

Assessing biological efficiency and economic advantages of intercropping and integrated soil fertility management in maize (*Zea mays L.*) and soybean (*Glycine max L.*) crops in a Sub-Saharan Africa Region

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ABSTRACT

The purpose of the present study was (i) to assess and compare different competition index and their relationship with yield component under different inorganic and organic fertilizers regimes; and (ii), to identify nutrient management regimes options that lead to higher component yield and income in a maize-soybean intercropping system in a Sub-Saharan Africa region. Field experiment was conducted at two sites in a savannah region of the DR-Congo following the randomized complete block design with six treatments replicated four times. Grain yield and yield components increased under integrated soil fertility management (ISFM) (mineral and organic fertilization combined) than other treatments at the two sites of the study. Organic biomass application resulted in similar grain yield production than the mineral fertilizer application. The required land decreased when soil was fertilized compared to the control. Land equivalent coefficient (LEC) was higher than 0.25 for all the treatments. Results showed favorable area-time equivalency ratio (ATER) for maize-soybean intercropping implying its intrinsic advantage over sole crops. Among all the treatments, integrated nutrient management (ISFM) resulted in higher yields and monetary advantage index (MAI) values for maize/soybean mixture compared to other treatments.

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Key words: Cropping system; Land equivalent ratio; Land equivalent coefficient; Area-time equivalency ratio; Monetary advantage index; Plant competition; maize and soybean yields; DR-Congo.

1. INTRODUCTION

Cereal-legume intercropping plays an important role in subsistence food production in both developed and developing countries (Dahmardeh et al., 2010). Intercropping offers potential advantages for resource utilization, decreased inputs and increased sustainability in crop production, but our understanding of interactions among intercropped species is still very limited (Dhima et al., 2007).

Therefore, intercropping is practiced in many parts of the world (Francis, 1986) because of somevarious advantages such as greater yield stability (Jensen, 1996), greater land-use efficiency (Ofori and Stern, 1987), increased competitive ability toward weeds, improvement of soil fertility due to the addition of N by fixation (Hauggaard-Nielsen et al., 2001), and some favorable exudates from the component legume (Ofori and Stern, 1987). Lithourgidis et al., (2006), demonstrated that Yields production under intercropping are higher than in sole cropping systems. This is because resources such as water, light and nutrients can be utilized more effectively than in the respective sole cropping systems (Li et al., 2006). Almost all reported intercropping combinations with a significant yield advantage were non legume/legume combinations (Morris and Garrity, 1993). Compared to corresponding sole crops, yield advantages have been recorded in many non legume/legume intercropping systems (Ghosh et al., 2006).

Maize and soybean are the staple foods for several communities in the DR-Congo, especially in the Greater Kasai region in the DR-CongoMaize based cropping systems are very popular in the tropics (Ayoola and Makinde, 2008). In general, the smallholder farms in the DR-Congo zone practice maize/legumes association (especially maize-soybean intercropping) without the use of fertilizer (Muyayabantu et al., 2012). In intercropping system, the cereal component, which usually is taller, has a faster-growing or more extensive root system, particularly a larger mass of fine roots (Lehmann et al., 1998), and is competitive for soil inorganic N (Carr et al., 2004).

Interspecific competition is defined as an interaction between two species that reduces the fitness of one or both of them (Crawley, 1997). Interspecies interactions, including above- and belowground competition and facilitation, play an important role in determining the structure and dynamics of plant communities in agriculture (Callaway, 1998; Aerts, 1999). According to Ghosh et al. (2006), imbalanced nutrient application coupled with low native soil N and P is a major constraint limiting productivity of intercropping systems in many soils. Nutrient use in

1 intercropping systems has received considerable attention despite difficulties in quantifying
2 beneficial or competitive effects.

3
4 The use of mineral fertilizers has been associated with increased soil acidity, nutrient imbalance
5 and soil degradation (Ayoola and Makinde, 2008). This shortcoming of organic fertilizer use has
6 motivated scientists to explore the benefit of organic manure use (Ayoola and Makinde, 2008).
7 Application of organic manure alone to sustain cropping has been reported to be inadequate due
8 to their relatively low nutrient contents and their inability to provide a sufficient amount of
9 nutrients (Palm et al., 1997). Integrated nutrient management approaches (Integrated Soil
10 Fertility Management or ISFM), in which both organic manure and inorganic fertilizers are used,
11 have been suggested (Palm et al., 1997). Supply of nutrients from the organic manures can be
12 complemented by enriching them with inorganic nutrients that will be released fast and utilized
13 by crops to compensate for their late start in nutrient release (Ayoola and Makinde, 2008).

14
15 Only limited studies have quantified the effect of integrated organic and inorganic management
16 on competitive ability of intercrop components. Positive effects of the application of inorganic
17 fertilizers on crop yields and yield improvements had been documented (Carsky and Iwuafor,
18 1999). Senaratne et al. (1993) reported improvement in the competitive ability of leguminous
19 plants in legumes/grass mixture with K application. Nutrients are released more slowly from
20 inorganic manure and they are stored for a longer time in the soil, thereby ensuring a long
21 residual effect (Sharma and Mittra, 1991; Abou el- Magd et al., 2005). It is hypothesized that
22 nutrient application of both organic and inorganic fertilizer, alone or in mixture, could influence
23 the economic advantage, competitive ability of component crops and yield of the intercropping
24 system and profitability by farmers.

25
26 The present study, therefore, attempts (i) to assess and compare different competition index and
27 their relationship with yield component under a varying set of nutrient applications (ii), to
28 identify nutrient management regimes options that lead to higher component yield and income
29 from the intercropping system.

30

2. MATERIALS AND METHODS

2.1. Location and site characterization

The study was carried out at two sites in Gandajika (Eastern Kasai) in the DR. Congo. Site 1 was located at INERA research station (23° 57'E, 06° 48'S and 754 m altitude) and site 2 in Mpiana (23° 56'E, 06° 36'S and 685 m altitude). The region falls within the Aw4 climate type according to Köppen classification characterized with 4 months of dry season (from mid-May to August) coupled with 8 months of rainy season, sometimes interrupted by a short dry season in January/February. Daily temperature averages 25°C and annual rainfall is close to 1500 mm. Typically, Gandajika soils consist of a collection of sandy on clay sediment more often based on a shallow lateritic old slab. The adsorption complex is fairly well saturated and there are still some weatherable minerals (Muyabantu et al., 2012a).

