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Effects of mineral and organic fertilizer inputs on the yield and economic profitability of a hybrid variety of maize (*Zea mays* L.), grown in the Korhogo region of Côte d'Ivoire

Kouame Konan*, **Coulibaly Lacina Fanlégué, Siené Laopé Ambroise Casimir, Conde Mariame, Kone Mamadou**

Plant Physiology Laboratory, UFR Biological Sciences, Peleforo Gon Coulibaly University, Korhogo, Côte d'Ivoire

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Abstract

In the Korhogo region, the supply/demand ratio for maize has remained low. Despite the importance given to this crop, its production still cannot meet the needs of this population thus becoming dependent on imports. This study was initiated to help increase maize production by assessing the effects of different types of mineral and organic fertilizers on maize yield and economic profitability. The experiment was carried out on the experimental site of the Peleforo Gon Coulibaly University of Korhogo, following a Fisher block device comprising 4 treatments and 4 repetitions. Treatments included control without fertilizer (T0) and 3 different types of fertilizer (T1 = organic fertilizer "Bio Deposit Elixir", T2 = organic fertilizer Phytobiological Aval and T3 = mineral fertilizer Yara Mila Actyva). The results obtained showed that yield and all its characteristics were improved by the different types of applied fertilizers. Yields were 12373 kg/ha for T3, 9153 kg/ha for T1, 6560 kg/ha for T2 and 5 972 kg/ha for T0. The profitability of mineral and organic fertilizers, determined from the net profit, varied according to the type of fertilizer. The contribution of mineral fertilizer, with a net profit of 1 546 680 F CFA, was the most economically profitable, therefore the most recommendable. In a context where the high price of fertilizers is very often a barrier to the intensification of maize cultivation, this study is a contribution to fertilization and adapted to the socio-economic conditions of the region, knowing the low income of farmers.

* **Corresponding Author:** Kouame Konan ✉ konanaubino@gmail.com

Introduction

The analysis of the situation and outlook on food security in Africa sub-Saharan shows a growing gap between consumption needs and food availability at the aggregate level of countries, households and individuals. This leads to malnutrition and marked under-nutrition (Dembele, 2001). This situation could worsen by 2050, following a very significant increase in the population (Lutz *et al*., 2001; Ezeh *et al*., 2012). Increasing the production of staple foods remains the only possibility of fight against the increase in the rate of poverty and undernourishment. Maize (*Zea mays* L.) is one of the three most widely grown cereals in the world (Nyembo, 2010). These fabulous statistics are due to the fact that all parts of the plant have an economic value (Nyembo *et al*., 2014). Maize is now considered the main food product in the Korhogo region and the fifth foodstuff in Côte d'Ivoire, and is reputed to be an exhausting plant with regard to exports of major minerals in in the straws. For example, a production of two tons of grain corn exports about 60 kg of nitrogen and more than half of the amount of nitrogen is in the grain after harvest (FAO, 2005).

In Côte d'Ivoire, in general, and in the Korhogo region in particular, the large production of this commodity is consumed in the form of flour and thus constitutes the basic food preferred by the majority of the population. Despite the importance given to this crop, its production still cannot meet the needs of this population thus becoming dependent on imports from West Africa.

The low yields obtained, generally less than 1000 kg per hectare (Nyembo *et al*., 2015), are the cause. This is partly due to the low use of improved genotypes and agricultural inputs, the amount of damage caused by various pests and poor farming practices (Nyembo *et al*., 2014). According to Useni *et al*. (2013), inadequate management of plant nutrition and low soil fertility are the main factors responsible for lower yields.

However, the soils of the north of the country, in general, and those of Korhogo, in particular, belong to the category ferruginous soils, characterized by an acidic pH (Cunha *et al*., 2009), a low organic matter content (Kasongo *et al*., 2013), the presence of low activity clays, mainly kaolinite (Qafoku *et al*., 2004) and the unavailability of nutrients such as K, P and N leached by wind and water erosion (Amede, 2003; Henao and Baanante, 2006). As a result, these soils are becoming increasingly unproductive and agricultural activity can only be achieved with significant nutrient inputs (Useni *et al*., 2013).

