Original Research Article

Effects of BK Fertilizer-based organic-mineral fertilization on the growth and yield of maize (Zea mays L.) in the Sudano-Guinean zone of Côte d'Ivoire : Bouaké case

ABSTRACT

Facing rapid population growth, land resources are becoming scarce and their degradation is increasing due to inappropriate practices. This study carried out to evaluates the agronomic potential of BK Fertilizer biofertilizer in improving maize productivity at the Food Crops Research Station of the National Agronomic Research Center (CNRA) in Bouaké, Côte d'Ivoire. A Fisher block trial with six treatments (four doses of BK Fertilizer, one control with mineral fertilizer and one absolute control) was conducted. Growth and yield parameters were evaluated. Results show significant differences between treatments ($P < 0.05$). Mineral fertilizer (MF) treatment showed the best performance for fresh ear weight (218.9 ± 12.3 g for 10 ears), while BK60+1/2MF treatment gave the highest 1000-grain dry weight (252.0 ± 8.5 g). Combined BK Fertilizer + half-dose mineral fertilizer treatments (T_3, T_4, T_5) showed promising intermediate performances with 24.5 to 26.6 ear-bearing plants compared to 20.7 for the absolute control. These results suggest that combined use of BK Fertilizer with low doses of mineral fertilizers could be a sustainable alternative to improve maize productivity while reducing dependence on chemical inputs.

Keywords*: Biofertilizer; BK Fertilizer; Yield; Maize; Bouaké; Côte d'Ivoire*

1. INTRODUCTION

Maize (*Zea mays* L.) is one of the most widely cultivated cereals in the world, with global production of 1.2 billion tons on 201 million hectares (FAO, 2020). In Africa, production reaches 90 million tons on 43 million hectares. In Côte d'Ivoire, this crop plays a central role in human and animal diets, with national production of 1.2 million tons on 56 million hectares (FAO, 2020) and estimated consumption of 28.4 kg per capita per year (Countrystat, 2013).
However, this production has declined significantly due to soil degradation. The depletion of soil organic matter, nitrogen, and other minerals is recognized as one of the main causes of declining agricultural productivity in tropical Africa (Kasongo *et al*., 2012). Soil acidity and its associated effects severely limit agricultural production. Aluminium and manganese toxicity, as well as nutrient deficiencies, negatively affect plant growth (Denaix *et al*., 2016). In sub-Saharan Africa, soil mineral nutrient stocks decline annually by 22 kg of nitrogen (N), 2.5 kg of phosphorus (P), and 15 kg of potassium (K) per hectare (Sanchez, 2002).
To address this situation, farmers traditionally rely on crop rotation, fallowing, intercropping, and, above all, mineral fertilization (Roose *et al*., 2008 ; Nyembo *et al*., 2013). While chemical fertilization has helped increase agricultural yields for several decades, it now presents major drawbacks: high costs that are unaffordable for smallholder farmers and negative impacts on soil microfauna.
The development of rational, efficient, accessible, and environment friendly fertilization techniques is therefore necessary. Organo-mineral fertilizers could offer a solution to this problem.
The objective of this study is to evaluate the effect of the biofertilizer BK Fertilizer on the growth and yield parameters of maize at the Food Crops Research Station (SRCV) of the CNRA in Bouaké, in central Côte d'Ivoire. It is based on the hypothesis that the application of BK Fertilizer, used alone or in combination with low doses of mineral fertilizers, could significantly increase corn productivity while providing a sustainable alternative to intensive mineral fertilization.

2. MATERIAL AND METHODS

2.1. Study site

The study was conducted at the Food Crops Research Station (SRCV) of the National Agricultural Research Center (CNRA) in Bouaké, located in central Côte d'Ivoire. The experimental plot covers an area of 884 m² (34 m × 26 m). The city of Bouaké exhibits agroecological conditions characteristic of the forest-savanna transition zone. The climate is of the Sudano-Guinean type, characterized by two distinct seasons: a rainy season from April to October, peaking between June and September, and a dry season from November to March, influenced by the harmattan. Average annual rainfall ranges from 1,000 to 1,200 mm, while temperatures fluctuate between 25 and 30 °C, with a small daily temperature range (FAO, 2015 ; SODEXAM, 2020). This climate is generally favorable for maize cultivation, although irregular rainfall patterns can affect yields. In terms of soil type, the soils are predominantly ferrallitic, with a sandy to sandy-clay texture, characterized by low organic matter content and limited chemical fertility, particularly in nitrogen, phosphorus, and potassium. These soils, subject to leaching and erosion processes, require appropriate management practices to maintain their productivity (IRD, 2012 ; FAO, 2015).