2.2. Experimental design and trial implementation

The study was undertaken during the long rain season in 2010-2011. In each site, three trials were conducted. The first trial consisted of maize alone, the second with soybean alone and the third was an association of maize and soybean. The experiment design for each trial was randomized complete block with six treatments and four replications. Each plot measured 3 x 4 meters. The treatments included a control (traditional method) or Without Fertilizer (WF); Conventional method or Mineral Fertilizer (MF) at 115-63-0; Biological method consisting of the application of *Entada abyssinica* biomasses (EAB) alone at 8 t ha⁻¹; *Tithonia diversifolia* biomasses (TDB) alone at 8 t ha⁻¹ and integrated soil fertility management (ISFM) method consisting of the application of MF at 57,5-31,5-0 combined with *E. abyssinica* at 4 t ha⁻¹ ½ (MF +EAB) and MF at 57,5-31,5-0 combined with *T. diversifolia* at 4 t ha⁻¹ ½ (MF +TDB). The experimental plots were left fallow for four months (May-September 2008). During the long growing rainy season, fresh *T. diversifolia* and *Entada* leaves were incorporated into the soil to 15 cm depth, three-days before planting. MF (DAP) was banded along the rows and incorporated into the soil 15 days after sowing. This MF treatment was coupled with urea application. Maize seeds (Mus 1 variety) were sown at 0.75 m x 0.50 m and 1 m x 0,5 m in monocrop and association trials, respectively. For each station, three seeds were sown. Maize in association plots were intercropped with soybean at 0.25 m in row. In monoculture, Soybean seeds were sown at 0.5 m x 0.25 m. Two weeks after sowing (2WAS), the maize and soybean seedlings were thinned to two plants per emplacement. For each treatment, the parameters assessed include

grain yield and yield components, different competition indices such as land equivalence ratio (LER), area x time equivalency ratio (ATER), land equivalent coefficient (LEC), competitive ratio (CR), relative crowding coefficient of both components (K), aggressivity (AGG); intercropping and monetary advantage index and Net benefits

2.3. Estimation of Agrobiological Parameters

2.3.1. Yield components

The maize and soybean intercropping expected yield were obtained by the relation:

$$IEY = \frac{MOY \times DIS}{100} \quad [1]$$

Where, IEY is the intercropping expected yield; MOY is the monocrop obtained yield for each culture and DIS is the each culture s' density in intercropping system.

Two types of results can be recorded: (1) mutual inhibition and underperformance yield when the intercropping obtained yields for each crop in the association is lower than its corresponding intercropping expected yield, (2) cooperation and yield-otherwise when the intercropping obtained yields for each crop in the association is higher than its corresponding intercropping expected yield (Willey, 1979). As it is difficult to compare the performance of two different culture in intercropping system (maize and soybean), maize grain yields were converted to soybean equivalent yield (SEY) as:

$$SEY (t. ha^{-1}) = \frac{Yield\ of\ maize\ (intercrop\ or\ sole) \times unit\ price\ of\ maize}{Unit\ price\ of\ Soybean} \quad [2]$$

The current market price of these two crops was used in calculating SEY in intercrop or in sole.

Reel intercropping soybean yield (RISY) was estimated as $RISY = SEY + ISOY$ [3]

Where ISOY is the intercropping soybean obtained yield. So the difference between RISY and sole soybean obtained yield (SSOY) represent the agronomic intercropping advantage (AIA) comparatively with respective sole crop.

2.3.2. Different competition indices

Intercrop advantage was calculated by the determination of land equivalent ratio (LER) (Ofori and Stern, 1987). The LER, an accurate assessment of the biological efficiency of the intercropping situation, was calculated as:

$$LER = (Y_{ab}/Y_{aa}) + (Y_{ba}/Y_{bb}) \quad [4]$$

Where Y_{aa} and Y_{bb} are yields as sole crops of a and b and Y_{ab} and Y_{ba} are yields as intercrops of a and b. Values of LER greater than 1 are considered advantageous.

The relative dominance of one specie (a) over the other (b) in the intercropping trial was estimated by the use of relative crowding coefficient (K) (Banik et al., 2006). K was calculated as: $K = (K_a \times K_b)$ [5]

Where, $K_a = Y_{ab} \times Z_{ba} / (Y_{aa} - Y_{ab}) \times Z_{ab}$

$K_b = Y_{ba} \times Z_{ab} / (Y_{bb} - Y_{ba}) \times Z_{ba}$,

Where, Y_{ab} and Y_{ba} were the yields of maize and soybean in the intercrop, respectively, Y_{aa} and Y_{bb} were the yields of maize and soybean in sole crop, respectively and Z_{ab} and Z_{ba} were the respective sown proportions (based on seed numbers) (Dhima et al., 2007) of maize and soybean in the in the intercropping systems. When the value of K is greater than 1.00, there is intercrop advantage; when K is equal to 1.00, there is no yield advantage; and when K is less than 1.00, there is a disadvantage.

Land equivalent coefficient (LEC), a measure of interaction concerned with the strength of relationship was calculated as,

$LEC = L_a \times L_b$ [6]

Where, L_a = LER of main crop and L_b = LER of intercrop (Adetiloye et al., 1983). For a twocrop mixture the minimum expected productivity coefficient (PC) is 25% that means, a yield advantage is obtained if LEC value exceeds 0.25.

Area-time equivalency ratio (ATER), the ratio of number of hectare-days required in monoculture to the number of hectare-days used in the intercrop to produce identical quantities of each of the components, was computed as:

$ATER = \frac{(R_y a x t_a) + (R_y b x t_b)}{T}$ [7]

Where, R_y = Relative yield of species 'a' or 'b' i.e., yield of intercrop (a or b)/yield of main crop, t = duration (days) for species 'a' or 'b' and T = duration (days) of the intercropping system (Hiebisich and Mc Collum, 1987).

Competitive ratio (CR) indicates the number of times by which one component crop is more competitive than the other. Relative species competition is often evaluated using competitive ratios (Putnam et al., 1984). This was calculated as:

$R_a = L_a / L_b \times Z_{ba} / Z_{ab}$ [8]

$R_b = L_b / L_a \times Z_{ab} / Z_{ba}$

Where R_a is the competitive ratio of crop a and L_a and L_b are the partial LERs of crops a and b respectively, Z_{ba} is the proportion of crop a in the ab intercrop and Z_{ab} is the proportion of crop b in the ab intercrop. If $R_a < 1$, there is a positive benefit and the crop can be grown in association; if $R_a > 1$, there a negative benefit. The reverse is true for R_b .

Aggressivity is another index that represents a simple measure of how much the relative yield increase in crop a is greater than that of crop b in an intercropping system. It was calculated as:

$$A_{ab} = (Y_{ab}/Y_{aa}Z_{ab}) - (Y_{ba}/Y_{bb}Z_{ba}) \quad [9]$$

Where Y_{aa} and Y_{bb} are yields as sole crops of a and b and Y_{ab} and Y_{ba} are yields as intercrops of a and b. Z_{ab} and Z_{ba} are the sown proportions of a and b in intercrop ab, respectively.

If $A_{ab} = 0$, both crops are equally competitive; if A_{ab} is positive, a is dominant; if A_{ab} is negative, a is the dominated crop (Ghosh et al., 2006).

