

Effect of organic and low inorganic fertilizers on yields in a maize-legume intercropping systems in two selected sites in Mozambique

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ABSTRACT

The study was carried out at Lichinga and Sussundenga Research Station to assess the effects of cow manure and inorganic fertilizer on height, Stover yield, grain yield, yield quality for both maize and legumes of a maize/legume intercrop. A factorial design experiment with a split plot arrangement and replicated three times per site was used. The treatments comprised two intercropping systems of maize/bean and maize/soybean and five fertilizer application rates: Control, cow manure (5 ton ha⁻¹), cow manure 1.25 ton ha⁻¹ + 100 kg NPK ha⁻¹, cow manure 2.5 ton ha⁻¹ + 50 kg NPK ha⁻¹ and 200 kg NPK ha⁻¹. Results showed that the Stover weight, plant height, hundred grain weight and grain yields had significantly differences ($P \leq 0.05$) when cow manure was combined with NPK fertilizers. Maize grown in Sussundenga gave higher values of Stover weight, plant height, hundred seed weight and total grain yield compared to Lichinga. In fact, higher maize growth parameters were improved by intercropping with common bean than in soybean in both locations, a fact attributed to the better utilization of the available resources by maize/common bean intercrop. Combination of 1.25 ton ha⁻¹ of cow manure and NPK 100 kg ha⁻¹ fertilizers significantly ($P \leq 0.05$) increased the yield of maize over application of cow manure or NPK alone and farmers are recommended to adopt this production system in the two sites.

Keywords: Cow manure, NPK fertilizer, and maize–legume intercrop.

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INTRODUCTION

In Sub-Saharan Africa (SSA), rainfed agriculture plays a critical role in food security at the national and household levels as it is characterized by low crop yields (Gassner et al., 2019; Parr et al., 1990). Much of the population in SSA cultivate maize (*Zea mays* L.) and common beans (*Phaseolus vulgaris* L.), which rank first and second in importance as staple foods (CIMMYT, 2003). Soybeans account for about 35% of total harvested area devoted to annual and perennial oil crops and its share in global oil crop output is estimated at 44% (FAO, 2004). In addition, 7.7M tons of soy oil (28.5%) was used as a feedstock in 2015 (Mielke, 2019).

Intercropping is the agricultural practice of cultivating two or more crops in the same field at the same time, is

an old and commonly used cropping system which aims to match crop demands to the available growth resources such as light, water and nutrients, as well as provide insurance against crop failure, optimize the use of land and increases monetary returns to the farmers while reducing labour costs (Lulie, 2017, 1988; Lithourgidis et al., 2011). Grain legumes have been recognised worldwide as an alternative means of improving soil fertility through their ability to fix atmospheric di-nitrogen (N₂) contributing to higher total crop yield compared with monoculture crops (Muoneke et al., 2007; Jørgensen and Møller, 2000). Maize legumes intercrops have been shown to be more productive than sole maize (Putnam et al., 1985; Marchiol et al., 1992).

Maintaining soil fertility and obtaining optimum crop yield are major components of sustainable agriculture. The beneficial effects of combined organic and inorganic nutrients on soil fertility have been repeatedly shown but the challenge has been the combination of organic manures of differing quality with inorganic fertilizers to optimize nutrient availability to plants (Palm et al., 1997; Bationo et al., 2004). Appropriate fertilizer use leads to increased crop yields and high crop recovery of applied nutrients. Studies by Qureshi (1990), Bhattacharyya et al. (2008), Negassa et al. (2002) and Zhao et al. (2009) reported that combined use of organic and inorganic fertilizers resulted in a higher increase in maize yield, soil organic matter (SOM), available N and P compared to sole application of inorganic fertilizer or sole farmyard manure. Besides, a strategy combining legume varieties in maize intercrop with mixtures of organic and inorganic fertilizers is likely to result to improved system productivity though N fertility contribution by bean or soybean to companion maize crop, as well as nutrient contributions by organic and inorganic resources (Njeru et al., 2010). The objective of the study was to evaluate the effect of integrated soil fertility management on maize performance and yield at Lichinga and Sussundenga in Mozambique.

