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Original Research Article

~~Assessment of soybean varieties on growth and production parameters in intercropping with maize in Kenya~~

Abstract

Soybeans which nodulate effectively with diverse indigenous rhizobia~~-~~are considered as promiscuous~~. As such~~ therefore ~~determination~~ of their suitability in the intercrop system is important. Three varieties namely ; GAZELLE, SB19 and TGX1990 – 5F were used in this study to assess ~~the most suitable promiscuous variety for~~ intercropping with maize at KALRO Embu and KALRO Mwea, Kenya ~~in~~ the long rain~~s~~ of 2016 and short rain~~s~~ of 2016-2017. The experimental design was laid out in randomised complete block design replicated three times with seven treatments where T1=SB19, T2 = GAZELLE, T3 = TGX1990 – 5F, T4 = SB19 + MAIZE, T5 = GAZELLE + MAIZE, T6 = TGX1990-5F + MAIZE, T7 = MAIZE (Duma 43). The spacing used was 80cm between rows of maize and 25cm within rows. Soybean was planted between 2 rows of maize at a spacing of 15cm within rows. The arrangement of intercropping was 1:1 ~~which means,~~ one row of maize ~~intercepted~~ with one row of soybean. Data collection was done on germination %, plant height (cm), 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. In addition, , shattering score (1-5), number of pods per plant, number of seeds per pod were collected for soybean only. Data were subjected to ANOVA and means separated using $LSD_{0.05}$. The results showed that growth and production parameters were ~~significant~~ different ($p \leq 0.05$). The sole crops showed the tallest plants compared to the intercropping indicating that intercropping reduced soybean plant height in both rainy seasons. Mwea recorded taller plants compared to Embu in both rainy seasons. TGX1990-5F showed tallest plants followed by SB19 while GAZELLE recorded the ~~lowest~~ plants ~~in~~ both sites in both rainy seasons. However, the earliest variety to 50 % flowering and 75 % maturity was SB19 followed by GAZELLE and the latest flowering and maturity variety was TGX1990-5F. Intercropping did not affect days to 50 % flowering and days to 75% maturity. Variety TGX1990-5F was most resistant to pod shattering while SB19 and GAZELLE were moderately resistant. Variety TGX1990-5F recorded the highest number of pods followed by SB19 while GAZELLE ~~presented~~ the lowest number of pods in sole crop and in intercropping. Intercropping reduced the number of pods per plant in both seasons. Mwea site ~~presented~~ the highest number of pods compared to Embu in both seasons. The number of seeds per pod was not reduced by intercropping and they ranged from ~~(1-3)~~ for all varieties. TGX1990-5F produced highest biomass followed by SB19 while GAZELLE recorded the lowest biomass at both sites and rain seasons. Intercropping reduced soybean yield biomass at both sites and both rains seasons. Mwea ~~produced~~ higher biomass compared to Embu for both seasons. TGX1990-5F recorded the highest soybean grain yields ~~between sites during the long rains (1.07 t ha^{-1}) and short rains (0.62 t ha^{-1}) compared to SB19 with lower soybean grain yields between sites (0.95 t ha^{-1} and 0.23 t ha^{-1}) during long rains and short rains respectively.~~ Intercropping reduced soybean grain yields compared to monocrops in both sites and seasons. GAZELLE had highest HI followed by SB19 while TGX190-5F recorded the lowest HI for both sites and seasons. Intercropping reduced HI in both sites and seasons. TGX1990-5F showed highest LER (1.7) compared ~~to (1.51) for~~ GAZELLE between sites in the long rains while in short season LER was 1.83 for TGX1990-5F compared to 1.19 for SB19 in between sites. LER showed advantage between component crops in both sites and seasons. Finally TGX1990-5F was ~~taken as~~ suitable promisuous soybean variety for intercropping with maize ~~because~~ it had good perfomance under intercropping compared to others.