Moreover, Banik et al. (2000) reported that the actual yield loss (AYL) index for specie a or b gave more precise information about the competition than the other indices between and within the component crops (a and b) and the behavior of each species in the intercropping system, as it is based on yield per plant. The AYL is the proportionate yield loss or gain of intercrops in comparison to the respective sole crop, i.e., it takes into account the actual sown proportion of the component crops with its pure stand. In addition, partial actual yield loss (AYL_a or AYL_b) represent the proportionate yield loss or gain of each species when grown as intercrops, relative to their yield in pure stand. The AYL is calculated according to the following formula (Banik, 1996):

$$AYL_{ab} = AYL_a + AYL_b \quad [10]$$

$$AYL_a = \left\{ \left[\frac{Y_{ab}/Z_{ab}}{Y_a/Z_a} \right] - 1 \right\} \text{ and } AYL_b = \left\{ \left[\frac{Y_{ba}/Z_{ba}}{Y_b/Z_b} \right] - 1 \right\}$$

Where Y_a and Y_b are the yields of maize and soybean, respectively, as sole crops and Y_{ab} and Y_{ba} are the yields of maize and soybean, respectively, as intercrops. Z_{ab} is the sown proportion of maize in mixture with soybean and Z_{ba} the sown proportion of soybean in mixture.

The AYL can have positive or negative values indicating an advantage or disadvantage accrued in intercrops when the main objective is to compare yield on a per plant basis.

2.4. Estimation of Economic Intercropping Advantage Parameters

The economic performance of the intercropping were evaluated to determine if maize yield intercropped with soybean under different organic and inorganic fertilizer regimes and additional

soybean yield could justify adoption of this intercropping system by farmers. Therefore, the economic analysis was carried out to estimate the net benefit and benefit cost ratio. A dominance analysis was completed and the no dominated treatments were further subjected to marginal rate analysis.

Moreover, none of the above competition indices provides any information on the economic advantage of the intercrop ping system. For this reason, the monetary advantage index (MAI) was calculated as:

$$MAI = \frac{(\text{monetary value of combined intercrops}) \times (LER - 1)}{LER} \quad [11]$$

The higher the MAI value the more profitable is the cropping system (Ghosh, 2004). Also, intercropping advantage (IA) was calculated using the following formula (Banik et al., 2000):

$$IA_{ma} = AY_{Lma} \times P_{ma} \quad [12]$$

$$IA_{sb} = AY_{Lsb} \times P_{sb}$$

Where P_{ma} is the commercial value of maize grain yield (the current price is DCF 300 per kg), and P_{sb} is the commercial value of soybean yield (the current price is DCF 900 per kg). With DFC: the Democratic Congolese Franc.

2.5. Data analysis

Data were subjected to analysis of variance (ANOVA) using GenStat Discovery Edition 3. Main effects were separated by least significant differences (LSD) at $P = 0.05$ level. The Weighted Least Squares Linear Regression was calculated to establish the correlation between HY and really obtained yield in intercropping for each culture (maize and soybean).

3. RESULTS

Both organic and mineral treatments produced higher values for expected and obtained soybean grain weight than the control at both sites (INERA and at Mpiana (Table 1). However, among all treatments, ISFM by $\frac{1}{2}$ (MF +EAB) and $\frac{1}{2}$ (MF +TDB) resulted in the most soybean grain for expected (IESY) and obtained (IOSY) yield at all sites than other treatments followed by conventional practice (MF) and biological agriculture (EAB and TDB) with a similar grain weight increase (Table 1). The IOSY is higher than the IESY in both experimental sites, regardless of the treatments. The highest IOSY and IESY were recorded in soybean under ISFM by $\frac{1}{2}$ (MF +EAB) and $\frac{1}{2}$ (MF +TDB) in the two sites.

The intercropping expected and obtained maize yield (IEMY and IOMY) for site 1 (INERA) and site 2 (Mpiana) are presented in Table 2. Maize under all applications produced higher values for expected (IEMY) and obtained (IOMY) grain yield than the control at both sites. ISFM with $\frac{1}{2}$ (MF +EAB) and $\frac{1}{2}$ (MF +TDB) is the best treatments followed by the conventional agriculture (MF), and the biological agriculture (EAB and TDB), respectively (Table 2). On the other hand, organic and inorganic fertilizer mixture (*T. diversifolia* +NP and *E. abyssinica* + NP) increased significantly the expected and obtained yields for maize (Table 2) and soybean (Table 1) in the intercropping treatment. The application of mineral fertilizer (NP) alone was second followed by the application of *Tithonia* or *Entada* alone. However, all fertilizers application increased significantly ($p = 0.05$) yields for maize and soybean compared to control.

Table 3 describes the actual yield loss for soybean and maize in an intercropping system. At site 1 (INERA), ISFM (EF+EAB and MF+TDB) rank first with an increase in intercrop soybean yield of 33.7 % (AYLsb=+0.337) and 30.9% (AYLsb=0.309) respectively compared to its sole crop yield. In contrast, under MF and in MF+EAB mixtures, the decrease of maize yield (-3% and -13.3% respectively) was observed.

At site 2 (Mpiana), the same treatments (MF and MAB plus MF+TDB) resulted in a significant decrease of maize yield in order of 10.5% (AYLma = -0.105), 10.9% (AYLma = -0.109) and 28.4% (AYLma = -0.284) compared to its respective sole crop. AYLsb ranged from +0.172 (EAB) to 0.370 (WF). The total AYL of the maize–soybean mixtures was positive (Table 3), indicating an advantage from intercropping over pure stands.

Soybean did compensate the yield loss of maize specie in mixture indicating an advantage of intercropping (AYL positive). Actual yield loss for soybean (AYLsb) is positive under all the

treatments at both sites 1 and 2, while the maize under MF and MF+EAB resulted in a negative actual yield loss at both sites. The lowest actual yield loss for maize (AYL_{ma}) was observed under MF+TDB (-0.284). But, Total actual yield loss (AYL_t) was positive under all the treatments at both sites. The highest AYL_t was observed under MF+TDB (0.455) at site 1 (INERA), but this value was not significantly different from the control (0.433). SEY increased with the application of mineral and organic fertilizers mixture at both sites. MF+TDB resulted in the highest SEY value (1.372 t ha⁻¹) followed by MF+EAB (1.039 t ha⁻¹) at site 1 (INERA). At site 2 (Mpiana site), MF+EAB ranked first (1.114 t ha⁻¹) followed by MF+TDB (1.082 t ha⁻¹). WF decreased significantly the SEY with the lowest value of 0.279 t ha⁻¹ and 0.355 t ha⁻¹ at site 1 (INERA) and site 2 (Mpiana), respectively.

Positive difference between SSY and RISY is observed under all the treatments and this in both sites (Table 4). In fact, the highest agronomic intercropping advantage (AIA) is observed under mineral-organic fertilizer mixture with value of +0.9732 t ha⁻¹ and +0.6492 t ha⁻¹ for MF+TDB; +0.6523 t ha⁻¹ and +0.7037 t ha⁻¹ for MF+EAB respectively at both sites. The lowest AIA is observed under the control (WF) with +0.6050 t ha⁻¹ at INERA and +0.1773 t ha⁻¹ at Mpiana site. Integrated soil fertility management (MF+TDB and MF+EAB) increased significantly ($P \leq 5\%$) SSY and RISY values at all sites.

Tables 5 and 6 describe the results of land equivalence ratio (LER), area-time equivalency ratio (ATER), land equivalent coefficient (LEC), competitive ratio of maize (CR_{ma}), competitive ratio of soybean (CR_{sb}), relative crowding coefficient of both components, aggressivity of maize (AGG. ma) and the aggressivity of soybean component (AGG. sb) at INERA and Mpiana sites respectively.

