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Evaluation of Different Types of Fertilization on the Productivity of A Cereal (*Zéa Mays*) in the Sudano-Sahelian Zone of Cameroon

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ABSTRACT

Climate change is hurting the agricultural sector through lower yields due to the loss of soil fertility. This study aims to replace chemical inputs with organic fertilizers that are less environmentally harmful. A maize variety (CMS 9015), developed by the Institute of Agricultural Research for Development and highly prized by the local population, was placed in a randomized Fisher block with 3 replications and 5 treatments: T0 = 0 amendment, T1 = NPK, T2 = Organic Matter, T3 = 50% (NPK + Organic Matter) and T4 = straw). The following parameters were observed: final germination percentage, Germination Rate Index, stem length, root length, number of secondary roots (flowering and fruiting), and grain yield. The results show that the best yields were obtained respectively by treatments T3 (4.03 Kg), T1 (3.00 Kg), T4 (2.67 Kg), T2 (2.33 Kg), and T0 (1.20 Kg).

Keywords: *Climate change, Sudano-Sahelian zone, maize, fertilizer, organic matter*

1. INTRODUCTION

In sub-Saharan Africa, the consequences of climate change are increasingly being felt, particularly in the agricultural sector, where yields are falling. This, combined with rapid population growth at a stable rate of 2.7% [1], is contributing to the failure to achieve food security and an increase in malnutrition [2], [3]. The effects of climate change, particularly the dry spells during the rainy season, are leading to a slowdown in crop growth and a proliferation of insects. These effects are leading to increased use of fertilizers and pesticides. However, given the precarious conditions in which producers in sub-Saharan Africa live (over the period 2005-2015, average annual agricultural productivity per worker in sub-Saharan Africa was US$1,109.30 [4], it is difficult, if not impossible, for them to have access to sufficient quantities. This results in huge losses, exacerbating food insecurity. To date, approximately 218 million people are undernourished [1]. Consequently, a substantial increase in food production is required to remedy this situation [5], [6], [7].

To increase food production, the availability and use of agricultural technologies such as improved varieties and fertilizers remain a central focus of agricultural policy in these countries [8]. The promotion of fertilize, respecially, has become a resounding theme across SSA in the past decades [9], [10], particularly following the first African Fertilizer Summit in Abuja, Nigeria in 2006 [11].

Producers, therefore, resort to the use of large quantities of chemical inputs (herbicides, fertilizers, pesticides) which have a negative impact not only on the environment[12],[13], [14], [15]but also on human health[16], [17], [18], [19].

Maize, Zea mays L. (corn), is the most abundantly produced cereal in the world after wheat [20], [21], [22]. It is grown on every continent except Antarctica. About 50 species exist and consist of different colors, textures, and grain shapes and sizes. White, yellow, and red are the most common cultivated maize types. The white and yellow varieties are preferred by most people, depending on the region [21].

Maize is the most important cereal crop in sub-Saharan Africa (SSA) [23], [24], [21], [25]and an important staple food for more than 1.2 billion people in SSA and Latin America[21]. More than 300 million Africans depend on maize as the main staple food crop. All parts of the crop can be used for food and non-food products. Maize accounts for 30–50% of low-income household expenditures in Africa. Over 30% of the caloric intake of people in Sub-Saharan Africa comes from maize[23], [26].For these reasons, many African producers who depend on maize as a staple food crop have adopted the increased use of fertilizers to maintain a steady supply, to the detriment of the effects they have on the environment and human health.

This is the background to the present study, which aims to compare chemical and/or organic amendments on cereal growth and yield.

2. STUDY AREA

The study area is located in the North region of Cameroon, Guider's district, specifically in the locality of Bang (Figure 1). The coordinates of the plot center are N 09° 52' 18.7'', E 13° 58' 55.69''.The North region is characterized by a Sudano-Sahelian climate with a long dry season from October to April and a short rainy season from May to September. Rainfall averages 1000 mm/year. Average temperatures are around 28°C, with maximums (45°C) reached in March-April.In Bang, the soils encountered are lithic soils developed on embrechites. These lithic soils are generally very sandy, with a fairly high percentage of gravel. Numerous boulders and rock outcrops are often visible on the surface, highlighting the intensity of the erosion. These soils are characterized by a fairly high proportion of gravel (20 to 40%). With very little clay (8-10%), coarse sand dominates (50-60%). The pH of these soils varies greatly from one place to another, ranging from 5.5 to 6.8. It is generally relatively homogeneous throughout the profile. The organic matter content is around 1%, with a C/N of 10 to 12. The exchange capacity is very low - 4 to 5 meq/100g and the saturation rate is around 70% [27].