2.2. Experimental setup

The experiment was set up using a Fisher block design with six (6) treatments (T_0 to T_5) repeated three (3) times, for a total of 18 plots. Each plot measures 40 m² (10 m × 4 m), with a distance of 1.5 m between plots and 2 m between blocks. The plant spacing used is 1 m between rows and 0.5 m between plants, resulting in a theoretical density of 20,000 plants per hectare. Each plot contains an average of 126 plants.

2.3. Treatments applied

The BK Organic Fertilizer used is an enriched organic product designed to improve soil fertility and plant nutrition. It contains microorganisms that act not only as a biofertilizer but also as a soil biostimulant. The six treatments studied are listed in Table 1.

Table 1. Description of the treatments applied

Treatment	Code	Detailed description
T_0	Absolute witness (AW)	Without the use of fertilizer
T_1	Mineral fertilizer (MF)	NPK 12-22-22 at 200 kg/ha before sowing + 46% N urea at 150 kg/ha 30 days after sowing (DAS)
T_2	BK 60	BK Fertilizer at 600 kg/ha (60 g/m²) before sowing + 400 kg/ha (40 g/m²) at 30 DAS
T_3	BK 30 + 1/2 MF	BK Fertilizer at 300 kg/ha (30 g/m²) before sowing + 200 kg/ha (20 g/m²) at 30 DAS + NPK 12-22-22 at 100 kg/ha + urea (46% N) at 75 kg/ha
T_4	BK 60 + 1/2 MF	BK Fertilizer at 600 kg/ha (60 g/m²) before sowing + 400 kg/ha (40 g/m²) at 30 DAS + NPK 12-22-22 at 100 kg/ha + urea (46% N) at 75 kg/ha
T_5	BK 90 + 1/2 MF	BK Fertilizer at 900 kg/ha (90 g/m²) before sowing + 600 kg/ha (60 g/m²) at 30 DAS + NPK 12-22-22 at 100 kg/ha + urea (46% N) at 75 kg/ha

2.4. Conducting the trial : from site preparation to plant protection

Site preparation began with manual weeding using a machete, followed by tilling the soil and staking out the locations of the individual plots. Seeding was done by hand, with three seeds per hole, followed by thinning to one plant per hole 15 days after germination. Manual weeding was performed twice using a hoe and a machete. Weeding was carried out every two weeks from sowing until fruit set. Insecticide spraying (EMACOTT: Emamectin Benzoate 50 g/kg) was performed weekly for one month after the plants emerged to control insect pests.

2.5. Data collection

The observations focused primarily on the following agromorphological parameters, measured 60 and 90 days after sowing (DAS) :

- Number of plants bearing ears per row (10 plants selected at random per plot);
- Average number of ears per plant;
- Number of rows of kernels per ear;
- Fresh weight of 10 ears (g);
- Dry weight of 1,000 kernels (g);
- Pest damage severity index.

The ears were harvested at physiological maturity (approximately 90 DAS), air-dried for 15 days, and then weighed. The 1,000 kernel weight was determined after complete drying.

2.6. Statistical analysis

The collected data were analyzed using a one-way analysis of variance (ANOVA) with a single factor (treatment) using the R software (version 4.5.2). Means were compared using Tukey's HSD test at a significance level of 5% ($P < .05$). Coefficients of variation (CV) were calculated to assess the variability of the data. Pearson correlation analyses were performed between the various yield parameters to identify significant relationships.

