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Economic efficiency of green maize intercropped with beans grown under Tithonia and inorganic fertilizer

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A field trial aimed at assessing the performance of maize and beans under intercropped systems was conducted in 2013 under three experimental components of maize, beans and maize-bean intercrop in a randomized complete block design (RCBD) with three replications. Each component was subjected to treatments that included: a control-without fertilizer (WF), mineral fertilizer (MF) at 150 kg/ha of 17:17:17, Tithonia biomass (TDB) at 8 tons/ha and integrated application of MF and TDB comprising 4 tons/ha Tithonia and 100 kg/ha mineral fertilizer (MF/TDB). The MF/TDB produced 21.7% higher green maize yields than control, while MF and TDB produced 8.96 and 7.52% higher yields, respectively than the control. The land equivalent ratios (LER) were higher than one in all the intercropping plots, thus indicating an optimum exploitation of the environmental resources. Control plots showed the highest yield advantage in terms of LER of 1.70. When maize yield was converted to bean equivalent yield (BEY), the intercropping BEY was higher than the BEY in the sole for all fertilizer types, thereby revealing an agronomic advantage. The actual yield loss (AYL) values for maize indicated a yield gain of between 11.2 and 15.05% when MF and MFTDB were used in the intercropping compared to the sole cropping. Beans recorded yield loss in all the fertilizer types except in TDB which had a yield gain of 20.45%. The economic performance of the intercropping systems, affirmed that the most advantageous fertilizer type for maize was MF/TDB with an IA of 6.566. The monetary advantage index (MAI) indicated a definite yield and economic advantage in maize-bean intercrop over their sole cropping, with integrated use of MF/TDB as nutrient sources being the most economical and advantageous fertilizer regime.

Key words: Economic efficiency, land equivalent ratio (LER), green maize, beans, intercropping advantage, monetary advantage index (MAI), *Tithonia diversifolia.*

INTRODUCTION

Self-sufficiency in maize (*Zea mays* L) production is a major strategy for achieving food security in Kenya. The strategy is adopted to avoid undue reliance on unstable and unpredictable world food markets and to generate incomes to farmers and landless laborers (Mousavi and Eskandari, 2011). Apart from being grown for grain, maize can be produced 'green' to be consumed as a vegetable. Land in the high rainfall areas of Kenya is

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limiting due to high population; hence, it has become necessary to adopt intercropping as a way of increasing the land food output. Intercropping systems are more productive than sole crops grown on the same land, because they are associated with greater yield stability, greater land-use efficiency, increased competitive ability against weeds, improvement of soil fertility due to N fixation, and some favorable root exudates from leguminous species incorporated in the systems (Mousavi and Eskandari, 2011; Lithourgidis et al., 2006).

In Kenya, maize is among the crops that have been intensely grown in a mixture with other crops, especially legumes. Farmers prefer the legumes due to their inherent properties like short duration and ability to fix nitrogen. However, while most reports on intercrops have indicated increase in maize yields, Musambasi et al. (2012) reported a low maize yield when maize and cowpea (*Vigna unguiculata*) were intercropped and a high yield when maize and field beans *(Phaseolus vulgaris* L.) were intercropped.

The author associated higher intercropping yields with better utilization of growth resources, such as water, light and nutrients compared to sole cropping systems. Intercropping kale (*Brassica oleracea* var. *acephala*) and beans has shown increased productivity in terms of land equivalent ratios (LER). Intercropping soybean and maize gave LER values of 1.40 and 1.29, respectively indicating that higher productivity per unit area was achieved by growing the two crops together than growing them separately (Ijoyah et al., 2013).

Continuous and intensive use of highly priced synthetic fertilizer materials for boosting crop productivity in the past decades has been linked to rapid decline in tropical soil fertility and crop productivity. However, with much research efforts, the use of organic fertilizers with or without mineral fertilizers has been recommended to improve soil fertility and crop productivity. To this end, *Tithonia diversifolia* green biomass has been reported to be an effective source of nutrients and has been used successfully to improve soil fertility and crop yields in Kenya (Aguyoh et al., 2010). It has the ability to decompose and release nutrients rapidly. The integration of Tithonia biomass (TDB) with MF is consequently essential to supply sufficient nutrients in the soil. Synthetic fertilizers are expensive for majority of the peasant farmers, while green manuring is unpopular, especially where no edible crop is produced.