Figure 1: Study area location

3. METHODOLOGY

The study was conducted during the 2023 cropping season in the locality of Bang. To carry out the work, materials and equipment had to be assembled and a test protocol established.

3.1- Vegetal material

The plant material used is an improved variety of maize appreciated by the local population, which is the CMS 9015 (POOL 16 DR-SR) maize variety. This is a composite variety developed in Cameroon by the Institute of Agricultural Research for Development in 1990. It has a cycle of between 90 and 95 days, and the height of the adult plant varies between 140 and 170 cm. The seed is white with a toothed texture. The yield is 4 to 5 t/ha and the plant is tolerant to drought and diseases (smut, curvilaria, and stripe) but highly susceptible to striga[28].

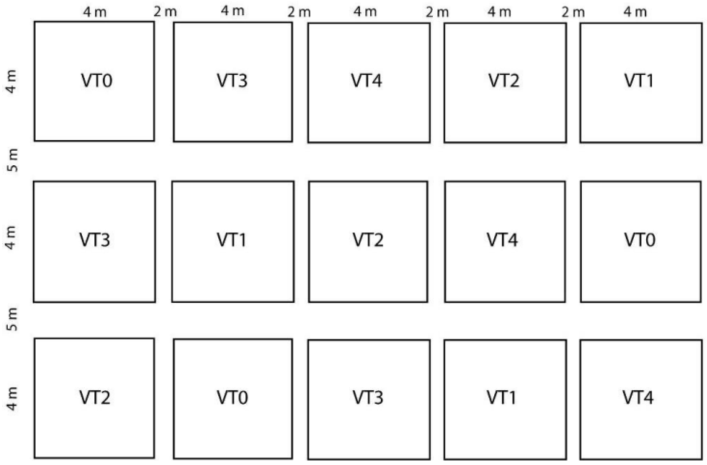
3.2- Fertilizer and agro-ecological practices

Three main products were used to fertilize the experimental plots: NPK chemical fertilizer formulated as 14 N-24 P_2O_5-14 K_2O-3.5 MgO, urea (46 N-0 P_2O_5-0 K_2O), and completely decomposed cow dung. An agroecological practice was also used, namely the system under plant cover with dried straw. Chemical fertilizer and urea were obtained on the market from approved distributor,s and the cow dung from farmers in the study area.

3.3- Experimental device

The experimental set-up was the randomized Fischer block type with 3 repetitions and 5 treatments (0 amendments, NPK, Organic Matter, 50% (NPK + Organic Matter), and straw). Each experimental unit (EU) had a surface area of 4m x 4m, i.e., 16 m^2. There were 5EUs per block, with a 2 m spacing between EU(Figure 2). Each block, therefore had an area of 112 m^2. As a result, 616 m^2 were requisitioned. The distance between the blocks was 5m.

The seedlings were sown on 08 July 2024 with 2 to 3 seeds per plot and a sowing density of 0.80m x 0.25m.



V : CMS 9015, T0 : Control, T1 : NPK, T2 : OrganicMatter (OM), T3 :50% (NPK+OM), T4 : Straw

Figure 2 : Experimental set-up

3.4- Treatment application

In all four treatments were administered as follows: The first treatment was T1 in which fertilizer (NPK) and urea were applied following the technical itinerary for maize production provided by the Institute of Agricultural Research for Development. This protocol stipulated that 10 days after germination, 0.32 kg of NPK mixed with 0.08 kg of urea were applied (base fertilizer). Then, 30 days after germination, 0.32 kg of urea was applied (cover fertilizer).

The second treatment was T2. Here, according to the Cameroonian Cotton Development Company (SODECOTON), you need 5 tons of organic matter to fertilize 1 hectare. Estimating from this assertion, each microplate of 4m x 4m, meaning 16 m^2 received 8 kg of fully decomposed cow dung fertilizer after sowing.