3. RESULTS

3.1. Effect of treatments on corn production parameters

3.1.1. <u>Number of plants bearing ears</u>

Figure 1A shows significant differences in the average number of plants bearing ears across treatment groups (F = 8.42; P < .001; CV = 9.3%). Treatments T3 (BK 30 + 1/2 MF) and T5 (BK 90 + 1/2 MF) yielded the highest values, with 26.6 ± 1.2 and 26.2 ± 1.4 plants, respectively, compared to those of T0 (20.7 ± 1.8 plants) and treatment T2 (BK 60) (19.8 ± 2.1 plants). The T1 (MF) and T4 (BK 60 + 1/2 MF) treatments yielded intermediate values of 25.2 ± 1.5 and 24.5 ± 1.6 plants, respectively, with no significant difference between them.

3.1.2. <u>Number of ears per plant</u>

The average number of ears per plant showed significant differences among treatments (F = 12.67; P < .001; CV = 11.2%). Treatment T_3 (BK 30 + 1/2 MF) had the highest value (39.8 ± 2.3). The T_1 (MF), T_4 (BK 60 + 1/2 MF), and T_5 (BK 90 + 1/2 MF) treatments showed intermediate values (between 33.3 ± 2.0 and 36.0 ± 1.9). In contrast, T_1 (MF), T_4 (BK 60 + 1/2 MF), and T_5 (BK 90 + 1/2 MF) treatments showed intermediate values (between 33.3 ± 2.0 and 36.0 ± 1.9). In contrast, treatments T_0 and T_2 (BK 60) recorded the lowest values (25.0 ± 2.5 and 22.8 ± 2.7, respectively) (Figure 1B).

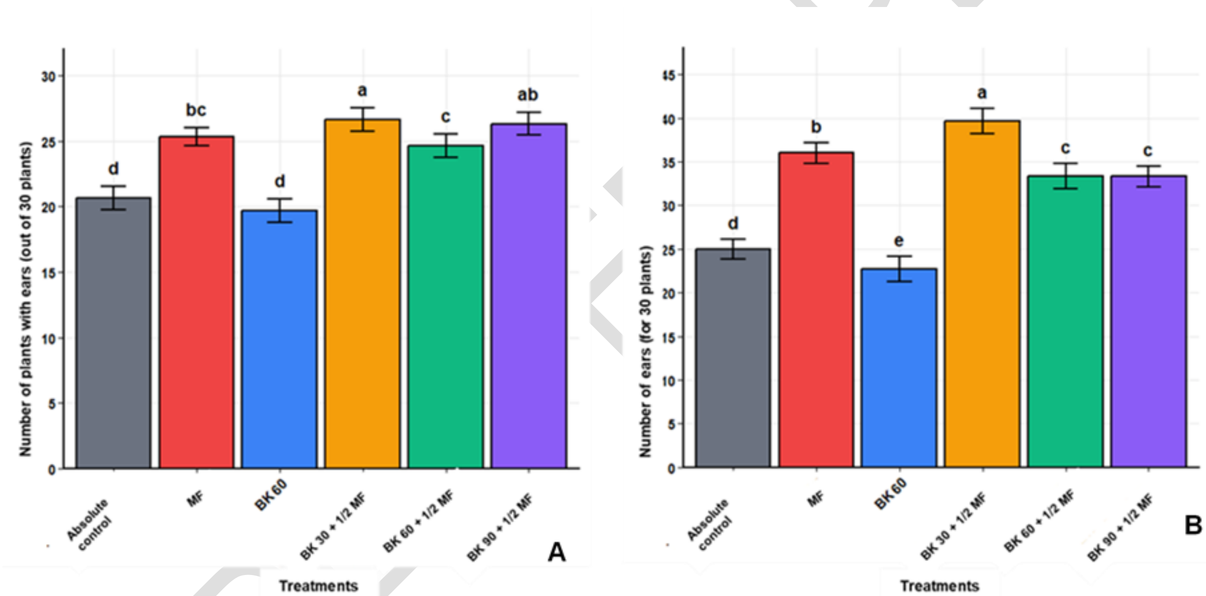

Figure 1. Effect of treatments on maize production parameters

(A) number of plants bearing ears per row (based on 30 plants observed) and (B) total number of ears per plant (based on 30 plants).
Error bars represent the standard error. Different letters indicate significant differences according to Tukey's HSD test (P < .05).