MATERIALS AND METHODS

Study area

The study was conducted under rainfed conditions at Lichinga and Sussundenga research stations in Mozambique. Lichinga station is located in Lichinga district to the west of the Niassa province and lies 12° 30' to 13° 27' S; 34°50' to 35°30' E while Sussundenga Agrarian research station is located in Manica province, central Mozambique and lies 19° 20' S; 33° 14' E, with an altitude of 620 m above sea level. The two sites have unimodal rainfall pattern occurring between November and April and the agricultural production is predominantly rain fed (MAE, 2005a,b). The major soils in the two sites are classified as ferralsols (FAO, 2006; WRB, 2015).

Soil and manure analysis

A composite soil sample was collected using a 600 cm³ soil auger at a depth of 15 cm at the start of the experiment for physical and chemical characterization of the soil. Soil texture was determined by the hydrometer method as described by Glendon and Doni (2002). Soil and cow manure samples were air-dried, ground and sieved to pass through a 2-mm for determination of pH water and salt at ratio of 1:2.5 between soil and water or salt using a pH-meter. Available phosphorous was determined according to Olsen et al. (1954): by first extracting a 5 g soil sample using the double-acid method (0.05N HCl in 0.025N H₂SO₄) and then measuring the concentration of phosphorous in the extract using an atomic absorption spectrophotometer (Buck scientific, 210 VGP, Cambridge, UK). Exchangeable bases (Ca, Mg, K and Na) were determined by displacing them from a soil sample using 0.1N ammonium acetate at pH 7.0. Calcium and magnesium were determined using an atomic absorption spectrophotometer (AAS) while sodium and potassium were determined using a flame-photometer (Olsen et al.,

1954).

The soils and cow manure samples were further passed through a 0.5 mm sieve for analysis of percent organic carbon (OC) and total nitrogen (TN). Organic carbon was determined by the Walkley and Black (1934) wet oxidation method as described by Nelson and Sommers (1996) while TN was determined using micro-Kjedahl method (Bremner, 1996).

Treatments and experimental design

The trials were laid out in a randomized complete block design (Moe et al., 2019) with split plot arrangement replicated three times and a control. The main plots in the experiments included two cropping systems (Maize/Soybean and maize/common bean intercrops) while the split plots were the fertilizer treatments: Cow manure at 5 ton ha⁻¹, Cow manure 1.25 ton ha⁻¹ + 100 kg NPK ha⁻¹, cow manure 2.5 ton ha⁻¹ + 50 kg NPK ha⁻¹ and 200kg NPK ha⁻¹ and a Control. Two maize seeds (variety Matuba), common bean (variety Meso Americano 117) and soybean (variety IAC 6) intercropping system were sown per hill and later thinned to one plant two weeks after emergence in order to achieve plant density of 64 plants of maize, 90 plants of common bean and 144 plants of soybean per plot (30) measuring 4 m × 5 m, with a path of 2 m between the main plots (cropping systems) and 1 m between replicates and the plots. This consisted of one row of soybean or common bean and two rows of maize and the NPK fertilizer used with 12:24:12 formula % ratio.

Weeding was done three times at 2, 7 and 10 weeks after planting. Pest were controlled by applying Cypermetrina™ at a rate of 500 ml ha⁻¹ in maize and Macozed™ at rate of 210 g/100 L of water for common bean and Soybean. In addition, Bandit™ was applied once in Sussundenga trial site at rate of 500 ml ha⁻¹ to prevent termite's damage to the crops.