To mitigate these declines, it is among other things, mineral fertilization by chemical fertilizers (Roose *et al*., 2008; Nyembo *et al*., 2012; Useni *et al*., 2012; Nyembo *et al*., 2013; Useni *et al*., 2013; Nyembo *et al*., 2015), organic fertilization through the use of compost, green manure, nitrogen-fixing legumes (Harmand and Ballé, 2001; Ilunga *et al*., 2015; Ilunga *et al*., 2016), manure, (Ganry *et al*., 2000), the use of cropping techniques through crop combinations, and rotations and rotations (Kouadio, 2003; Melendez *et al*., 2003. Lompo, 2008. Roose *et al*., 2008). These different proposals have a financial impact that cannot be borne by the farmer who practices subsistence farming. Searching for relief alternatives is very important. It is in this context that this study was initiated, with a view to reducing costs and optimizing profits.

Thus, the general objective of this study is to explore the profitability path of the different types of mineral and organic fertilizers used as fertilizers on a hybrid maize variety, in Korhogo, one of the main maize production areas, in the grassy savanna of northern Côte d'Ivoire. The following hypotheses have been made: (i) the use of chemical and organic fertilizers increases the yield of corn, (ii) there is a type of fertilizer that makes the maize crop profitable.

Material and methods

Study site

The study was conducted in Korhogo commune, located in northern Côte d'Ivoire, whose geographical coordinates are 9° 26 'north longitude and 5° 38' west latitude. The climate of the zone, Sudanese type, is characterized by an alternation of two seasons. A long dry season, from October to May, precedes the rainy season, marked by two rainy peaks, one in June and the other in September. The area is also characterized by average temperatures ranging between 24 and 33 °C and a monthly average humidity of 20%. The annual rainfall is between 1100 and 1600 mm and the duration of insolation is 2600 hours per year.

The soil is of tropical ferruginous type, formed on granite who's leaching more or less intense, has reduced the fertility. The relief is generally flat and scattered in places by inselbergs (Koffie and Yéo, 2016).

Plant material

The plant material used was a hybrid variety of maize, called "Komsaya". This variety is characterized by the yellow color of the grains produced and a yield of up to 4 to 6 t/ha, under the best growing conditions. It usually produces on average two ears per foot. The average length of its cycle is about 90 days. The grains produced by this variety are particularly rich in lysine, tryptophan and provitamin A. This variety is most often recommended for feeding children (Anonyme, 2016).

Fertilizer products

Fertilizer products consisted of two different types of organic fertilizer and a mineral fertilizer.

First, a mineral fertilizer, called "Yara Mila Actyva" or (YMA), existing in the granulated form and of composition NPK 23-10-5 + 3S + 2MgO + 0.3 Zn;

Second, a foliar organic fertilizer, called "Bio Deposit Elixir" (BDE), used in liquid form and composed of sapropile (mud organic substances) and peat (product of the decomposition of herbaceous plants in stagnant water);

Third, an organic fertilizer of plant origin, called "Phytobiological Aval Fertilizer" (EPA), found in the powdery form. It consists of organic substance of vegetable origin.

Experimental device and treatments and their application

The experimental setup consisted of Fischer blocks, completely randomized, with 4 treatments and 4 replicates (blocks).

The study consisted of 16 elementary plots. Each elementary plot consists of 32 maize plants, transplanted on 4 lines of 8 girdles, at intervals of 0.30 m x 0.80 m. The elementary plots and blocks were, respectively, separated by a distance of 1 m and 1 m.

The 4 treatments studied are the following:
T0: control without fertilizer input;
T1: organic foliar fertilizer "Bio Deposit Elixir" or BDE;

T2: organic fertilizer Phytobiological Aval or EPA;
T3: mineral fertilizer Yara Mila Actyva or YMA.

These different treatments were applied during the vegetative phase of maize. The period of application and the doses used depend on the type of fertilizer.
The solution of organic foliar fertilizer (BDE) (T1) was obtained by a mixture of 12 ml of this fertilizer and 20 l of water. This mixture was applied on the whole aerial part of the corn plants. A total of 4 applications were made during different periods of the vegetative phase. These periods are the 7^{th}, 21^{th}, 35^{th} and 49^{th} days after sowing (DAS).

The Phytobiological Organic Fertilizer Downstream (T2) was applied in a crown around each maize plant. Two applications, at different doses, were made during the vegetative phase. The first application, with a dose of 30 g/plant, was carried out on the 20^{th} DAS and the second took place on the 40^{th} DAS, with a dose of 20 g/plant.

