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EFFECTS OF LIQUID ORGANIC FERTILIZER ON SOIL CHEMICAL PARAMETERS: MAIZE COMPONENTS AND YIELDS

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ABSTRACT

Burkina Faso, like other countries, is facing the challenge to increase agricultural production face in the strong demographic growth. Agricultural production is hampered by declining soil fertility, which compromises crop yields. The aim of this study is to help increase crop yields and soil fertility. A completely randomised block design with three replications comprising five (05) treatments was set up. The fertilizers used were : NPK (15-15-15), urea (46%N) and liquid organic fertilizer. The liquid organic fertilizer was made using cowpea flour neem leaves. Sugar and animal waste (cow dung and urine). Soil samples were taken at six periods. The first sample was taken before sowing. Followed by four more during cultivation and one just after harvesting. Measurements of height and diameter of the rod were taken on the 30th. 45th. 60th and 75th day after sowing.

Harvest results show that T1 recorded the best pH-water value (6.75) and total phosphorus (410.66 mg/kg). The T4 gave the highest levels of organic carbon (1.5%) and total nitrogen (1.44%). Concerning the CEC, the highest content is obtained with T2 with a value of 10.23 cmol/kg. As for total potassium, the highest content is in T3, at 652.44 mg/kg.

At the maturity, T2 has the highest average diameter at 16.35 mm. In terms of height, the absolute control present the tallest plants with an average value of 1.41m.

The highest yields were obtained with T4 (1983.23 kg/ha), followed by T2 (1834.9 kg/ha). T1 (1723.43 kg/ha) and T3 (1557.12 kg/ha). Liquid organic fertilizer has been effective in producing grain yields at a rate of 40.58%.

The liquid organic fertilizer applied alone has high carbon, total nitrogen, total phosphorus, total potassium and CEC content compared with the control. It was also efficient in grain yield production with a rate of 40.58%. In fact, it is imperative to carry out a test in a paysan environment before popularizing it.

Keywords: Maize, Liquid organic fertilizer, Mineral fertilizer, Yields, Soil characteristics, Burkina Faso.

1 INTRODUCTION

Burkina Faso, like other countries, faces the challenge of increasing agricultural production to meet the needs of its rapidly growing population while protecting the environment (Kouakou. 2004). Additionally, population growth, combined with climate variability and intensive agricultural practices. Leading to the ongoing degradation of arable land, resulting in low crop yields particularly for grains, including corn. However, cereals play a very important role both in terms of the area under cultivation and in terms of human consumption (Anihouvi *et al.*. 2016). Among cereals, corn is a staple food of great importance in the diets of African populations due to its high calorie and protein content (Macauley and Tabo, 2015). In Burkina Faso, it ranks third after millet and sorghum in terms of production area and consumption (INSD, 2018). However, it is one of the crops with the highest mineral nutrient requirements. necessitating the use of fertile soils and effective soil fertility management systems (Maltas *et al.*. 2012). As a result, soil degradation and declining soil fertility are major constraints on its productivity (Bationo *et al.*, 2004).

Thus, to address declining yields and increase maize productivity. Researchers have developed several technology packages, such as improved varieties, crop rotation (Koulibaly *et al.*, 2016), the introduction of legumes into crop rotations (Bado *et al.*, 2012). Crop residue management (Koulibaly *et al.*, 2010; Ouattara *et al.*, 2011; Abdou *et al.*, 2016; Koulibaly *et al.*, 2017) and the combined use of mineral fertilizers and organic manure (Koulibaly *et al.*, 2015; Akanza *et al.*, 2016) and erosion control measures (Zougmore, 2003). Despite these various techniques which are implemented to varying degrees for economic and social reasons the decline in soil fertility and corn productivity continues. For this reason, it is necessary to examine the issue and find other alternatives to solve the problem. However, for better management and sustainable improvement of soil fertility, the use of liquid organic fertilizers that protect soil biodiversity appears to be the best option. Satisfactory results have already been demonstrated in the studies by Tshimbombo *et al.* (2018) and Kotaix *et al.* (2019) on soil chemical properties, crop components and yields. In Burkina Faso, Zoungrana's (2021) findings showed that liquid fertilizer improves the yield of Brachiaria and Mucuna in forage crops.