3.2. Components of corn yield

3.2.1. <u>Number of rows of kernels per ear</u>

Figure 2 shows that the treatments had a significant effect on the average number of rows of kernels per ear (F = 3.21; P = .032; R^2 = 3.8%). The T_1 (MF) and T_4 (BK 60 + 1/2 MF) treatments had the highest values, with 13.7 ± 0.3 and 13.6 ± 0.3 rows per ear, respectively, while T_2 (BK 60), T_3 (BK 30 + 1/2 MF), and T_5 (BK 90 + 1/2 MF) show values ranging from 13.4 ± 0.4 to 13.5 ± 0.3 rows. T_0 recorded the lowest value (13.1 ± 0.4 rows), although this difference was not statistically significant compared to the other treatments, except for T_1 and T_4.

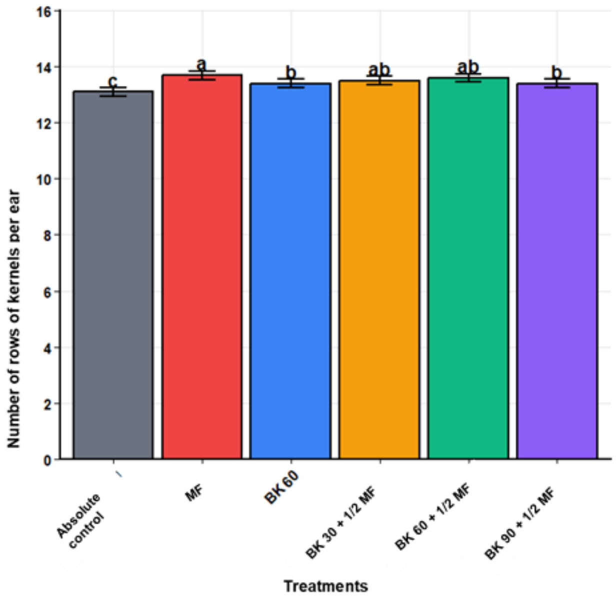

Figure 2. Average number of rows of kernels per ear by treatment

Error bars represent the standard error. Different letters indicate significant differences according to Tukey's HSD test (*P* < .05).

3.2.2. Fresh weight of ears and dry weight of 1,000 kernels

An examination of Figures 3A and 3B revealed significant differences between treatments in the fresh weight of 10 ears (F = 15.83; *P* < .001; CV = 8.7%) and the dry weight of 1,000 grains (F = 6.94; *P* = .002; CV = 5.4%), respectively. For the fresh weight of 10 ears, treatments T_1 (MF) and T_4 (BK 60 + 1/2 MF) had the highest values, at 218.9 ± 12.3 g and 218.2 ± 11.8 g per 10 ears, respectively. In contrast, treatments T_2 (BK 60) and T_0 had the lowest weights, at 193.1 ± 14.2 g and 191.6 ± 15.1 g, respectively (Figure 3A).
With regard to the dry weight of 1,000 grains, treatments T4 (BK 60 + 1/2 MF) and T2 (BK 60) recorded the highest means, at 252.0 ± 8.5 g and 246.3 ± 9.2 g, respectively. The T_0 (absolute control) and T_3 (BK 30 + 1/2 MF) treatments showed intermediate values of 235.3 ± 10.1 g and 234.0 ± 9.8 g. Treatments T_1 (MF) and T_5 (BK 90 + 1/2 MF) recorded the lowest weights at 226.7 ± 8.9 g and 225.0 ± 10.5 g, which were significantly lower (*P* < 0.05) than those of treatments T_4 and T_2 (Figure 3B).