Mineral fertilizer Yara Mila Actyva (T3) was buried at a depth of 2 cm and 5 cm around each plant. The first application was made, with a dose of 15 g/plant, the 15^{th} DAS and the second was carried out the 30^{th} DAS, at a dose of 30 g/plant.

Measured parameters

Various yield parameters were measured per basal plot during the study. The number of ears per plant was determined by counting all the ears formed by each foot. The length of the ears was obtained by measuring the length of each ear produced.

The diameter of the ears was determined from the circumference of the base of each ear. The dry weight of each ear was obtained by weighing each ear after removal of the spathes. The number of grains per ear was estimated by counting all the grains carried by each ear, after ginning. The weight of the grains per ear was determined by weighing all the grains carried by each ear.

The weight of 1000 grains was obtained by weighing 1000 grains, after ginning and counting. The weight of the grain-free ear was determined by weighing. The yield represented by the grain tonnage (Y) and its components, which are the number of ears of corn (NE), the weight of grains the ears per plant (WGE) and the average weight of the grains of an ear (AWG) have were obtained by individual harvests. The number of ears is obtained by counting all the ears harvested per plant. The weight of the grains of the ears per plant is evaluated by weighing all the grains carried by the ears of a foot of maize. The average grain weight of an ear is determined from the following formula:

$$AWG = WGE / NE, \text{ where} \quad (1)$$

AWG: Average weight of grains of an ear (kg)
WGE: Weight of grains the ears per plant (kg)
NE: Total number of ears per plant
The yield or tonnage of grain (TG / ha) is calculated from the formula below:

$$Y/ha = NE * AWG * D, \text{ with} \quad (2)$$

Y/ha: Yield per hectare (kg),
NE/plant: Number of ears per plant,
AWG: Average weight of the grains of an ear (kg),
D: Planting density with a standard of 100,000 plants/ha or 20 kg/ha.

The economic analysis performed on the yield provided by each type of fertilizer applied was based on the determination of the rate of return of fertilizer application through net profit (Bn). This net profit (Bn) is a function of the following formula:

$$Bn = Bb - Vi. \text{ With} \quad (3)$$

Bn is the net profit (F CFA/ha), Bb is the gross profit (F CFA/ha /) and Vi is the total investment value (F CFA/ha).

The use of the different costs and expenses made it possible to calculate the gross profit of each type of fertilizer (Bb) (Tx) and the total investment cost of each treatment (Vi) (Tx) according to the following equations:

$$Bb\ (Tx) = Y * Py, \text{ with} \quad (4)$$

Bb is the gross profit of the Tx treatment (F CFA/ha), Y is the yield obtained from the use of the type of fertilizer or treatment Tx (kg/ha) and Py is the price of kg of grain of corn (160 F CFA/kg).

$$Vi\ (Tx) = (Qx * Px) + \Sigma Cx, \text{ with} \quad (5)$$

Qx is the total amount of fertilizer used for the Tx treatment (kg or ml of fertilizer/ha), Px is the price of the fertilizer unit (700 F CFA/kg for the mineral fertilizer, 500 F CFA/kg for organic fertilizer PBA and 2000 F CFA for organic fertilizer BDE) and ΣCx represents the total sum of the fertilizer application cost (6000 F CFA/ha for mineral fertilizer, 6000 F CFA/ha for organic fertilizer PBA and 4000 F CFA/ha for organic fertilizer BDE), seed cost (2500 F CFA/kg) and fixed cost and labor (161000 F CFA/ha).

Data processing and analysis

The data, collected and recorded using the Excel spreadsheet, was subjected to an analysis of variance using the XLSTAT version 7.5 software.

The significance level of differences between means was estimated using the Duncan test at the 5% threshold. Correlations, Principal Component Analysis (PCA) and Ascending Hierarchical Classification (AHC) were performed using the Statistica Version 7 software.

Results and discussion

Results

Effect of different types of fertilizers applied on production parameters

The averages of the production characteristics obtained after input of the different types of fertilizer are presented in Table 1. In the analysis of this table, it appears that differences were observed between the averages of the number of grains per head, the weight of 1000 grains, the length of the ears, the diameter of the ears, the number of ears per plant, the weight of the grains per ear and the yield obtained with the various treatments.

However, in terms of the weight of the straw and the above-ground biomass, no difference was observed between the averages obtained for the different treatments applied.