According to Gosh et al. (2006) imbalanced nutrient application coupled with low N and P content represent major constraints that limit crop productivity in intercropping systems in many soils where intensive cropping systems are practiced.

Osman at al. (2011) using monetary advantage index (MAI) reported significantly higher economic benefit when two rows of cowpea and one row of millet were intercropped compared to a mixture with one row of each of the crops. Although a number of field studies have been carried out to compare economics of the sole crop yield when taken along with other crops in the system, adequate techniques that could take care of the ecological relationships amongst the Maize-Beans intercrop has not been well elucidated. The objective of the study was to establish economic advantage of maize-beans intercrop when grown under Tithonia and/or synthetic fertilizer.

MATERIALS AND METHODS

The study was conducted at a private farm very close to Kimathi University in Nyeri, Kenya from March to July, 2014 and repeated from August to December, 2014. The area lies at 1815 m above sea level with average minimum and maximum temperatures of 12.2 and 23.2°C, and mean annual rainfall of 928 mm. The soils are well drained, extremely deep with dark reddish brown color, friable clay with an acidic humic top soil (Jaetzold and Schmidt, 2006).

The study was conducted under three cropping patterns consisting of maize alone, maize/beans intercropped, and beans alone. The experimental design was randomized complete block design (RCBD) with four fertilizer treatments and three cropping patterns in three replications. Four fertilizer methods were studied, control without fertilizer (WF); MF 17-17-17 at 150 kg/ha; TDB alone at 8 t ha^{-1} and a combination of MF at 100 kg/ha with TDB at 4 t ha^{-1} ½ (MF+TDB). The experiment was conducted on an area of 33 × 18 m divided into 3 blocks of 18 × 10 m each separated by a 1 m space. The blocks were divided into plots of 3 × 4 m (12 m^2) each with an inter-plot spacing of 0.5 m. Tithonia green leaves were obtained from young tender branches of Tithonia trees, cut and shredded into smaller fragments of less than 5 cm in length with stem girths ranging from 2.8 cm to 4.2 cm enriched with ash, and composted in polythene-aligned pits for three weeks. Initial analysis of soil and chemical composition of Tithonia manure were conducted before planting (Tables 1 and 2).

Three days before planting, TDB was incorporated into the soil at 15 cm depth. Maize (Duma 43) and bean (Mwitemania) seeds from Kenya Seeds Company were sourced from a local agro-supplier in Nyeri. Three maize seeds per hole were sown at a spacing of 0.75 × 0.5 m and 1 × 0.5 m in mono crop and intercrop, respectively. Maize in association plots were intercropped with beans at a spacing of 0.20 m in row. In monoculture, three beans seeds were sown at 0.5 × 0.20 m. Two weeks after sowing (WAS), maize and bean seedlings were thinned to two plants per stand to achieve recommended population of 64 plants per plot (53,333 plants/ha) in sole maize, 240 plants per plot (200,000 plants/ha) in sole bean. In the maize-bean intercropped plots, there were 48 maize plants/plot (40,000 plants/ha) and 160 bean plants/plot (133,333 plants/ha).

Maize was harvested green after attaining physiological maturity and the number of cobs and their weights were recorded from ten randomly selected plants. For the beans, total number of pods and grains per pod per plant were counted from ten randomly selected plants.

LER was used to determine the intercrop advantage as follows:

$$LER = (Yab/Yaa) + (Yba/Ybb) \quad (1)$$

where Yaa and Ybb were yields of sole maize and beans, respectively, while Yab and Yba were crop yields in the maize/bean intercrops for maize and beans, respectively and values of LER greater than 1.0 were considered advantageous (Ofori and Stem, 1987).

Intercropping expected yield of maize and beans was estimated based on the following formula:

$$IEY = MOY \times DIS/DIM \quad (2)$$

Table 1. Initial soil analysis from the experimental site.

Parameter	Units	Value
pH	pH Value	5.2
Organic carbon content	g/kg	39.7
Total nitrogen content	g/kg	3.09
Phosphor stock	mmol P/kg	9.5
K (exch. Potassium)	mmol+/kg	5.6
Mg (exch. Magnesium)	mmol+/kg	35.8
Ca (exch. Calcium)	mmol+/kg	108
Cation exchange capacity	mmol+/kg	178
Clay content	g/kg	720
Sand content	g/kg	70

Table 2. Chemical composition of Tithonia biomass manure.