Keywords: *Maize-Soybean intercropping system, Suitable promiscuous soybean, Soybean genotype*

1. Introduction

Low crop production is a common issue which many farmers are facing through in Africa (Chianu *et al*., 2009). The problem is more pronounced in legume production and combined with soil infertility and reduction of the amount of nitrogen fixed biologically 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 (Burstin *et al.*, 2011). Among those 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 (Matusso *et al.*, 2012). Flexibility, growth of income, reduction of threat, soil development fertility and maintenance, are major reasons of intercropping for many farmers (Thyamini *et al*., 2010). In addition, intercropping cereal-legume have good capacity to reduce weeds development, while cereals in sole crop needs more space to produce the same yield compared to intercrop (Ijoyah, 2012). 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 (Masuda and Goldsmith, 2009). Therefore the percentage of soybean production held by each Africa's country including the 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% (Abuli, 2016). This shortage is coved 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 (Abuli, 2016). 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

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which are composed of 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 (Puji *et al.*, 2014). 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 (Matusso *et al.*, 2012). However, this technique has been demonstrated as system which can be highly effective compared to monocrop, also improving the ecosystem (Remison, 1978). Intercropping maize-soybean is taken 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 (Thyamini *et al.*, 2010). Intercropping is playing vital role in subsistence food supply in advanced and developing nations (Belel *et al.*, 2014). Leguminous crops are able to fixe N and that N fixed in intercropping is an important resource for the cereals in growing time (Bhagat *et al.*, 2006). 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. Soybeans which can produce effective nodules with diverse native rhizobia are referred to promiscuous soybeans (Kueneman *et al.*, 1998). 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 (Mpepereki *et al.*, 2000). There is need, ~~therefore,~~ to ~~determine~~ promiscuous soybean varieties with better agronomic traits for intercropping with maize in Kenya. ~~Hence the research in this study for assessing the most suitable promiscuous soybean variety for intercropping with maize was conducted at Mwea and Embu in Kenya~~.

2. Materials and Methods

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 00^0 37'S and a longitude of 37° 20'E in Kenya (kirinyaga county, 2014 and Embu county, 2014). The land preparation was done by ploughing using ox-draw equipment as is common in the area. The experiment was laid out as a randomized complete block design (RCBD) replicated three times with seven treatments ~~including:~~ T1: SB19 (Hybrid), T2: GAZELLE (Local), T3: TGX1990-5F (Hybrid), T4: SB19+MAIZE, T5: GAZELLE+MAIZE, T6: TGX1990-5F+MAIZE, T7: MAIZE (DUMA 43). The spacing used was: Monocrop soybean: (40 cm x 15 cm), Soybean intercropped with maize: (80 cm x 15 cm), Monocrop maize: (80 cm x 25 cm), Maize intercropped with soybean: (80 cm x 25 cm). The arrangement of intercropping was 1:1 with one row of maize intercepted by one row of soybean. The experiments received a basal application of 10.5 kg of DAP per site at the rate of 250kg ha^{-1} , meaning that each plot received 300 g of fertilizer and the application was done by row (Roy *et al*., 2006). The first season was planted on 9th Jun 2016 at Embu and on 10th at Mwea. The second season was planted on 8th November 2016. Because of insufficient rain fall, the trials received supplement by irrigation but the situation of rain fall was drastic and so bad in the second season.

2.1 Assessment of the most promiscuous soybean variety for intercropping with maize

2.1.1 Germination percentage

The data for germination percentage was collected considering germinated plants multiply by 100 divided by the total number of grains sown. The germination unit was in percentage As follows;

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

2.1.2 Plant height

Plant height was done using tape measure, from the bottom of the plant till the end of the plant for maize and soybean. Five plants were taken as sample per plot in the middle to avoid influence of others plots. After measuring height of five plants, the average was computed in order to get the plant height for one plant (Naim *et al*., 2012).

2.1.3 Days to 50% to flowering and days to 75% to maturity

This parameter was estimated by counting the number of days taken for each variety in the field after 50 percentage of soybeans or maize to flowering from the sowing date. The same procedure was done also estimating days to 75 percentages to maturity for soybean and maize.

2.1.4 Biomass for plant

The biomass of plant was done using the electronic balance, measuring the weight of five plants and the total biomass obtained was divided by five in order to get the average biomass of one plant (Naim *et al*., 2012). Biomass data was collected during the harvesting time. The biomass in t ha^{-1} was obtained by taking the quantity of biomass per plot and extrapolating it per ha.