Table 1. Mean values of maize production parameters based on applied fertilizers.

Treatments	Number of grains per ear	Weight of grains per ear (g)	Yield (kg/ha)	Weight of 1000 grains (g)	Weight of grains free ear (g)	Weight of straw (kg)	Aboveground biomass (kg)	Length of ear (cm)	Diameter of ear (mm)	Number of ears per plant
To (control)	269 c	28.78 c	5 972 c	107 d	72 b	1.30 a	1.44 a	11.2 c	11.4 c	1.15 b
Organic fertilizer BDE	372 b	58.78 b	9 153 b	158 b	111 ab	1.17 a	1.41 a	13.5 b	12.8 ab	1.10 b
Organic fertilizer PBA	342 bc	41.32 b	6 560 bc	121 c	84 b	1.17 a	1.33 a	12.4 bc	12.6 b	1.05 b
Mineral fertilizer YMA	476 a	81.87 a	12 373 a	172 a	148 a	1.67 a	1.88 a	16.6 a	13.7 a	2.05 a

In the same column, the values followed by the same letter are not significantly different (Duncan, 5%).

At the level of the number of grains per ear, the weight of the grains per ear, the yield, the length of the ear and the diameter of the ear, the results showed the formation of three homogeneous groups. With average values of 476 grains per year, 12373 kg/ha (yield), 81.87 g (weight of kernels per year), 16.6 cm (ear length) and 13.7 cm (diameter of the ear), the first group consists of the averages obtained with the use of mineral fertilizer YMA. This treatment (mineral fertilizer) made it possible to obtain the highest averages. The second group consists of the averages obtained with organic fertilizers (BDE and PBA), at the level of these different measured parameters. As for the third group, it is formed by averages obtained with the control without organic fertilizer and mineral. This treatment gave the lowest averages at these different parameters.

These averages were 269 grains, 28.78 g, 5972 kg/ha, 11.2 cm and 11.4 cm, respectively for the number of grains per head, the weight of the grains per head, the yield, the length of ear and ear diameter (Table 2).

Table 2. Correlations between the variables studied.

Variables	Number of grains/ear	Yield	Weight of 1000 grains	Weight of ear free grains	Length of ear	Diameter of ear	Number of ears/plant
Number of grains/ear	1						
Yield	0.960	1					
Weight of 1000 grains	0.926	0.956	1				
Weight of ear free grains	0.973	0.998	0.962	1			
Length of ear	0.992	0.983	0.926	0.989	1		
Diameter of ear	0.984	0.908	0.915	0.930	0.954	1	
Number of ears/plant	0.829	0.869	0.686	0.856	0.884	0.724	1

In bold, significant values (off diagonal) at the alpha threshold = 0.05 (bilateral test).

The results obtained also showed the formation of two homogeneous groups in terms of the number of ears per plant. The first group, with an average of 2.05 ears, consists of the averages obtained with the mineral fertilizer. This treatment gave the highest average. The second group, with the lowest averages, is formed by those obtained with the other three treatments (control, organic fertilizer BDE and organic fertilizer PBA). These averages ranged from 1.05 to 1.15 ear per plant (Table 2).

Study of correlations between variables

Correlations between the different parameters for the maize variety were studied.

Table 1 presents the Pearson correlation matrix between these studied parameters. The analysis in this table reveals the existence of positive and significant correlations between the parameters. These correlations are as follows:

The number of kernels per head and the yield (R^2 = 0.960), the weight of the grainless cob (R^2 = 0.973), the length of the cob (R^2 = 0.992), the diameter of the cob (R^2 = 0.984);

The yield and weight of 1000 grains (R^2 = 0.956), the weight of the grainless cob (R^2 = 0.998), - the length of the cob (R^2 = 0.983);

The weight of 1000 grains and the weight of the grainless cob (R^2 = 0.962);

The weight of the grainless ear and the length of the ears (R^2 = 0.989);

The length of the ears and the diameter of the ears (R^2 = 0.954).

All the parameters studied (number of grains per ear, yield, weight of 1000 grains, weight of the grainless ear, length of the ear and the number of ears per plant) establish correlations whose distribution is presented by the figure 1.

