). Analysis of the interaction effect revealed that huge differences in maize yields between mono cropping and other cropping systems occurred only top dressing was done with CAN75N but not with other fertilizer treatments. In Teso, significant main effect was only found for fertilizer treatments, F (4, 30) = 14.96, p<.0001. A significant interaction between cropping system and fertilizer was also found F (8, 24) = 3.47, p=0.009. Maize yield in Teso was abnormally low (mean= 0.2 t/ha) because the crop was infected with Maize Necrosis disease in the season.

Soy bean yields in 2012 long rains season is presented in Table 4.

Table 4. Soy bean yields (t/ha) in 2012 long rain season

Site	Crop system	Treatments (each treatment replicated 3 times)					Total
		CAN30N	CAN75N	FYM30N	FYM75N	Control	
Bungoma	Mono	1.36+0.14	1.32+0.26	1.40+0.16	1.37+0.24	0.93+0.04	1.27a+0.24
	MBILI	0.53+0.01	1.12+0.12	1.02+0.05	1.68+0.05	0.47+0.08	0.96b+0.46
	Conventional	0.72+0.05	0.82+0.09	0.93+0.06	1.05+0.08	0.62+0.11	0.82c+0.17
	Total	0.87k+0.38	1.08l+0.26	1.12l+0.23	1.37m+0.30	0.68n+0.22	1.02+0.36
Vihiga	Mono	1.41+0.03	1.62+0.05	1.37+0.17	1.56+0.12	0.82+0.17	1.36a+0.31
	MBILI	1.08+0.05	1.72+0.01	1.21+0.09	1.26+0.05	0.43+0.07	1.14b+0.41
	Conventional	1.02+0.07	1.09+0.01	1.10+0.12	0.95+0.04	0.18+0.04	0.91c+0.33
	Total	1.17k+0.18	1.53l+0.27	1.23k+0.16	1.26k+0.27	0.51m+0.29	1.14+0.40
Teso	Mono	1.12+0.09	1.23+0.01	1.26+0.13	1.5+0.04	0.66+0.08	1.15a+0.29
	MBILI	0.84+0.03	1.21+0.02	1.03+0.05	1.26+0.06	0.39+0.05	0.95b+0.32
	Conventional	0.47+0.07	0.68+0.02	0.64+0.14	1.02+0.08	0.24+0.02	0.61c+0.27
	Total	0.81k+0.28	1.04l+0.26	0.97l+0.28	1.26m+0.21	0.43n+0.19	0.43+0.19

Key: CAN = calcium ammonium nitrate; FYM = Farmyard manure; SED = Standard errors of the Difference; Conv. = conventional. For every county, means with the same letter in a row (for crop system) or column (for fertilizer treatment) are not significantly different at p<0.05 by the Tukey HSD test. All yields are in t/ha (tonnes/hectare)

3.2.2 Effect of Cropping System, Fertilizer Treatment and Interaction on Crop Yield

In Bungoma, significant main effects of cropping system, F (2, 30) = 48.00, p<0.0001 and fertilizer treatments, F (4, 30) = 37.47, p<.0001 on the yield of soy bean were found. The results showed that the highest soy bean yield was found in the mono crop (1.27 t/ha), followed by MBILI (0.96 t/ha), and were lowest in conventional farming (0.82 t/ha). FYM, applied at 75 kg/N per hectare produced the highest yield of soy bean (1.37 t/ha). Analysis of the interaction between crop system and fertilizer treatments showed that whereas the mono crop system in contrast with other systems produced superior yields when CAN was used, MBILI produced the highest yields with FYM75N compared to other crop systems. Yields in Vihiga were similar to those in Bungoma. In Teso, both crop system, F (2, 30) = 205.05, p < 0.0001 and fertilizer treatments, F (4, 30) = 155.37, p<.0001 had a significant influence on crop yield. The highest soy bean yields were produced with FYM75N (1.26 t/ha), followed by both CAN75N (1.04 t/ha) and FYM30N (0.97 t/ha), and then by, CAN30N (0.81 t/ha). Mono produced the highest yields (1.15 t/ha), followed by MBILI (0.95 t/ha) and conventional (0.61 t/ha).

3.3 Land Equivalent Ratio (LER)

Table 5 presents the total LER for the two growing seasons in the study.

Table 5. Effect of cropping system on land equivalent ratio for maize and soy bean

Cropping System	Grain	Stover
Conventional	1.24b	1.26b
MBILI	1.43a	1.46a
Mono crop	1.00c	1.00c
LSD	0.1558	0.1101

Key: Means with the same letter down a column are not significantly different at p<0.05 by the LSD test

An ANOVA was conducted to test whether the type of cropping system could influence the LER and was found to be significant at p<0.05. The total LERs for MBILI and conventional intercropping systems were greater than one in all the three sites during 2011 short rains and 2012 long rains while the LER for mono crop was 1.00. This showed that the two systems had an advantage over sole cropping in land use. However, MBILI had a greater yield advantage than conventional intercropping system. MBILI had 43% and 46% while conventional had 24% and 26% yield advantage over mono cropping in grain yields, respectively.