However, the reality is that these liquid organic fertilizers are still rarely used by farmers, given their availability, cost and the accessibility of the ingredients used in their production. It is therefore important to offer other liquid organic fertilizers that are less expensive and easy to make from more readily available materials.

The objective of this study was to develop a liquid organic fertilizer that is easy to produce and low-cost, with the aim of helping to increase corn yields.

2 MEHODOLOGY

2.1 Preparing Liquid Fertilizer

The liquid organic fertilizer was prepared using cowpea meal, neem leaves and cow manure, with 1 kg of each ingredient. Next, we added 1 liter of cow urine and 1/4 kg of light brown sugar. Finally, the water is added in accordance with the specified volume ratio, which is 10 liters. The concentrated solution was stored in a barrel for 10 days before being filtered. To prepare the liquid fertilizer for application, we diluted 1 liter of the concentrated solution with 100 liters of water, following the recommendations of the NGO Educational Hunger Organization (ECHO).

2.2 Experimental Design

The experimental design was a completely randomized block design with 5 treatments and 3 replicates (blocks). Each block consisted of 10 corn plants.

The treatments were as follows:

- T0: no fertilizer application
- T1: application of liquid organic fertilizer
- T2: application of mineral fertilizer at the recommended rate
- T3: application of liquid organic fertilizer + mineral fertilizer at the recommended rate
- T4: application of liquid organic fertilizer + ½ of the recommended rate of mineral fertilizer.

2.3 Crop Establishment and Maintenance

Semi-manual sowing was performed at a rate of two seeds per hole. Thinning was carried out at 10 days after sowing (DAS) to leave one plant per hole. Crop maintenance consisted of applications of mineral fertilizers and liquid organic fertilizer. NPK mineral fertilizer (15-15-15) and 46% urea were applied at rates of 200 and 150 kg/ha, respectively. The liquid fertilizer was applied at a rate of 0.35 L per hole. Watering was carried out.

2.4 Agronomic Parameters Measured

Observations were made on a sample of ten (10) plants randomly selected from each experimental plot, while avoiding edge effects and included stem diameter at the collar and plant height at 30, 45, 60 and 75 days after sowing (DAS). The grain yield from the usable plot was obtained after sun-drying to achieve a moisture content of 14%. To do this, a sample was taken and tested using a moisture meter. The grains were then cleaned of all impurities through winnowing and sorting. The yield was determined using the following formula:

$$\text{Yield per grain} = (\text{Weight per grain (g)} * 10.000 \text{ m}^2) / (\text{Effective area of the basic plot} * 1.000 \text{ g})$$

2.5 Soil Analysis Methods

Soil samples were collected before. During and at harvest. They were dried, ground and sieved using 2-mm and 0.5-mm sieves before being submitted for chemical analysis at the IN.E.R.A. Farako-Bâ Soil-Water-Plant Laboratory. The soil analyses covered the following parameters: pH, organic carbon, total N. P and K and cation exchange capacity (CEC).

Soil pH is measured using an electronic pH meter with a glass electrode in an aqueous suspension with a soil-to-solution ratio of 1:2.5 (1 g of soil per 2.5 mL of water), in accordance with the AFNOR NF ISO 10-390 standard. Total organic carbon was determined by thermal oxidation (135 °C for 1 hour) in an acidic medium using potassium dichromate, in accordance with standard NF ISO 14-235. Total nitrogen was determined by mineralization and distillation using the Kjeldahl method in accordance with AFNOR ISO 11-261. For total phosphorus, the soil samples were first heat-mineralized with a mixture of H₂SO₄ and SeH₂O₂. Subsequently, total phosphorus (P-total) was determined in the mineralized samples using an SKALAR automatic colorimeter (Segmented Flow Analyzer, model SAN plus 4000-02, Skalar, Netherlands). Total potassium was determined using a flame photometer (JENCONS PFP 7, Jenway LTD, Felsted, England).