All the treatments resulted in LER values higher than 1.00. MF+TDB treatment resulted in the highest LER value (1.23), but not significantly different than the control (WF = 1.22) (Table 5). Soybean intercropped with maize had under all treatments ATER values higher than 1.00. MF+TDB resulted in the highest ATER (1.27) value, followed by MF+EAB with an ATER value of 1.21. LEC values ranged from 0.50 (MF+EAB) to 0.79 (WF). The highest LEC values were under WF (0.79) and MF+TDB (0.74) treatments. The lowest LEC (0.50) was observed under MF+EAB treatments. Maize intercropped with soybean showed a positive K value that higher than 1.0 for all the treatments. The highest K was observed under MF+TDB (3.36) followed by MF+EAB (2.48) and TDB (2.13). In general, Competitive ratio values for maize (CR_{ma}) were higher than competitive ratio values for soybean (CR_{sb}), except for the control

1 treatment. Aggressivity of maize (AGG.ma) was generally positive, except for WF, while that of
2 the soybean (AGG.sb) was negative (Table 5).

3
4 The same trend was observed at site 2 (Mpiana)(Table 6). All the treatments had LER values
5 higher than 1.00. WF treatment gave the highest LER value (1.52), while MF+TDB application
6 resulted in the lowest LER of 1.040. Soybean intercropped with maize (under all treatments) had
7 an ATER value that was higher than 1.00. MF+TDB and MF+EAD had the highest ATER (1.33
8 and 1.24 respectively) followed by TDB (1.23). LEC values ranged from 0.38 (MF+TDB) to
9 1.29 (WF). Soybean intercropped with maize resulted in LEC values higher than 1 for the control
10 treatment; all others treatments had LEC values of 0.79, 0.75, 0.51 for TDB, EAB, MT and
11 MF+EAB, respectively. The lowest LEC (0.38) was observed in the MF+TDB treatment. Maize
12 combined with soybean showed K values higher than 1.0 for all the treatments. The highest K of
13 5.32 was observed for the MF+TDB treatment followed by MF+EAB (3.08) and EAB (2.48)
14 treatments. Competitive ratios for maize (CRma) were consistently higher than those for soybean
15 (CRsb), except for maize-soybean intercropping in control, and EAB application where the CR
16 values were at par. Aggressivity of maize (AGG.ma) was generally positive, while that of the
17 soybean (AGG.sb) was negative (Table 6).

18
19 The MAI values were positive for all organic and inorganic fertilization regimes in both sites
20 (Table 7), indicating a yield advantage. The highest MAI values for maize-soybean mixture were
21 observed *Tithonia*-mineral fertilizer mixture (343891) followed by MF+EAB application
22 (164565) at site 1 (INERA). The same trend was observed at site 2 (Mpiana). MF+TDB
23 treatment resulted in a significantly ($p \leq 0.05$) higher MAI (298139) compared to other treatments,
24 followed by the MF+EAB (234126) treatment. The total IA for maize and soybean mixture,
25 which is an indicator of the economic feasibility of intercropping systems, revealed the most
26 advantageous mixtures crop under all the organic and inorganic regimes in both sites. ISFM
27 (MF+TDB) rank first with a total IA value of +328.11 and +469.23 at sites 1 and 2, respectively,
28 followed by MF+EAB at both sites. Contrary to maize-soybean mixture, maize under MF and
29 MF+EAB resulted in a negative partial IA (-9.09 and -39.9 respectively) at site 1 (INERA). The
30 same trend was observed at site 2 (Mpiana). However at site 2, MF+TDB treatment resulted in
31 the lowest negative partial IA (-85.33) in sole maize (Table 7).

32
33 Results from Table 8 show the cost-benefit analysis of maize/soybean in sole and intercropping
34 system at INERA site, in which the reduction in the yield of maize was compensated for by the
35 soybean grain yield. A greater yield was obtained from the ISFM (MF+TDB and MF+EAB)

1 treatment in intercrop and sole maize and soybean resulting in a higher total income. Crop under
 2 MF+TDB rank first, with gross income values of CDF 1960000 ha⁻¹ and CDF1080000 ha⁻¹ for
 3 maize-soybean intercropping and sole soybean crop respectively. It should be pointed out that 1
 4 USD dollar was equivalent to 900 CDF (Congolese Franc) at the time of the present study. In
 5 sole maize crop, MF+EAB and MF+TDB generated the highest gross incomes. The cost of
 6 production was higher when MF was used to produce maize and soybean in monoculture and in
 7 intercropping system. The ISFM was second while the control treatment cost the least to produce
 8 maize and soybean (CDF 291000 ha⁻¹, CDF 259000 ha⁻¹ and CDF 323000 ha⁻¹ for maize-
 9 soybean intercrop, sole maize, and sole soybean, respectively). Soybean under MF application
 10 had a negative net income (CDF-383413 ha⁻¹) indicating the decline of soybean production. The
 11 highest net income were observed under MF+TDB (CDF 1130000 ha⁻¹) for maize-soybean
 12 intercropping and under MF+EAB and MF+TDB for sole maize, with a net income of CDF
 13 1400000 ha⁻¹ and CDF 1380000 ha⁻¹, respectively (Table 8). The costs benefit ratio decreased
 14 when the net benefit increase. A negative cost benefit ratio, indicates that the cost of production
 15 is higher than the corresponding gross income. The same trend observed for cost-benefit
 16 analysis at site 1 (INERA) (Table 8) recur in the relative results to the cost-benefit analysis of
 17 maize/soybean in sole and intercropping system at site 2 (Mpiana) (Table 9).

18
 19 Also, a greater net income was obtained from TDB, EAB alone and MF+EAB in intercrop with a
 20 net income value of CDF 1040000 ha⁻¹, CDF 1020000 ha⁻¹ and CDF 1010000 ha⁻¹, respectively.
 21 These values were not statistically different with the values for the MF+TDB treatment. In sole
 22 maize crop, ISFM (MF+EAB and MF+TDB) treatments resulted in the highest net income that
 23 was significantly (p=5%) different from the control. In general the cost of production was higher
 24 at site 1 (INERA) compared to site 2 (Mpiana).

25

4. DISCUSSION

In the present study, effects of integrated soil practices management on crop competition, yields components and economics advantage in maize-soybean intercropping system in a savannah region of the DR-Congo was investigated. The intercropping expected soybean yield (IESY) was higher than intercropping obtained soybean yield regardless of the treatments for both study sites. The opposite was observed for maize. In most cases such as in the present study, one of the species components of the intercropping system could present an intercropping obtained yield higher than the intercropping expected yield, while the another component is disadvantaged by its association with the first. The first is called dominant component and the second dominated component (Huxley and Maingu, 1978). Maize can be considered based on the results of the present study as the dominant component and soybeans as a dominated component. Thus, transgressive situation is observed, because the intercropping mixture obtained yield under each treatment is higher than the corresponding intercropping expected maize yield which is considered as the most productive component (dominant). Based on Willey (1979), there was an over-performance for the maize-soybean mixture. The decline in soybean yield recorded was then offset by the surplus of maize yield that was recorded.

