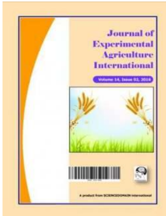

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Effect of Intercropping Maize and Promiscuous Soybean on Growth and Yield

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Authors' contributions

This work was carried out in collaboration between all authors. Authors JMK and HMJP drafted the paper. Author HMJP analyzed the data alone. Authors JWM, FMO and FMN proofred the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

An study was carried out in Kenya to assess the suitability of three promiscuous soybean varieties (SB19, GAZELLE and TGX1990-5F) intercropped with Maize (Duma 43). A randomised complete block design was used replicated three times with seven treatments. The arrangement of intercropping was 1:1. Data collection included germination %, plant height, days to 50% flowering, days to 75% maturity, yield biomass per plant, 100 grain weight, grain yield, harvest index and Land Equivalent Ratio for both crops. Shattering score, pods per plant, and seeds per pod for soybean only. Data were subjected to ANOVA and means separated using $LSD_{0.05}$. The results showed that the earliest variety to 50% flowering and 75% maturity was SB19 ($p \leq 0.05$) followed by GAZELLE while the latest variety was TGX1990-5F. Intercropping did not affect days to 50% flowering, days to 75% maturity and seeds per pod. Variety TGX1990-5F was resistant to pod shattering while others were moderately resistant. TGX1990-5F recorded the highest plant height, pods per plant, soybean biomass, grain yield and LER while GAZELLE had higher HI and SB19 recorded higher seeds per

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pod in sole crop and in intercrop in both sites and rainy seasons. Intercropping reduced soybean plant height, pods per plant, soybean yield biomass, soybean grain yield and soybean HI in both sites and seasons. LER showed advantage between component crops in both seasons.TGX1990-5F was suitable promisuous soybean variety for intercropping with maize because it had good perfomance under intercropping compared to others.

Keywords: Intercropping; maize; soybean; land equivalent ratio; promiscuous soybean.

1. INTRODUCTION

Low crop production is a common issue which many farmers are facing in Africa [1]. The problem is more pronounced in legume production and combined with soil infertility and other ecosystems parameters. Previous studies indicate that, in the beginning of agriculture leguminous plants were important for the human consumption and many leguminous plants provide unique proteins for human beings. The protein content in leguminous plants is a supplement to cereals forming good mixture for balanced nutrient supply, especially in developing nations [2]. Among legumes, soybean (*Glycina max*) is known for its supply of high quality protein (40%) higher compared to other leguminous crops. Therefore, with the increase of population of Kenya today, it will be better to find an agronomic system which will help us have sustainable agriculture to increase productivity of soybean. Intercropping system is among the systems which are used by many small scale farmers in Kenya. Cereals and legumes which are known to be grown in intercrop by growers, this may be because of the legumes capacity to improve soil fertility and reduce soil erosion [3]. Flexibility, growth of income, reduction of threat, enhancement of soil fertility and maintenance, are major reasons of intercropping for many farmers [4]. In addition, intercropping cereals-legumes have good capacity to reduce weeds development, while cereals in sole crop needs more space to produce the same yield compared to intercrop [5]. Soybean is among main legumes which are more produced in the world. The major countries that produce the crop are led by USA with (46%), followed by Brazil with (20%), Argentina (13.5%) and China (9%); other countries producing soybean include India, Paraguay, Canada and Indonesia. Africa contributes only 1% of soybean production [6]. Therefore the percentage of soybean production held by each Africa's country including Kenya is quite low. Annual demand for soybean in Kenya can surpass 100,000 MT which is among the biggest in the East African area. Soybean production is less than 5,000 MT annually, giving a shortage of more than 95% [7]. This shortage is covered by importation. Nevertheless, two regions in Kenya are contributing to soybean production which are: Kakamega, Siaya, Bungoma, Vihiga, Busia, Trans Nzoia, Homa Bay, Migori, Kisii and Nyamira counties (western area) and Kirinyaga, Embu, Meru and Tharaka Nithi Counties (Central highlands region). Western area is producing more than central region highlands. Kenya imports soybean from Uganda, Malawi, Zambia, Zimbabwe, Argentina, India and recently Brazil [7]. In this case, improving intercropping system of cereals and legumes in Kenya would be necessary in order to help small scale farmers increase their yield per unit area. That assumption can be achieved correctly after finding solutions to many research's gaps of soybean which include breeding for biotic constraints (diseases and pests), a biotic stresses (drought, water logging), grain quality improvement (high oil and protein content), as well as other agronomic traits such as keeping green grains and reduced pod shattering [8]. Planting two or more crops in the same season in the field is known as intercropping which is a sustainable agricultural technique and it uses nutrients better than monocrop [3]. However, this technique has been demonstrated as system which can be highly effective compared to monocrop, also improving the ecosystem [9]. Intercropping maize-soybean is considered as a good substitute for supplying nitrogen and raising maize production. Small scale famers prefer intercropping mixing many crops together without worrying about the species, but considering compatible plants is a major point in intercropping in terms of growth pattern, land, light, water use efficiency and fertilizer usage [4]. Intercropping is playing vital role in subsistence food supply in advanced and developing nations [10]. Leguminous crops are able to fix N and that N fixed in intercropping is an important resource for the cereals in growing time [11]. This led to development of promiscuous soybeans varieties that fix N without artificial rhizobia. However, there are no studies that have been done to assess the suitability of these varieties in the intercrop system. In addition, the effect of intercropping maize and promiscuous soybean varieties on several agronomic traits is not well understood. Soybean which can produce effective nodules with diverse native rhizobia are referred to as promiscuous soybeans [12]. Promiscuous soybean allows smallholder farmers to get seeds which can produce high yield, maintaining cropping system, increasing soil fertility, producing more protein and oil content, while soybean which need artificial inoculant increase input decreasing productivity per unit of area [13]. There is need, to determine promiscuous soybean varieties with better agronomic traits for intercropping with maize in Kenya.

2. MATERIALS AND METHODS

2.1 Description of the Study Areas

The experiments were conducted in Embu and Mwea during two rain seasons of (2016 and 2017). KALRO-Embu is located between latitudes 0° 08'35''S and a longitude 37°27 ′02″ E while KALRO-Mwea is located at a latitude of 00° 37'S and a longitude of 37° 20'E in Kenya [14,15]. During the experiment period the rainfall was 3.21 mm and 0.007 mm at Embu and Mwea, respectively. The mean temperature and relative humidity were respectively 21.42℃ and 63.54% at Mwea and 20.3℃ and 64.43% at Embu. The land preparation was done by ploughing using ox-draw equipment as is common in the area.

2.2 Experimental Treatment and Design

Three promiscuous soybean varieties : hybrid SB19, local variety GAZELLE and hybrid TGX1990-5F were evaluated by intercropping with maize (variety Duma). For each soybean variety one row was planted between every two rows of maize. Controls consisted of plots planted with soybean and maize pure stand. The experiment was laid out in a randomized complete block design (RCBD) and each treatment was replicated three times. In the monocrop soybean plots a spacing of 40 cm x 15 cm was used while in the intercrop plots the spacing was 80 cm x 15 cm, The maize monocrop was planted at a spacing of 80 cm x 25 cm and 80 cm x 25 cm for the intercropped plots to give an arrangement of 1:1, with one row of soybean between every two rows of maize. The experiments received a basal application of 10.5 kg of DAP per site at the rate of 250 kg ha^{-1} or 300 g per each plot [16]. The experiment was planted for two seasons in both sites between June 2016 March 2017. The trials received supplement by irrigation as required. Data was collected on agronomic parameters, yield and yield components, harvest index and land equivalent ratios.

2.3 Determination of Agronomic Parameters

The agronomic parameters determined were germination percentage, plant height, nodulation, days to flowering and maturity. Germination percentage was determined by counting the number of emerged plants multiplied by 100 divided by the total number of seeds sown as follows:

$$\text{Germination } \% = \frac{Germinated\ seed}{Seed\ \ sown}\ x\ 100$$

Plant height was determined by measuring the height from the bottom to the tip of the plant. Five plants were sampled from the middle of each plot and the average was computed for each treatment [17]. Nodulation was assessed one month after sowing by carefully digging up each plant and carefully removing the soil around the roots by placing in a basin of water. The numbers of nodules were counted on each plant. Days to 50% to flowering and days to 75% to maturity were estimated by counting the number of days from sowing taken for each variety to attain 50% of the plants to flower and mature, respectively. The values were converted into percentage.

2.4 Determination of Yield and Yield Components

The yield and yield components assessed were number of pods per plant, biomass, shattering score and grain yield. Biomass per plant was determined at harvest by taking the weight of five plants per plot and the average biomass for one plant was calculated by dividing the obtained value by five [17]. The total biomass per hectare was determined by weighing the all the biomass in each plot and extrapolating to per hectare. The number of pods per plant was taken by counting all pods on the five sampled plants and divided by five to obtain the average number of pods per plant at harvest time. The number of seeds in the five sampled pods from the five plants was counted and the value divided by five to get the average seeds per pod. Shattering score was assessed at maturity by taking 30 dried pods, placing them in khaki envelope and exposing to the sun for seven days and the number of shattered pods in each day was counted. The values were converted to percentage as follows:

$$\text{Shattered pods }\% = \frac{Number\ of\ pods\ shattered}{Number\ of\ pods\ taken\ as\ sample}\ x\ 100$$

The percentage shattering was scored as follows: 1 = No pod shattering (Very Resistant); 2 = < 25% pod shattering (Resistant); 3 = 25-50% pod shattering (Moderately Resistant); 4 = 51-75% pod shattering (Highly susceptible); 5 = > 75% pod shattering (Very Highly susceptible) [18]. The grain yield of soybean and maize was determied by harvesting the middle rows in each plot. The harvested soybean plants for each plot were threshed separately, winnowed and and weighed. In the case of maize the ears from each plot were harvested, shelled separately and weighed. The grain yield per plot was extrapolated to to tones per hectare. The yield data was used to calculate the harvest index as follows [19]:

$$\text{HI} = \frac{Grain\ yield\ T\ /ha}{Biomass\ yield\ T/ha}\ x\ 100$$

One hundred grains weight for each of soybean and maize crop was determined by taking the weight of 100 large-sized grains for each crop while the 1000 grain weight was determined by weighing 1000 small grains as described by [20].