Parameter	Units	Value
pH	pH value	6.53
Organic carbon content	g/kg	29.57
Total nitrogen content	g/kg	2.5
Phosphor stock	mmol P/kg	0.34
K (exch. Potassium)	mmol+/kg	3.2
Mg (exch. Magnesium)	mmol+/kg	44
Ca (exch. Calcium)	mmol+/kg	60
Cation exchange capacity	mmol+/kg	168

where IEY is the intercropping expected yield, MOY is the mono crop obtained yield for each crop, DIS and DIM are the crop's density in intercropping and mono cropping systems.

To compare the yields of maize and beans, maize yields were converted into bean equivalent yield (BEY) as described by Prasad and Srivastava (1991):

$$BEY\ (t/ha) = Yield\ of\ maize \times Unit\ price\ of\ maize/Unit\ price\ of\ bean \quad (3)$$

The current market price of these two crops was used in calculating BEY in intercrop and in sole. The BEY in intercropping is yield of intercrop beans plus BEY of intercrop maize. The difference between BEY in the intercrop and BEY in the sole represent the agronomic intercropping advantage (AIA) over respective sole crops.

The actual yield loss (AYL) of either maize or beans (AYLa or AYLb) relative to their yield in pure stand was used to calculate the proportion of yield loss or gain of either maize or beans when grown as intercrop according to the formula by Banik et al. (2000) as follows:

$$AYLab = AYLa + AYLb \quad (4)$$

$$AYLa = (Yab/Zab/Ya/Za) – 1 \text{ and } AYLb = (Yba/Zba/Yb/Zb) – 1$$

where Ya and Yb are the yields of maize and beans, respectively, as sole crops and Yab and Yba are the yields of maize and beans in the maize/beans intercrops. Zab and Zba are proportion of maize and beans, respectively. Positive AYL indicates an advantage while negative value indicates disadvantage of the intercrop. This is useful when the main objective is to compare yield on individual plant basis.

To evaluate if the combined yields of maize and beans could be high enough for the farmers to adopt the intercropping system, the economic performance of the two crops grown together was evaluated according to the formula by Ghosh et al. (2006). The higher the MAI value was, the more profitable the cropping system. The MAI was calculated as:

$$MAI = (LER-1) / LER \quad (5)$$

Economic advantage of the intercrop was calculated using the following formula given by Banik et al. (2000):

$$IAma = AYLma \times Pma \text{ and } IAb = AYLb \times Pb \quad (6)$$

where Pma is the commercial value of maize yield (the current price per 110 kg bag of green maize is Ksh 4800), while Pb is the commercial value of beans and the current price per 90 kg bag of beans is Ksh 5400.

Because there were no significant differences among the parameters tested when the data for the two trials were subjected to planned F tests, the data were pooled and analyzed using SAS version 9.1. Significantly different treatment means were separated by Duncan Multiple Range Test at $P \leq 0.05$ levels.

RESULTS

Yields of both sole and mixed crops treated with Tithonia and MF were 24 tons/ha (50% more than the control) and