In the third trail T3, and as with treatment T1, the NPK and urea fertilizers were applied per the technical itinerary for maize production provided by the Institute of Agricultural Research for Development. Cow dung was added to these chemical inputs. Each input was applied at 50% of the required quantity. So, 10 days after emergence, 0.16 kg of NPK mixed with 0.04 kg of urea and 4 kg of cow dung were applied. 30 days after emergence, 0.16 kg of urea was applied.

Finally, the fourth treatment was T4. The straw was put in place 10 days after emergence to allow the plants to emerge fully from the soil.

3.5- Data collection and analysis

The various data collected during this study concern : (1) final germination percentage (FGP), (2) Germination Rate Index (GRI), (3) stem length (flowering), (4) root length (flowering), (5) number of secondary roots (flowering), (6) stem length (fruiting), (7) root length (fruiting), (8) number of secondary roots (fruiting), and (9) grain yield.

The data collected was processed using Microsoft Excel and then analyzed by ANOVA using XLSTAT software version 2023.3.1. (1416).

4. RESULTS

The various results obtained are shown in Table 1. The averages obtained for each treatment were compared.

4.1- Final germination percentage and Germination Rate Index

The values for the final germination percentage per block ranged from 45.42% to 91.67%, with an average of 76% ± 13.06. The best percentage was obtained in Block 2, followed by block 3 and finally block 1 (Figure 3a). The same observation was made for the germination rate index, where the minimum and maximum values were 18.16% and 36.67 % respectively, for an average of 30% ± 5.18. The best percentage was obtained in block 2, followed by block 3 and finally block 1 (Figure 3b). A comparison of the averages obtained per block (Tables 2 and 3) shows that there is no significant difference in the values obtained in the different blocks, which demonstrates that the surface area used for the study is homogeneous and therefore has no impact on the parameters measured.

Table 1: Field data

Experimental unit	FGP (%)	GRI (%)	SL_FL (cm)	RL_FL (cm)	NSR_FL	SL_FR (cm)	RL_FR (cm)	NSR_FR	Grain_yield (Kg)
Block 1_VT0	58.33	23.33	195.00	23.00	27.00	220.00	24.00	38.00	0.60
Block 2_VT0	85.00	34.00	195.00	22.00	27.00	200.00	25.00	38.00	1.00
Block 3_VT0	45.42	18.16	197.00	21.00	27.00	200.00	25.00	38.00	2.00
Average T0	**62.92**	**25.16**	**195.67**	**22.00**	**27.00**	**206.67**	**24.67**	**38.00**	**1.20**
Block 1_VT1	83.33	33.33	196.00	22.00	26.00	200.00	25.00	39.00	5.00
Block 2_VT1	82.50	33.00	198.00	24.00	29.00	200.00	27.00	40.00	3.00
Block 3_VT1	74.58	29.83	198.00	20.00	28.00	200.00	25.00	37.00	1.00
Average T1	**80.14**	**32.05**	**197.33**	**22.00**	**27.67**	**200.00**	**25.67**	**38.67**	**3.00**
Block 1_VT2	58.75	23.50	197.00	24.00	28.00	200.00	27.00	39.00	4.00
Block 2_VT2	85.00	34.00	197.00	24.00	30.00	200.00	25.00	38.00	1.00
Block 3_VT2	82.08	32.83	190.00	22.00	27.00	200.00	25.00	36.00	2.00
Average T2	**75.28**	**30.11**	**194.67**	**23.33**	**28.33**	**200.00**	**25.67**	**37.67**	**2.33**
Block 1_VT3	66.67	26.67	198.00	23.00	30.00	200.00	26.00	38.00	4.00
Block 2_VT3	75.00	30.00	197.00	23.00	29.00	210.00	25.00	37.00	4.00
Block 3_VT3	85.00	33.00	197.00	22.00	27.00	200.00	25.00	38.00	4.10
Average T3	**75.56**	**29.89**	**197.33**	**22.67**	**28.67**	**203.33**	**25.33**	**37.67**	**4.03**
Block 1_VT4	80.00	32.00	197.00	23.00	29.00	220.00	26.00	36.00	4.00
Block 2_VT4	91.67	36.67	195.00	21.00	27.00	200.00	25.00	38.00	3.00
Block 3_VT4	86.67	34.67	200.00	22.00	27.00	210.00	25.00	38.00	1.00
Average T4	**86.11**	**34.45**	**197.33**	**22.00**	**27.67**	**210.00**	**25.33**	**37.33**	**2.67**

FGP : Final Germination Percentage ; GRI: Germination Rate Index; SL: Stem Length; RL: Root Length; NSR: Number of Secondary Roots; FL: Flowering; FR: Fruiting.