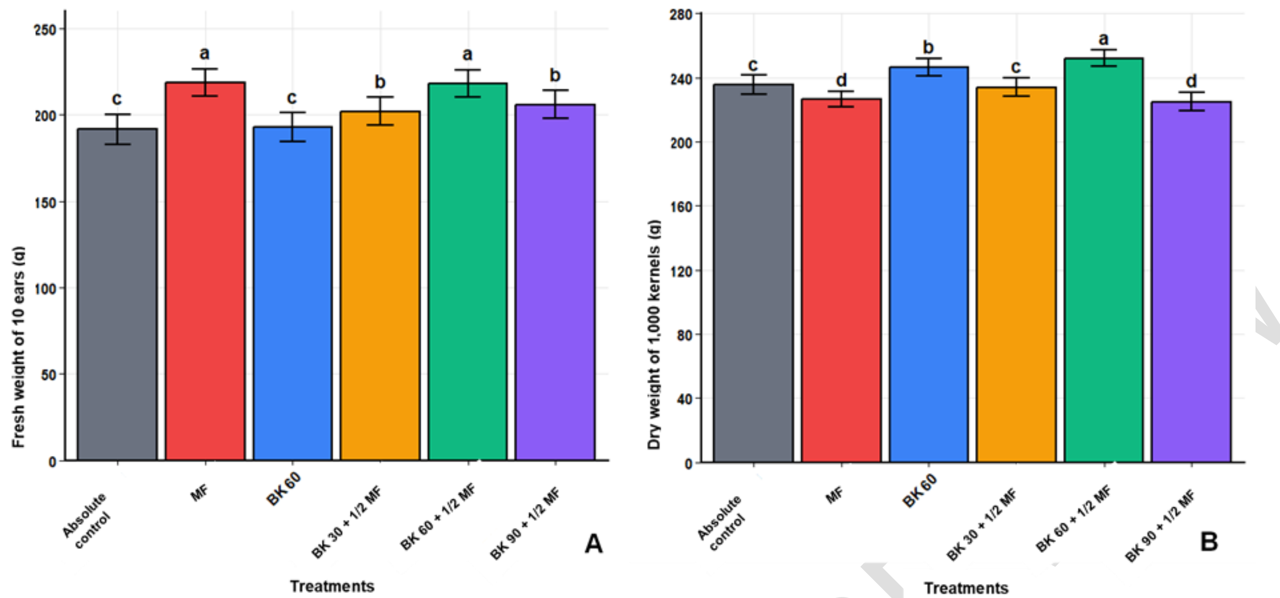

Figure 3. Components of maize yield according to the treatments applied : (A) fresh weight of 10 ears and (B) dry weight of 1,000 kernels

Error bars represent the standard error. Different letters indicate significant differences according to Tukey's HSD test (*P* < .05).

3.3. Severity of pest attacks

Figure 4 shows moderate pest infestations, particularly from caterpillars, under treatments T_4 (BK 60 + 1/2 MF), T_5 (BK 90 + 1/2 MF), T_2 (BK 60), and T_1 (MF). In contrast, treatments T_3 (BK 30 + 1/2 MF) and T_0 showed greater resistance, with the lowest severity indices

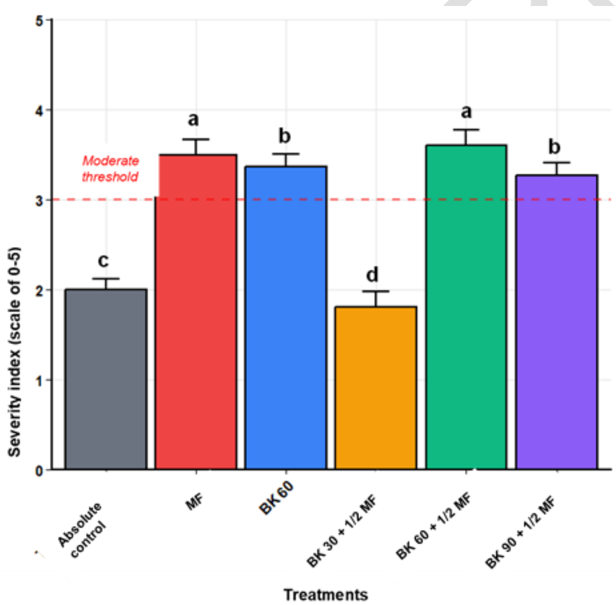

Figure 4. Disease and pest severity indices for maize crops based on the treatments applied

Error bars represent the standard error. Different letters indicate significant differences according to Tukey's HSD test (*P* < .05).

3.4. Correlation analysis of parameters

Table 2 shows a strong correlation between, on the one hand, the number of plants bearing ears and the number of ears per plant (r = 0.87, $P < .001$) and, on the other hand, the fresh weight of the ears (r = 0.76, $P < .01$). The fresh weight of the ears is strongly correlated with the number of rows of kernels per ear (r = 0.81, $P < .001$). However, the 1,000 grain weight shows no significant correlation with the other parameters, suggesting that it is influenced by different factors. Pearson's correlation analysis reveals several significant relationships among the yield parameters (Table 2).