2.5 Calculation of Land Equivalent Ratio

The land equivalent ratio was calculated to determine the performance of the Maize-Soybean intercrop system using the following formula as described by [21]:

$$LER = \frac{YSB\ in\ mixed\ stand}{YSB\ in\ pure\ stand} + \frac{YMZ\ in\ mixed\ stand}{YMZ\ in\ pure\ stand}$$

Where,

LER = Land equivalent ratio
Y_{SB} = Yield of soybean crop
Y_{MZ} = Yield of maize crop

2.6 Mwea and Embu Sites Soil Characteristics

The soil characterisation showed that the nutrients were moderated for feeding plant except P which was high in both sites and seasons (Tables 1 and 2).

2.7 Data Analysis

The data was analyzed using Gen stat program fourth edition, 2013 and the comparison between means was used for the parameters which presented the significant difference. Thus, the least significant difference (LSD) was used to differentiate the means on threshold of ($p \leq 0.05$) [22].

Table 1. Soil chemical characteristics for Mwea and Embu sites before sowing (Long rains 2016-2017)

Sites	Ph	%	%	Cmol/kg				P ppm				
		N	0C	K	Na	Ca	Mg	P	Mn	Zn	Fe	Cu
MWEA	5.70	0.19	1.89	1.10	0.60	1.43	0.95	145.0	65.20	0.85	60.34	1.64
EMBU	6.01	0.29	2.84	1.40	0.45	0.68	0.66	22.1	32.50	2.40	19.66	1.50

Tabele 2. Soil chemical characteristics for Mwea and Embu sites before sowing (Short rains 2016)

Sites	Ph	%	%	Cmol/kg				P ppm				
		N	0C	K	Na	Ca	Mg	P	Mn	Zn	Fe	Cu
MWEA	4.28	0.23	2.45	0.4	0.61	4.20	1.87	5.83	76.50	7.60	103.50	2.10
EMBU	5.06	0.14	1.37	1.15	0.45	4.50	1.45	151.7	72.30	6.50	115.20	1.50

3. RESULTS

3.1 Soybean Growth and Production Parameters

During the long rains of 2016, germination for soybeans did not give significant different in the sole and the intercrop between the sites. However, during the short rains, significant differences were observed in the sole crops and the intercrops between the sites. Germination % was higher during the long rains recording 90% compared to the short rains recording between 67 and 79% (Table 3). Soybean plant height (PH) showed significant difference ($p \leq 0.05$) between sites and seasons. Soybean PH ranged from 40.83 cm to 61.80 cm between sites in the long rains while it ranged from 46.63 cm to 67.50 cm in the short rain season between sites too. During the short rain season, soybean PH ranged from 55.40 cm to 71.53 cm at Mwea while it ranged from 37.87 cm to 54 cm at Embu in sole crop and intercrop. The sole crops showed the highest PH compared to intercropping. Varieties differed in terms of PH. TGX1990 – 5F recorded the tallest plants height of 55.87 cm and 44.27 cm followed by SB19 with 43.2 cm and 33.9 cm while Gazelle recorded the shortest PH of 30.40 cm and 34.9 cm respectively in sole crops and intercrop at Embu in long rains. At Mwea, TGX1990-5F recorded the tallest PH followed by SB19 while GAZELLE as the shortest (47.13 cm) in sole crops and intercrop both rainy seasons. Varieties differed in terms of plant height in short rains. TGX1990-5F showed the tallest PH followed by compared to GAZELLE with the smallest PH in sole crop and intercrop respectively at Embu and Mwea. Intercropping affected negatively the PH compared to the results obtained in sole crop (Table 3). Days to 50% flowering and 75% maturity in the sole crops and the intercrops systems differed between the sites ($p \leq 0.05$). However, the trend for flowering and maturity was similar for the 2 seasons. Days to 50% flowering ranged from 69 days to 84 days at Embu while at Mwea it ranged from 48 days to 64 days among varieties in both seasons. In addition, days to 75% maturity ranged from 95 days to 121 days at Embu and 80 days to 95 days at Mwea in both seasons. For days to 50% flowering, variety SB19 took 49 and 69 days to flower while the last variety to flower was TGX1990-5F which took 64 days and 84 days at Mwea and Embu respectively. The same trend was observed in days to 75% maturity where variety SB19 took 80 and 95 days to mature while the late variety TGX1990-5F took 95 and 121 days at Mwea and Embu respectively. Nevertheless, intercropping did not reduce days to 50% to flowering and 75% to maturity both sites and both seasons (Table 3).

Soybean nodulation showed significant difference ($P \leq 0.05$) between sites. The number of nodules ranged from 33 to 47 at Mwea while Embu ranged from 29 to 43. Variety TGX1990-5F recorded the highest number of nodules followed by GAZELLE while SB19 recorded the lowest number of nodules in the sole crops and in intercrop in both sites and in both rainy seasons (Table 4). Intercropping did not reduce the number of nodules per plant.

3.2 Soybean Yield and Yield Components

The number of pods per plant showed significant difference between sites in the sole crop and in intercrops in the long rains. The short rains did not show significant difference between sites. The number of pods ranged from 46 to 107 at Mwea, while it ranged from 13 to 82 at Embu in both sole crop and intercrop. During the long rain season, variety TGX1990-5F presented the highest number of pods followed by SB19 in sole crop in both sites. GAZELLE recorded the lowest number of pods in intercropping at Mwea and Embu sites. During the short rains the number of pods was reduced at both sites compared to the long rains of 2016. The number of pods per plant ranged from 11 to 57 at Mwea and from 10 to 33 at Embu in sole crop and in the intercrop. TGX1990-5F recorded the highest number of pods and GAZELLE had the lowest number of pods. Intercropping affected negatively the number of pods per plant both seasons. Mwea site had the highest number of pods compared to Embu in both seasons (Table 4). However, the number of seeds per pod in long rains of 2016 did not show significant difference between sites. The seeds per pod ranged from 2 to 2.7 at Mwea while they ranged from 1.6 to 2 at Embu. The number of seeds per pod differed significantly during the short rains between sites and ranged from 2 to 3 at Mwea and from 2 to 2.7 at Embu. SB19 showed the highest number of seeds per pods of 3 followed by GAZELLE with 2.5 while TGX199-5F showed 2.07 at Mwea. Intercropping did not reduce the number of seeds per plant. Mwea site showed higher number of seeds per pod compared to Embu both seasons (Table 4).Shattering score (SH) showed significant difference between sites and seasons ($p \leq 0.05$). The shattering score ranged from 11% to 36% at

Mwea while at Embu it ranged from 8% and 30%. GAZELLE recorded the highest SH of 23.3% and 30% followed by SB19 with 20% and 25% while TGX1990-5F recorded the lowest SH of 11% and 8% in sole crops and intercrop respectively at Embu in the long rains. At Mwea, GAZELLE recorded the highest of SH of 23% and 36.67%compared to SB19 (20.7% and 16.3%) and TGX1990-5F (11% and 15%) in sole crops and intercrops during the long rain seasons. During the short rains, SH was ranged between 16% and 30% at Mwea, while Embu presented SH ranging from 16% to 52%. GAZELLE presented the highest SH followed by SB19 and TGX1990-5F was the last in sole crop at Embu and Mwea in long rainy respectively. However, SB19 presented higher SH in intercrops followed by GAZELLE compared to TGX1990-5F with the lowest SH at Embu and Mwea respectively in short rains. Thus, following the shattering score scale, TGX1990 – 5F variety was resistant to pod shattering because it's score shattering scale was 2, while GAZELLE with and SB19 were moderately resistant to pod shattering (Table 5). Intercropping did not affect soybean pod shattering.

During the long rains of 2016, hundred grain weight (100 GW) showed significant difference ($p \leq 0.05$) between sites. It ranged from 14 g to 27 g at Mwea while at Embu it ranged from 14 g to 24 g. There were differences among the varieties in the sole and intercrop system. In the sole crop GAZELLE recorded the highest GW of 24.33 g followed byTGX1990-5F with 18.33 g while SB19 had the lowest GW of 16.67 g in sole crops at Mwea. In the same site, variety SB19 recorded the highest GW of 27 g followed by TGX1990-5F with 20.33 g while GAZELLE recorded the lowest GW of 14.67 g in the intercrop. In Embu during the long rains GAZELLE recorded GW of 24.71 g higher than 16.47 g for SB19 and TGX1990-5F 16.10 g in sole crops while in intercrop SB19 recorded the highest compared to GAZELLE and TGX1990-5F. However, 100 GW did not have significant difference between sites in the short rains but significant differences were observed among treatments both sites. Mwea presented the highest 100 GW compared to Embu in both seasons. Depending on the results obtained in the sole crop and in intercropping, intercropping affected negatively 100 grain weight and the long rains 2016 had higher amount of 100 grain weight compared to the short season (Table 6). Soybean biomass showed significant difference ($p \leq 0.05$) between sites and seasons. Biomass from Mwea ranged among 3 t ha^{-1} to 12 t ha^{-1} while biomass from Embu ranged 2 t ha^{-1} to 14 t ha^{-1}. TGX1990-F had the highest biomass of 12.9 t ha^{-1} and 10.6 t ha^{-1} followed bySB19 with 8.23 t ha^{-1} and 4.48 t ha^{-1} and GAZELLE presented the lowest biomass with 7.89 t ha^{-1} and 3.54 t ha^{-1} respectively in sole crops and inintercrop at Mwea. TGX1990-5F showed the highest biomass of 14.7 t ha^{-1} followed by SB19 with 7.29 t ha^{-1} while GAZELLE recorded the lowest biomass of 5.38 g in sole crops at Embu in long rains. Variety TGX1990-5F showed the highest biomass followed by SB19 while GAZELLE recorded the lowest biomass in sole crop and in intercrop at Embu in the long rains. The short rains produced the lowest biomass compared to the long rains (Table 6).

Soybean yield showed significant difference ($p \leq 0.05$) between sites in the long rains 2016. Soybean yield ranged from 0.6 t ha^{-1} to 3.7 t ha^{-1} at Mwea recording higher yields than Embu where soybean yield ranged from 0.44 t ha^{-1} to 2.17 t ha^{-1} both sites in sole crop and intercrop in the long rain seasons. However, in the short rains, soybean yield ranged from 0.3 t ha^{-1} to 1.4 t ha^{-1} at Mwea recording lower yields than Embu where soybean yield ranged from 0.15 t ha^{-1} to 1.75 t ha^{-1} both sites in sole crop and intercrop. In both rain seasons, TGX1990-5Fpresented the highest yield followed by SB19 while GAZELLE showed the lowest yield in the sole crop and intercrop at Mwea. However, at Embu, variety GAZELLE presented higher grain yields of 2.17 t ha^{-1} followed by SB19 with 1.44 t ha^{-1} compared to TGX1990-5F which recorded the lowest yield of 0.91 t ha^{-1} in sole crop. However, TGX1990-5F recorded the highest grain yield of 0.43 t ha^{-1} followed by 0.39 t ha^{-1} for GAZELLE while SB19 recorded the lowest grain yield of 0.15 t ha^{-1} in intercrops. Mwea produced higher yield compared to Embu in both seasons. Intercropping reduced soybean grain yield in both sites and seasons (Table 7).