In addition, the most soybean grain for expected (IESY) and obtained (IOSY) yield observed under ISFM [$\frac{1}{2}$ (MF +EAB) and $\frac{1}{2}$ (MF +TDB)] at all sites compared to other treatments can be ascribed to the positive effect of fertilizers in improving soil fertility. De Ridder and Van Kaulem (1990) reported that the use of both inorganic and organic fertilizers often results in synergism and improvement of nutrient and water use efficiency. In fact, Ghosh et al. (2006) reported an increase in seed yield of soybean intercrop with sorghum under integrated use of organic and inorganic fertilizers and the decrease of intercrop soybean yield under mineral fertilizer (N-P-K) application. As noted by many studies the integration of organic and inorganic nutrient inputs increases fertilizer use efficiency and provides a more balanced supply of nutrients to the crop (Mugendi et al., 1999). The results concur also with the findings of Mafongoya and Naïr (1997) who reported significant maize yield increases following application of green manure. In the present study, similar expected and obtained yield for soybean and maize under MF, TDN and EAB application were observed. The inorganic fertilizer provides a large part of the nutrients and the organic fertilizer increases soil organic matter status, structure, and buffering capacity (Maatman et al., 2007; Muyayabantu et al. 2012b). The organic matter also improves phosphorus (P) availability through reduction of the P sorption capacities of soil (Easterwood and Sartain, 1990; Nziguheba, 2007) and supply of the P release during their

decomposition (Nziguheba et al., 2002; Nziguheba, 2007). High rates of inorganic P fertilizer has been suggested as one of the strategies for managing high P-fixing soils (Sanchez and Jama, 2002) and organic sources of nutrient contents (Maatman et al., 2007). Conventional practice (MF) and biological agriculture (EAB and TDB) increased similarly the grain weight.

It was also revealed that ISFM (EF+EAB and MF+TDB) increased intercrop soybean yield at site 1 (INERA). The positive interaction effect of organic and inorganic mixture (ISFM) could be responsible of this increase of soybean yield. However, the positive AYL for maize-soybean mixtures recorded for all the treatments at both sites indicate an intercropping advantage over corresponding pure stands. Soybean could compensate the yield loss of maize species under MF and MF+EAB at site 1 (INERA) and under the same treatments plus MF+TDB at site 2 (Mpiana) (AYL_{ma} negative). These results corroborate with the data reported by Dhima et al. (2007) on competition indices of common vetch and cereal intercrops in two seeding ratio. AYL index can give more precise information than the other indices on inter- and intra- specific competition of the component crops and the behavior of each species involved in the intercropping systems.

The superiority of SEY, ISFM [$\frac{1}{2}$ (MF +EAB) and $\frac{1}{2}$ (MF +TDB)] treatments application on crop yields for both components (maize and soybean) could be explained by the synergism of organic and inorganic fertilizers mixture and its ability to improve the availability of nutrient into the soil and water use efficiency. The results are consistent with Ayoola and Makinde (2008) who reported that a better maize growth by the enriched cow dung compared to the sole inorganic fertilizer application. This suggests that organic manure from EAB and TDB can be enriched with inorganic nutrients to generate an initial, fast release of nutrients to plants, prior to the release of nutrients from the organic source. This is expected to solve the typical shortcoming of slow initial release of nutrients from sole organic manure application. Comparable yields were reported with N-enriched cow dung (Ayoola and Makinde, 2008). Ayoola and Agboola (2002) reported that maize performed better in terms of growth, yield and yield components with fortified organic manure than either sole organic or sole inorganic fertilizers. Similar responses have been also reported on maize (Adeniyi and Ojeniyi, 2005), rice (Satyanarayana et al., 2002) and sorghum (Bayu et al., 2006). Murwira and Kirchmann (1993) had observed that the nutrient use efficiency of a crop is increased through a combined application of organic manure and mineral fertilizer.

The AIA results in the present study are consistent with these findings. The highest agronomic intercropping advantage (AIA) is observed under mineral-organic fertilizer mixture. This could

be due to a higher RISY obtained under these fertilizer regimes compared to its respective soybean sole yield (SSY). But, in general, all treatments resulted in higher a RISY than their respective SSY expressed by the positive AIA at both sites. Yield advantages have been recorded in many nonlegume/legume intercropping systems compared to corresponding sole crops. This includes maize (*Zea mays* L.)/soybean (Ghaffarzadeh et al., 1994), sorghum/soybean (Elmore and Jackobs, 1986), wheat (*Triticum aestivum* L.)/mungbean [*Vigna radiata* (L.) R. Wilczek] (Chowdhury and Rosario, 1994), barley (*Hordeum vulgare* L.)/medic (*Medicago* spp.) (Moynihan et al., 1996), canola (*Brassica* spp.)/soybean (Ayisi et al., 1997), groundnut (*Arachis hypogaea* L.)/pearl millet [*Pennisetum glaucum* (L.) R. Br.] (Ghosh and Devi Dayal, 1998), maize/faba bean (*Vicia faba* L.) (Li et al., 1999), pearl millet/cluster bean [*Cyamopsis tetragonoloba* (L.) Taub.] (Yadav and Yadav, 2001), groundnut/cereal fodders (Ghosh, 2004), barley/pea (*Pisum sativum* L.) (Chen et al., 2004), and faba bean/barley (Trydeman-knudsen et al., 2004).

The LER gives an accurate assessment of the biological efficiency of the intercropping situation. The trade-off between increasing the yield of suppressing species and decreasing that of the suppressed species has three possible outcomes for intercropping systems, i.e., yield advantage ($LER > 1$), yield disadvantage ($LER < 1$), and the intermediate result ($LER = 1$) (Vandermeer, 1989). The results of the present study revealed crop complementarities in maize/soybean intercropping and yield advantage, as LER and K values are greater than unity. This corroborated with the findings of Ghosh et al. (2006).

The results of this research also indicate that between 5% and 23% more land would be required under sole systems to get the same amount of grain yield compared to the intercropping at site 1 (INERA) and 4% - 53% more land would be required at site 2 (Mpiana site). Specifically, at site 1 (INERA), the land required in monocrop were 22 % for WF, 23 % for MF+TDB, 15 % for TDB and 10 % for MF+EAB and MF. Therefore, a surface excess of 5 % only is required for EAB. At site 2 (Mpiana), the required lands were 53 % (WF), 27 % (TDB), 20 % (EAB), 13 % (MF+EAB), 10 % (MF) and 4 % for MF+TDB. However, these results show that, the required land decreases when soil is fertilized compared to the control without any fertilization.

In general, the non legume crop is considered a suppressing crop in legume/non legume associations like sorghum/pigeonpea (Tobita et al., 1996), groundnut/cereal fodders (Ghosh, 2004), and soybean/sorghum (Ghosh et al., 2006). This was shown to be true in maize/soybean intercropping in the present study as indicated by aggressivity. Maize is a dominant species

(positive aggressivity) and soybean a dominated species (negative aggressivity) except under WF (control) where the reverse was observed. This could be due to poor initial fertility level responsible of slow growth of maize, favoring soybean component with their ability to fix atmospheric nitrogen.