Distribution of treatments and parameters studied in the plan formed by the axes

The distribution of applied treatments and the different parameters studied in the plane formed by the axes are presented in Figure 1. Explaining nearly 98.32% of the variability expressed, these are the first two axes of the principal component analysis which have been taken into account. On the F1 axis that has absorbed the highest percentage of variability (89.84%), the variables are the weight of 1000 grains, the diameter of the ear, the number of grains per ear, the weight of the ear. grain-free ear, yield and length of ear. These parameters were positively correlated to the F1 axis.

The second axis, which absorbed about 8.48% of the variability, is defined on the negative side by the number of ears per plant.

According to the Biplot plan (Figure 1), each of the four treatments studied is located in a quarter of a plane, drawn by the first two axes. The treatments using organic fertilizers (BDE and PBA) are located in the same quarter of plan, while the treatments with the mineral fertilizer and the witness each occupy a quarter of plan. The quarter of plan representing the control without fertilizer organic fertilizers (BDE and PBA) does not include any parameters studied. As for the mineral fertilizer, Figure 1 shows a comparison between this treatment and all the other parameters studied.

Economic optimization of the use of different types of fertilizers

The economic viability of using the different types of fertilizer was essentially based on the specific yield (Y/ha) following the determination of net profit (Bn) provided by each type of fertilizer applied. The net profit was obtained after deducting between the receipt from the price of maize grains (gross profit or Bb) and the accumulated expenses (total investment cost). For the occasion, the prices considered are those which are in force in 2018. Thus, the purchase price of the seeds is fixed at 2500 F CFA/kg and the fixed and labor costs are estimated at 161 000 F CFA/ha while the kg of corn is sold at the floor price of 160 F CFA. Regarding the purchase price of the fertilizer, it is estimated at 700 F CFA per kg of mineral fertilizer, 500 F CFA per kg of organic fertilizer PBE and 2000 F CFA/12 ml of organic fertilizer BDE. The spreading cost is estimated at 6000 F CFA/ha for mineral and organic fertilizer PBE and 4000 F CFA for organic fertilizer BDE. Table 3 shows the added values produced per hectare resulting from the use of each type of fertilizer on this plot. An analysis of this table shows that the total investment cost increases according to the type of fertilizer applied. This cost ranged from 267,000 (organic fertilizer BDE) to 433,000 F CFA (mineral fertilizer) per hectare, with the highest investment costs obtained with the application of organic fertilizer (300 kg/ha). Net profit (Bn) depends on the type of fertilizer applied. It reaches a maximum of 1 546 680 F CFA/ha with a quantity of 300 kg/ha of mineral fertilizer, then decreases gradually with the application of organic fertilizer. Organic fertilizer BDE recorded a net profit of 1 197 480 F CFA/ha.

As for the organic fertilizer PBA, the net profit procured was 676,600 F CFA/ha. Mineral fertilizer, being economically the most profitable, shows that the use of mineral fertilizer under maize cultivation is very interesting.

Table 3. Effects of the different treatments applied on the economic profitability of the maize crop.

Treatments	Fertilizer quantity (kg ou ml/ha)	Price of fertilizer purchase (Fcfa/ha)	Spreading cost (FCFA/ha)	Cost of purchase of seeds (Fcfa/ha)	Fixed cost and labor (Fcfa/ha)	Total cost (F CFA**)**	Yield (kg/ha)	Gross profit (F CFA/ha**)**	Net profit (F CFA/ha)
To (control)	0	0	0	50 000	161 000	211 000	5 972	955 520	744 520
Organic fertilizer BDE	240 ml	40 000	16 000	50 000	161 000	267 000	9 153	1 464 480	1 197 480
Organic fertilizer PBA	300	150 000	12 000	50 000	161 000	373 000	6 560	1 049 600	676 600
Mineral fertilizer YMA	300	210 000	12 000	50 000	161 000	433 000	12 373	1 979 680	1 546 680

NB: Planting density is 100000 plants/ha (20 kg); Price of fertilizer purchase: YARA fertilizer is 700 F CFA/kg; organic fertilizer BDE is 2000 F CFA/12 ml; organic fertilizer PBA is 500 F CFA/kg; Mineral spreading cost and organic fertilizer PBA is 6000 F CFA/ha; cost of spreading organic fertilizer BDE is 4000 F CFA/ha; Cost of purchase of seeds is 2500 F CFA/kg; Fixed cost and labor is 161500 F CFA/ha; Selling price of grain corn is 160 F CFA/kg.