Harvest index (HI) showed significant difference between sites and seasons ($p \leq 0.05$). HI ranged from 0.17 to 0.42 at Mwea while Embu HI ranged from 0.10 to 0.54. SB19 variety presented the highest HI of 0.42 and 0.18 followed by 0.33 and 0.17 for GAZELLE while TGX1990-5F recorded the lowest HI of 0.29 and 0.17 in sole crops and in intercrops respectively at Mwea in long rainy seasons. However, GAZELLE presented higher HI of 0.48 followed by SB19 with 0.21 HI compared to TGX1990-5F with the lowest HI of 0.06 in sole crops at Embu long rain season. However, SB19 and TGX1990-5F recorded the

Table 3. Percent germination, plant height, days to 50% flowering and 75% maturity of Maize at Embu and Mwea during long rain 2016 and short rain 2016-2017

Long rains 2016												
Treatment	**Germination (%)**			**Plant height**			**Days to 50% floweing**			**Days to 75% Maturity**		
	Embu	**Mwea**	**Mean**	**Embu**	**Mwea**	**Mean**	**Embu**	**Mwea**	**Mean**	**Embu**	**Mwea**	**Mean**
Sole Maize	99.33a	99a	99.17a	112.1a	112.1a	112.1a	83.7b	64a	73.83a	120a	100a	110a
SB19 + Maize	99.33a	100a	99.67a	127.8a	127.7a	127.8a	84.7b	63.7a	74.16a	120.33a	101.67a	111a
Gazelle + Maize	99.67a	98.33a	99a	119.4a	119.5a	119.5a	83b	64a	73.5a	120a	100.33a	110.17a
TGX1990-5F+ Maize	100a	100a	100a	121.1a	118.9a	120a	85.33a	64.3a	74.83a	121a	101.33a	105.67a
Mean	99.58	99.33	99.33	120.1	119.55	119.83	84.16	64	74.08	120.33	100.83	110.58
LSD	20.34	6.66	8.9	32.25	31.44	33.4	2.13	1.37	8.97	1.91	1.97	5.16
CV%	10.9	3.4	5.5	13.4	13.2	13.6	1.3	1.1	7.4	0.8	1.0	4.0
Short rains 2016-2017												
Treatment	**Germination (%)**			**Plant height**			**Days to 50% floweing**			**Days to 75% Maturity**		
	Embu	**Mwea**	**Mean**	**Embu**	**Mwea**	**Mean**	**Embu**	**Mwea**	**Mean**	**Embu**	**Mwea**	**Mean**
Sole Maize	94.67a	100a	97.34a	164a	193.7a	178.9a	77.33a	63.67a	70.5a	113.3a	100a	106.7a
SB19 + Maize	98.67a	96.67a	97.67a	161.3a	172a	166.7a	77.67a	63.67a	70.67a	113.67a	100a	106.8a
Gazelle + Maize	97.67a	98.87a	98.27a	175.3a	178.8a	177.1a	77.33a	64a	70.67a	114.33a	100.67a	107.5a
TGX1990-5F+ Maize	83.20a	97.67a	90.44a	172a	178.4a	175.2a	77.33a	64a	70.67a	113.3a	100.33a	106.7a
Mean	93.55	98.30	95.93	168.15	180.73	174.44	77.42	63.84	70.63	113.65	100.25	106.9
LSD	20.34	6.66	8.9	20.16	33.75	33.4	1.52	1.37	8.97	1.91	1.49	5.16
CV%	10.9	3.4	5.5	6.0	11.5	13.6	1.0	1.1	7.4	0.8	0.7	4.0

LSD = Least significant difference. Means bearing the same letter are not significantly different (p ≤ 0.05)

Table 4. Shatering score, nodulation per plant, number of pod per plant, seed per pod for soybean during long rain 2016 and short rain 2016-2017

Long rains 2016												
Treatment	**Shattering score**			**Nodules/ plant**			**Pods/ plant**			**Seeds/ pod**		
	Embu	**Mwea**	**Mean**	**Embu**	**Mwea**	**Mean**	**Embu**	**Mwea**	**Mean**	**Embu**	**Mwea**	**Mean**
SB19	20abc	20.7ab	20.33b	30.4a	34.87b	32.6b	42.1a	81.3ab	61.7b	1.93a	2.3a	2.1a
GAZELLE	23.3ab	23ab	23.17b	32.9a	36.60b	34.8b	24.4a	61.3a	42.85b	2a	2.2a	2.1a
TGX1990-5F	11cd	11cd	11.00c	43.6b	46.87a	42.24a	82.7a	107.2a	94.95a	1.93a	2.7a	2.3a
SB19+MAIZE	25ab	16.3ab	20.67b	33.07a	35.53b	34.3b	13.0a	49.3b	31.15c	1.6a	2.3a	1.95a
GAZELLE+MAIZE	30a	36.67a	33.33a	29.87a	33.90b	31.8b	23.8a	46.7b	35.25c	1.8a	2.3a	2.05a
TGX1990-5F+MAIZE	8d	15ab	11.50c	43.40b	47.47a	45.44a	44.5a	106.8a	75.65b	1.7a	2.5a	2.1a
Mean	19.56	20.45	20.00	35.54	39.20	36.87	38.4	75.4	56.86	1.8	2.4	2.1
LSD0.05	5.26	12.76	8.25	5.59	3.33	4.03	32.79	34.78	26.02	0.52	0.49	0.48
CV%	14.8	34.3	21.3	8.7	4.7	6.6	46.9	25.3	36.7	15.6	11.5	13
Short rains 2016-2017												
Treatment	**SH**			**NODP**			**NPODP**			**SEEDPP**		
	Embu	**Mwea**	**Mean**	**Embu**	**Mwea**	**Mean**	**Embu**	**Mwea**	**Mean**	**Embu**	**Mwea**	**Mean**
SB19	25.56^{b}	18.33^{c}	21.9c	29.80b	35.3b	32.55b	22.5ab	57.7a	40.1a	2.6a	3b	2.8a
GAZELLE	46.63^{a}	30.66^{a}	38.64a	32.33b	36.4b	34.36b	33.3a	36.5ab	34.9a	2.7a	2.5ab	2.6b
TGX1990-5F	16.64^{b}	16.66^{d}	16.65c	43.73a	46.8a	45.26a	33.7b	48.4b	41.05a	2.4a	2.07a	2.2b
SB19+MAIZE	52.22^{a}	30.33^{a}	41.28a	28.07b	33.9b	30.98b	14.6b	24.3ab	19.45a	2.6a	2.4ab	2.5b
GAZELLE+MAIZE	18.89^{b}	30.00^{a}	24.45b	33.67b	35.1b	34.39b	17.1b	11.7a	14.4a	2.2a	2.7ab	2.45b
TGX1990-5F+MAIZE	13.33^{b}	25.00^{b}	19.17c	43.40a	46.8a	45.1a	10.6b	41.1ab	25.85a	2.08a	2.1ab	2.09b
Mean	28.87	25.16	27.02b	35.16	39.5	37.3	21.96	36.6	32.5	2.4	2.5	2.4
LSD0.05	13.43	0.94	8.25	5.66	2.71	4.03	14.12	33.04	26.02	0.45	0.52	0.48
CV%	25.6	2.3	21.3	8.9	3.8	6.6	35.4	49.6	36.7	10	11.6	13

LSD: Least significant difference, CV: Coefficient of variation, Means bearing the same letter are not significantly different ($p \le 0.05$)

Table 5. Soybean pod shattering and shattering scores at Mwea and Embu for long rains 2016 and short rains 2017

	Long rains 2016			Short rains 2016-2017		
Sites/ Treatment	**Mean shattering %**	**Shattering scores**	**Shattering reaction classification**	**Mean shattering %**	**Shattering scores**	**Shattering reaction classification**
EMBU						
SB19	20abc	2	R	25.56 b	3	MR
GAZELLE	23.33ab	2	R	46.63 a	3	MR
TGX1990-5F	11cd	2	R	16.64d	2	R
SB19+MAIZE	25ab	3	MR	52.22a	4	HS
GAZELLE+MAIZE	30a	3	MR	18.89b	2	R
TGX1990-5F+MAIZE	8d	2	R	13.33b	2	R
CV%	14.8	-		25.6	-	
$LSD_{0.05}$	5.26	-		13.42	-	
MWEA						
SB19	20.67ab	2	R	18.33^{c}	2	R
GAZELLE	23ab	2	R	30.66^{a}	3	MR
TGX1990-5F	11cd	2	R	16.66^{d}	2	R
SB19+MAIZE	16.33ab	2	R	30.33^{a}	3	MR
GAZELLE+MAIZE	36.65a	3	MR	30.00^{a}	3	MR
TGX1990-5F+MAIZE	15 ab	2	R	25.00^{b}	3	MR
CV%	34.3	-		0.94	-	
$LSD_{0.05}$	12.76	-		23.35	-	

CV: Coefficient of variation, LSD: Least significant difference. The scoring rate was as follows: 1 = No pod shattering (Very Resistant); 2 = < 25% pod shattering (Resistant); 3 = 25-50% pod shattering (Moderately Resistant); 4 = 51-75% pod shattering (Highly susceptible); 5 = > 75% pod shattering (Very Highly susceptible). R: Resistant, MR: Moderately Resistant, HS: Highly Susceptible, VR: Very Resistant, VHS: Very Highly Susceptible

highest HI of 0.28 compared to GAZELLE with the lowest HI of 0.10 in intercrops at Embu long rain season. The short rains showed lower HI than the long rains. However, GAZELLE showed the highest HI of 0.39 and 0.20 followed by SB19 with HI of 0.36 and 0.10 compared to TGX1990-5F with the lowest HI of 0.26 and 0.17 respectively in sole crop and intercrop at Embu in short rain season. Intercropping reduced HI at both sites and both seasons. Mwea produced the highest HI in both season compared to Embu (Table 7). LER did not give significant difference between sites in the long rains 2016. LER differed among treatments at Mwea where it ranged from 1.3 to 1.9. At Embu, LER did not give significant difference among treatments and it ranged from 1.5 to 1.8. TGX1990-5F showed the highest LER of 1.9 followed by SB19 with LER of 1.5, while GAZELLE presented the lowest LER of 1.3 at Mwea in long rain season. At Embu, SB19 showed the highest LER of 1.8 followed by GAZELLE with LER of 1.7 while TGX1990-5F produced the lowest LER of 1.5 in the long rains 2016. During the short rains LER showed significant difference between sites ($p \leq 0.05$). LER ranged from 1.10 to 2 at Mwea while at Embu LER it ranged from 1.06 to 1.62. TGX1990-5F showed the highest LER of 2.04 followed by SB19 with 1.31 while GAZELLE presented the lowest LER of 1.10 at Mwea. Embu did not give significant difference among treatments but TGX1990-5F showed higher LER of 1.62 followed by GAZELLE with LER of 1.53 while SB19 showed the lowest LER of 1.07 in the short rains. LER showed advantage between maize-soybean intercropped because it recorded higher value than 1 (Table 7).