According to Willey and Rao (1980), CR gives a better measure of competitive ability of the crops and can prove a better index as compared to K and aggressivity. The CR of maize for most treatment was > 1 , and the CR value of soybean for most treatment was < 1 . This indicates an advantage in yield compared with sole crops under these treatments. This further suggests that maize in the intercropping system is less competitive than the associated soybean.

Land equivalent coefficient (LEC) was greater than 0.25 under all treatments at both sites. According to Adetiloye et al. (1983), for a two-crop mixture, the minimum expected productivity coefficient (PC) is 25%, that is, a yield advantage is obtained if LEC value exceeds 0.25. This indicates that soybean can grow in mixture with maize under all treatments without major inconvenience. In fact, in the present study, intercropping yield advantage was observed under all the treatments in both sites, indicating an absolute yield advantage of soybean when intercropped with maize. Yilmaz et al. (2008) had reported similar findings in maize- legume intercropping systems in the East Mediterranean region.

ATER values produced under all the treatments were higher than 1.0, confirming further advantage of intercropping of soybean with maize at both sites. The ATER values obtained in this study implied that between 17% to 27% more hectare days would be required under sole cropping than when the soybean was intercropped with maize at site 1 (INERA). At site 2 (Mpiana), 20% to 33% more hectare days would be required under sole cropping than when soybean was intercropped with maize.

A definite yield advantage was observed under all the treatments with a positive MAI value. But among all treatments, integrated nutrient management (MF+TDB and MF+EAB) resulted in a higher MAI value for maize/soybean mixture at both sites (INERA and Mpiana). The results of the present study corroborate with the finding of Ghosh et al. (2009). They reported that under integrated use of organic- and inorganic-fertilizer, the soybean equivalent yield and monetary advantage index were higher than for the control and the inorganic-fertilizer treatments. The same reason could be evoked for IA. The IA which is also an indicator of the economic feasibility of intercropping systems, indicated that the most advantageous treatments application in the maize/soybean mixtures were integrated nutrient management followed by MF, TDB and

EAB application. The fact that MAI and IA values were positive suggests that these fertilizer application had the highest economic advantage in the intercropping systems (Dhima et al., 2007) whereas all the others, which had negative values, showed an economic disadvantage.

A greater yield was obtained from ISFM (MF+TDB and MF+EAB) in intercrop and for sole maize and soybean crop that resulted in a higher total income at both sites. At INERA site, crop under MF+TDB ranked first, with gross income values of CDF1960000 ha⁻¹ and CDF1080000 ha⁻¹ for maize-soybean intercropping and sole soybean crop, respectively.

Intercropped maize/soybean generated higher values of GI and net benefits than their respective sole systems under integrated nutrient management. This is probably because of the additional yield and values of the two components. Egbe (2005) had made similar observations in pigeon pea/sorghum and pigeon pea-/maize intercropping studies. Njoroge et al. (1993) estimated the net benefit of intercropping coffee with food crops by subtracting the total variable costs from the gross profits. Similarly, Egbe (2005) had estimated the total profit and the marginal benefit; cost ratio from investment on different farm inputs used in pigeon pea/sorghum intercropping system by computing returns per naira invested (RI). The use of TDB and EAB alone can be justified as fertilizer to generate greater net benefits than the application of mineral fertilizer in maize/soybean intercropping and sole crop of each of component. This could be due to the fact that, mineral fertilizer cost more than organic fertilizer. The large profit generated in maize/soybean intercropping compared to respective sol crop might probably be the result of the high yield and price of soybean compared to maize. MF+TDB and MF+EAB were indeed more profitable treatments than the other treatments. Based on the analyses completed in the presented study, organic fertilizer application can be recommended for its reasonable cost compared to the mineral fertilizer and their moderated profit. Site 2 (Mpiana) could be considered as more fertile than site 1 (INERA). This explained the relative increase in the GI observed at this site 2.

5. CONCLUSION

Integrated nutrient management (MF+TDB and MF+EAB) resulted in a significantly higher grain yield than the control. There was a significant variability in competitive index among the various treatments. Land equivalent ratio (LER), area–time equivalency ratio (ATER), decreased with fertilizer application at both sites. Land equivalent coefficient (LEC) was higher than 0.25 for all the treatments, an indication of yield advantages over the control. Relative crowding coefficient (K) was higher under integrated soil fertility management than under other

treatments. In general, at both sites, aggressivity was negative for soybean and positive for maize indicating that maize is a dominant crop and soybean a dominated crop. Soybean intercropped with maize resulted in a high yield components, high gross income and net benefits under MF+TDB and MF+EAB. Application of MF resulted in the lowest net benefit and negative net benefit for sole soybean crop indicating the disadvantage of this application. These results suggest that maize/soybean intercropping system is biologically and economically efficient and more profitable under ISOM with MF+EAB and MF+TDB. However, application of *Entada* and *Tithonia* alone could be sufficient to produce a moderate production, compared to mineral fertilizer, in this intercropping system when farmers lack possibility to purchase mineral fertilizer.

ACKNOWLEDGEMENT

This research was conducted through a partnership between Laurentian University (Ontario, Canada), University of Kinshasa (DR-Congo), and Caritas Congo. The authors are grateful to the Canadian International Development agency (CIDA) for financial support.

COMPETING INTERESTS

Authors have declared that no competing interests exist

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Table 1: Soybean expected and obtained grain yield following mineral and organic fertilization at INERA (site 1) and Mpiana (site 2) in Gandajika (DR-Congo).

Fertilizer	Sites			
	Site 1 (INERA)		Site 2 (Mpiana)	
	IESY	IOSY	IESY	IOSY
	(t ha ⁻¹)			
WF (Control)	0.2650c	0.2875c	0.2950c	0.4225c
MF	0.4650b	0.5325b	0.5425b	0.6575b
EAB	0.4750b	0.4850b	0.5600b	0.6200b
TDB	0.4500b	0.5125b	0.5300b	0.6600b
½ (MF +EAB)	0.5675a	0.7050a	0.6575a	0.8550a
½ (MF +TDB)	0.6000a	0.7300a	0.6750a	0.8650a
CV (%)	11.55		9.72	
LSD (row)	0.0841		0.0855	

In the colon, means sharing by common letter are not significantly different from one another at 5 % level.

IESY=intercropping expected soybean yield, IOSY= intercropping obtained soybean yield.

WF = without fertilization; MF= mineral fertilization; EAB= *Entada abyssinica* biomass; TDB = *Thithonia diversifolia* biomass.