2.6 Data Processing and Analysis

The collected data were entered and processed using Microsoft Excel 2013. Statistical analyses were performed using R software version 3.6.2. A normality test was performed and based on the results. The variables were subjected to either a nonparametric test (Kruskal-Wallis test) or a parametric test (ANOVA). The comparison of means for the ANOVA was performed using Tukey's test. The significance level for all tests was 0.05.

3 RESULTS AND DISCUSSION

3.1 Effects of Different Fertilizers on Soil Chemical Parameters

Table 1: Effect of Treatments on Soil Water Ph

Treatments	Water pH				
	30 DAS	45 DAS	60DAS	75 DAS	80 DAS
Initial soil	6.28±0.03	6.28±0.03bc	6.28±0.03a	6.28±0.03c	6.28±0.03c
T0	6.31±0.18	6.60±0.02ab	6.58±0.03a	6.71±0.11ab	6.75±0.017a
T1	6.37±0.04	6.76±0.16a	6.73±0.13ab	6.65±0.02a	6.75±0.01a
T2	6.15±0.10	5.97±0.17de	6.31±0.18a	6.53±0.1a	6.51±0.07ab
T3	6.18±0.22	5.61±0.05e	6.29±0.1a	6.4±0.05a	6.35±0.07bc
T4	6.11±0.06	6.07±0.03cd	6.37±0.3a	6.54±0.16a	6.42±0.02bc
Probability	0.19	0.006**	0.023*	0.001**	0.008**

T0: no fertilizer applied; T1: liquid organic fertilizer applied; T2: mineral fertilizer applied at the recommended rate; T3: liquid organic fertilizer + mineral fertilizer applied at the recommended rate; T4: liquid organic fertilizer + ½ of the mineral fertilizer applied at the recommended rate. * significant p-value. **highly significant p-value

The treatments had a significant effect on soil pH regardless of the sampling date, except at 30 days after sowing. At the first three measurement dates as well as at harvest (80 days after sowing), treatment T1 which received only liquid organic fertilizer showed the highest average values. This can be explained in part by the pH value (6.98) of the applied liquid fertilizer which tends toward neutrality. Additional, chemical fertilizers contribute to soil acidification making mineral nutrients unavailable to plants. The decrease in pH in plots treated with chemical fertilizers indicates that these fertilizers have an acidifying effect on the soil in Pô and Tiébélé. Burkina Faso (Nignan, 2017). Uyo and Elemo (2000) made the same observation regarding Nigerian soils. At 75 DAS, the control (T0) recorded the highest value. This is certainly due to interactions between plants and the soil that create imbalances in its chemical parameters.

Table 2: Effect of Treatments on the Average Organic Carbon Content in the Soil

Treatments	Organic Carbon (%)				
	30 DAS	45 DAS	60 DAS	75 DAS	80 DAS
Initial soil	1.24 ±0.05bc	1.24 ±0.05ab	1.24 ±0.05a	1.24 ±0.05b	1.24 ±0.05a
T0	1.34± 0.12ab	1.25±0.08abc	1.29±0.01a	1.19±0.04b	1.19±0.03e
T1	1.32± 0.02ab	1.11±0.08a	1.15±0.005a	1.10±0.041a	1.37±0.14ab
T2	1.13± 0.04c	1.21±0.04ab	1.276±0.03a	1.25±0.03b	1.476±0.07abc
T3	1.21± 0.01bc	1.23±0.03ab	1.270±0.07a	1.27±0.11ab	1.47±0.07abc
T4	1.49± 0.02a	1.36±0.04d	1.273±0.05a	1.3±0.05ab	1.5±0.02abc
Probability	0.011*	0.007**	0.145	0.027*	0.001**

Statistical analyses revealed a significant difference in organic carbon content among the treatments at all sampling dates except during the flowering stage (60 days after sowing). Treatment T4, which received liquid fertilizer plus half the recommended dose of mineral fertilizer, had the highest carbon content. This is due to the combined effect of the fertilizers, The small amount of chemical fertilizer likely had no negative effect on soil biology, which in turn led to the normal mineralization of organic matter and the release of carbon. The application of liquid fertilizer plus half the mineral fertilizer had a positive effect on carbon enrichment during and at the end of the growing season, demonstrating a significant difference between the treatments. In contrast, at 60 DAS, the control (without fertilizer application) yielded the highest average. This result could be explained by the soil's initial carbon content, as well as the fact that establishing a crop can improve the soil's chemical properties through the release of carbon-rich root exudates.