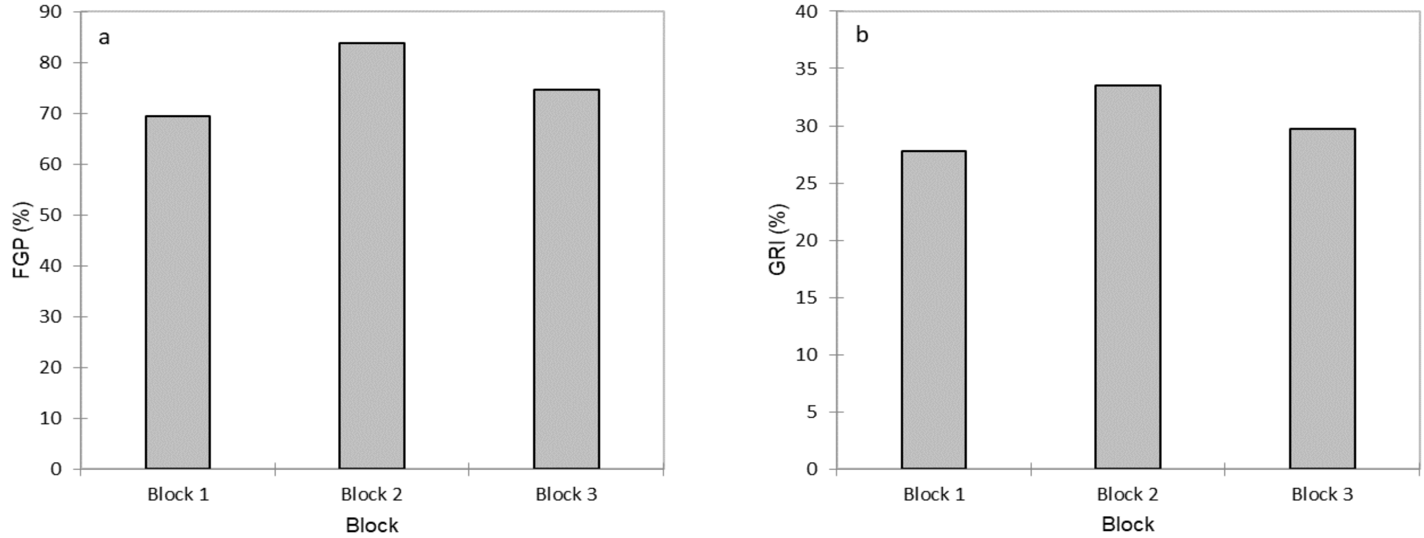


Figure 3 : a) Average FGP and b) GRI values by block

Table 2: Variance analysis of FGP

Source	DF	Sumofsquares	Meanofsquares	F	Pr > F	Significance codes of p-values
Model	2.000	531.416	265.708	1.719	0.221	°
Error	12.000	1854.921	154.577			
Corrected total	14.000	2386.336				

Calculated against the model Y=Average(Y)
*Significance codes : 0 < *** < 0.001 < ** < 0.01 < * < 0.05 < . < 0.1 < ° < 1*

Table 3 : Variance analysis of GRI

Source	DF	Sum of squares	Mean of squares	F	Pr > F	Significance codes of p-values
Model	2.000	86.196	43.098	1.786	0.209	°
Error	12.000	289.582	24.132			
Corrected total	14.000	375.778				

Calculated against the model Y=Average(Y)
*Significance codes : 0 < *** < 0.001 < ** < 0.01 < * < 0.05 < . < 0.1 < ° < 1*

4.2- Stem length, root length, and number of secondary roots (flowering)

The various parameters mentioned above were measured at the flowering stage precisely 60 days after sowing.
Stem length ranged from 190 to 200 cm, with an average value of 196.47 ± 2.23 cm. Treatments T1, T3, and T4 had the highest values (197.33 cm), followed by treatment T0 (195.67 cm) and treatment T2 (194.67 cm, Figure 4a). By comparing the averages obtained for each treatment (Table 4). The stem length variable did not show any significant difference between the different treatments applied.
The length of the main root varies between 20 and 24 cm. The average is 22.4 ± 1.18 cm. The highest value was observed with treatment T2 (23.33 cm), followed by treatment T3 (22.67 cm) and treatments T0, T1, and T4 (22 cm, Figure 4b). The analysis of variance for this variable (Table 5) shows that there was no significant difference between the different treatments.
The number of secondary roots ranged from 26 to 30, with an average of 27.87 ± 1.25. Treatment T3 (28.67) had the highest number of secondary roots, followed by T2 (28.33), T1 and T4 (27.67), and T0 (27.00, Figure 4c). However, a comparison of the averages for each treatment (Table 6) shows that there is no significant difference between them.