The maize and legume were harvested at physiological maturity. Data regarding grain yield, Stover weight, 100-grain weight and plant height were recorded during the growing period and at harvest. The maize grain yield and Stover was weighed from the net harvest of 12.48 m² quadrat and converted into tons ha⁻¹. Grain yield and Stover data were determined according to Equations 1 and 2.

$$\text{Stover (ton/ha)} = \frac{\text{Fresh Stover Weight} \times (100 - \text{moisture content of fresh grain (\%)})}{(100 - \text{moisture content of grains at 12.5\%})} \times \left\{ \frac{10}{\text{harvested area}} \right\} \quad (1)$$

$$\text{Grain yield (ton/ha)} = \frac{\text{Fresh grain weight (kg)} \times (100 - \text{Moisture content of fresh grain (\%)})}{100 - \text{moisture content of grains at 12.5\%}} \times \frac{10}{(\text{Plot area (m}^2\text{)})} \quad (2)$$

Statistical analysis

Data was subjected to analysis of variance (ANOVA) using GENSTAT version 15 statistical package (Lane and Payne, 1998) where F significant means were separated using least significant difference (LSD) and results reported at 95% level of confidence.

RESULTS AND DISCUSSION

Stover yield in Lichinga and Sussundenga

The Stover yield is presented in Table 1. The maize

Table 1. Stover weight of various treatments at end of harvest in both study locations in ton ha⁻¹.

Location	Cropping system	Control	Manure (5t)	Manure (2.5 t) + NPK (50 kg)	Manure (1.25 t) + NPK (100 kg)	NPK (200 kg)	CS mean	L mean
Lichinga	Maize/bean	2.9	3.61	3.8	6.85	3.55	4.14	4.55b
	Maize/soybean	4.27	4.93	4.97	6.27	4.35	4.96	
Sussundenga	Maize/bean	4.11	8.27	7.73	11.14	8.33	7.92	7.52a
	Maize/soybean	3.61	6.5	7.33	10.47	7.64	7.11	
Mean (fertilizer)		3.72 ^c	5.83 ^b	5.96 ^b	8.68 ^a	5.97 ^b		
Mean (maize/bean)							6.03	
Mean (maize/soybean)							6.03	

Key: Means with same letters are not significantly different according to Duncan multiple range test at $P < 0.05$; F = Fertilizer; CS = Cropping system; L = Location.

Stover yields were increased by the fertilizer treatments in both cropping systems. The results showed that the applied fertilizer treatments, cropping systems and location, increased significantly ($P < 0.05$) maize Stover yields when compared to the control. In maize/soybean intercropping system, the control plots that had no fertilizers application gave the lowest maize Stover yield values of 2.9 (maize bean) and 3.61 (maize/soybean) ton ha⁻¹ in Lichinga and Sussundenga experimental sites, respectively while the highest values of 6.85 and 10.47 ton ha⁻¹ (both for maize/bean) were obtained from cow manure (1.25 ton ha⁻¹) + NPK (100 kg ha⁻¹) in Lichinga and Sussundenga experimental sites, respectively (Table 1). In maize/common bean intercropping system, maize Stover yield of 6.85 and 11.14 ton ha⁻¹ was significantly higher ($P \leq 0.05$) with application of cow manure (1.25 ton ha⁻¹) + NPK (100 kg ha⁻¹) compared to control plots with 4.27 and 3.61 ha⁻¹ in Lichinga and Sussundenga sites, respectively. This could be attributed to increased robust growth in terms of plant height (Table 2) where fertilizer and manure were applied coupled with the benefits of intercropping. For example, the maize plant height for maize/bean and maize/soybean was 183.64 and 178.50 cm compared to 174.9 and 178.11 cm for control in Sussundenga. This is again replicated in Lichinga where fertilizer and manure were applied coupled with intercropping had maize height of 140.28 and 130.17 cm compared to control with 136.3 and 123.78 cm for maize/bean and maize/soybean, respectively (Table 2). This robustness in growth could have increased the leaf area index, which in turn may have promoted photosynthate production as well as extensive rooting to harness nutrients and water that enhance high Stover yield in the combined treatments.