Table 3: Effect of Treatments on the Average Total Nitrogen Content in the Soil

Treatments	Total Nitrogen (%)				
	30 JAS	45 DAS	60 DAS	75 DAS	80 DAS
Initial soil	0.11±0.004bc	0.11±0.004bc	0.11±0.004ab	0.11±0.004a	0.11±0.004a
T0	0.125±0.007ab	0.118±0.007abc	0.121±0.005d	0.112±0.006a	0.122±0.004b
T1	0.124±0.005ab	0.108±0.005c	0.105±0.002a	0.109±0.003a	0.135±0.009c
T2	0.104±0.002c	0.114±0.002bc	0.11±0.003bc	0.12±0.008ab	0.139±0.007c
T3	0.120±0.002b	0.122±0.003ab	0.11±0.005bc	0.12±0.007ab	0.143±0.008d
T4	0.149±0.001a	0.132±0.0005a	0.122±0.006d	0.126±0.004d	0.144±0.005d
Probability	0.01*	0.022*	0.007**	0.029*	0.0006***

With regard to total nitrogen, the results of the statistical analysis showed a significant difference among the treatments at all sampling periods. Treatment T4 gave the highest nitrogen concentrations on all dates. The likely explanation for these results may be related to the low doses of NPK and urea, which did not significantly affect the pH. However, pH is a key factor in nutrient availability. The combination of the two fertilizers may also be a factor. A small amount of mineral fertilizer will quickly dissolve in the liquid fertilizer and immediately enter the soil solution. This demonstrates the effectiveness of combining liquid organic fertilizer with half the recommended dose of mineral fertilizer.

Table 4: Effect of Treatments on the Average Total Phosphorus Content in the Soil

Treatments	Total Phosphorus (mg/kg)				
	30 DAS	45 DAS	60 DAS	75 DAS	80 DAS
Initial soil	230.66±31.53d	230.66±31.53a	230.66±31.53	230.66±31.53a	230.66±31.53c
T0	318±16.52bcd	300.33±17b	371.66±77.59	310±13.74bc	292.33±14.2bc
T1	301±43.48cd	316.66±26.85b	339±31.17	291.66±12.09b	410.66±73.92a
T2	466.66±106.5abc	416.66±80.02c	423.33±58.34	396.33±9.45de	355±25.23abc
T3	513±20.78a	487±33.06cd	397.33±31.26	410.3±48.01de	388.66±22.18a
T4	497.66±25.65ab	402.33±72.47c	416.66±57.57	357.33±25.89d	361.66±21.9ab
Probability	0.014*	0.0004***	0.063	0.016*	0.017*

An analysis of the results for total phosphorus revealed a significant difference between the treatments at all time points except at 60 DAS. In fact, in the first two samples (30 DAS, 45 DAS) and the second-to-last sample (75 DAS), high total phosphorus levels were observed in T3. This result is due to the high content of major nutrients in mineral fertilizers and also to the combination (liquid fertilizer and the recommended dose of mineral fertilizers), which is expected to provide greater benefits. Segda et al. (2013) demonstrated in Bagré that mineral fertilization (with NPK) increases phosphorus content. At the 60-day-after-sowing (DAS) stage, treatment T2 had the highest value, which is likely due to its low pH (6.31) compared to the other treatments. This certainly reduced the plants' uptake of phosphorus. However, at that time, the crop was in the flowering stage, when the need for water and minerals is high. As for the yield (80 DAS), the highest average was observed in T1. This is due to the frequency of liquid fertilizer applications, which led to a buildup of phosphorus in the soil. Furthermore, during the maturity stage, plants do not require sufficient mineral nutrients to function properly. The performance of T1 observed at harvest confirms that the liquid fertilizer improves the phosphorus content in the soil.