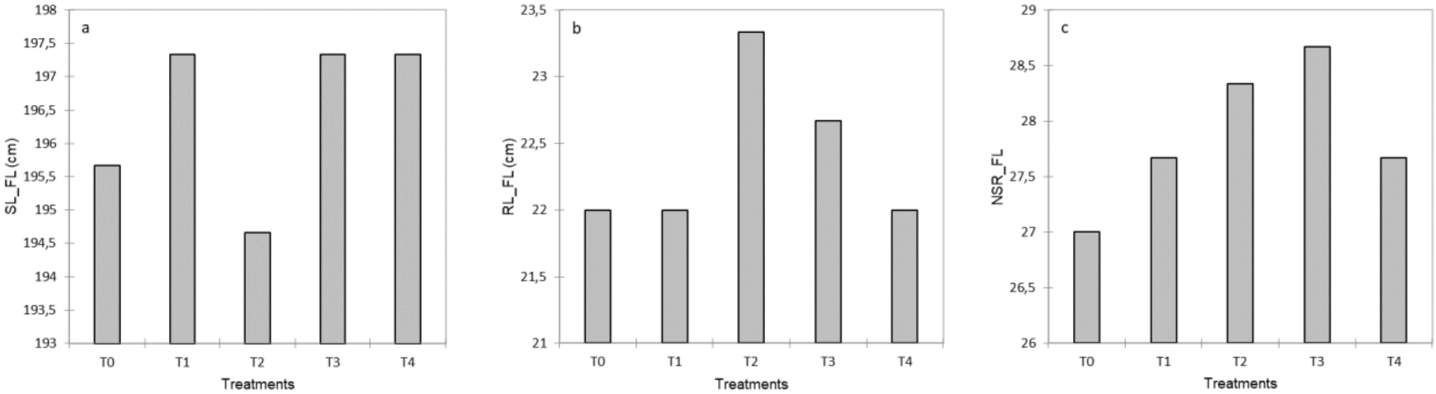


Figure 4: Flowering parameters: a) stem length; b) root length; c) number of secondary roots

Table 4 : Variance analysis of stem length

Source	DF	Sumofsquares	Meanofsquares	F	Pr > F	Significance codes of p-values
Model	4.000	18.400	4.600	0.896	0.501	°
Error	10.000	51.333	5.133			
Corrected total	14.000	69.733				

Calculated against the model Y=Average(Y)
*Significance codes : 0 < *** < 0.001 < ** < 0.01 < * < 0.05 < . < 0.1 < ° < 1*

Table 5: Variance analysis of root length

Source	DF	Sumofsquares	Meanofsquares	F	Pr > F	Significance codes of p-values
Model	4.000	4.267	1.067	0.696	0.612	°
Error	10.000	15.333	1.533			
Corrected total	14.000	19.600				

Calculated against the model Y=Average(Y)
*Significance codes : 0 < *** < 0.001 < ** < 0.01 < * < 0.05 < . < 0.1 < ° < 1*

Table 6: Variance analysis of the number of secondary roots

Source	DF	Sumofsquares	Meanofsquares	F	Pr > F	Significance codes of p-values
Model	4.000	5.067	1.267	0.760	0.574	°
Error	10.000	16.667	1.667			
Corrected total	14.000	21.733				

Calculated against the model Y=Average(Y)
*Significance codes : 0 < *** < 0.001 < ** < 0.01 < * < 0.05 < . < 0.1 < ° < 1*

4.3- Stem length, root length, and number of secondary roots (fruiting)

These different parameters were measured 90 days after sowing.
Stem length ranged from 200 to 220 cm, with an average of 204 ± 7.37 cm. Treatment T4 recorded the longest stems (210 cm), followed by T0 (206.67 cm), T3 (203.33 cm), and T1 and T2 (200 cm, Figure 5a). The analysis of variance (Table 7) shows that there is no significant difference between the values obtained for the different treatments.
The length of the main root ranged from 24 to 27 cm, with an average of 25.33 ± 0.82 cm. The highest values were observed with treatments T1 and T2 (25.67 cm), followed by T3 and T4 (25.33 cm), and finally T4 (24.67 cm, Figure 5b). The analysis of variance (Table 8) shows that there was no significant difference between the values obtained for the different treatments.