However, the Stover yield was about 7.5% higher in the maize/common compared to maize/soybean intercropping. The higher Stover yield recorded by cow manure (1.25 ton ha⁻¹) + NPK (100 kg ha⁻¹) treatment could be attributed to synchronized slow release of nutrients throughout the growing season and amelioration of soil by organic matter (Rop et al., 2020; Rop et al.,

2019) from manure. The dinitrogen fixed by legumes in the maize-legume intercropping system could also have played a role in the increased Stover yield. Additionally both organic and inorganic fertilizers were applied. The inorganic fertilizer was immediately available for the plant and it may also have helped in the increased mineralization process of the organics (microbes use the fertilizer as source of energy) (Karuku and Mochoge, 2018; Karuku, 2019) and biological N-fixation by rhizobium (Yassine et al, 2018). Collectively all this process leads to improved soil structure, porosity, water holding capacity and fertility (Karuku et al., 2014, 2012), which contributed to the increased yields (Chepkemoi et al., 2019; Karuku et al., 2019). The results supported the fact that combining organic and inorganic fertilizers increases nutrients availability to maize crop (Berga et al., 2001; Chepkemoi et al., 2019). Uenosono et al. (2004), found that nitrogen in cow manures remained available up to active tillering stage and up to panicle formation stage. These findings are consistent with studies conducted by Achieng et al. (2010), Makinde and Ayoola (2010) and Xiaonbin et al. (2001), who reported an increase of maize Stover yield when farmyard manure was combined with inorganic fertilizers. Moe et al. (2019) observed that the organic fertilizer (total N $\geq 4\%$) with the EMN method enhances higher N availability in each year while Continuous application of organic fertilizer (total N $< 4\%$) over two years effectively increased N availability in the second year.

The maize average Stover yield recorded higher weight in Sussundenga at 7.52 ton ha⁻¹ compared to maize grown in Lichinga (4.55 ton ha⁻¹), which resulted in 39.5% reduction in Stover yield Lichinga compared to Sussundenga and this was attributed to differences in soil properties and climatic conditions in the two sites. For example, the nutrient content (Table 3) of the Sussundenga soils may have accounted for the observed decrease in Stover yield compared to Lichinga soils. Also, the observed higher Stover yields in Lichinga (Table 1) could be due to lower content of secondary minerals such as Ca (Table 3) which increases the feed value of

Table 2. The maize plants heights in various treatments 130 days after planting in both study locations in centimeters.

Location	Cropping system	Control	Manure (5t)	Manure (2.5 t) + NPK (50 Kg)	Manure (1.25 t) + NPK (100 kg)	NPK (200 kg)	CS Mean	L Mean
Lichinga	Maize/bean	136.33	140.28	142.17	145.56	140.06	140.8	138.4b
	Maize/soybean	123.78	130.17	145.58	152.5	127.94	135.9	
Sussundenga	Maize/bean	174.9	183.94	183	196.11	178.39	183.3	181.8a
	Maize/soybean	178.11	178.5	183	184.06	178.33	180.4	
Mean (fertilizer)		153.28 ^b	158.2 ^{ab}	163 ^{ab}	169.6 ^a	156.2 ^b		
Mean (maize/bean)							158.2	
Mean (maize/soybean)							162.1	

Key: Means with same letters are not significantly different according to Duncan multiple range test $P < 0.05$; F = Fertilizer; CS = Cropping system; L = Location; ns = not significant.

Table 3. Initial soil physical and chemical properties at 0-15 cm depth for Lichinga and Sussundenga research stations in Mozambique.