Table 5: Effect of Treatments on the Average Total Potassium Content in the Soil

Treatments	Total Potassium (mg/kg)				
	30 DAS	45 DAS	60 DAS	75 DAS	80 DAS
Initial soil	636.13±48.93abc	636.13 ±48.93	636.13 48.93 a	636.13 48.93	636.13 48.93
T0	635.43±1.21bc	652.44±28.25	538.26±48.93a	489.33±48.93	538.27±0.00
T1	603.51±28.24c	554.58±28.24	505.64±28.25a	554.58±28.24	570.89±28.24
T2	701.37±56.5abc	636.13±48.93	554.58±2.24a	554.58±28.24	603.51±28.24
T3	782.93±84.75a	619.82±28.24	505.64±28.25a	603.51±56.49	652.44±74.74
T4	717.69±28.24ab	619.82±56.50	554.58±28.24a	554.57±56.50	554.57±56.50
Probability	0.026*	0.199	0.055	0.084	0.056

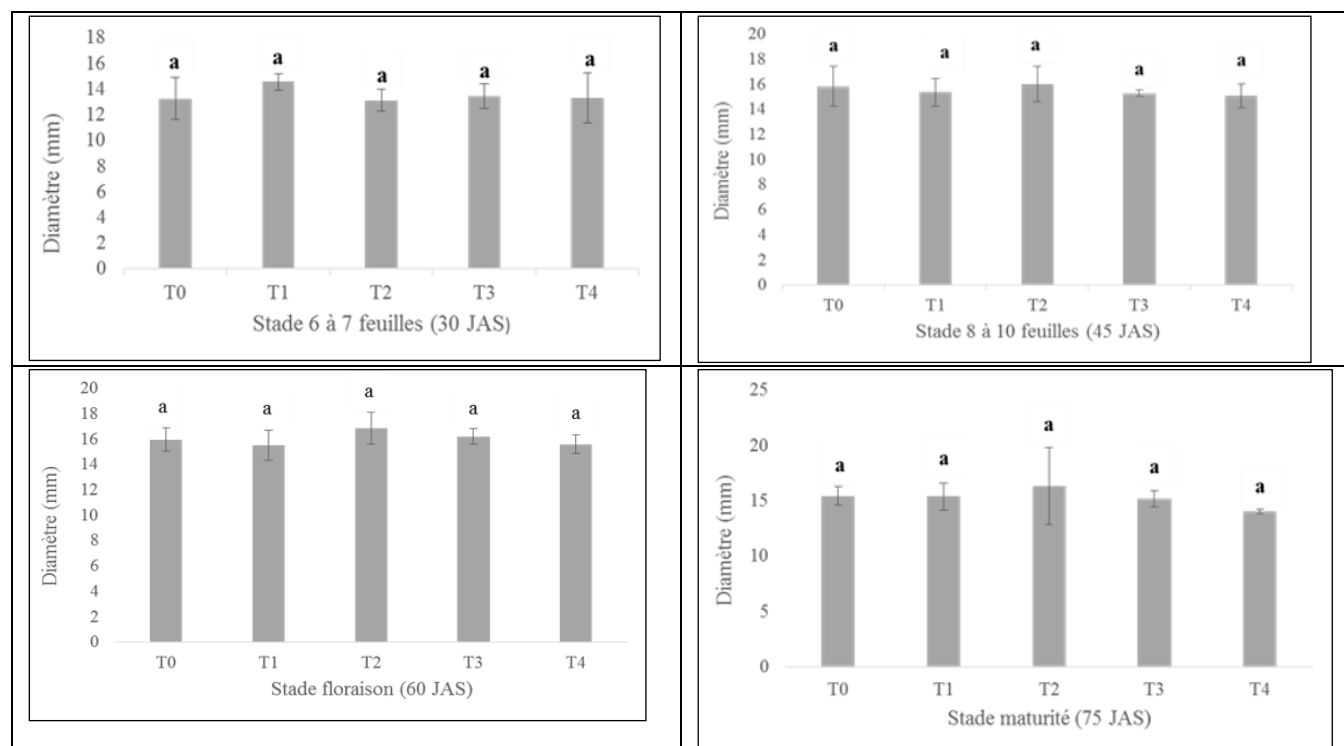
At the conclusion of our study on total potassium, we found that the statistical results showed no significant difference between the treatments at any of the sampling periods except for the 30-day-after-sowing (DAS) period. In fact, at 60 DAS and 75 DAS, the high averages were obtained with the initial soil. This could be attributed to the soil's fertility with respect to this element, given that the soil was collected from a forest where the organic matter content is high. The decrease in potassium content in the treatments is, of course, related to the plants' uptake of potassium, given its role in crop growth and development. As a reminder, potassium improves the plant's water balance and increases its tolerance to drought, frost and salinity (FAO, 2003). It enhances the plant's response to phosphorus and reduces lignification, thereby increasing the risk of lodging (Lanyon and Smith, 1985). However, at 30 DAS and at harvest (80 DAS), the T3 treatment showed high potassium levels. This is likely due to the effect of the mineral fertilizer application that took place five days before the sample was collected. As for the 45-day-after-sowing (DAS) sample, the T0 treatment stands out for its high total potassium content. This is certainly related to its pH (6.60), which is higher than that of the other treatments and conducive to microbial activity, ensuring the decomposition of organic matter followed by the release of nutrients into the soil.