Table 2. Pearson correlation matrix between maize yield parameters

Parameters	Plants bearing ears	Number of ears /plant	Rows of kernels /ear	Fresh weight 10 ears	Weight 1,000 seeds
Plants bearing ears	1,00	-	-	-	-
Number of ears /plant	$0,87^{***}$	1,00	-	-	-
Rows of kernels / ear	$0,52^{*}$	$0,48^{*}$	1,00	-	-
Fresh weight 10 ears	$0,76^{**}$	$0,69^{**}$	$0,81^{***}$	1,00	-
Weight 1,000 seeds	$-0,24^{ns}$	$-0,31^{ns}$	$0,15^{ns}$	$-0,08^{ns}$	1,00

**P < .05 ; **P < .01 ; ***P < .001 ; ns = non significatif*

3.5. Summary of agronomic performance

Table 3 presents a comparative summary of the relative performance of each treatment compared to the absolute control (T0 = 100%). Table 3 shows that the combined treatments (T3, T4, T5) result in substantial yield increases compared to the absolute control, with gains of up to 59% in the number of ears per plant (T3) and 29% in the number of ear-bearing plants (T3).

Table 3. Relative performance of treatments compared to the absolute control (T0)

Treatment	Vector plants (%)	Ear/plant (%)	Fresh ear weight (%)	Weight 1,000 seeds (%)
T_0 (Witness)	100	100	100	100
T_1 (MF)	122	144	114	96
T_2 (BK 60)	96	91	101	105
T_3 (BK 30 + 1/2 MF)	129	159	105	99
T_4 (BK 60 + 1/2 MF)	118	140	114	107
T_5 (BK 90 + 1/2 MF)	127	133	107	96

4. DISCUSSION

The study was conducted as part of an effort to optimize cultural factors with a view to improving maize yields. In practical terms, it aimed to increase the productivity of this crop through better management of production factors, particularly growth and yield parameters. The observations made during this study highlighted the effects of applying BK Fertilizer, either alone or in combination with mineral fertilizers, on the agronomic performance of corn.

4.1. Effect of treatments on maize production parameters

Overall, the application of various doses of organo-mineral fertilizers resulted in a significant improvement in maize production parameters compared to the unfertilized control. More specifically, treatment T_3 (BK 30 + 1/2 MF) performed best compared to treatment T_0, particularly in terms of the number of plants bearing ears and the average number of ears per plant. This result demonstrates the remarkable effect of the combined use of fertilizers particularly mineral and organic fertilizers on improving crop productivity. Our results corroborate those of Muyayabantu *et al.* (2012), who demonstrated that the application of organo-mineral fertilizers promotes the growth and development of maize under field conditions, resulting in a significant improvement in yield. Furthermore, Mulaji (2011) emphasized that the application of various types of organic matter and mineral fertilizers to increase the availability of soil nutrients for plants is one of the promising approaches for boosting agricultural production in smallholder farming systems. Thus, Pypers *et al.* (2010) demonstrated that organo-mineral fertilizers increase crop yields in soils by 40 to 100 percent. As for the plants in the control treatment, the low yield obtained can be attributed to the soil's lack of nutrients, as demonstrated by Siene *et al.* (2020). Indeed, these authors noted that the lack of nutrients in the soil could also be the underlying cause of the low crop productivity.

4.2. Components of corn yield

The highest yields were obtained with treatments T_1 (MF) and T_4 (BK 60 + 1/2 MF) in terms of the number of rows of kernels per ear, the fresh weight of 10 ears, and the dry weight of 1,000 kernels, compared to the control T_0. These results suggest a relationship between maize and fertilizers, as highlighted by numerous studies (Andric *et al.*, 2012 ; Nazli *et al*., 2014). These authors have shown that fertilizer application ensures stable maize yields in terms of both quantity and quality. Boldea *et al.* (2015) also demonstrated that increased maize yields are closely linked to the amounts of mineral fertilizers particularly nitrogen (N), phosphorus (P), and potassium (K) applied to the soil.