2.1.5 Shattering score

This parameter was assessed at maturity time by taking 30 dried pods and putting them in khaki envelope and exposing them on sun for 7 days counting the number of shattered pods per days and converting it in percentage.

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

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The scoring rate of pod shattering 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) (Haruna, 2010; Krisnawati & Adie, 2017)

2.1.6 Number of pods per plant

The number of pods per plant was taken by counting all pods which were on the five plants taken as sample size, divided by five to get the pods average per plant at harvest time.

2.1.7 Number of seed per pod

The number of seeds per pod was taken counting all seeds which were in the five pods taken randomly on five plants as sample size, divided by five to get the seeds average per pod.

2.1.8 Nodulation assessment

Nodulation assessment was done one month after sowing in both sites. The crops were dug up, deposed carefully in the basin and after that, nodules were counted pouring water on the roots of each plant exposed in the basin in order to see carefully all the nodules.

2.1.9 Yield of soybean and maize

The harvesting of soybean and maize were done taking all the plants from the middle of the plot for each component crop at the maturity time. Soybean plants for each plot were threshed on the mat then winnowing and putting it in paper bag. The weight for soybean grains was obtained using electronic balance. After getting yield for each plot in grams, it was extrapolated in tonne per her. The maize ears from each plot were removed on stems at maturity time and grains were shelled from the stalk and conserved in paperbag. The weight for maize grains was obtained using electronic balance. After getting yield for each plot in grams, it was extrapolated in tonnes per her.

2.1.10 Performance of the intercropping Maize – Soybean systems estimated by LER

To evaluate the intercrop's performance, land equivalent ratio was calculated using formula provided by Amanullah *et al.* (2016) as follows:

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

Where

LER = Land equivalent ratio

Y_{SB} = Yield of soybean crop

Y_{MZ} = Yield of maize crop.

21.11 Harvest index

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 (Wnuk *et al*., 2013)**.** The model formula used to compute HI was**:**

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

2.1.12 One hundred grains weight

100 grains weight was measured using electronic balance taking 100 grains from harvested soybean and maize grains. 100 grains are used for the biggest grains size while 1000 grains are used for the smallest grains size as outlined by Aziz *et al*., (2012).

2.1.13 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 ($p \leq 0.05$) (ILRI-ICRAF, 2007).

3.RESULTS

3.1.1 Weather data during the experiment duration Long rain 2016

The mean rain falls (mm) during the experiment duration were 3.21 mm and 0.007 mm at Embu and Mwea respectively. ~~Rain fall from Mwea were very negligible.~~ However, the mean ~~for~~ temperature and relative humidity were ~~respectively~~ 22°C and 63.54 % ~~at Mwea. The average of the temperature from Embu was 20°c~~.

3.1.2 Germination ~~of soybean~~

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 1).

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3.1.3 ~~Soybean~~ plant height

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 55.40cm to 71.53cm at Mwea while it ranged from 37.87cm to 54cm 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 44.27cm followed by SB19 with 43.2cm 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, variety 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 intems of plant height in short rains. Variety 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 1).

3.1.4 Days to 50 % flowering and 75 % maturity ~~for soybean~~

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 (Table1).

Table 1: Soybean germination percentage, plant height, days to 50% flowering and days to 75% maturity both rainy seasons at Embu and Mwea during long rain 2016 and short rain 2016-2017