Discussion

Effect of different types of fertilizers applied on production parameters and distribution of treatments and parameters studied

This study demonstrated the ability of mineral and organic fertilizers to improve fruiting and maize yield on Korhogo ferruginous soil. These results are similar to those obtained in other regions of sub-Saharan Africa, notably, by Ademiluyi and Omosoto (2007) on maize in Nigeria and Kaho *et al.* (2011) on the same crop in Cameroon, showing that the overall trend in the evolution of soil properties tested and yield was up compared to control treatment and mineral and organic fertilization.

In this experiment, we obtained an improvement of the production parameters, with the contribution of the different types of fertilizers. It therefore appears that the site of the study optimizes fertilizers according to the initial chemical composition of the soil (Yeledhalli *et al.*, 2008; Bodruzzaman *et al.*, 2010).

Mineral and organic manures had a significant influence on the growth and development of the maize plant vegetative system.

The study showed a significant improvement in production characteristics and maize grain yield, with a supply of mineral fertilizer and organic fertilizer compared to the control without fertilizer.

The production characteristics of the number of grains per ear, the weight of 1000 grains, the weight of the grainless ear, the length of the ear, the diameter of the ear and the number of ears per plant and Yield was significantly improved by mineral fertilizer (YARA) compared to organic fertilizers and control. This situation would explain the close link between the mineral fertilizer treatment and all the parameters studied in the Biplot plane formed by the two axes. Chemical fertilizer input significantly increased corn yield compared to control plots and organic fertilizers.

The desirability of using mineral fertilizers is revealed here, in that almost all agronomic parameters have increasing values with the increase of the fertilizer dose. The beneficial effects of chemical fertilization through agriculture have been demonstrated by many authors (Batiano *et al.*, 2004; FAO, 2005). Mineral fertilizers have greater agronomic efficiency because their mineral elements are available and easily absorbed by crops compared to organic fertilizers.

This gradual increase in the improvement of production parameters by mineral fertilizer is largely due to its availability of mineral elements which create the best mineral nutrition conditions for maize plants.

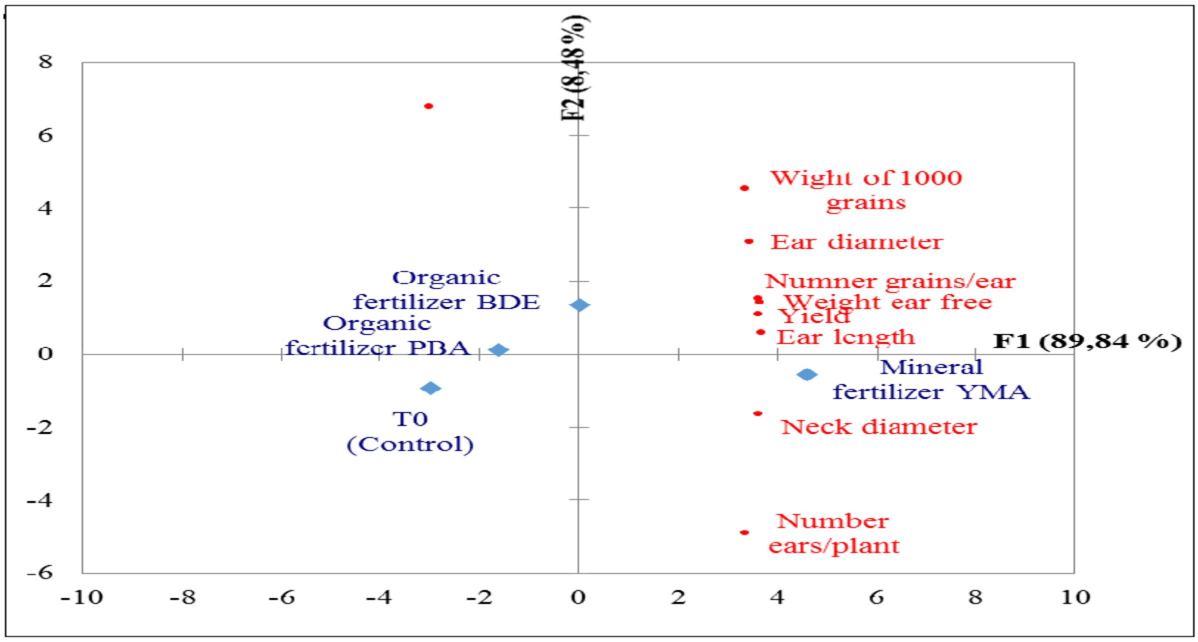

Fig. 1. Distribution of treatments and the parameters studied in the Biplot plan.