Table 2: Maize expected and obtained yield following mineral and organic fertilization at INERA (site 1) and Mpiana (site 2) in Gandajika (DR-Congo)

Fertilizer	Sites			
	Site 1 (INERA)		Site 2 (Mpiana)	
	IEMY	IOMY	IEMY	IOMY
	(t ha ⁻¹)			
WF (Control)	1.0500d	0.9750d	1.1875d	0.9850d
MF	4.2300b	2.9625bc	4.6075b	2.9525bc
EAB	3.1800c	2.4450c	3.1500c	2.7900c
TDB	3.5425c	2.7050bc	3.1800c	2.8200c
½ (MF +EAB)	5.1050a	3.1875b	5.3375b	3.4175a
½ (MF +TDB)	4.9875a	4.1850a	6.3850a	3.3175ab
CV (%)	12.00		11.00	
LSD (row)	0.5084		0.5294	

In the colon, means sharing by common letter are not significantly different from one another at 5 % level.

IEMY=intercropping expected maize yield, IOMY= intercropping obtained maize yield.

WF = without fertilization; MF= mineral fertilization; EAB= *Entada abyssinica* biomass; TDB = *Thithonia diversifolia* biomass;

Table 3: Soybean equivalent yield (SEY) (tha^{-1}), actual yield loss of maize (AYLm), and actual yield loss of soybean (AYLsb), in an intercropping system following mineral and organic fertilization at INERA (site 1) and Mpiana (site 2) in Gandajika (DR-Congo)

Treatment	Site 1 (INERA)				Site 2 (MPIANA)			
	Actual yield loss			SEY	Actual yield loss			SEY
	Maize	Soybean	Total		Maize	Soybean	Total	
WF(Control)	0.279 ^a	0.154 ^b	0.433 ^a	0.318 ^e	0.370 ^a	0.389 ^a	0.7597 ^a	0.355 ^e
MF	-0.030 ^d	0.228 ^b	0.198 ^{cd}	0.966 ^b	-0.105 ^c	0.298 ^b	0.1934 ^e	0.963 ^c
EAB	0.070 ^c	0.037 ^c	0.107 ^d	0.797 ^d	0.216 ^b	0.172 ^b	0.3878 ^c	0.910 ^d
TDB	0.087 ^c	0.209 ^b	0.296 ^b	0.882 ^c	0.220 ^b	0.269 ^b	0.4883 ^b	0.919 ^d
1/2(MF+EAB)	-0.133 ^e	0.337 ^a	0.204 ^c	1.039 ^b	-0.109 ^c	0.383 ^a	0.2744 ^d	1.114 ^a
1/2(MF+TDB)	0.145 ^b	0.309 ^a	0.455 ^a	1.372 ^a	-0.284 ^d	0.365 ^a	0.0807 ^f	1.082 ^b

In the colon, means sharing by common letter are not significantly different from one another at 5 % level.
 WF = without fertilization; MF= mineral fertilization; EAB= *Entada abyssinica* biomass; TDB = *Thithonia diversifolia* biomass;

Table 4: Sole soybean yield (SSY) (t ha^{-1}), reel intercropping soybean yield (RISY) (t ha^{-1}), and agronomic intercropping advantage (AIA) following mineral and organic fertilization at INERA (site 1) and Mpiana (site 2) in Gandajika (DR-Congo)

Fertilizer	Site					
	INERA			MPIANA		
	SSY	RISY	AIA	SSY	RISY	AIA
WF (Control)	0.5107 ^c	0.6050 ^e	0.0943 ^e	0.5677 ^c	0.7450 ^d	0.1773 ^e
MF	0.8943 ^b	1.5025 ^c	0.6082 ^b	1.0410 ^b	1.6225 ^c	0.5815 ^{bc}
EAB	0.9337 ^b	1.2725 ^d	0.3400 ^d	1.0753 ^b	1.5300 ^c	0.4547 ^d
TDB	0.8663 ^b	1.3950 ^{cd}	0.5287 ^c	1.0200 ^b	1.5525 ^c	0.5325 ^c
1/2 (MF +EAB)	1.0920 ^a	1.7425 ^b	0.6523 ^b	1.2663 ^a	1.9700 ^a	0.7037 ^a
1/2 (MF +TDB)	1.1543 ^a	2.1275 ^a	0.9732 ^a	1.2983 ^a	1.9475 ^b	0.6492 ^b
Mean site	0.91	1.4408	0.5328	1.0447	1.5612	0.5150
CV (%)	7.99	9.57		7.99	9.57	

In the colon, means sharing by common letter are not significantly different from one another at 5 % level.

WF = without fertilization; MF= mineral fertilization; EAB= *Entada abyssinica* biomass; TDB = *Thithonia diversifolia* biomass;

Table 5: Maize-soybean intercropping yield advantage based on different competition indices from field trials at site 1 (INERA) in Gandajika (DR-Congo).

Treatment	LER	ATER	Competitive ratio		LEC	K	Aggressivity	
			Maize	Soybean			Maize	Soybean
WF(Control)	1.22 ^a	1.17 ^c	0.92 ^e	1.13 ^a	0.79 ^a	1.45 ^e	-0.125 ^e	0.125 ^a
MF	1.10 ^{ab}	1.17 ^c	1.31 ^b	0.84 ^d	0.54 ^{cd}	1.66 ^{de}	0.258 ^b	-0.258 ^d
EAB	1.03 ^b	1.18 ^c	1.03 ^d	1.03 ^b	0.58 ^c	2.48 ^b	0.034 ^d	-0.034 ^b
TDB	1.15 ^{ab}	1.17 ^c	1.13 ^c	0.92 ^c	0.64 ^b	2.13 ^c	0.122 ^c	-0.122 ^c
½(MF+EAB)	1.10 ^{ab}	1.21 ^b	1.6 ^a	0.65 ^e	0.50 ^d	2.00 ^d	0.470 ^a	-0.470 ^e
½(MF+TDB)	1.23 ^a	1.27 ^a	1.12 ^c	0.89 ^b	0.74 ^a	3.36 ^a	0.164 ^c	-0.164 ^c

In the colon, means sharing by common letter are not significantly different from one another at 5 % level.

LER= Land equivalent ratio, ATER= area-time equivalent ratio, LEC= land equivalent coefficient, K= relative crowding coefficient. WF = without fertilization; MF= mineral fertilization; EAB= *Entada abyssinica* biomass; TDB = *Thithonia diversifolia* biomass;

Table 6: Maize-soybean intercropping yield advantage based on different competition indices from field trials at site 2 (Mpiana) in Gandajika (DR-Congo)..

Treatment	LER	ATER	Competitive ratio		LEC	K	Aggressivity	
			Maize	Soybean			Maize	Soybean
WF(Control)	1.52 ^a	1.20 ^d	0.83 ^d	1.22 ^a	1.29 ^a	1.24 ^c	0.019 ^e	-0.019 ^a
MF	1.10 ^{bc}	1.20 ^d	1.47 ^b	0.70 ^c	0.51 ^d	1.83 ^b	0.403 ^b	-0.403 ^c
EAB	1.200 ^{bc}	1.21 ^d	0.97 ^{cd}	1.04 ^b	0.75 ^c	2.48 ^{ab}	0.043 ^c	-0.043 ^b
TDB	1.270 ^b	1.23 ^c	1.09 ^c	0.93 ^b	0.79 ^b	1.96 ^b	0.049 ^c	-0.049 ^b
½(MF+EAB)	1.13 ^b	1.24 ^b	1.61 ^{ab}	0.63 ^{cd}	0.51 ^d	3.08 ^{ab}	0.492 ^b	-0.492 ^c
½(MF+TDB)	1.040 ^c	1.33 ^a	1.97 ^a	0.54 ^d	0.38 ^e	5.32 ^a	0.650 ^a	-0.650 ^d

In the colon, means sharing by common letter are not significantly different from one another at 5 % level.