Long rains 2016												
	GRM			PH			D50PF			D75PM		
Treatment	Embu	Mwea	Mean	Embu	Mwea	Mean	Embu	Mwea	Mean	Embu	Mwea	Mean
SB19	96.0a	97.5a	96.75a	43.2b	59.13ab	51.17b	69.3b	49b	59.15b	95.3d	80c	87.5c
GAZELLE	98.3a	98.7a	98.5a	30.4c	47.13b	38.77c	68.3b	49.3b	58.8b	100c	84.6b	92.5b
TGX1990-5F	98.0a	95.6a	96.8a	55.87a	67.73a	61.80a	84.6a	64a	74.3a	121a	95.3a	107.5a
SB19+MAIZE	98.0a	95.6a	96.8a	33.9ab	50.53b	42.20c	69.6b	49.3b	59.45b	96.3d	80c	87.5c
GAZELLE+MAIZE	98.0a	94.9a	96.5a	34.9ab	46.80b	40.83c	69.3b	48.6b	58.95b	102b	84.3b	92.5b
TGX1990-5F+MAIZE	96.3a	93.7a	95.0a	44.27b	64.40a	54.33b	84.3a	64a	74.15a	121a	95a	107.5a
Mean	97.43	96.0	96.7	40.41	55.95	48.18	74.23	54.03	64.13	105	86.67	95.83
LSD0.05	4.65	3.07	4.19	10.52	11.5	3.37	1.6	0.802	1.27	1.24	0.0802	0.99
CV%	2.6	1.8	10.3	14.3	11.68	13.6	1.7	1.2	1.2	0.9	1.2	0.6
Short rains 2016-2017												
	GRM			PH			D50PF			D75PM		
Treatment	Embu	Mwea	Mean	Embu	Mwea	Mean	Embu	Mwea	Mean	Embu	Mwea	Mean
SB19	83.0a	76.5a	79.8a	47.40ab	71.53a	59.47a	69.33b	49b	59b	95c	80.66c	87.8c
GAZELLE	77.5a	80.3a	78.9a	44.67ab	56.83b	50.75a	69.33b	49.33b	59b	100.3b	85b	92.6b
TGX1990-5F	75.3a	71.7a	79.4a	54.00a	81.00a	67.50a	84.67a	64.67a	74a	121a	95.33a	108.2a
SB19+MAIZE	67.3a	71.7a	69.5b	42.07ab	63.20b	52.63a	69b	49.33b	59.17b	95c	80.33c	87.6c
GAZELLE+MAIZE	67.7a	69.0a	68.3b	37.87b	55.40c	46.63b	69b	48.6b	58.8b	100b	85b	92.5b
TGX1990-5F+MAIZE	62.3a	72.0a	67.2b	52.53a	67.40b	59.97a	84a	64a	74a	120.3a	95a	107.5a
Mean	72.18	73.5	73.85	46.41	65.89	56.15	74.22	53.98	63.99	105.15	86.6	95.83
LSD0.05	20.76	17.51	4.19	8.86	11.5	3.37	1.6	1.2	1.27	0.802	0.40	0.99
CV%	15.8	12.8	10.3	10	12.8	13.6	1.7	0.9	1.2	0.7	0.6	0.6

LSD: Least significant difference, GRM: Germination, PH: Plant height (cm) and D50PF: Days to fifty percent to flowering. Means bearing the same letter are in the same group

3.1.5 ~~Soybean~~ shattering score

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 ~~considering the scale shattering score~~ (Table 3). Intercropping did not affect soybean pod shattering.

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3.1.6 Nodulation ~~of soybean~~ per plant

~~Soybean number of nodules~~ showed significant difference ($P \leq 0.05$) between sites but ~~the seasons were not significantly different.~~ The number of nodules ranged from 33 to 47 at Mwea while Embu ranged from 29 to 43. Variety TGX1990-5F ~~presented~~ 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 2). Intercropping did not reduce the number of nodules per plant.

3.1.7 Number of pods per plant ~~for soybean~~

The number of pods per plant ~~presented~~ significant difference between sites in the sole crop and in intercrops in the long rains. The short rains did not show the significant ~~different~~ 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 2).

3.1.8 Number of seeds per pod ~~for soybean~~

However, the long rains 2016 did not show significant difference ~~of 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. 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 ~~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 at Mwea. Intercropping did not have ~~bad~~ influence on number of seeds per plant. Mwea site ~~presented the biggest~~ number of seeds per pod compared to Embu both seasons (Table 2).

Table 2: ~~Soybean~~ shattering 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												
	SH			NODP			NPODP			SEEDPP		
Treatment	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												
	SH			NODP			NPODP			SEEDPP		
Treatment	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, ~~D70PM: Days to seventy percent to maturity~~, SH: Shattering score, NODP: Nodulation per plant. Means bearing the same letter are in the same group

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Table 3 : 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: Last 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).

3.1.9 ~~One~~ hundred grain weight ~~for soybean~~

During the long rains of 2016, ~~100~~ 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 ranged from 14 g to 24 g. There were ~~varietal~~ differences among the varieties in the sole and intercrop system. In the sole crop GAZELLE ~~presented~~ the highest GW of 24.33g followed byTGX1990-5F with 18.33g 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 4).