3.3 Maize Growth and Production Parameters

3.3.1 Germination rate, plant height, days to 50% flowering and Days to 75% to maturity

Germination percentage and plant height of maize intercropped with soybeans and sole crops did not show significant difference both sites and both rain seasons. However, the days to 50 % flowering for maize were between 83-85 at Embu and 63-64 at Mwea for the long rains of 2016 while it took 77 days at Embu, and 63-64 days at Mwea for the short rains of 2016-2017. The days to 75% maturity were between 120-121 at Embu while at Mwea crops did not produce ears because of MLN which attacked the crops for the long rains 2016, but for the shot rains 2016-2017, MLN did not appear in the field. Days to 75% to maturity did not show significant difference between sites and seasons. The significant difference for 100 GW was shown in the short rains of 2016-2017 at Mwea and ranged from 19 g to 21 g. 100 GW from Embu ranged from 31 g to 34 g. Mwea did not produce maize grains because of MLN which destroyed plant in long rain 2016. Embu produced higher amount of 100 GW both seasons compared to Mwea in sole crop and in intercropping. However, plant biomass showed significant difference between sites and seasons. The biomass ranged from 5 t ha^{-1} to17 t ha^{-1} in sole crop and in intercropping at Mwea while plant biomass was among 12 t ha^{-1} to 15 t ha^{-1}at Embu. During the short rains of 2016-2017, plant biomass ranged from 3.66 t ha^{-1} to 17 t ha^{1} at Mwea and 12 t ha^{-1} to 23 t ha^{-1} at Embu in sole crop and in intercropping. Embu produced the highest plant biomass both seasons. Intercropping did not affect plant biomass both sites and seasons. Maize grain yield did not give significant difference between sites and seasons. Mwea site did not produce maize grain yield because of MLN which attacked crops in the long rains season 2016 but the experiment produced biomass which helped us to calculate LER. Maize grain yield ranged from 4.45 t ha^{-1} to 5.67 t ha^{-1} at Embu. During the short rains 2016-2017, maize grain yield ranged from 2.63 t ha^{-1} to 3.53 t ha^{-1} at Mwea while Embu maize grain yield was among 7.49 t ha^{-1} 9.62 t ha^{-1} in intercropping and in sole crop. Mwea produced the lowest amount of maize grain yield compared to Embu. Embu produced the highest amount of maize yield during the short rains 2016-2017 than the long rains 2016. Intercropping did not reduce maize grain yield both sites and seasons (Table 8).

Table 6. Hundred grain weight, biomass from Embu and Mwea during long rain 2016 and short rain 2016-2017

Long rains 2016						
Treatment	**100 grain weight**			**Biomass (t ha^{-1})**		
	Embu	**Mwea**	**Mean**	**Embu**	**Mwea**	**Mean**
SB19	16.47b	16.67c	16.57b	7.29b	8.23c	7.72c
GAZELLE	24.71a	24.33ab	24.52a	5.38b	7.89c	6.6c
TGX1990-5F	16.10b	18.33bc	17.22b	14.7a	12.9a	13.8a
SB19+MAIZE	24.05a	27.00a	25.52a	2.23b	4.48d	3.35c
GAZELLE+MAIZE	14.69b	14.67c	14.68b	2.92b	3.54d	3.23c
TGX1990-5F+MAIZE	14.49b	20.33abc	17.41b	7.51b	10.6ab	9.05b
Mean	18.42	20.22	19.32	6.67	7.9	7.3
LSD0.05	2.256	6.557	3.741	6.85	2.51	4.56
CV%	6.7	17.8	14.2	56.4	17.4	48.8
Short rains seasons						
Treatment	**100 grain weight**			**Biomass (t ha^{-1})**		
	Embu	**Mwea**	**Mean**	**Embu**	**Mwea**	**Mean**
SB19	13.09ab	11.24b	12.17a	2.57bc	4.92a	3.7b
GAZELLE	14.27a	12.98ab	13.63a	4.30a	4.84a	4.5b
TGX1990-5F	11.95ab	12.43ab	12.19a	3.98ab	10.06a	7.02a
SB19+MAIZE	10.23b	11.45b	10.84a	1.63c	3.43a	2.53b
GAZELLE+MAIZE	14.35a	12.79ab	13.57a	2.09c	2.11a	2.1b
TGX1990-5F+MAIZE	14.24a	14.62a	14.43a	2.98abc	5.86a	4.42b
Mean	13.02	12.58	12.80	2.9	5.2	4.04
LSD0.05	3.130	2.671	3.741	9.39	41.35	4.56
CV%	13.2	11.7	14.2	29.4	72.4	48.8

Least significant difference, CV: Coefficient of variation. Means bearing the same letter are not significantly different ($p \leq 0.05$)

Table 7. Yield, Harvest index and Land equivalent ratio in long rain at Embu and Mwea during long rain 2016 and short rain 2016-2017

Treatment	Yield t ha^{-1}			Harvest Index			Land Equivalent Ratio		
	Embu	Mwea	Mean	Embu	Mwea	Mean	Embu	Mwea	Mean
SB19	1.44b	3.1bc	2.27a	0.21c	0.42a	0.32a	1.8a	1.5b	1.66a
GAZELLE	2.17c	2.6b	2.38a	0.48ab	0.33ab	0.41a	1.7a	1.3b	1.51a
TGX1990-5F	0.91ab	3.7c	2.31a	0.06c	0.29ab	0.18b	1.5a	1.9a	1.7a
SB19+MAIZE	1.08b	0.8a	0.94b	0.54a	0.18b	0.36a	1.7a	1.5b	1.61a
GAZELLE+MAIZE	0.75ab	0.6a	0.68b	0.28c	0.17b	0.11b	1.8a	1.3b	1.56a
TGX1990-5F+MAIZE	0.44a	1.7ab	1.07b	0.10c	0.17b	0.14b	1.5a	1.9a	1.7a
Mean	1.13	2.08	1.61	0.28	0.26	0.25	1.66	1.6	1.63
LSD0.05	0.06	0.86	0.64	0.24	0.86	0.18	0.40	0.27	0.47
CV%	3.2	22.3	32	46.6	22.3	45.1	13.3	9.5	18.8
Treatment	**Yield t ha^{-1}**			**Harvest Index**			**Land Equivalent Ratio**		
	Embu	**Mwea**	**Mean**	**Embu**	**Mwea**	**Mean**	**Embu**	**Mwea**	**Mean**
SB19	0.92a	1.3a	1.11b	0.36ab	0.3a	0.33ab	1.07a	1.31ab	1.19b
GAZELLE	1.75a	1.4a	1.58a	0.39a	0.3a	0.35a	1.53a	1.10a	1.31b
TGX1990-5F	0.98a	0.7bc	0.84b	0.26abc	0.1a	0.18ab	1.62a	2.04b	1.83a
SB19+MAIZE	0.15a	0.3c	0.23b	0.10c	0.2a	0.15b	1.07a	1.31ab	1.19b
GAZELLE+MAIZE	0.39a	0.3c	0.35b	0.20abc	0.2a	0.2ab	1.53a	1.10a	1.32b
TGX1990-5F+MAIZE	0.43a	0.8b	0.62b	0.17bc	0.2a	0.19ab	1.62a	2.04b	1.83a
Mean	0.77	0.8	0.85	0.25	0.22	0.24	1.40	1.48	1.45
LSD0.05	1.09	0.39	0.64	0.19	0.23	0.18	0.69	0.43	0.47
CV%	77.2	26	32	43.6	61.8	45.1	24.9	16	18.8

Least significant difference, CV: Coefficient of variation. Means bearing the same letter are not significantly different (p ≤ 0.05)

Table 8. Maize hundred grains weight, biomass, and grain yield at Embu and Mwea during long rain 2016 and short rain 2016-2017

Long rains 2016									
Treatment	**100 grain weight (g)**			**Biomass(t ha^{-1})**			**Grain yield(t ha^{-1})**		
	Embu	**Mwea**	**Mean**	**Embu**	**Mwea**	**Mean**	**Embu**	**Mwea**	**Mean**
Sole Maize	28.32a	0.00	14.16a	12.7a	3.66b	8.15b	4.53a	0.00	4.53a
SB19 + Maize	26.92a	0.00	13.46a	15.32a	17.68a	16.51a	5.67a	0.00	5.67a
Gazelle + Maize	28.45a	0.00	14.23a	13.55a	17.35a	15.45a	5.65a	0.00	5.65a
TGX1990-5F+ Maize	26.48a	0.00	26.48a	13.78a	5.15b	9.47b	4.45a	0.00	4.45a
Mean	27.54	0.00	13.77	13.84	10.96	12.4	5.08	0.00	5.08
LSD	9.12	-	6.337	5.01	1.41	5.8	1.93	-	1.79
CV%	16.6	0.00	19.0	18.1	16.4	25	19	0.00	25.4
Short rains 2016-2017									
Treatment	**100 grain weight (g)**			**Biomass(t ha^{-1})**			**Grain yield (t ha^{-1})**		
	Embu	**Mwea**	**Mean**	**Embu**	**Mwea**	**Mean**	**Embu**	**Mwea**	**Mean**
Sole Maize	30.32a	20.62ab	25.47a	12.7b	3.66b	8.2b	8.18a	3.53a	5.86
SB19 + Maize	31.58a	21.22a	26.40a	15.3b	4.46b	9.89b	7.40a	3.47a	5.43
Gazelle + Maize	34.12a	19.15b	26.64a	23.12a	17.35a	20.23a	9.62a	2.63a	6.12
TGX1990-5F+ Maize	32.81a	20.23ab	26.52a	22.67a	12.1b	17.36a	9.40a	3.00a	6.2
Mean	32.21	20.30	26.26	18.46	9.38	13.92	8.65	3.15	5.9
LSD	12.46	1.893	6.337	6.64	9.74	5.8	3.17	17.9	1.79
CV%	19.4	4.7	19.0	15.1	31.3	25	18.3	28.3	25.4

LSD: Least significant difference, CV: Coeffient of variation. Means bearing the same letter are in the same group

Maize HI did not show significant difference between sites and seasons ($p \leq 0.05$). Mwea site did not produce HI because of maize which were destroyed by MLN that why they did not produce maize grain yield which could help for computing HI. Embu HI for long rains 2016 recording among 0.32 to 0.42. In addition, in the short rains Mwea HI ranged from 0.1 to 1.23 while Embu HI was between 0.33 to 0.43. Intercropping did not reduce maize HI both sites and seasons (Table 9).