Table 6: Effect of Treatments on Soil Cation Exchange Capacity

Treatments	Cation Exchange Capacity (cmol/kg)				
	30 DAS	45 DAS	60 DAS	75 DAS	80 DAS
Initial soil	8.46±0.17a	8.46±0.17a	8.46±0.17f	8.46±0.17a	8.46±0.17a
T0	10.51±0.38b	8.82±0.39ab	9.51±0.31de	9.01±0.15b	9.75±0.33b
T1	10.63±0.47b	9.06±0.29ab	8.9±0.32d	9.53±0.27bc	10.12±0.34bc
T2	10.80±1.11b	8.81±0.48ab	10.92±1.13abc	9.24±0.43b	10.23±0.44bc
T3	10.83±1.59b	9.81±0.16c	10.35±0.77ab	9.49±0.37bc	9.71±0.08b
T4	8.86±0.28c	10.04±0.27cd	9.49±0.14a	9.58±0.33bcd	9.76±0.01b
Probability	0.012*	0.0003***	0.002**	0.005**	0.006**

As for the CEC, statistical analyses revealed a highly significant difference at the 5% level between the treatments across all time periods. In fact, all treatments improved the soil's CEC compared to the control. For the samples collected at 45 DAS and 75 DAS, the highest averages were recorded for T4. These results could be explained by the high organic matter content of the soil in this treatment. At these two time points, 45 and 75 DAS, the CEC values are 2.35 and 2.24 respectively. These values are high compared to those of the other treatments. However, organic matter influences exchange capacity through charge fixation. This finding corroborates that of Lompo (2005), who showed that organic matter increases cation exchange capacity. With regard to the 60 JAS and at harvest, the highest values were observed with T2. This could be related to the effect of the mineral fertilizer in terms of its mineral nutrient content.

3.2 Effects of Treatments on Maize Stem Diameter and Plant Height

**Figure 1: Effect of treatments on stem diameter**

For diameter, the results of our various treatments showed no significant differences at the 5% significance level at any of the measurement periods. Nevertheless, slight variations were observed among the treatments from one period to the next. At the 6- to 7-leaf stage (30 DAS), the highest average diameter was observed in T1, with a value of 14.54 mm. This result may be explained by the fact that the nutrients contained in the liquid fertilizer are immediately available to the plants. Yahaya (2009) demonstrated that in urine (a component of liquid organic fertilizer), nutrients exist in ionic form and are easily absorbed by plants. As for the 8- to 10-leaf stages, flowering and maturity, the T2 treatment yielded the highest average diameters, which were 16.02 ; 16.85 mm and 16.35 mm respectively. This can be attributed to the high nutrient content of chemical fertilizers.