Characteristic	Soil		Manure	
	Lichinga	Sussundenga	Lichinga	Sussundenga
Sand (%)	29.50	28.50	ND	ND
Silt (%)	18.00	13.50	ND	ND
Clay (%)	52.50	58.00	ND	ND
Textural class	Clay	Clay	NA	NA
CEC (cmol+ kg ⁻¹)	27.80	25.80	1.30	1.37
Na (cmol+ kg ⁻¹)	2.10	0.68	Trace	0.53
Mg (cmol+ kg ⁻¹)	1.75	5.20	0.26	0.28
K (cmol+ kg ⁻¹)	9.63	1.58	0.53	0.18
Ca (cmol+ kg ⁻¹)	2.96	15.63	0.30	0.88
Total Nitrogen (%)	0.69	0.78	0.21	0.24
Available P (ppm)	1750	1875	333	211
Organic C (%)	6.78	7.70	1.13	1.43
C:N Ratio	1:9.7	1:9.8	1:5	1:6
pH KCl (ratio 1:2.5)	7.11	8.05	4.42	4.90
pH water (ratio 1:2.5)	7.53	9.15	5.07	5.77

Key: ND = Not determined; NA = Not applicable.

forage and Mg that allows synthesis of organic compounds useful for plant growth compared with Sussundenga soils with higher Ca and Mg content as reported by Cakmak et al. (2010). Despite that Sussundenga also had lower rainfall and higher temperatures in January and February leading to lower maize Stover yields unlike Lichinga.

Plant height of maize in Lichinga and Sussundenga

The maize plant heights 130 days after planting are presented in Table 2. Organic and inorganic fertilizer treatments in both cropping systems increased the maize height in both Lichinga and Sussundenga. The results indicated a significant difference ($P < 0.05$) between fertilizer treatments and cropping systems on plant

heights in both locations. It was observed that in Lichinga and Sussundenga, plots treated with both cow manure (1.25 ton ha⁻¹) and NPK (100 kg ha⁻¹) had greater plant height (169.56 cm) compared to those with sole cow manure (5 ton ha⁻¹) treatment; combined cow manure (2.5 ton ha⁻¹) + NPK (50 kg ha⁻¹) and NPK alone at 200 kg/ha (158.22, 163.44 and 156.18 cm, respectively). This could be attributed to better crop nutrition coming from both inorganic and organic sources unlike manure source alone. The combined N supplied from both 100kg NPK and manures could have adequately met the crop demand hence the observed results. Also the inorganic source from 100 kg ha⁻¹ NPK source is readily available for crop use and can also act as a primer to enhance faster nutrient release by manure through mineralization process (Karuku, 2019). This therefore implies that combined organic and NPK fertilizers at 100 kg ha

increased plant height compared to other treatments. Shah et al. (2009) and Makinde and Ayoola (2010) in their studies observed that application of organic and inorganic fertilizers significantly increased maize plant height. Ghafoor and Akhtar (1991) in their studies in Pakistan reported similar results where application of high N rates combined with manure significantly increased maize height.

Intercropping maize with legumes had significant effect on maize plant height. However, insignificant average higher values of maize plant height was recorded in maize/common bean (162.08 cm) compared to maize/soybean (158.20 cm) intercrop, a 2.4% of increase in plant.

Regarding both locations, maize in Sussundenga was taller (181.83 cm) than in Lichinga (138.44 cm), a 23.86% increase in maize height (Table 2). The higher plant height recorded in Sussundenga is probably due to greater level of available phosphorus (1875 ppm) compared to Lichinga (1750 ppm). Soil P availability during maize seedling development is an important determinant of growth as it enhances root growth and development (Razaq et al., 2017). Barry and Miller (1989) reported a significant increase in growth parameters in response to phosphorus availability before the 6-leaf stage (V6) compared to addition of P after this stage. The high maize height in Sussundenga may also be attributed to the amount of rainfall received during the critical period of plant growth in March (265 mm) compared to Lichinga (204 mm). Because of the immobility of phosphorus in soil, surface soil strata, enriched by the deposition of plant residues over time, generally have greater phosphorus availability than subsoil strata and root traits that enhance topsoil foraging are therefore important for phosphorus acquisition (Lynch, 2011).