The best yield performance was observed with mineral fertilizers. This could be explained by the nature of plant uptake. Indeed, Nyembo *et al*. (2012) and Ilunga *et al*. (2018) demonstrated that, because mineral fertilizers are more soluble, they release the mineral elements N, P, and K in ionic form, which can be rapidly and directly assimilated by plants. However, regarding the dry weight of 1,000 seeds, treatments T_1 (MF) and T_5 (BK 90 + 1/2 MF) recorded the lowest weights. This finding can be explained by the excessive amounts of fertilizer applied. Useni *et al.* (2014) found that excessive fertilizer application can lead to low crop yields, as there is an application threshold for any fertilizer applied to the soil.

4.3. Severity of pest and disease outbreaks

Attacks were moderate under treatments T_4 (BK 60 + 1/2 MF), T_5 (BK 90 + 1/2 MF), T_2 (BK 60 alone), and T_1 (MF). In contrast, treatments T_3 (BK 30 + 1/2 MF) and T_0 resulted in greater resistance, as evidenced by lower severity indices. These results therefore suggest that there is a nonlinear relationship between fertilization and pest resistance : the absence of fertilizer or low fertilizer application rates can reduce the attractiveness of the plants, while moderate fertilization improves their tolerance. In contrast, high doses appear to disrupt this balance by promoting vegetation that is more vulnerable and more susceptible to infestations (Zhai *et al*., 2022).

4.4. Correlation analysis of parameters

Our results showed a significant positive correlation between the number of plants bearing ears and the number of ears per plant; between the number of plants bearing ears and the fresh weight of the ears; and between the fresh weight of the ears and the number of rows of kernels per ear. This significant positive correlation between these parameters suggests favorable environmental conditions that enhance the overall vigor of the plants, thereby resulting in more ears, higher fresh ear weights, and a greater number of rows of kernels per ear. These results could be explained, first and foremost, by the vigor of the plants, which are capable of developing not only a main ear but also secondary ears, thereby increasing the number of ears per plant (Haegele *et al.,* 2014). Second, through improved nutrition, particularly in potassium, which increases the number of kernels per ear and, consequently, the fresh weight of the ears (Fromme *et al*., 2019). Finally, through plant vigor, which produces a larger, better-structured ear, further promoting rows of kernels and increasing the fresh weight of the ear (Haegele *et al*., 2013).

4.5. Summary of agronomic performance

The best agronomic performance was achieved with the combined treatments (T_3, T_4, T_5) compared to the control. These results may be explained by the fact that these treatments provide nutrients in sufficient quantities that are readily available and assimilable by the plant, thereby ensuring higher yields, as noted by Kouakou *et al*. (2025) in their study on tomatoes. Soro's (2022) research also revealed a significant increase in tomato yields through the combined application of BK Fertilizer organic fertilizer and mineral fertilizers. However, the poor performance observed in the treatments without fertilizer and those using only BK Fertilizer may highlight the limitations of fertilizer-free approaches or those with improperly adjusted doses, as Kouakou et al. (2025) have pointed out.

CONCLUSION

The study, which examined the effect of BK Fertilizer on maize growth and yield, highlights the agronomic benefits of this biofertilizer in improving maize growth and yield. The results of the study revealed that the agromorphological parameters evaluated varied significantly depending on the treatments applied. The mineral fertilizer (MF) treatment yielded the highest fresh weight of the ears, while the BK60+1/2 MF treatment produced the highest dry weight per 1,000 seeds. These results show that a balanced organic-mineral fertilization program not only increases maize productivity but also reduces the amount of mineral fertilizer used, thereby lowering production costs and minimizing the risk of soil degradation. BK Fertilizer thus appears to be a sustainable and promising alternative for maize production systems in Côte d'Ivoire. However, further trials spanning multiple growing seasons and conducted on different soil types are still needed to determine the optimal application rates and assess the long-term effects on soil fertility and farm profitability. Further long-term studies will be needed to better understand changes in soil fertility and to determine the optimal application rates for BK Fertilizer.

Disclaimer (Artificial Intelligence)

Author(s) hereby declares that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during writing or editing of this manuscript.

Competing Interests

Authors have declared that no competing interests exist.

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