The number of secondary roots varied between 36 and 40, with an average of 37.87 ± 1.06. The highest number of secondary roots was obtained with treatment T1 (38.67), followed by T0 (38.00), T2 and T3 (37.67), and finally T4 (37.33, Figure 5c). The analysis of variance (Table 9) shows that there is no significant difference between the values obtained for the different treatments.

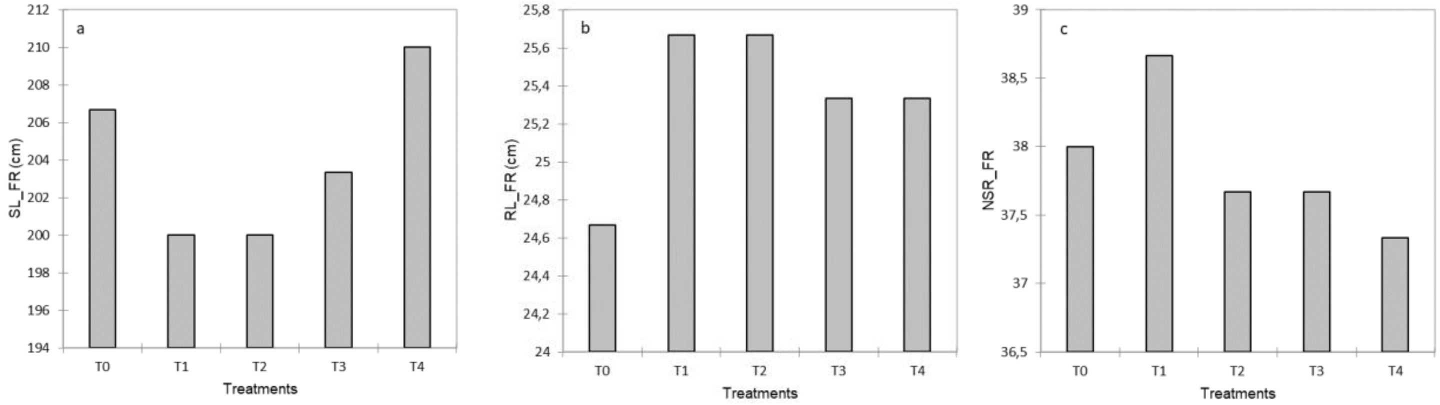


Figure 5: Fruiting parameters: a) stem length, b) root length, c) number of secondary roots

Table 7: Variance analysis of stem length

Source	DF	Sumofsquares	Meanofsquares	F	Pr > F	Significance codes of p-values
Model	4.000	226.667	56.667	1.063	0.424	°
Error	10.000	533.333	53.333			
Corrected total	14.000	760.000				

Calculated against the model Y=Average(Y)
*Significance codes : 0 < *** < 0.001 < ** < 0.01 < * < 0.05 < . < 0.1 < ° < 1*

Table 8: Variance analysis of root length

Source	DF	Sumofsquares	Meanofsquares	F	Pr > F	Significance codes of p-values
Model	4.000	2.000	0.500	0.682	0.620	°
Error	10.000	7.333	0.733			
Corrected total	14.000	9.333				

Calculated against the model Y=Average(Y)
*Significance codes : 0 < *** < 0.001 < ** < 0.01 < * < 0.05 < . < 0.1 < ° < 1*

Table 9: Variance analysis of the number of secondary roots

Source	DF	Sumofsquares	Meanofsquares	F	Pr > F	Significance codes of p-values
Model	4.000	3.067	0.767	0.605	0.668	°
Error	10.000	12.667	1.267			
Corrected total	14.000	15.733				

Calculated against the model Y=Average(Y)
*Significance codes : 0 < *** < 0.001 < ** < 0.01 < * < 0.05 < . < 0.1 < ° < 1*

4.4- Grain yield

The various yields obtained varied between 0.6 and 4.03 kg, with an average of 2.65 ± 1.49 kg. The highest yields were obtained with treatment T3 (4.03 Kg), followed by T1 (3.00 Kg), T4 (2.67 Kg), T2 (2.33 Kg), and T0 (1.20 Kg, Figure 6). A comparison of the different seed weights obtained shows that there were no significant differences for the different treatments applied (Table 10).