Maize hundred grain in both locations

The maize 100 grains weight (g) are presented in Table 4. The results indicated that 100 grains weight was significantly ($P < 0.05$) affected by both cow manure & NPK inorganic fertilizer and location. Generally, maize 100 grains weight increased with application of combined 1.25 tons cow manure and 100 kg ha⁻¹ NPK fertilizer in both locations. Applications of cow manure (5 ton ha⁻¹), NPK (200 kg ha⁻¹) and combined cow manure (1.25 ton ha⁻¹) + NPK (100 kg ha⁻¹) treatments gave statistically higher 100 seed weight than control plots. The higher N ($P < 0.05$) content plus other nutrients supplied from both inorganic and manures could have led to better crop performance compared to the control and hence the observed results. Quansah (2010) obtained significant increase in maize 100 grains weight where a combination of poultry ($P < 0.05$) manure and NPK fertilizers was applied compared with sole application of organic or mineral fertilizer.

The cropping system had no significantly difference on maize 100 grains weight between them though maize average 100 grains weight recorded insignificant higher values in maize/common bean (26.21 g) treatment compared to maize/soybean (25.96 g) intercrops, a 5% reduction in hundred grains weight in maize/soybean.

Sussundenga produced significantly ($P < 0.05$) higher 100-maize grain seed weight of 31.21 g compared to Lichinga at 20.95 g (32.7% less in Lichinga) (Table 4). The prevailing environmental conditions such as temperature, rainfall and soil nutrient contents may have been more favourable for maize growth and development in Sussundenga.

Maize grain yield

The results of maize grain yield (ton ha⁻¹) are presented in Table 5. The maize grain yield was influenced by combination of cow manure and inorganic fertilizer at specified ratios. Higher maize grain yield at 7.57 ton ha⁻¹ were recorded in plots treated with 1.25 ton ha⁻¹ cow manure + 100 kg ha⁻¹ NPK. Sole application of 5 ton ha⁻¹ cow manure, combination of 2.5 ton ha⁻¹ ha of cow manure + 50 kg ha⁻¹ NPK and sole 200 kg ha⁻¹ NPK had total maize grain yield less by 15, 16 and 15%, respectively compared to 1.25 kg ha⁻¹ cow manure in combination with 100 kg ha⁻¹ NPK. Control plots had the lowest grain yields of 5.11 ton ha⁻¹ which represents the traditional production practices by majority of the peasant farmers who have no access to credit or other sources of income to enable them purchase inputs. The data therefore indicate that a combination of cow manure at 1.25 ton ha⁻¹ + NPK at 100 kg ha⁻¹ could be a likely candidate for improving crop yield in the study areas. It can be associated to the better synchronization of nutrient therefore release and supply rate by cow manure at 1.25 ton ha⁻¹ + NPK at 100 kg ha⁻¹ hence efficient utilization by maize crop in the study. Smaling et al. (1992), Palm et al. (1997) and Bationo et al. (2004) similarly observed that the combined use of organic and inorganic fertilizers resulted in higher yields than either source used alone. The results also agree with those of Wanyonyi et al. (2004), Negassa et al. (2002; 2005), who reported increased maize grain yield through integrated use of low dose of NP fertilizers with different organic fertilizer sources and rates such as farmyard manure. Baghdadi et al. (2018) concluded that Combining chemical fertilizers with chicken manure (CM) in a 50:50 ratio and applying 50% NPK+50% CM+BF produced fresh forage and dry matter (DM) yields that were similar to those produced in the 100% nitrogen (N), phosphorus (P), potassium (K) treatment.

Intercropping systems (maize-legumes) had a significant effect ($P < 0.05$) on maize grains yield at both locations with higher maize grain yield values of 6.68 ton ha⁻¹ recorded in maize/common bean compared to 5.77 ton ha⁻¹ for maize/soybean intercrop which is a 16% yield

Table 4. Weight of 100 grains of maize in grams of various treatments in both study locations.