Table 9. Maize harvest index, land equivalent ratio at Embu and Mwea during long rain 2016 and short rain 2016-2017

Long rains 2016			
Treatment	**HI**		
	Embu	**Mwea**	**Mean**
Sole Maize	0.35a	0	0.35a
SB19 + Maize	0.38a	0	0.38a
Gazelle + Maize	0.42a	0	0.42a
TGX1990-5F+ Maize	0.32a	0	0.32a
Mean	0.37	0	0.37
LSD	0.15	-	0.75
CV%	20.8	-	147.8
Short rain s 2016-2017			
Treatment	**HI**		
	Embu	**Mwea**	**Mean**
Sole Maize	0.43a	0.23a	0.33a
SB19 + Maize	0.33a	0.20a	0.27a
Gazelle + Maize	0.42a	0.15a	0.29a
TGX1990-5F+ Maize	0.42a	1.23a	0.83a
Mean	0.4	0.45	0.43
LSD	0.14	1.78	0.75
CV%	17.6	197.7	147.8

Harvest index, LER: Land equivalent ratio, LSD: Least significant difference, CV: Coeffient of variation. Means bearing the same letter are in the same group

4. DISCUSSION

4.1 Soybean and Maize Growth Paramaters

4.1.1 Germination rate in percentage (%)

During the short rains significant difference ($p \leq 0.05$) was observed in the sole crops and the intercrops between the sites but not in the long rains. Germination % was higher during the long rains recording 90% compared to the short rains that recording between 67 to 79%. The good performance in germination % could be due to supplemental irrigation to rain fall at both sites. Germination % of Maize did not show significant difference between sites both seasons ($p \leq 0.05$). Intercropping did not reduce the germination % of maize and soybean at both sites and seasons. Mwea site presented higher amount of germination % for maize than Embu for both seasons. This could be due to the presence of water for irrigation on time at Mwea while at Embu some time the water was not available in time. The poor germination % for the short rain seasons can be justified by the drought which was pronounced during critical growth phase of crops, hence, the high temperature could have reduced germination %. This agrees with Wang, (2005) who reported that, high temperatures (>15℃) and insufficient soil water reduced germination % in his experiment on different crops grown by farmers. Soybean plant height showed significant difference ($p \leq 0.05$) between sites and seasons. Mwea recording the tallest plant height ranging from 47 to 67 cm while Embu presented the shortest plant height ranged between 40 to 55 cm in the long rains. Plant heights ranging from 46 to 67 cm between sites. GAZELLE had the lowest plant height compared to other varieties. TGX1990 – 5F recorded the highest PH in sole crop and in intercrop at both sites. The tallest PH at Mwea could have been induced by the water for irrigation which was available on time compared to Embu where crops got irrigation water after long time of struggle with the drought. However, the presence of water at Mwea allowed nutrients uptake for the crops compared to Embu. These results confirm results for [23]. Who said that insufficient water supply can limit efficient nitrogen up take for good growth condition of plant while [24]. reported that water stress reduces plant nutrients uptake and reduces photosynthesis. Maize PH did not show significant difference in both sites and in two seasons. Maize plant height was 112 cm to 119 cm at Mwea compared to Embu where it was 112 cm to 120 cm. The short PH for maize at Mwea in long rain could be justified by MLN incidence and severity which were more pronounced at Mwea than Embu. During the short rains, Mwea regestred maize PH of 172 cm to 193 cm while Embu recorded maize PH ranging from 161 cm to 175 cm. The tallest maize PH recorded for the short rains at both sites can be attributed to the absence of MLN which would have reduced growth conditions for the maize. Also, the tallest soybean at Mwea for the long rains can be justified by the poor developpment of maize leaves attacked by MLN, thus the shading effect and competition from maize was minimal.However, all soybean varieties recorded the tallest PH in sole crops compared to the intercrops both rain seasons. For instance, TGX1990-5F recorded 54 cm in sole and 52.2 cm in intercrop at Embu while it recorded 81 cm in sole and 67.40 cm in intercrop at Mwea. This could be attributed to the effect of shading where taller crops compete with shorter crops for sunlight, water, nutrients and air. These results confirm [25]. Results, that; soybean is susceptible to moisture competition, probably a result of relatively small root system and inherently low water use efficiency. While [5]. reported that, light interception in intercropping had negative impact on plant height for short crops than taller crops compared to sole cropping. In addition, maize PH was not affected by intercropping in both sites and seasons. This agrees with [26], who reported that, PH did not show significant difference among sole maize and intercropped maize while [27], also found that maize in intercropping with cowpea did not have any effect on maize plant height. Days to 50% flowering and 75% maturity for soybean in the sole and the intercrop systems differed between the sites ($p \leq 0.05$). However the trend for days to 50% flowering and days to 75% maturity was similar for the 2 seasons. Days to 50% to flowering ranged from 69 days to 84 days at Embu while at Mwea it ranged from 48 days to 64 days among varieties in both seasons. In addition, days to 75% to maturity ranged from 95 days to 121 days at Embu and 80 days to 95 days at Mwea in both seasons. Days to 50% flowering and 75 % maturity were low at Mwea compared to Embu. This might be due to the fact that, Mwea is in low altitude compared to Embu with high altitude. Higher altitude could increase days to 50% flowering and 75% maturity while lower altitude could narrow 50% flowering and 75% maturity. For days to 50% flowering, the early variety to flowering SB19 took 49 days while the late variety to flowering TGX1990-5F took 64 days at Mwea in both seasons. The early variety to flower SB19, took 69 days while the late variety to 50% flowering TGX1990 – 5F took 84 days at Embu. However, the early variety to 75% to maturity SB19 took 80 days while the late variety TGX1990-5F took 95 days at Mwea. The early variety to 75% to maturity SB19 took 95 days while the late variety TGX1990-5F took 121 days both seasons. This variation could be justified by genetic makeup of different varieties. The variation in flowering and maturity could also be attributed to the climatic conditions in which the experiments were conducted. Mwea site is low altitude which resulted to the early crop maturity, while Embu high altitude enhanced the late crops maturity. This has also been reported by [28]. who said that, soybean varieties can be early maturing because of some genetic characteristics or environment. Nevertheless, intercropping did not reduce soybean and maize days to 50% flowering and 75% maturity at both sites and both seasons. This agrees with [29]. who reported that, intercropping of maize and beans had no effect on days to 50% flowering and 75% maturity of both component crops. Days to 50% flowering and days to 75% to maturity for maize did not give significant difference both sites and both rainy seasons. Soybean biomass showed significant difference ($p \leq 0.05$) between sites and seasons. TGX1990-F had the highest biomass of 12.9 t ha^{-1} followed bySB19 with 8.23 t ha^{-1} in sole crop and GAZELLE presented the lowest amount of biomass of 3.54 t ha^{-1} in intercropping at Mwea. TGX1990-5F presented the highest biomass of 14.7 t ha^{-1} compared to SB19 with the lowest biomass of 7.29 t ha^{-1} in sole crop at Embu. The high biomass production of TGX1990-5F compared to other varieties could be justified by its high plant height, vigor and yield. This agrees with [28]. Who reported that, high biomass production for soybean varieties could be due to their agronomic performances. SB19 produced the lowest amount of biomass in intercropping in the long rains of 2016. The short rains showed the lowest amount of biomass compared to the long rains. TGX1990-5F showed the highest biomass of 10t ha^{-1} in sole crop while GAZELLE presented the lowest amount of biomass of 2.11 t ha^{-1} at Mwea in intercropping. At Embu, GAZELLE showed the highest amount of biomass of 4.3 t ha^{-1} in sole crops while SB19 showed the lowest amount of biomass of 1.63 t ha^{-1} in intercropping. Intercropping reduced plant biomass in both seasons. Mwea produced higher soybean biomass compared to Embu in both seasons. The highest soybean biomass produced at Mwea compared to Embu could be attributed to the availability of water from irrigation as supplement for rain fall at Mwea than Embu. Also it could be explained by the DAP applied before planting both sites. This finding agrees with [30]. who said that, application of fertilizer which contain nitrogen would be also the base of high biomass production. However, [31] reported that, intercropping of climbing bean, cowpea with corn improved total fresh yield biomass of the component crops. Therefore, intercropping system increases not only yield stability but also mixed crops yielding more biomass than monocrops [32]. In addition, intercropping system reduced soybean biomass production [33,34]. However, maize biomass showed significant difference between sites and seasons. The biomass ranged from 5 t ha^{-1} to17 t ha^{-1} in sole crop as in intercropping at Mwea while plant biomass was from 12 t ha^{-1} to 15t ha^{-1} at Embu. During the short rains of 2016-2017, maize biomass ranged from 3. 66 t ha^{-1} to 17 t ha^{-1} at Mwea and 12 t ha^{-1} to 23 t ha^{-1} at Embu in sole crop as in intercropping. Embu produced the highest amount of maize biomass both seasons. The higher maize biomass produced at Embu than Mwea in long rains could be justified by the minimal incidence and severity of MLN at Embu compared to Mwea where MLN presented maximal incidence and severity on maize which could result to reduction of maize biomass production. For the short rains, the high maize biomass produced could be due to the good adaptation of the variety Duma 43 at Embu than Mwea. It can also be explained by the climatic conditions, because Embu is in high altitude which increased the number of days of vegetation, hence the biomass increased while the low altitude for Mwea reduced the number of days of vegetation hence the reduction of biomass. Intercropping did not affect maize biomass both sites and seasons. These results agree with [35] who reported that intercropping of cereal-legumes did not affect maize biomass.