The addition of mineral fertilizers considerably increases pollen production (Nyembo *et al.*, 2013). Which improved the rate of fertilization of flowers. The mineral fertilizer, judiciously used, makes it possible to increase crop yields in large proportions. As such, it is a determining factor in agricultural yields (Nyembo *et al.*, 2015).

Mineral fertilizers provide high yields and good quality of grain corn and forage corn. However, these fertilizers can have negative impacts on the environment if their use is not optimized (Marcus and Simon, 2015).

Regarding the contribution of mineral fertilizers, Pypers *et al* (2010) found that they increase 40 to 100% of crop yield in Kalongo and Civu soils, in South Kivu, in the Democratic Republic of Congo. These results are consistent with our results, as there was a yield increase of more than 100% with the mineral fertilizer treatment.

The ears harvested from mineral fertilizer plots are higher in weight compared to plots fertilized with organic and unfertilized fertilizers. This would be due to the availability of nutrients such as nitrogen by fertilizer because it increases the yield and its components (Torbert *et al.*, 2001). Several authors have found similar results, showing the importance of mineral fertilizer in increasing the weight of the ear (Jaliya *et al.*, 2008; Asghar *et al.*, 2010; Nyembo *et al.*, 2012). This confirms the allegations of Useni *et al.* (2014) showing that the increase in the number of ears leads to an increase in yield since the yield is the sum of individual weights of each ear. Thus, many studies have examined the need for the use of mineral fertilizers (Nyembo *et al.*, 2012; Useni *et al.*, 2012, Nyembo *et al.*, 2013; Useni *et al.*, 2013; Nyembo *et al.*, 2015). They have the advantage of making the mineral elements available to the plant as quickly as possible, thus favoring better production and productivity (Nyembo *et al.*, 2012).

The study also showed that all production characteristics and yield were significantly improved by organic fertilizer compared to control without fertilizer.

Organic fertilizer BDE and PBA had a much greater influence on maize plant production in the field, compared to the control without fertilizer, an improvement of all measured yield characteristics. This is explained by the amount of mineral elements available to the plants. In fact, organic fertilizers are an important source of mineral elements.

The beneficial effects of organic fertilizers on crop production have been proven by many researchers and it has been shown that the application of organic fertilizers improves the physical, chemical and biological properties of the soil (Aggelides and Londra 2000). Nutrients in organic fertilizers increase crop yield (Cogger *et al*., 2001) by improving the physical, chemical and biological properties of soil (FAO, 2006). Reed *et al.* (1991) and N'dayegamiye *et al.* (2007) reported that composted organic fertilizer applications, as a source of nutrients, affected corn grain yield, indicating that the fertilizer value of these fertilizers was comparable to that of fertilizers minerals. In the same vein, Roose *et al*., (2008) found that tomato yield was significantly increased by sludge application of emptying septic tanks.

In addition, the application of human feces as organic fertilizer recycles nutrients and eliminates the need for chemical fertilizers in cropland (Cogger *et al.* 2001).

The addition of organic fertilizers leads to the acceleration of microbial biomass activity and the improvement of the availability of organic matter to soil micro-organisms (Kemmit *et al.*, 2006). The mineralization of organic matter through the acceleration of microbial biomass activity, would be favored by increasing nitrogen content in organic fertilizers and soil pH (Kemmit *et al*., 2006). The use of organic amendments is based on the fact that they play an important role on various soil properties (Mbonigaba, 2007; Rakotoson, 2011).

This effect would be due to the nitrogen resulting from the mineralization of the applied organic fertilizers. However, as various authors have shown, nitrogen is the most important element for the life of the plant. Nitrogen is the engine and is used to build all the green parts that ensure the growth and life of plants (Lafond, 2004; Galla *et al.,* 2011); because nitrogen plays a key role in plant metabolism (FAO, 2005).