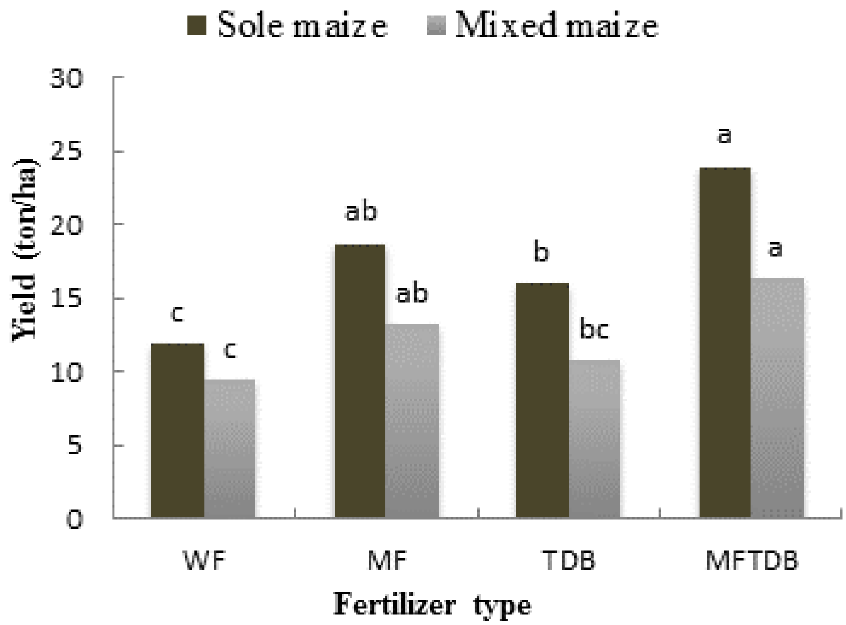

Figure 1. Yield of sole and mixed maize (tons/ha) as affected by Tithonia manure and mineral fertilizer.

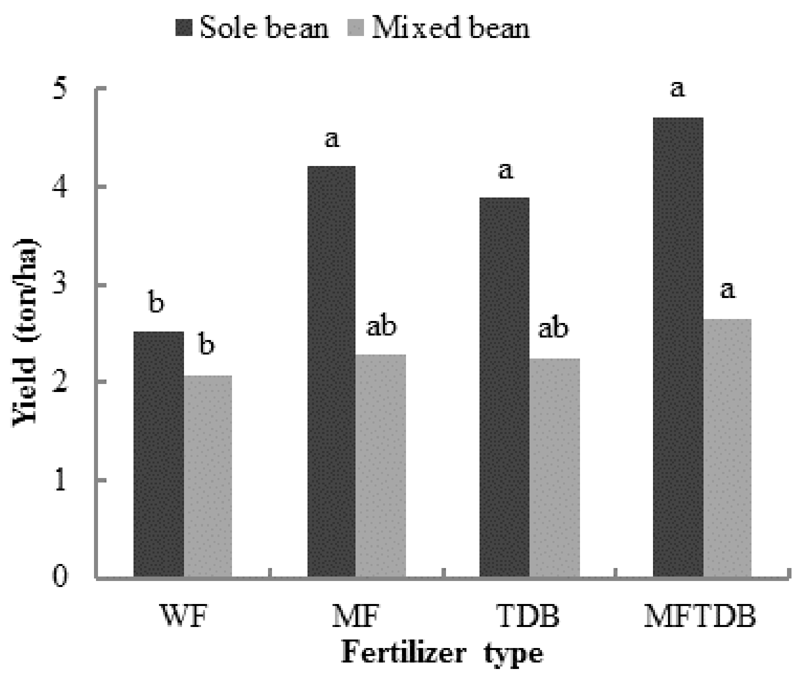

Figure 2. Yield of sole and mixed beans (ton/ha) as affected by Tithonia manure and mineral fertilizer.

16 ton/ha (42% more than the control), respectively (Figure 1). The yields of beans showed a similar trend with application of Tithonia manure and MF. Sole beans performed better than intercropped beans. Integrated nutrient application in mixed crop produced 21.7% higher yields than control, while sole application of MF and TDB produced 8.96 and 7.52% higher yields than the control (Figure 2).

In general, LER for maize and beans was higher than 0.50 in all fertilizer types. LER for maize of 0.83 was the

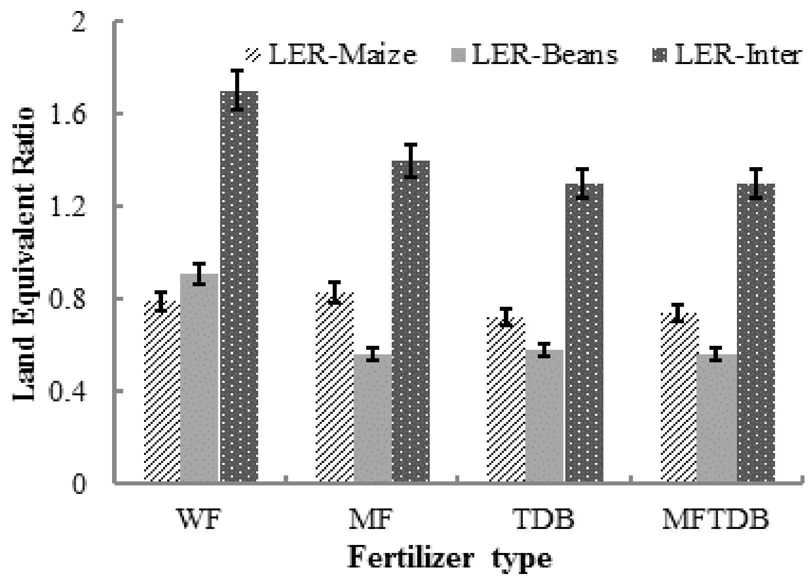

Figure 3. Effect of Tithonia manure and mineral fertilizer application on expected intercropping expected yield.