3.1.10 ~~Soybean~~ biomass

Soybean biomass showed significant difference ($p \leq 0.05$) between sites and seasons. The biomass from Mwea ranged among 3 t ha^{-1} to 12 t ha^{-1} while biomass from Embu ranged among 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 by SB19 with 8.23 t ha^{-1} and 4.48 t ha^{-1} and the variety which presented the lowest biomass is GAZELLE with 7.89 t ha^{-1} and 3.54 t ha^{-1} respectively in sole crops and in intercrop at Mwea. The variety for TGX1990-5F showed the highest biomass of 14.7 t ha^{-1} followed by SB19 with 7.29 t ha^{-1} and of biomass 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 4).

Table 4: ~~Soybean 100~~ grain weight, biomass at Embu and Mwea during long rain 2016 and short rain 2016-2017

	Long rains 2016					
	100GW			BIOM		
Treatment	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					
	100GW			BIOM		
Treatment	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

100GW: 100 Grain weight (g)**, BIO: Biomass** (T ha^{-1})

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3.1.11 ~~Soybean~~ yield

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, TGX1990-5F presented 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 yield 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 at Embu. Mwea produced higher yield compared to Embu both seasons. Intercropping reduced soybean grain yield in both sites and seasons (Table 5).

3.1.12 ~~Soybean~~ harvest index

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 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, variety 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 shotrt rain season. Intercropping reduced HI both sites and both seasons. Mwea produced the highest HI in both season compared to Embu (Table 5).

3.1.13 Land Equivalent Ratio

LER did not give significant difference between sites in the long rains 2016. LER differed among treatments at Mwea where it ranged among 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 seasons. At Embu, the variety of 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 was among 1 .06 to 1.62. Variety TGX1990-5F showed the highest LER of 2.04 followed by SB19 with 1.31 while the variety of 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 5).

Table 5: ~~Soybean~~ yield ~~in~~, Harvest index and Land equivalent ratio in long rain at Embu and Mwea during long rain 2016 and short rain 2016-2017

	YTHA			HI			LER		
Treatment	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
	YTHA			HI			LER		
Treatment	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

YTHA: Yield in tone per ha, HI: Harvest index, LER: Land Equivalent Ratio, LSD: Least significant difference, CV: Coefficient of variation

3.1.14 Germination rate, plant height, days to 50 % flowering and Days to 75% to maturity for Maize

Germination % of maize (DUMA 43) intercropped with soybeans and sole crops did not show significant difference both sites and both rain seasons. In addition, maize plant height did not also give significant difference among treatments and sites in intercropping and in sole crops ($P \leq 0.05$). However, the days to 50 % flowering for maize were between 83-85 at Embu and 63-64 at Mwea for the long rains 2016 while it took 77 days at Embu, and 63-64 days at Mwea for the short rains 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 (Table 6) 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.

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Table 6: Germination %, plant height, days to 50 % flowering, days to 75 % maturity at Embu and Mwea of Maize during long rain 2016 and short rain 2016-2017

Long rains 2016												
	GRM			PH			D50PF			D75PM		
Treatment	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												
	GRM			PH			D50PF			D75PM		
Treatment	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

GRM: Germination, PH: Plant height (cm) and D50PF: Days to 50 percent to flowering, Days to 75 percent to maturity, LSD: Least significant difference. Means bearing the same letter are in the same group

3.1.15 One hundred grain weight, biomass per plant and yield for Maize

The significant difference for 100 GW was ~~shown~~ in the short rains 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} to 17 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 ~~(Table 7)~~. Maize grain yield did not give significant difference between sites and seasons. Mwea site did not produce maize grain yield beause 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} atEmbu. During the short rains 2016-2017, maize grain yield ranged among 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 7).

Table 7 One hundred grains weight, biomass, and maize grain yield at Embu and Mwea of Maize during long rain 2016 and short rain 2016-2017

	Long rains 2016								
	100GW			BIOM			GY		
Treatment	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								
	100GW			BIOM			GY		
Treatment	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

100GW: 100 grain weight, BIOM: Biomass in T ha-1, GY: Grain Yield in T ha^{-1}, LSD: Least significant difference, CV: ~~Coeffient~~ of variation. Means bearing the same letter are in the same group

3.4.15 Maize harvest index

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 8).