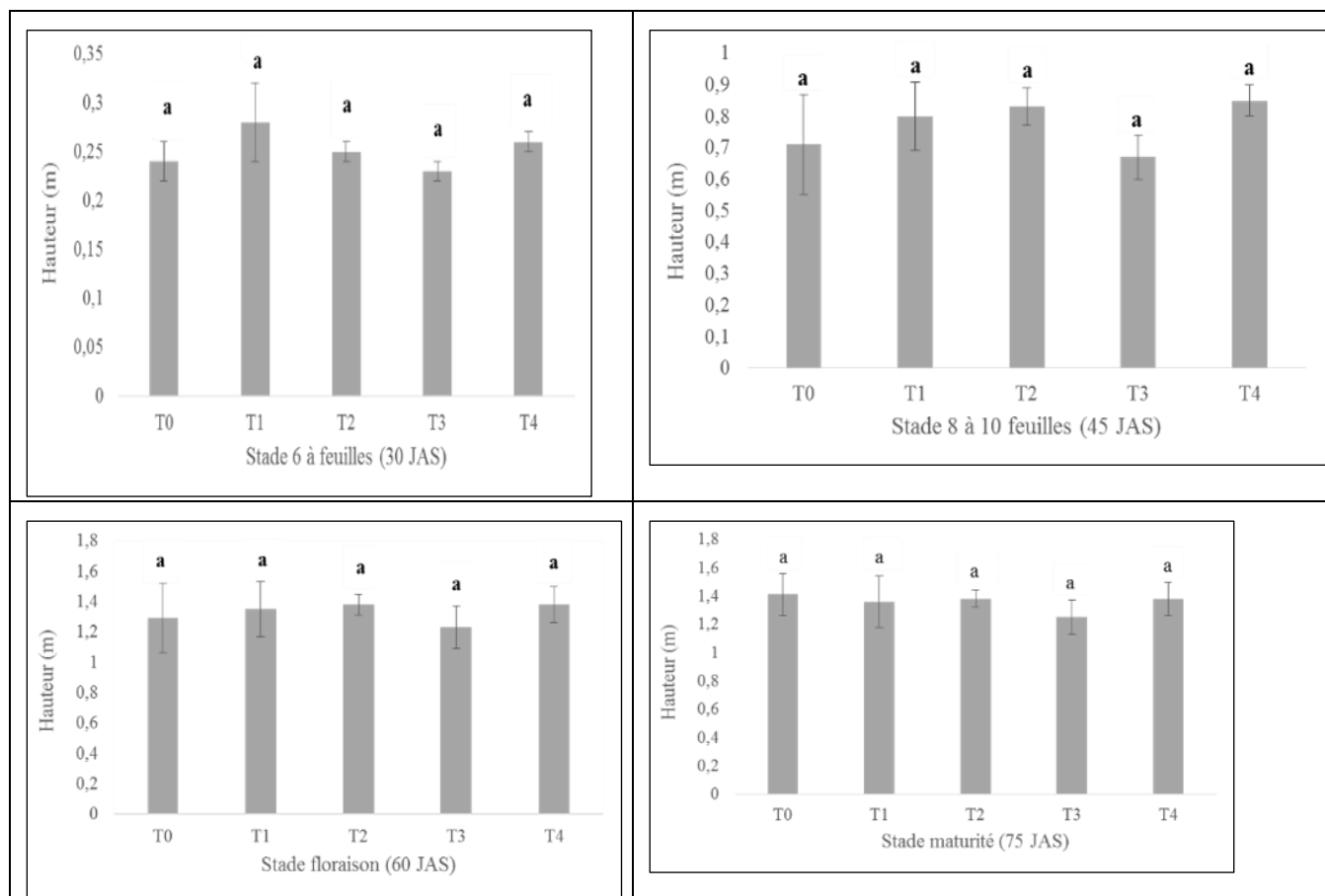


Figure 2: Average stem height by treatment

With regard to plant height, statistical analysis shows that the treatments had no effect on the average plant height at any of the measurement stages. However, variations of varying degrees were observed among the treatments at each stage. This is the case at the 6- to 7-leaf stage (30 DAS), where the highest value is observed with treatment T1, averaging 0.28 m. This could be explained by the effectiveness of the liquid fertilizer, given its nutrient content and its pH, which promotes the mobility of mineral elements. There is also its soluble form, which facilitates the uptake of minerals compared to granular forms, which must undergo a mineralization process before entering the soil solution to be absorbed by plants. This enables the plants to absorb nutrients in a timely manner, which has an immediate impact on their growth and development. This finding is consistent with that of Zoungwana (2021), who showed that when liquid organic fertilizer is applied on the same day as mineral fertilizer, the effect of the liquid organic fertilizer is more immediately noticeable on corn plants compared to that of the mineral fertilizer. As for the 8- to 10-leaf stage (45 DAS), treatment T4 had the highest value, at 0.85 m. This result can be explained by two hypotheses: first, the low dose of mineral fertilizer, which had no negative effect on soil pH. Nothing hindered the availability of mineral nutrients to the plants, allowing them to grow rapidly compared to the other treatments. Another hypothesis is that there was better interaction between the liquid fertilizer and the low-dose mineral fertilizer, resulting in good plant growth. This result contradicts the study by Tshimbombo et al. (2018), conducted in the Congo, which found that liquid organic fertilizer (D.I.GROW) has a greater