4. Discussion

Generally, maize yields were found to be significantly higher in both the mono cropping system (mean yield: 2.00 t/ha) and MBILI system (mean yield: 1.77 t/ha) compared to conventional farming (mean yield: 1.27 t/ha). On the other hand, soy bean yields were found, overall, to be significantly higher in the mono cropping system (mean: 1.00t/ha) compared to both MBILI (mean: 0.75t/ha) and conventional system (mean: 0.59t/ha). Unlike maize, soy bean is a crop that is capable of utilizing both soil N (mostly in the form of nitrate) and atmospheric N (through symbiotic nitrogen fixation) (Vera et al., 2002). Higher maize yields in the mono cropping system could be explained by the fact that the maize obtained optimum nutrients and other resources from fertilizers/manures applied or those inherent in the soils, as there was little competition from other crops. Maize growing in the MBILI system, could benefit from the nitrogen fixed by legume crop, explaining the higher maize yields. Maize yields in the conventional system, could be lower than in the MBILI system because the latter system allows more light penetration for the under-storey plant component, without changing the plant densities, improves root distribution and reduces belowground competition (Woomer, 2007; Woomer et al., 2004).). Woomer *et al*. (2004) demonstrated that more than 50% higher light penetration in MBILI cropping system and also suggested that superior crop yields were related to additional advantages in root distribution and reduced below ground competition. Studies have indicated that the MBILI system, when combined with adjusted nutrient inputs, resulted in superior and robust improvements in crop yields and economic benefits, relative to the conventional intercropping system (Mucheru-Muna et al., 2010).

Soy bean yields were highest in the mono crop system because growing, solely; the crop faced no competition for resources such as mineral nutrients from applied fertilizers/manures. The yields for soy bean were lower in both the MBILI and conventional system possibly because although the crop expended resources to fix nitrogen for the maize crop, it could have received little in compensation, reducing its yield. The soy bean haulm yield reflected this pattern of grain yield, suggesting that a similar explanation could be applied.

For maize crop, top dressing with CAN75N and planting with FYM75N were found to significantly increase yields, compared to either top dressing with CAN30N or planting with FYM30N. Each of these treatments was significantly greater relative to the control. Patel *et al* (2006), Kostandi and Soliman (2008) and Younas *et al*. (2002) reported that increasing nitrogen levels increased grain yield and dry matter production, which were related to differences in size of photosynthetic surface and to the relative efficiency of total sink activity. According to them, the higher yields were due to higher number of grains per cob and higher weight of the grains. Thus, higher crop yields in the study could result from more availability of nitrogen to plants. However, a finding that could be important from this study is that there were no significant differences in both maize and soy bean yields between CAN75N and FYM75N or between CAN30N and FYM30N. This suggested that manure application, when applied at equivalent level of N, could produce similar yields as those in inorganic N fertilizer applications. Given the prohibitive costs of fertilizers and the possibility of decreasing soil productivity in the long run due to soil mining and environmental pollution Kiani et al., 2005; Billen *et al*., 2014), the results suggest that where farmers could access cheap sources of FYM, they should consider using them *in lieu* of top dressing with nitrogenous fertilizers.

An analysis of various interactions between the main factors showed that CAN generally produced higher yields with monocrop system whereas MBILI system was superior when FYM is used. FYM can increase crop production through a variety of ways: provision of additional nitrogen, provision of phosphorus, provision of potassium, e.t.c increased soil organic matter, and improved soil water holding capacity (McAndrews et al., 2006; Barbazan, 2004; Hati et al., 2006). This suggests that using the MBILI system with organic fertilizers could be a better option than opting for mineral fertilizers, because of the latter’s high costs, soil mining and environmental pollution.

The mean LER values were always greater than 1.0 in both MBILI and conventional systems showing that although mono cropping had higher yields, intercropping was advantageous over sole cropping. This is in agreement with Li et al., (2006) who reported that resources such as water, light and nutrients were better utilized in intercropped than in the respective sole cropping systems. A LER greater than 1.0 has been reported with bean maize intercropping (Odendo et al., 2011; Saban et al., 2007).

5. Conclusions

The study investigated the effects of different cropping systems, N fertilizer and manure applications on the yield of maize and soy beans in the Western region of Kenya. Though sole cropping system leads to higher yields in grains, intercropping has more yield advantage compared to mono cropping. MBILI system is superior in yields compared to intercropping conventional system. The greater LER of the intercrops was mainly due to a greater resource use and complementarity than when the species were grown together. This shows that intercropping system can significantly benefit the smallholder by increasing yield on a limited amount of land, and reducing risk of total crop failure, such as, from prolonged drought.

Manure, where cheaply obtained and applied properly, could produce similar yields as those in fertilizer applications, which could reduce the cost of farming, environmental pollution and soil mining in the long run.

This study recommends that the most optimal system for growing soya bean and maize that maximises yield in an economically and environmentally beneficent way is a MBILI system with an organic source of N.

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