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Table 8: Maize harvest index, Land Equivalent Ratio at Embu and Mwea during long rain 2016 and short rain 2016-2017

		Long rains 2016	
	HI		
Treatment	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	
	HI		
Treatment	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 Discussions

4.1 Growth paramaters

4.1.1 Germination rate in percentage (%) for soybean and Maize

During the long rains of 2016, germination % for soybeans was not different in the sole crop and the intercrops between the sites. However, during the short rains significant difference was 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 that recording between 67 to 79%. The good prefomance in germination % during the long rains could be due to spplemental irrigation to rain fall at both sites which was more available in the long rains than in the short rains . Germination % of Maize did not show significant difference between sites both seasons ($p \leq 0.05$). Germination % of maize ranged from 98 % to 100 % at Mwea, while it ranged from 99 % to 100 % at Embu in the long rains 2016 in intercropping and in sole crops. This can be attributed to the soil conditions of Embu, which was lighter than Mwea with heavy clay soil. In addition, the cooler and wetter conditions for the first season may have increased germination % in both sites. The short rains presented the lowest germination % than the long rains 2016. Mwea germination % start from 96.67 % to 100 % and 83.20 to 98.67 % at Embu. Intercropping did not reduce the germination % of maize and soybean both sites and seasons. Mwea site presented higher amount of germination % for maize than Embu 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°C) and insufficient soil water reduced germination % in his experiment on different crops grown by farmers.

4.1.2 Plant height for soybean and Maize

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 were ranging from 46 to 67 cm between sites. GAZELLE was the variety which had the lowest plant height compared to other varieties with 44.67cm and 56.83cm at Embu and Mwea respectively in sole crop. TGX1990 – 5F recorded the highest PH of 54 cm and 81 cm for Embu and Mwea respectively in sole crop too. 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. On the other hand, this could be due to genetic makeup of each variety. However, the presence of water at Mwea allowed nutrients uptake for the crops compared to Embu. These results confirm results for Hermanson (2015) who said that insufficient water supply can limit efficient nitrogen up take for good growth condition of plant while Rezaei *et al.* (2009) 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 54cm 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 Simpson's (1999) results, that; soybean is susceptible to moisture competition, probably a result of relatively small root system and inherently low water use efficiency. While Ijoyah (2012) reported that, light interception in intercropping had negative impact on plant height for short crops than taller crops

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compared to sole cropping. In addition, maize PH was not affected by intercropping in both sites and seasons. This agrees with Muoneke *et al*. (2007), who reported that, PH did not show significant difference among sole maize and intercropped maize while Thobatsi (2009), also found that maize in intercropping with cowpea did not have any effect on maize plant height.

3.5.1.3 Days to 50 % flowering and Days to 75 % maturity for soybean and maize

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 which is 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 Sileshi (2013) 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 Abubaker (2008) 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 to75 % to maturity for maize did not give significant difference both sites and both rainy seasons.

3.5.1.4 Biomass yield for soybean and maize

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 by SB19 with 8.23 t ha^{-1} in sole crop and the variety which presented the lowest amount of biomass is GAZELLE with 3.54 t ha^{-1} in intercropping at Mwea. The variety 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 Sileshi (2013) 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 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 and GAZELLE presented the lowest amount of biomass for 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 by 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 Mugendi *et al*. (2010) who said that, application of fertilizer which contain nitrogen would be also the base of high biomass production. However, Geren *et al*. (2008) 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 (Karpenstein-machan and Stuelpnagel, 2000). In addition, intercropping system reduced soybean biomass production (Sarkodie & Kahaman, 2012) and (Fujita, 1992). However, maize biomass showed significant difference between sites and seasons. The biomass ranged from 5 t ha^{-1} to 17 t ha^{-1} in sole crop as in intercropping at Mwea while plant biomass was among 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 agrees with Presad and Brook (2005) who reported that intercropping of cereal-legumes did not affect maize biomass.