Location	Cropping system	Control	Manure (5t)	Manure (2.5 t) + NPK (50 kg)	Manure (1.25 t) + NPK (100 kg)	NPK (200 kg)	CS Mean	L Mean
Lichinga	Maize/bean	19.23	22	19.64	22.5	22.33	21.14	21 ^b
	Maize/soybean	18.63	22	20	23.67	19.67	20.79	
Sussundenga	Maize/bean	30.33	30.67	31.64	32.14	31.64	31.28	31.2 ^a
	Maize/soybean	29	31	32	32.67	31	31.13	
Mean (fertilizer)		24.30 ^b	26.42 ^a	25.8 ^{ab}	27.75 ^a	26.2 ^a		
Mean (maize/bean)							25.96	
Mean (maize/soybean)							26.21	

Key: Means with same letters are not significantly different according to Duncan multiple range test at $P < 0.05$; F = Fertilizer; CS = Cropping system; L = Location; ns = not significant.

Table 5. Total Maize yield at harvest in ton ha⁻¹ under various treatments in the two study locations.

Location	Cropping system	Control	Manure (5t)	Manure (2.5 t) + NPK (50 kg)	Manure (1.25 t) + NPK (100 kg)	NPK (200 kg)	CS Mean	L Mean
Lichinga	Maize/bean	3.67	4.51	4.17	5.42	4.14	4.38 ^a	3.7 ^b
	Maize/soybean	1.6	1.74	3.67	5.41	2.55	2.99 ^b	
Sussundenga	Maize/bean	8.12	9.93	9.28	10.18	9.49	9.40 ^a	9.0 ^a
	Maize/soybean	7.05	9.06	8.25	9.28	9.06	8.54 ^b	
Mean (fertilizer)		5.11 ^c	6.31 ^{bc}	6.34 ^{bc}	7.57 ^a	6.31 ^b		
Mean (maize/bean)							5.77 ^b	
Mean (maize/soybean)							6.89 ^a	

Key: Means with same letters are not significantly different according to Duncan multiple range test at $P < 0.05$; F = Fertilizer; CS = Cropping system; L = Location; ns = not significant.

reduction in maize/soybean.

The maize grain yield was significantly influenced by location with average maize grain ($P < 0.05$) yield of 9 ton in Sussundenga, a 58.9% increase in total maize grain yield compared to Lichinga with 3.7 ton ha⁻¹. This was probably due to low rainfall received at the site in April (73 mm) during the grain filling period compared to Sussundenga where 295.6 mm rain was recorded. The interaction between locations, fertilizer treatment and cropping systems had no significant effect in maize grain yield (Table 5). In fact, higher maize growth parameters were improved by intercropping with common bean than in soybean in both locations, a fact attributed to the better utilization of the available resources by maize/common bean intercrop. Results show that not only the integrated use of organic and inorganic fertilizers but also the use of legumes crops could to be incorporated to improve maize yield. This indicates that intercropping of a cereal with legumes and incorporation manure improved soil fertility, however, this is dependent on the particular legumes species used (Nzabi et al., 2002). In the case of maize-soybean intercrop, there could be some attributes between the two crops that are yet to be defined by further research that led to lower yields of maize.

CONCLUSIONS

- A combination of 1.25 ton ha⁻¹ of cow manure and 100 kg ha⁻¹ NPK fertilizers significantly increased the yield of maize over application of cow manure or NPK alone and farmers need to adopt this production system to increase yields.
- Maize yields remain more stable in maize/common bean than in maize/soybean intercropping.
- The farmers with limited resources may intercrop maize with common bean and fertilize it with cow manure at the rate of 1.25 ton ha⁻¹ together with NPK (100 kg ha⁻¹) in the study area of Lichinga and Sussundenga.
- Long term research of the treatments used in this study should be carried out to further ascertain their effects on the physico-chemical properties of the soil.

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