Indeed, Cobo *et al*. (2002) showed that the rate of decomposition of organic matter and the increase in yields were closely related to the timing of nutrient release and uptake by the plant. Faced with this fact, Ilunga *et al.* (2015) and Ilunga *et al.* (2016) suggested the use of organic fertilizers as crop fertilizer. However, the release of the elements by organic matter is gradual and slow (Bot and Benites, 2005), sometimes the annual plant does not even benefit at the desired time (Giroux *et al*., 2007; Pang and Letey, 2000). In addition, their use requires large quantities, which limits their use of organic fertilizer in annual culture. Liquid organic fertilizers can be applied to the soil or leaves depending on the needs of the plants, the level of soil fertility and especially the type of fertilizer. They improve plant resistance to diseases, increase yields and also improve soil fertility. They are, therefore, comparable to solid organic fertilizers.

The control without fertilizer generally had much smaller effects on the improvement of all measured production parameters. This may be due to the fact that the soils of the control would contain very few nutrients necessary to improve the production characteristics and yield of maize plants. The low production of control soils can be attributed to the characteristic factors of acid soils: acid pH, Al and Mg toxicity, nutrient deficiencies (Ca, Mg, P, K, B and Zn) (Mulaji, 2010). In addition, on the control plots, the absence of organic and mineral inputs is accompanied by a loss of organic matter and nutrients, acidification of the soil, a reduction in biomass and microbial activity, phosphorus insolubilization (Deblay, 2006) which together lead to under-production of maize plants.

The absence of fertilizer inputs and the lack of mineral elements are accompanied by a loss of organic matter and nutrients, soil acidification, a reduction in biomass and microbial activity. (Grantz *et al.*, 1999).

The results, thus obtained, showed the importance of organic and mineral fertilization for maize cultivation, through an improvement of production growth parameters, on the soils of the Korhogo region. Failing to apply the mineral fertilizer, for the cultivation of corn, organic fertilizers BDE and PBA could be used because of their efficiency on the yield.

Economic optimization of the use of different types of fertilizers

The economic analysis, based on accumulated data for obtaining farm income (net profit), was made by the difference between the revenue from the sale of maize grains provided by each type of fertilizer and on the other hand, all investment costs.

Less productive fertilizer significantly reduces the economic viability of fertilizers under crops by decreasing net profit. This is linked to the high and less productive production cost of organic fertilizers that significantly reduce the profitability of fertilizer input.

The application of a fertilizer is profitable when the increase in the value of production (gross profit) it provides is greater than the cost of the input and the additional costs that result (Wolff, 1995). The economic analysis based on the determination of net profit shows that the net benefits of all the different types of fertilizer applied are higher than that of the control without fertilizer; therefore fertilizer inputs have been economically profitable.

The resulting net profit allowed us to determine the types of manure that best value the supply of mineral and organic fertilizer under maize cultivation in the conditions of northern Côte d'Ivoire. These types of fertilizers are therefore considered economically optimal for maize cultivation.

The economically optimal types of fertilizer must allow farmers to largely cover the relative costs involved and allow them to earn very attractive profits. This proves that there is a need to determine the type of fertilizer adapted to the new hybrid maize variety in a pedoclimatic context that is less and less favorable to the production of this speculation.

The most profitable type of fertilizer is the one with the highest net income. In this study, mineral fertilizer (YARA), having produced the highest net profit, was considered economically profitable and recommended to farmers in the locality of northern Côte d'Ivoire. However for a long-term production, the supply of mineral fertilizers only is not advised.

In fact exclusively mineral fertilization accentuates the decrease of organic carbon and the desaturation of the complex in exchangeable bases; and further increases the exchange acidity consisting essentially of exchangeable aluminum (Yaro *et al.*, 1997).

Conclusion

The results obtained in this study reveal that the different types of fertilizer (organic and mineral) applied have influenced all the observed parameters of yield with its components (number of grains per spike, weight of grain-free spike)., the length of the ears, the diameter of the ears, the number of ears per plant, the weight of the grains per year). Yield varied between 5972 kg/ha (control) and 12373 kg/ha (mineral fertilizer).

The study, relating to the profitability of mineral and organic fertilizers under maize cultivation, showed that the treatment, with the mineral fertilizer, having obtained the greatest net profit (1 546 680 F CFA), is the most profitable and recommendable for maize growing.

The results of the present study, which showed the profitability of the mineral fertilizer, command to continue it in all the agroecological zones, by varying the doses, with a view to making the necessary adjustments to the types and doses popularized, to avoid that fertilizer does not lead to the development of the vegetative phase at the expense of the reproductive phase of maize.

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