4.2 Maize and Soybean Production Parameters

During the long rains of 2016, the number of pods per plant presented significant differences between sites in the sole crop as in the intercrop. The short rains did not show significant differences between the sites. TGX1990-5F had the highest number of pods of 107 followed by SB19 with 81 pods per plant in sole crop. GAZELLE showed the lowest number of pods of 46 in intercropping at Mwea. TGX1990-5F recorded the highest number of pods of 82.7 in sole crop while GAZELLE had the lowest number of pods of 13 in intercropping at Embu in the long rains of 2016. The difference between varieties in pod production could be due to genetic characteristics for each variety. During the short rains the number of pods was reduced in both sites compared to the long rains of 2016. TGX1990-5F recorded the highest number of pods and GAZELLE presented the lowest number of pods in sole crops and in intercropping. The reduction of the number of pods per plant in the short rains could be explained by the critical climatic conditions like insufficient rainfall which reduced the growth of the plant. Intercropping reduced the number of pods per plant for both seasons. These findings concurs with [36] who reported that, the number of pods per plant can be reduced by intercropping when the component crop has capacity to develop large leaves which causes shading hence photosynthesis is reduced as key point of pod formation. Mwea site presented the highest number of pods compared to Embu in both seasons. The highest number of pods presented by Mwea site is explained by the unhealthy conditions of maize associated with MLN which developed small quantities of leaves and which could not intercept sufficient light and compete more efficiently on nutrients uptake with soybean [37] in the first season, while in the second season, the highest amount of pods per plant can be explained by the quantity of water which was given to the plants as supplement to rainfall by irrigation. In addition, the long rains in 2016 did not show significant difference in seeds per pod between sites. The seeds per pod ranged from 2 to 2.7 at Mwea while they ranged from 1.6 to 2 at Embu. GAZELLE showed the highest number of seeds per pod of 2 at Embu while it received the lowest amount of seed per pod of 2.2 at Mwea in sole crop than other varieties. SB19 showed the lowest amount of seeds per pods of 1.6 at Embu in sole crop. The number of seeds per pod differed significantly during the short rains between sites and ranged from 2 to 3 at Mwea and from 2 to 2.7 at Embu in sole crop and in intercrop respectively.

SB19 presented the highest number of seeds per pods of 3 followed by GAZELLE with 2.5 and the last was TGX199-5F with 2.07 in sole crop at Mwea. Intercropping reduced the number of pods per plant. Mwea site presented the highest number of seeds per pod compared to Embu for both seasons. This can be attributed to the unhealthy conditions of maize infected by MLN which developed small quantities of leaves that could not intercept more light for photosynthesis and compete more efficiently on nutrients uptake with soybean [37]. The situation was not good for the short rains of 2016-2017 where the number of seeds per pod was reduced to 43.82% at Mwea for TGX1990-5F and 23.80% of the same variety. That could be attributed to unreliable rainfall that was received in the short rains season in both sites, hence the crops were unable to achieve good formation of pods and seeds [38]. Intercropping did not reduce the number of seeds per pod both sites and in two seasons. This agrees with [39] Who said that, the number of flowers for cowpea per plant were decreased by intercropping but that cropping system didn't decrease significantly the number of seeds per pods and weight of seeds. Shattering score showed significant difference between sites and seasons ($p \le 0.05$). The shattering score ranged from 11% to 36% at Mwea while shattering score for Embu ranged from 8% to 30% in sole crop and in intercropping The high number of pods shattering at Mwea compared to Embu can be justified by the low altitude of Mwea which could increase temperature (22℃), hence increasing the shattering score compared to Embu with high altitude and low temperature (20℃), hence reducing the shattering score. This agrees with [18] who reported that, soybean varieties possessing resistance to pods shattering resistance is most important in improvement of soybean in the tropics where the temperature can lead to the loss of yield through pods shattering. GAZELLE presented the highest shattering score of 36.67% in intercropping, followed by SB19 (20.7%) in sole crop while TGX1990-5F showed the lowest shattering score of 11% in the sole crop at Mwea. TGX1990-5F presented the lowest shattering score of 8% at Embu in intercropping in compared to GAZELLE which showed the highest shattering score of 30% followed by SB19 (25%) in intercropping too in the long rains of 2016. The high shattering score for GAZELLE could be justified by its genetic characteristic to pod shattering compared to other varieties. During the short rains, shattering score ranged between 16% and 30% at Mwea, while Embu presented shattering score ranging from 16% to 52%. The highest shattering score at Embu could be explained by the drought which occurred during the harvesting period and insufficient water for irrigation at Embu than Mwea. These results are corroborated by [40] who reported that, different weather patterns, especially temperature and rain fall in each year might be essential factors affecting pods shattering patterns. However, GAZELLE presented the highest amount of shattering score of 30.66% compared to TGX1990-5F which had the lowest shattering score of 16.66% in sole crops at Mwea. SB19 showed the highest shattering score for 52.22% while TGX1990-5F showed the lowest shattering score of 13.33% in intercropping. Thus, following the shattering score scale, TGX1990 – 5F was among varieties which were resistant to pod shattering because it's score shattering scale was 2, and GAZELLE with SB19 were among varieties which were moderately resistant to pod shattering considering it's scale shattering score which was many times 3 than 2 in two rains seasons [18]. Intercropping did not increase pod shattering. TGX1990-5F can be recommended to the small scale farmers in the tropical conditions because it was resistant to pod shattering following the scale of pod shattering score.

Hundred grain weights showed significant difference ($p \le 0.05$) between sites in the sole crop and in intercropping. SB19 recorded the highest 100 grain weight of 27 g compared to GAZELLE which recorded the lowest 100 grain weight of 14.67 g in intercropping at Mwea. GAZELLE presented the highest 100 grain weight of 24.71 g in sole crop while it showed the lowest 100 grain weight in intercropping at Embu. However, 100 grain weight did not have significant difference between sites in the short rains but significant difference was observed among treatments in both sites. TGX1990-5F showed the highest 100 grain weight of 14.62 g in intercropping while SB19 presented the lowest 100 grain weight of 11.24 g in sole crop at Mwea. GAZELLE showed the highest 100 grain weight of 14.27 g in sole crop compared to SB19 which had the lowest 100 grain weight of 10.23 g at Embu. Mwea presented the highest 100 grain weight than Embu at both seasons. The higher 100 grain weight for Mwea compared to Embu could be due to the better adaptation of varieties at Mwea compared to Embu. This could also result from the availability supplemental irrigation at Mwea compared to Embu in two rainy seasons. However, on the results obtained in the sole crop and in intercropping, intercropping reduced soybean 100 grain weight. Similar results were obtained by [41] who reported that maize-soybean intercropping reduced 100 grain weight for soybean during two years (2007) and (2008). In addition, [42] found that, 100 grain weight was significantly reduced by intercropping of soybean-sugarcane, by 16.12 to 9.53% respectively in sole crops compared to intercrop. For [43], maize-soybean intercropping affected negatively 100 grain weight in intercropping than in sole crop in one season (2002). The long rains of 2016 had a higher 100 grain weight compared to the short season. This could due to the sufficient water which was available during the first season than the second allowing for good formation of grain. However, 100 grain weight for maize did not give significant difference between sites for the long rains of 2016. Mwea did not produce maize grains because of MLN which destroyed the grain. Mwea 100 GW ranged from 26 g to 28 g .The significant difference for 100 GW was visible in the short rains 2016-2017 at Mwea, where it ranged from 19 g to 21 g. 100