LER= Land equivalent ratio, ATER= area-time equivalent ratio, LEC= land equivalent coefficient, K= relative crowding coefficient. WF = without fertilization; MF= mineral fertilization; EAB= *Entada abyssinica* biomass; TDB = *Thithonia diversifolia* biomass;

Table 7: Monetary advantage index and intercropping advantage of different fertilization regimes in Soybean-maize intercrop system at site 1 (INERA) and site 2 (Mpiana) in Gandajika (DR-Congo).

Fertilizer	INERA				MPIANA			
	IA			MAI	IA			MAI
	Maize	Soybean	Total		Maize	Soybean	Total	
WF(Control)	21.10 ^d	33.65 ^c	54.75 ^d	50735 ^d	64.67 ^b	158.41 ^b	223.08 ^c	58580 ^d
MF	-9.09 ^e	209.69 ^b	200.61 ^c	118793 ^c	-31.38 ^c	274.15 ^b	242.77 ^c	116259 ^c
EAB	83.62 ^a	141.80 ^b	225.42 ^c	99534 ^c	-85.33 ^d	335.96 ^a	250.63 ^c	231196 ^b
TDB	26.08 ^c	192.00 ^b	218.08 ^c	133048 ^{bc}	65.86 ^b	247.29 ^b	313.16 ^b	204334 ^b
½(MF+EAB)	-39.9 ^f	310.07 ^a	270.21 ^b	164565 ^b	-32.59 ^c	352.35 ^a	319.76 ^b	234126 ^b
½(MF+TDB)	43.56 ^b	284.55 ^a	328.11 ^a	343891 ^a	111.13 ^a	358.10 ^a	469.23 ^a	298139 ^a

In the colon, means sharing by common letter are not significantly different from one another at 5 % level.

MAI=monetary advantage index, IA=intercropping advantage. WF = without fertilization; MF= mineral fertilization; EAB= *Entada abyssinica* biomass; TDB = *Thithonia diversifolia* biomass.

Seeding ratio maize: soybean was 51:49, based on seed numbers.

Table 8: Cost of production, gross income, and net income (CDF/ha) for soybean intercropped with maize under different mineral and inorganic fertilization regimes at site 1 (INERA) in Gandajika (DR-Congo).

Cropping system	Fertilizer	Cost of production (CDF)	Gross income (CDF)	Cost benefit ratio	Net income (CDF)
Intercropping					
Maize/soybean	WF (Control)	291000	556569 ^e	2.1	265569 ^d
Maize/soybean	MF	1174200	1.38E+06 ^c	6.7	205356 ^e
Maize/soybean	EAB	410600	1.17E+06 ^d	1.54	760960 ^c
Maize/soybean	TDB	410600	1.28E+06 ^d	1.5	873698 ^b
Maize/soybean	½ (MF +EAB)	824400	1.60E+06 ^b	2.1	778529 ^c
Maize/soybean	½ (MF +TDB)	824400	1.96E+06 ^a	1.7	1.13E+06 ^a
Sole					
maize	WF (Control)	259000	450000 ^d	2.4	191000 ^e
maize	MF	1142200	1.81E+06 ^b	2.7	670300 ^d
maize	EAB	378600	1.36E+06 ^c	1.4	983900 ^c
maize	TDB	378600	1.47E+06 ^c	1.34	1.10E+06 ^b
maize	½ (MF +EAB)	792400	2.19E+06 ^a	1.6	1.40E+06 ^a
maize	½ (MF +TDB)	792400	2.17E+06 ^a	1.6	1.38E+06 ^a
Soybean					
soybean	WF (Control)	323000	469813 ^e	3.2	146813 ^d
soybean	MF	1206200	822787 ^c	-2.15	-383413 ^e
soybean	EAB	442600	858973 ^c	2.1	416373 ^a
soybean	TDB	442600	797027 ^d	2.25	354427 ^a
soybean	½ (MF +EAB)	856400	1.00E+06 ^b	6.75	148240 ^c
soybean	½ (MF +TDB)	856400	1.08E+06 ^a	4.7	228587 ^b

In the colon, means sharing by common letter are not significantly different from one another at 5 % level. WF = without fertilization; MF= mineral fertilization; EAB= *Entada abyssinica* biomass; TDB = *Thithonia diversifolia* biomass;

Note that the conversion rate between the Congolese franc (CDF) and USD dollar was \$1USD = 900 CDF during the experimental period.

Table 9: Cost of production, gross income, and net income (CDF/ha) for soybean intercropped with maize under different mineral and inorganic fertilization regimes at site 2 (Mpiana) in Gandajika (DR-Congo).

Cropping system	Fertilizer	Cost of production (CDF)	Gross income (CDF)	Cost benefit ratio	Net income (CDF)
Intercropping					
Maize/soybean	WF (Control)	263800	683013 ^e	1.63	419213 ^b
Maize/soybean	MF	1147000	1.49E+06 ^c	4.33	344249 ^c
Maize/soybean	EAB	383400	1.41E+06 ^d	1.4	1.02E+06 ^a
Maize/soybean	TDB	383400	1.43E+06 ^{cd}	1.4	1.04E+06 ^a
Maize/soybean	½ (MF +EAB)	792800	1.81E+06 ^a	1.8	1.01E+06 ^a
Maize/soybean	½ (MF +TDB)	792800	1.79E+06 ^b	1.8	998053 ^a
Sole crop					
maize	WF (Control)	240800	467500 ^e	2.1	226700 ^d
maize	MF	1124000	1.98E+06 ^c	2.33	851000 ^c
maize	EAB	360400	1.35E+06 ^d	1.4	989600 ^b
maize	TDB	360400	1.36E+06 ^d	1.4	1.00E+06 ^b
maize	½ (MF +EAB)	769800	2.29E+06 ^b	1.5	1.52E+06 ^a
maize	½ (MF +TDB)	769800	2.74E+06 ^a	1.4	1.97E+06 ^a
Sole crop					
soybean	WF (Control)	286800	522253 ^e	2.22	235453 ^c
soybean	MF	1170000	957720 ^{cd}	- 4.5	-212280 ^d
soybean	EAB	406400	989307 ^c	1.7	582907 ^a
soybean	TDB	406400	938400 ^d	1.8	532000 ^a
soybean	½ (MF +EAB)	815800	1.17E+06 ^b	3.4	349227 ^b
soybean	½ (MF +TDB)	815800	1.19E+06 ^a	3.14	378667 ^b

In the colon, means sharing by common letter are not significantly different from one another at 5 % level.

WF = without fertilization; MF= mineral fertilization; EAB= *Entada abyssinica* biomass; TDB = *Thithonia diversifolia* biomass.

Note that the conversion rate between the Congolese franc (CDF) and USD dollar was \$1USD = 900 CDF during the experimental period.