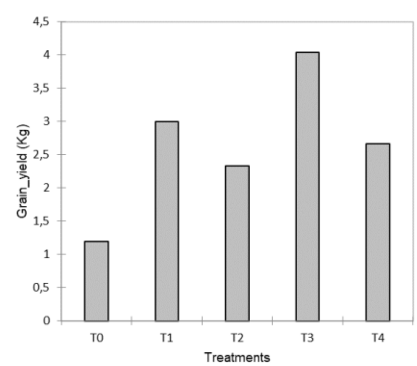


Figure 6: Different grain yields

Table 10: Variance analysis of grain yield

Source	DF	Sumofsquares	Meanofsquares	F	Pr > F	Significance codes of p-values
Model	4.000	12.717	3.179	1.730	0.220	°
Error	10.000	18.380	1.838			
Corrected total	14.000	31.097				

Calculated against the model Y=Average(Y)
*Significance codes : 0 < *** < 0.001 < ** < 0.01 < * < 0.05 < . < 0.1 < ° < 1*

5. DISCUSSION

5.1-Final Germination Percentage and Germination Rate Index

The final germination percentage and the germination rate index depend mainly on the germination capacity of the seeds, but also on the physicochemical properties of the soil. These parameters were measured when no treatment had been applied, so the absence of any significant difference between the different blocks highlights the homogeneity of the experimental plot. Similar results were reported by[29].

5.2- Maize growth components and yields

The plant height, root length, and number of secondary roots can serve as important indices that directly reflect the growth of the maize plants [30]. Plant height is one of the maize growth parameters that is affected by N availability[31], [32] and is essential in determining grain yield grains [33], [34].

In general, plants treated with mineral fertilizer and/or organic matter have higher growth parameter values than the control (T0). This implies that fertilization improves the chemical properties of the soil [35], [36] and therefore can impact crop growth parameters such as plant height[37].In addition, soil fertility inputs with mineral fertilizer consistently led to greater plant height, which was attributed to the readily available N. Various studies have reported a significant increase in maize plant height with mineral fertilizer application [38], [31]. Several authors have also reported an increase in plant height of various crops as a result of fertilizer application, for instance, [39] and [40] [41] and [36] also reported that a combination of organic inputs and mineral fertilizer showed an increase in plant height.[42] Also reported increased plant height in treatments using organic resources.

Similarly, the same observations made for plants whose soil is covered with straw (T4) show that yields are higher than those of the control. This shows that straw also plays a role in improving the soil's physico-chemical properties, particularly its water content and structure, as it adds more C sources and other nutrients to the soil[43].

In this study, fertilizer (organic and mineral) applications also increased the grain yield of maize over the control. The differences in the yield may be a result of the soil and the field management practices. The increase in grain yield recorded in the organic and mineral-treated soil compared to the unamended plot might be attributed to improvement in the maize water use and nutrient availability as a result of fertilizer addition. Our results are in agreement with numerous studies which have shown that the addition of organic manures exerts multiple benefits on crop productivity and soil fertility including improvement of soil structure [44], [45], [43] and stimulation of nutrient availability and microbial activity resulting in high yields [46], [47] and carbon sequestration [48], [49].

Although there was no significant difference between the yields obtained by the different treatments, treatment T3 obtained the best yield. This is consistent with the work of[50], who showed that manure and P application are the most important factors for maize yields.

6. CONCLUSION

The main objective of this study is to compare chemical and/or organic amendments on the growth and yield of a cereal based on data obtained within the defined experimental set-up. A comparison of the results obtained for both growth and yield showed that there were no significant differences between the different treatments. However, as far as growth parameters are concerned, the best results were obtained with the mineral and/or organic fertilizer treatments. About yield, the treatment consisting of a mixture of mineral fertilizer (50%) and manure (50%) obtained the best yield. It is therefore important to raise people's awareness of the benefits of using this mixture. The aim is to ensure sustainable management of natural resources, particularly soil and water.

DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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