Table 3. Effect of Tithonia manure and mineral fertilizer on intercropping expected maize and bean yield (tons/ha).

Fertilizer type	IEMY	IOMY	IEBY	IOBY
WF	10.74[a]*	11.34[c]	2.01[b]	2.50[b]
MF	16.84[a]	15.91[ab]	3.37[a]	2.74[ab]
TDB	14.43[a]	12.92[bc]	3.11[a]	2.70[ab]
MF/TDB	21.57[a]	19.55[a]	3.77[a]	3.19[a]

*Means followed by the same letters within a column are not significantly different according to Duncan's Multiple Range Test at P ≤ 0.05. IEMY: Intercropping expected maize yield; IOMY: intercropping obtained maize yield; IEBY: intercropping expected bean yield; IOBY: intercropping obtained bean yield. WF: without fertilizer, MF: mineral fertilizer, TDB: *Tithonia diversifolia* biomass.

highest when MF was used. The control gave the highest LER for beans at 0.91. The lowest LER for maize at 0.72 was obtained when Tithonia manure was used. MF (0.56) gave the lowest LER for beans. However, under intercropping, all the fertilizer types gave a LER of more than 1.0, with the highest and lowest from WF (1.70) and TDB (1.30), respectively (Figure 3)

Intercropping Expected Maize Yield (IEMY) was higher than the intercropping obtained maize yield (IOMY) for all fertilizer types. The shortfall between the expected and obtained maize yield was highest in integrated nutrient application at 1.683 tons. IEMY was not significantly different at P ≤ 0.05 in all the fertilizer types (Table 3). Intercropping Expected Bean Yield (IEBY) was higher than the intercropping obtained bean yield (IOBY) as obtained for all the fertilizer types. The shortfall between the expected and obtained bean yield was highest (0.526 tons) when MF was used (Table 3).

BEY was influenced by application of Tithonia manure and MF in both sole and mixed cropping. The highest BEY in sole cropping was obtained from integrated manure at 20.92 tons/ha. Although fertilizer types did not show significant difference in the BEY; however, a higher yield was recorded for all fertilizer types compared to control. The BEY in the intercrop was higher across the fertilizer types indicating a yield advantage, but the highest BEY was recorded in MFTDB and MF at 24.11 and 19.08 tons/ha, respectively. Although the highest intercrop yield advantage expressed by use of integrated Tithonia manure and MF was 46.45% (Figure 4).

AYL for maize had positive values when MF (0.112) was used and the control had positive values indicating an advantage of the association. The AYL for beans was however negative for all the fertilizer types except for the control (0.3663). The total AYL was all negative for the different fertilizer types indicating an intercrop disadvantage

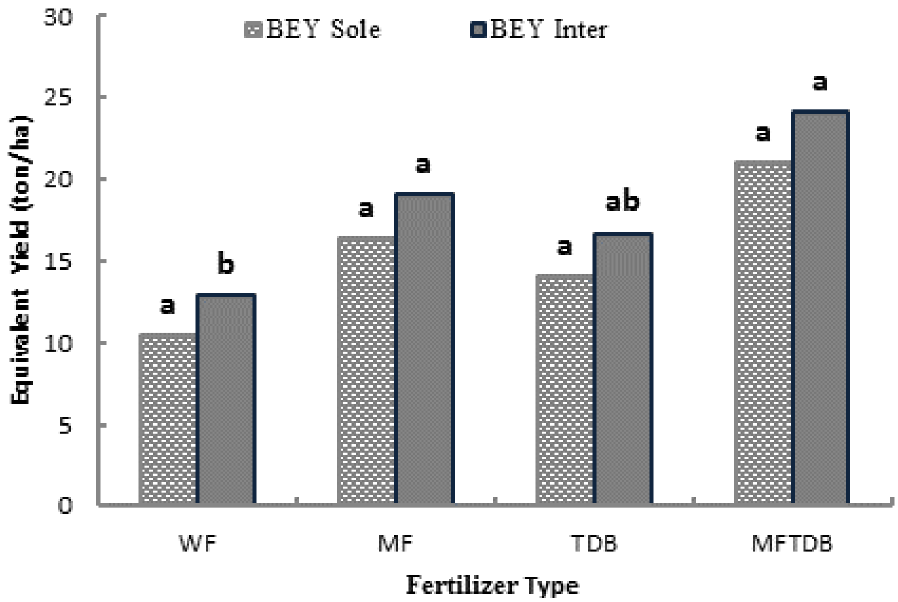

Figure 4. Effect of Tithonia manure and mineral fertilizer on bean equivalent yield.