GW from Embu ranged from 31 g to 34 g. Embu produced higher 100 GW in both seasons compared to Mwea in sole crop and in intercropping respectively. The high 100 grain weigh from Embu compared to Mwea can be explained by the good performance of variety maize Duma 43 used at Mwea compared to Embu. GAZELLE variety can be recommended as sole crop because it showed higher 100 GW while SB19 and TGX1990-5F can be recommended for intercropping. Soybean yield showed significant difference ($p \leq 0.05$) between sites in the long rains of 2016. Soybean yield ranged from 0.6 t ha^{-1} to 3.7 t ha^{-1} at Mwea compared to Embu where soybean yield ranged from 0.44 t ha^{-1} to 2.17 t ha^{-1}. TGX1990-5F presented the highest yield of 3.7 t ha^{-1} in sole crop while GAZELLE showed the lowest yield of 0.6 t ha^{-1} in intercropping at Mwea. At Embu, GAZELLE presented the highest yield of 2.17 t ha^{-1} in sole crops compared to TGX1990-5F which recorded the lowest yield of 0.44 t ha^{-1} in intercropping. The short rains recorded the lowest yield compared to the long rains of 2016. Mwea yield ranged from 0.3 t ha^{-1} to 1.4t ha^{-1} and Embu yield ranged from 0.15 t ha^{-1} to 1.75 t ha^{-1}. GAZELLE recorded higher yield of 1.4 t ha^{-1} in sole crops than SB19 with 0.3 t ha^{-1} at Mwea in intercropping. variety GAZELLE recorded the highest yield of 1.7 t ha^{-1} compared to SB19 with the lowest yield of 0.15 t ha^{-1} in intercropping. Mwea produced higher yield compared to Embu in both seasons. The higher soybean yield from Mwea than Embu for both seasons could be explained by the adaptation of the genotypes cultivated which could be perform better at Mwea than Embu. In addition, the irrigation on time as supplement for rainfall for Mwea compared to Embu provided more moisture for genotypes to produce better yield. Intercropping system reduced soybean yield both sites and seasons. That could be due to competition between soybean and maize for water, nutrients, air and light compared to the sole crops [21,36,37]. However, [44] reported that the yield of soybean decreased in intercropping with maize than sole crops and maize benefits more from intercropping than soybean. In addition, [45] reported that, the roots of crops in intercropping compete for growth factors such as nutrients, light and moisture which may reduce legumes yield in cereal-legumes intercropping. For [33] legumes could become pest in an intercropping system by shading the components crop(s) and thereby reducing yield. [37] Further showed that indeed cowpea yields were depressed due to shading in intercropping while maize gained from this intercropping.However maize grain yield did not give significant difference in the sole and intercrop at Embu ($p \leq 0.05$). Mwea maize production was infested by MLN disease especially in the long rains seasons of 2016 but the experiment produced biomass which was used to calculate LER. Maize yield ranged from 4.45 t ha^{-1} to 5.67 t ha^{-1} at Embu. During the short rains 2016-2017, maize grain yield ranged from 2.63 t ha^{-1} to 3.53 t ha^{-1} at Mwea while at Embu maize yield was 7.49 t ha^{-1} and 9.62 t ha^{-1} in intercropping as in sole crop. Mwea produced the lowest amount of maize yield compared to Embu. Embu produced the highest amount of maize yield during the short rains of 2016-2017 compared to the long rains of 2016. The higher maize yield production for Embu compared to Mwea could be justified by adaptation of the variety (Duma 43) at Embu compared to Mwea. Intercropping did not reduce maize yield both sites and seasons. MLN incidence and severity was significantly different between sites ($p \leq 0.05$). The highest MLN scoring (5) was recorded at Mwea. Embu had low incidence and severity. This situation could be due to environmental differences in the two sites. Mwea site is in low altitude with high temperature while Embu site is in high altitude with low temperature. The high temperature of Mwea could have accelerated the development of MLN incidence and severity compared to Embu. This agrees with [46] who reported that, the incidence and severity of MLN varies with plant age, time of infection, genotype and environment. However, Mwea lost total maize grain yield through MLN attack, and only the biomass was harvested. This results are corroborated by [47] who reported that, the losses of maize production due to MLN is between 50% and 90% depending on varieties. Soybean Harvest Index (HI) showed significant difference between sites and seasons ($p \leq 0.05$). HI was 0.17 to 0.42 at Mwea while Embu showed HI of 0.10 to 0.54 in sole crop as in intercropping. SB19 variety presented the highest HI of 0.42 and TGX1990-5F showed the lowest HI of 0.17 at Mwea. However, SB19 showed the highest HI of 0.54 while TGX1990-5F showed the lowest HI of 0.10 in intercropping at Embu in the long rains of 2016. The short rains showed the lowest HI compared to the long rains. Mwea site did not show significant difference among treatments and HI ranged from 0.1 to 0.33 while Embu HI differed and ranged from 0.1 to 0.39 in sole crop. GAZELLE gave the highest HI of 0.3 in sole crop and TGX1990-5F presented the lowest HI of 0.1 at Mwea in sole crop. GAZELLE showed the highest HI of 0.39 in sole crop compared to SB19 which showed the lowest HI of 0.10 in intercropping at Embu. Intercropping reduced HI in both sites and both seasons. This agrees with [17], who said that, the higher plant population in intercrops decrease HI while lower plant population in sole crops tend to increase HI. Mwea produced the highest HI both seasons than Embu. The highest HI produced at Mwea compared to Embu could confirm the highest soybean yield recorded as results to sufficient water which was provided by rainfall and irrigation to supplement rainfall at Mwea. During the long rains at Embu SB19 produced low yield of 1.08 t ha^{-1} with high HI of 0.54 in intercrops. This finding agrees with [48] who reported that, grain yield and harvest index of grain legumes are highly variable and even plant with good health sometimes give poor yields. The cause of that variability in grain yield and low HI are under research until now. In addition [19] reported that, for wheat or cereals, the main progress in breeding for higher yields is obtained principally between man-made selection forces for the harvest index (HI), that is, an increased plant capacity to allocate biomass (assimilates) into the formed reproductive parts. The relationships of harvest index with biomass and grain yield follow the multiplicative yield component model, in which grain yield is a product of harvest index and biomass yield. However, morpho-physiological assessment done by researchers in a modern wheat collection says that the increased partitioning of the dry matter into grains already attained its physiological justified limit (HI value of around 0.6). In addition, GAZELLE showed higher yield of 2.17 t ha^{-1} at Embu with higher HI of 0.48 in the long rains seasons in sole crops. This agrees with [19], whore ported that, the higher HI exhibited the higher grain yield in his experiment on cereals-legumes. This could be due to assimilation of the biomass in grain yield by GAZELLE compared to other varieties. This was in agreement with [49] who reported that, low biomass production yield allowed higher HI production hence higher grain yield production. Maize HI did not show significant difference between sites and seasons ($p \le 0.05$). HI for Mwea was not calculated because of MLN which attacked Maize and the grain yield was lost completely in the long rain season. Embu HI for long rains 2016 ranged from 0.32 to 0.42. For the short rains Mwea HI ranged from 0.1 to 1.23 while Embu HI was between 0.33 to 0.43. Intercropping did not reduce maize HI both sites and seasons. This results agrees with [50,51] who reported that, maize HI was stable in sole crops and in intercrops when it was intercropped with sunflower and soybean. The higher HI can also be attributed to the observed increases in nutrients at both sites which could have been due to beneficial effects of intercropping maize and soybean (Tables 8 and 9)

4.3 Yield Advantage Assessed by Land Equivalent Ratio

LER did not give significant difference between sites in the long rains of 2016. LER differed among treatments at Mwea where it ranged from 1.3 to 1.9. Embu did not show significant difference and LER ranged from 1.5 to 1.8. TGX1990-5F showed the highest LER of 1.9 at Mwea while GAZELLE presented the lowest LER of 1.3. However, TGX1990-5F showed the lowest LER of 1.5 at Embu compared to SB19 which presented the highest LER of 1.8 in the long rains 2016. During the short rains LER showed significant difference between sites ($p \le 0.05$). LER ranged from 1.10 to 2 at Mwea while at Embu LER was 1 .06 to 1.62. Variety TGX1990-5F showed the highest LER of 2.04 and GAZELLE variety presented the lowest LER of 1.10 at Mwea. Embu did not give significant difference among treatments but TGX1990-5F showed the highest LER of 1.62 while SB19 showed the lowest LER of 1.06. TGX1990-5F was taken as the best promiscious soybean for intercropping with maize because it showed land equivalent ratio with advantage for the components crops. The Land Equivalent ratio showed the advantage between component crops because it was higher than 1. This finding agrees with [52,53,54,55] who recorded LER greater than 1.00 in cereals-legumes cropping system. Variety TGX1990-5F recorded the highest LER of 1.62 at Embu. [56,57], confirmed that, land equivalent ratio of 1.62 means that an area shown as sole crops, need 62% more land to produce the same yield as the same area planted in an intrecrops combination. In addition, [58] reported that, the use of N increased LER and showed efficient utilisation of land in different planting pattens. [59] also reported that, cropping system improved total yield which was maried with greater land equivalent ratio.

5. CONCLUSION

The study revealed that growth parameters and production paramaters for soybean decreased in intercropping than in the sole crop. Maize was not affected significantly by intercropping. GAZELLE gave the highest yields followed by

TGX1990-5F and SB19 showed the lowest yields in sole crop between sites in the long rains 2016. The short rains showed significant difference between sites. This season showed the lowest yields between sites compared to the long rains of 2016. Variety TGX1990-5F recorded the highest yields in the intercrop followed by GAZELLE and SB19 was the last. LER for TGX1990-5F was 1.7 followed by SB19 (1.66) and SB19 recorded the lowest LER of (1.51) between sites in the long rains 2016. However, LER for TGX1990-5F was 1.83 followed by GAZELLE (1.31) and SB19 recorded the lowest LER of (1.19) between sites in the short rains. Based on the yield and yield component performance both in the sole and the intercrop as well as LER, variety TGX1990-5F was émergéd as the most suitable promisuous soybean for intercropping with maize.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Chianu JN, Nkonya EM, Mairura FS, Chianu JN, Akinnifesi FK. Biological nitrogen fixation and socioeconomic factors for legume production in sub-Saharan Africa. Agriculture Sustainable Development, Lilongwe, Malawi. 2009; 31(2011):309–329. Available:https://doi.org/10.1007/978-94-007-0394-0_17
2. Burstin J, Gallardo K, Mir RR, Varshney RK, G. Duc JB, Karine G, GDU. Improving protein content and nutrition quality. Biology and Breeding of Food Legumes. International Crops Research Institute for Semi-Arid Tropics (ICRISAT). 2011;1-34. ISBN: 9781845937669
3. Matusso JMM, Mugwe JN, Mucheru-Muna M. Potential role of cereal-legume intercropping systems in integrated soil fertility management in smallholder farming systems of sub-Saharan Africa Résumé. Third RUFORUM Biennial Meeting 24 - 28, Entebbe, Uganda Willey, (September). 2012;29.
4. Thyamini HS, BI. Review on maize based intercropping. Journal of Agronomy, Departement of Crop Science, Faculty of Argiculture, Eastern University, Sri Lanka. 2010;9(3):135-145.
5. Ijoyah MO. Review of intercropping research: Studies on cereal-vegetable based cropping system. Scientific Journal of Crop Science, Makurdi, Nigeria. 2012; 1(3):55–62. Available:https://doi.org/10.14196/sjcs.v1i3.326
6. Masuda T, Goldsmith PD. World soybean production: Area harvested, yield, and long-term projections. International Food and Agribusiness Management Review, Urbana, Illinois. 2009;12(4):143–162.
7. Abuli. A brief history of soybean production in Kenya. Research Journal of Agriculture and Environmental Management. Kenyatta University, Nairobi, Kenya. 2016;5(2):058-064.
8. Puji Lestari, Sutrisno IMT. QTL study to reveal soybean response on abiotic and biotic stresses. Jurnal Agro Biogen. 2014; 10(3):109–114.
9. Remison. Neighbour effects between maize and cowpea at various levels of N and P. Expl Agric. 1978;14:205-212.
10. Belel MD, Halim RA, Rafii MY, Saud HM. Intercropping of corn with some selected legumes for improved forage production: A review. Journal of Agricultural Science, University of Putra Malaysia, Malaysia. 2014;6(3):48–62. Available:https://doi.org/10.5539/jas.v6n3p48
11. Bhagat SB, Chavan SA, Zagade MV, Dahiphale AV. Intercropping groundnut and sweet corn at different fertility levels and row proportions. Indian J. Crop Science, Dapoli, India. 2006;1(1-2):151-153.
12. Kueneman E, Pulver E. Identification of promiscuous nodulating soybeans efficient in N2 fixation. Colleccion Historica, Cali, Colombia. 1998;2:1-24.
13. Mpepereki S, Javaheri F, Davis P, Giller KE. Soyabeans and sustainable agriculture; Promiscuous soyabeans in southern Africa. Field Crops Research. 2000;65(2–3):137–149.