4.2 Production parameters

4.2.1 Number of pods per plant and seeds per pod

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. Variety TGX1990-5F recorded the highest number of pods of 82.7 in sole crop while

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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 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 of rainfall which reduced the growth of the plant. Intercropping reduced the number of pods per plant both seasons. These findings concurs with (Sloger, 1969) 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 (Kinama *et al*., 2011) 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 of 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.

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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 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 photosyenthesis and compete more efficiently on nutrients uptake with soybean (Kinama *et al.*, 2011). The situation was not good for the short rains 2016-2017 where the number of seeds per pod was reduced at 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 (Shadreck, 1999). Intercropping did not reduce the number of seeds per pod both sites and in two seasons. This agrees with Legwaila *et al.* (2012) 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.

4.2.2 Shattering score

Shattering score showed significant difference between sites and seasons ($p \leq 0.05$). 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°C), hence increasing the shattering score compared to Embu with high altitude and low temperature (20°C), hence reducing the shattering score. This agrees with Haruna (2010); Krisnawati and Adie (2017) 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 for 36.67 % in intercropping, followed by SB19 (20.7 %) in sole crop while TGX1990-5F showed the lowest shattering score for 11 % in the sole crop at Mwea. variety 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 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 Zhang & Bellaloui (2012) 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 (Haruna, 2010; Krisnawati & Adie, 2017). Intercropping did not increase pod shattering. Variety TGX1990-5F can be recommended to the small scale farmers in the tropical conditions because it was resistant to pod shattering following the the scale of pod shattering score.

4.2.3 Hundred grain weight for soybean and maize

100 grain weight showed significant difference ($p \leq 0.05$) 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 10.23g 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 good 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 Undie *at al.* (2012) who reported that maize-soybean intercropping reduced 100 grain weight for soybean during two years (2007) and (2008). In addition, Li *et al.* (2013) found that, 100 grain weight was significantly reduced by intercropping of soybean-sugarcane, by 16.12 to 9.53 % respectively in sole crop compared to intercrop. For Mbah *et al.* (2007), 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 the variety of maize Duma 43 used at Mwea compared to Embu. GAZELLE variety can be advised for the sole crop because it showed higher 100 GW while SB19 and TGX1990-5F can be advised for intercropping.

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4.2.4 Soybean and maize grain yield

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 scrop while GAZELLE showed the lowest yield of 0.6 t ha^{-1} in intercropping at Mwea. At Embu, variety 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 1.4 t 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 (Sloger, 1969, Kinama et al.,2007 and Amanullah *et al.,* 2016). However, Issahaku (2010) reported that the yield of soybean decreased in intercropping with maize than sole crops and maize benefits more from intercropping than soybean. In addition, Rana and Rana (2011) 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 Sarkodie and Kahaman (2012) legumes could become pest in an intercropping system by shading the components crop(s) and thereby reducing yield. Kinama et al., 2007 further showd 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 2016-2017 compared to the long rains 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 Nelson *et al*. (2011) 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 Miano (2010) who reported that, the losses of maize production due to MLN is between 50% and 90% depending on varieties.

4.2.5 Soybean and Maize harvest index

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. The variety for 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 Naim *et al*. (2012), 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 Ayaz (1994) 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 Wnuk *et al*. (2013) 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 Wnuk *et al*. (2013)**,** who reported 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 Scott (1977) 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 ($p \leq 0.05$). 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

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between 0.33 to 0.43. Intercropping did not reduce maize HI both sites and seasons. This results agrees with Sadras *et al.* (2001); Stoltz and Nadeau (2014) who reported that, maize HI was stable in sole crops and in intercrops when it was intercropped with sunflower and soybean.

4.2.6 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 ($p \leq 0.05$). 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 Sullivan (2003) Hugar and Palled (2008); Addo-Quaye (2011); Yusuf *et al.* (2012) who recorded LER greater than 1.00 in cereals-legumes cropping system. Variety TGX1990-5F recorded the highest LER of 1.62 at Embu. Sylvia (1999) and Dariush *et al*. (2006), 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, Khan Zada *et al.* (1988) reported that, the use of N increased LER and showed efficient utilisation of land in different planting pattens. Adam and Mohammed (2012) also reported that, cropping system improved total yield which was maried with greater land equivalent ratio.

Conclusion

The study reveled 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 identified as the most suitable promisuous soybean for intercropping with maize.

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