Table 4. Effect of Tithonia manure and mineral fertilizer on actual yield loss (AYL).

Fertilizer type	AYL $_{maize}$	AYL $_{bean}$	AYL
WF	0.0498[a]	0.3663[a]	0.4162[a]
MF	0.112[a]	-0.1621[a]	-0.0501[a]
TDB	-0.036[a]	-0.1353[a]	-0.1712[a]
MF/TDB	-0.0159[a]	-0.1534[a]	-0.1692[a]

*Means followed by the same letters within a column are not significantly different according to Duncan's Multiple Range Test at P ≤ 0.05. AYL: Actual yield loss; WF: without fertilizer; MF: mineral fertilizer; TDB: *Tithonia diversifolia* biomass.

(IA) (Table 4).

IA in maize was 4.89 more profitable where MF was used, but there was an intercrop disadvantage when Tithonia manure was used alone; however, the IA for maize was not significantly different at P ≤ 0.05. There was an intercrop disadvantage for beans in all the fertilizer types. The application of Tithonia manure and MF influenced the MAI. The highest MAI was obtained when integrated manure was used with MAI of 253. Although the means were not significantly different at P ≤ 0.05, but integrated manure application produced 35% more profit than the control (Table 5).

DISCUSSION

The results from this study showed that the highest green maize and bean yields were obtained from the sole cropping plots across the fertilizer types presumably due to the absence of competition from companion crop. However, the combined yields of green maize and beans in the intercropped system were better than the sole yield of either of the two crops. Being a heavy feeder of nutrients, maize productivity is largely dependent on nutrient management. Spatial separation and therefore acquisition of major growth resources at different times in maize and beans could be used to explain the biggest complementary and yield advantage observed (Ofori and Stern, 1987). Another advantage of the intercrop was the complementarity of the maize/bean association as reported by Matusso et al. (2012); that the cereal may be more competitive than the legume for soil mineral N, but the legume fixes N symbiotically making nitrogen available for both crops.

The finding of the present study agrees with many scientists who have worked with cereal-legume intercropping systems (Egbe, 2010; Ghosh et al., 2006; Matusso et al., 2012; Osman et al., 2011) and proved its success compared to mono crops especially for smallholder farmers who aim at minimizing risks against total crop failures and also get different products for the family's food and income. Beans in the intercrop for this

Table 5. Effect of Tithonia manure and mineral fertilizer on the intercropping advantage (IA) and monetary advantage index (MAI).

Fertilizer type	IA_{maize}	IA_{bean}	MAI
WF	2.175^{a}*	21.98^{a}	202.4^{a}
MF	4.889^{a}	-9.73^{a}	227.1^{a}
TDB	-1.569^{a}	-8.12^{a}	164.0^{a}
MF/TDB	-0.692^{a}	-9.2^{a}	253.4^{a}

*Means followed by the same letters within a column are not significantly different according to Duncan's Multiple Range Test at P ≤ 0.05 WF: without fertilizer; MF: mineral fertilizer; TDB: *Tithonia diversifolia* biomass.

present study generally yielded lower than their counterparts in sole which could possibly be due to the shading effects of maize that significantly reduced light interception potential of the associated beans and reduced their photosynthetic assimilation capacity (Ghosh et al., 2006). Reduced photosynthetic assimilation could have resulted in limited food supply for associated *rhizobium* bacteria, thus consequently diminishing their atmospheric fixation capacity.