Available:https://doi.org/10.1016/S0378-4290(99)00083-0
14. Kirinyaga C. Kirinyaga county transition implementation plan, Office of the Governor, Kirinyaga county, KUTUS, Kenya, P.O.Box 260-10034. 2014;1-64.
15. Embu C. Office of the controller of budget embu county budget implementation review report first quarter Fy 2013 / 2014, Nairobi, Kenya,(October 2013); 2014.
16. Roy R, Finck A, Blair G, Tandon H. Nutrient management guidelines for some major field crops. Plant Nutrition for Food Security. 2006;349.
17. Naim AM El, Jabereldar AA, Ahmed SE, Ismaeil FM, Ibrahim EA. Determination of suitable variety and plants per stand of cowpea (*Vigna unguiculata* L. Walp) in the Sandy. 2012;2(1):1–5. Available:https://doi.org/10.5923/j.als.20120201.01
18. Krisnawati A, Adie MM. Variability on morphological characters associated with pod shattering resistance in soybean. Biodiversitas, East Java, Indonesia. 2017;18(1):73–77. Available:https://doi.org/10.13057/biodiv/d180111
19. Wnuk A, Górny AG, Bocianowski J, Kozak M. Visualizing harvest index in crops. Communication in Biometry and Crop Science. 2013;8(2):48–59.
20. Aziz A, El-razek AA. Yield and its components of maize / soybean intercropping systems as affected by planting time and distribution. Australian Journal of Basic and Applied Sciences, Tanta University, Egypt. 2012;6(13):238–245.
21. Amanullah, Faisal Khan, Haji Muhammad AUJ, GA. Land equivalent ratio, growth, yield and yield components response of mono-cropped vs. inter-cropped common bean and maize with and without compost application. Agriculture and biology journal of north america, University of Agriculture Peshawar, Khyber Pakhtunkwa-Pakistan. 2016;40–49. Available:https://doi.org/10.5251/abjna.2016.7.2.40.49
22. ILRI-ICRAF. Discovery Edition 3; 2007.
23. Hermanson R, William P, Cathy P, Robert S, laudio S. Nitrogen Use by Crops and the Fate of Nitrogen in the Soil and Vadose Zone, Washington State University and Washington Departement of Ecology, Washington, USA. 2015;1-1-248.
24. Rezaei M, Vahed HS, Amiri E, Motamed MK, Azarpour E. The effects of irrigation and nitrogen management on yield and water productivity of rice. 2009;7(2):203–210.
25. Simpson JA. Effects of shade on maize and soybean productivity in tree based intercrop system. Master of Science Thesis, University of Guelph, Canada, USA. 1999;1-116.
26. Muoneke CO, Ogwuche MAO, Kalu BA. Effect of maize planting density on the performance of maize / soybean intercropping system in a guinea savannah agroecosystem. Journal of Agricultural Research. 2007;2(December):667–677.
27. Thobatsi T. Growth and yield responses of maize (*Zea mays* L.) and cowpea (Vigna unguiculata L.) in an intercropping system. Master of Science in Agronomy Thesis, University of Pretoria, Pretoria, South Africa. 2009;1-159.
28. Sileshi D. Evaluation of soybean varieties under different planting pattens for intercropping in sugarcane at finchaa sugarestate. Master of Science Thesis in Agriculture, Haramaya University, western ethiopia, Ethiopia. 2013;1-77.
29. Abubaker S. Effect of plant density on flowering date, yield and quality attribute of bush beans (*Phaseolus vulgaris* L.) under center pivot irrigation system. American Journal of Agriculture and Biological Sciences, Al Balqa' Applied University, Salt, Jordan. 2008;3(4):666–668.
30. Mugendi E, Gitonga N, CR, MJ. Biological Nitrogen fixation by promuscuous soybean in the central highland of Kenya: Response to Inorganic fertilizer soil amendments. World Journal of Agricultural Sciences. Nairobi, Kenya. 2010;6(4):381-387.
31. Geren H, Avcioglu R, Soya H, Kir B. Intercropping of corn with cowpea and bean: Biomass yield and silage quality. African Journal of Biotechnology, Ege University, Izmir, Turkey. 2008;7(22): 4100–4104.
32. Karpenstein-machan M, Stuelpnagel R. Biomass yield and nitrogen fixation of legumes monocropped and intercropped with rye and rotation effects on a subsequent maize crop. Plant and Soil, University Kassel -Witszenhausen, Witzenhausen, Germany. 2000;218:215–232.
33. Sarkodie J, Kahaman A. Spatial arrangements and time of introducing an

intercrop on the productivity of component crops in maize - soybean intercropping systems. Interational Journal of Science and Advanced Technology,University of Science and Technology, Kumasi, Ghana. 2012;2:103-107.

34. Fujita K, Ofosu-budu Kwabena G. Biological nitrogen fixation in mixed legume-cereal cropping systems. Plant and Soil, University of Hawai, Honolulu, Hawaii, USA. 1992;141:1-225.

35. Prasad RB, Brook RM. Effect of varying maize densities on intercropped maize and soybean in Nepal. Experimental Agriculture. 2005;41(3):365–382. Available:https://doi.org/10.1017/S0014479705002693

36. Sloger C. Symbiotic effectiveness and N2 fixation in nodulated soybean. Plant Pysiol, Beltsville, Maryland. 1969;44(577):1666–1668.

37. Kinama JM, Ong CK, Stigter CJ, Ng JK. Hedgerow intercropping maize or cowpea / senna for drymatter production in semi-arid Eastern Kenya. Journal of Agricultural Science and Technology B 1. 2011;372-384.

38. Shadreck N. Water use efficiency and economic effects of a maize -lagume intercropping system. Master of Science Thesis in Agonomy,University of Zambia, Lusaka, Zambia. 1999;1-108.

39. Legwaila GM, Marokane TK, Mojeremane W. Effects of intercropping on the performance of maize and cowpeas in Botswana. International Journal of Agriculture and Forestry, Gaborone, Botswana. 2012;2(6):307–310. Available:https://doi.org/10.5923/j.ijaf.20120206.07

40. Zhang L, Bellaloui N. Effects of planting and maturity dates on shattering patterns under early soybean production system. American Journal of Plant Science, 2012; 119–124.

41. Undie UL, Uwah DF, Attoe EE. Effect of Intercropping and crop arrangement on yield and productivity of late season maize / soybean mixtures in the humid environment of South Southern Nigeria. 2012;4(4):37–50. Available:https://doi.org/10.5539/jas.v4n4p37

42. Li X, Mu Y, Cheng Y. Effects of intercropping sugarcane and soybean on growth, rhizosphere soil microbes, nitrogen and phosphorus availability. Acta Physiol Plant, Krakow, China. 2013;1113–1119. Available:https://doi.org/10.1007/s11738-012-1148-y

43. Mbah EU, Muoneke CO, Okpara DA. Effect of compound fertilizer on the yield and productivity of soybean and maize in soybean/ maize intercrop in southeastern Nigeria. Tropical and Subtropical Agroecosystems, Mérida, Yucatan, México. 2007;7(2):87-95.

44. Issahaku A. Spatial arrangements and time of introduction an intercrop on the productivity of component crops in Maize - soybean intercropping systems, Master of Science in Agronomy Thesis, Kwame Nkrumah University of Science and Technology , Ghana, Accra. 2010;1-116.

45. Rana SS, Rana MC. Cropping system. 2011;176062.

46. Nelson S, Brewbaker J, Hu J. Maize Chlorotic Mottle. 2011;1(December):1–6.

47. Miano DW. Maize lethal necrosis disease: A real threat to food security in the eastern and central africa. College of Agriculture Sciences, University of Nairobi, Kenya. 2010;1-11.

48. Ayaz S. Variability of harvest index in four grain legumes species. Doctor of Philosophy thesis, Lincoln University, Canterbury, New Zealand. 1994;1-229.

49. Scott. Components of grain yield in wheat. Doctor of Philosophy Thesis, University of Canterbury, New Zealand. 1977;1-179.

50. Sadras O, Calvin PA, Helianthus L, Triticum L. Quantification of grain yield response to soil depth in soybean. Agronomy Journal. 2001;93:577–583.

51. Stoltz E, Nadeau E. Field crops research effects of intercropping on yield, weed incidence , forage quality and soil residual N in organically grown forage maize (*Zea mays* L .) and faba bean (*Vicia faba* L .). Field Crops Research, Orebro, Sweden. 2014;169:21–29.

52. Sullivan. Intercropping principles and production practices. Agronomy System Guide, Fayetteville, Arkansas. 2003;1-12.

53. Hugar HY, Palled YB. Effect of intercropped vegetables on maize and associated weeds in maize-vegetables intercropping systems. Karnataka Journal of Agricultral Science, Karnataka, India. 2008;21(2):159–161.

54. Addo-Quaye AA, Darkwa AA, Ocloo GK. Growth analysis of component crops in maize -soybean intercropping system as affected by time of planting and spatial

arrangement. ARPN Journal of Agricultural and Biological Science, University of Cape Coast, Ghana. 2011;6(6):34–44.
55. Yusuf Bissallah, Aiyelari A, Audu. Evaluation of the planting schedule of soyabean (*Glycine max* L. Merril) /maize (*Zea mays*) Intercrop systems for optimum yields in the guinea savanna of Nigeria. Continental J. Agriculture Science. 2012; 6(3):50–55.
Available:https://doi.org/10.5707/cjagricsci.2012.6.3.50.55
56. Sylvia. Comparing yields with land equivalent ratio (LER). Agricultural and Natural Resources, Fact Sheet. 1999;532: 2980:1–2.
57. Dariush M, Ahad M, Meysam O. Assessing the land equivalent ratio of two corn varieties intercropping at various levels in Karaj, Iran. College of Agriculture of Tehran University Islamic Azad University of Ramhormoz, Khosestan, Iran Manuscript. 2006;7(2):359–364.
58. Khan Zada SA, Nazar MS. Land equivalent ratios, relative yields and relative yield totals of intercropping maize and soybean. Journal of Agriculture Research, Pakistan, 1988;9(4):453-457.
59. Adam S, Mohammed A. Assessing the land equivalent ratio (LER) of Two Leguminous Pastures (CLITORIA and SIRATRO) Intercropping at Various Cultural Practices and Fencing at ZALINGEI – Western Darfur State - Sudan. ARPN Journal of Science and Technology, University of Zalingei-Zalingei-western Darfur state, Sudan. 2012;2(11):1074–1080.

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