Application of combined Tithonia manure and mineral fertilizer (MFTDB) produced the highest amount of green maize and beans. These findings were in agreement with those of Aguyoh et al. (2010) who reported a significant and positively correlated increase in total yield of watermelon with increasing application rates of *T. diversifolia* manure, enhancing the yields by between 8.5 and 31% in plants subjected to the highest level of tithonia (5.4 t/ha) compared to the control. Jeptoo et al. (2013) also found out that application of *T. diversifolia* manure resulted in increased total fresh root weight, dry root and shoots biomass and root volume of carrots compared to the control. Rahman et al. (2013) also found out that application of farmyard manure at the rate of 5 tons ha^{-1} contributed about 25 to 30 kg N ha^{-1} to the maize crop.

Integration of nutrients however increased yield and other yield attributes indicating the enhancement of nutrients availability to the plants which could be due to the fact that application of nitrogen in the presence of organic manures helps mineralization process by minimizing C/N ratio. Integrated use of organic manure and chemical fertilizer increased water stable aggregates which could be attributed to the beneficial effects of certain polysaccharides formed during decomposition of organic residues by microbial activity as well as cementing action of bacteria and fungi (Rahman et al., 2013). Growing a legume in the cropping sequence has special significance in the maintenance of soil fertility and crop productivity, because of its unique ability to fix and utilize atmospheric nitrogen.

Intercropping Expected Yield (IEY) of both maize and beans was higher than the Intercropping Obtained Yield (IOY) for all the fertilizer types. The results showed that the individual plant performance was lower in the intercrop and therefore a mutual inhibition and underperformance of both maize and beans in the association was due to crowding, nutrient sharing and shading effects between the maize and bean plants. As it is usually difficult to compare the performance of two different crops in an intercropping system, the yields of maize were converted to the yields of beans; BEY.

The yield advantage in terms of BEY in this study was higher in maize/bean intercropping system than in sole cropping of either crop thereby revealing an agronomic advantage that ranged from 13 to 19%. The yield response due to Tithonia manure and MF was consistent over the study period, where the integrated nutrient application recorded the highest BEY, but the lowest for the control. These findings corroborates the report of Ghosh et al. (2006) who observed a soybean equivalent yield (SEY) of 60% yield advantage from intercropping over sole soybean when sub soiling over conventional tillage was used. Egbe (2010) however found out that SEY figures were not significantly different when different densities of sorghum and soybean were used.

The IA for maize which is an indicator of the economic feasibility of intercropping systems, affirmed that the most advantageous fertilizer type was MF with the highest IA of 4.889. There was intercropping disadvantage for beans for all the fertilizer types except when Tithonia manure was used. IA was depressed when Tithonia manure was used. The present study is in agreement with Yilmaz et al. (2007) who showed intercrop disadvantage at different densities of common bean and cowpea in maize-common bean and maize-cowpea intercrops. Takim (2012) also found out that there was IA for maize and intercrop disadvantage for cowpeas in maize-cowpea intercrop. Beans responded well to Tithonia manure application and had a higher IA than all other fertilizer regimes.

Monetary advantage (MA) of intercropping was used to calculate the absolute value of the genuine yield advantage. Dhima et al. (2007) assuming that the appropriate economic assessment of intercropping should be in terms of increased value per unit area of land. The result showed that the MAI values were positive in all the fertilizer types and therefore a definite yield and economic advantages in maize-bean intercrop over their sole cropping. The highest MAI of 253 was obtained in the integrated nutrient supply with MF/TDB treated plots, which implied that it was the most economical and advantageous fertilizer regime. This could be attributed to the complementarity of the two crops in the mixture. Dhima et al. (2007) obtained the highest MAI values from the common vetch–oat mixture (105.29) at the 65:35 seeding ratio followed by the common vetch-wheat mixture (59.93) at the 55:45 seeding ratio. The author reported that if LER and relative crowding coefficient (K) values were high, then there was an economic benefit expressed with MAI values such as obtained in this study.

Conclusions

The study proves that the use of Tithonia manure and/or MF (17:17:17) affect growth and yield of maize and beans whether grown alone or in a mixture. The intercropping of maize and beans, regardless of the fertilizer regimes has agro-biological advantages over individual crops. The LER were higher than one in all intercropping plots indicating an optimum exploitation of the environmental resources. The yield advantage in terms of BEY was higher with an agronomic advantage of 13 to 19%. Generally, maize dominated beans except when Tithonia manure was used. The IA and MAI indicated a definite yield and economic advantages in maize-bean intercrop over their sole cropping.

Conflict of Interests

The authors have not declared any conflict of interests.

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