effect on maize height compared to liquid fertilizer combined with half the recommended dose of mineral fertilizers. This difference can be explained by the fact that this fertilizer contains all the ionic elements. It also contains plant growth hormones. During the flowering and maturity stages, the T2 and T4 treatments had the same average height of 1.38 m. This is likely due to the high levels of certain nutrients in the soil for these treatments, particularly total nitrogen. The specific case of T2 may be due to the rate of mineral fertilizer application. Siri (2015) demonstrated that there is a close correlation between the rates of mineral fertilizer applied and both growth and yield. The specific case of T2 may be due to the rate of mineral fertilizer application. Siri (2015) demonstrated that there is a close correlation between the rates of mineral fertilizer applied and both growth and yield.

3.3 Effects of Treatments on Corn Grain Yield

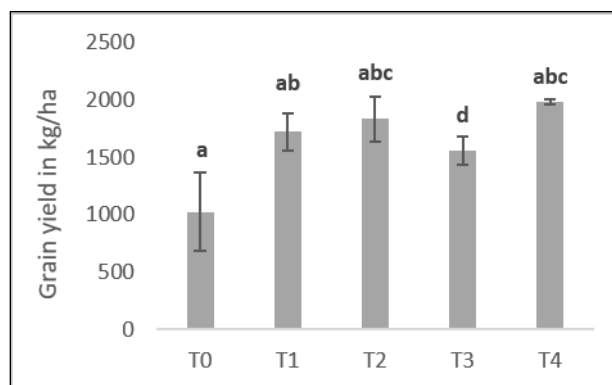


Figure 3: Effect of Different Treatments on Grain Yield

The ANOVA revealed a significant difference ($p = 0.049$) in grain yield among the different treatments. Treatment T4 gave the highest grain yield. This could be explained by the availability and quantity of major nutrients particularly potassium present in the soil. However, potassium plays a role in increasing grain size and weight. This finding contradicts that of Tshimbombo et al. (2018), who showed that applying mineral fertilizer alone yields a higher grain yield compared to liquid organic fertilizer alone, as well as the combination of liquid fertilizer and half the recommended amount of mineral fertilizer. The yield in T1 was higher than that of the absolute control. This demonstrates the effectiveness of liquid organic fertilizer in improving crop yield. This result is consistent with that of Supriyono et al. (2022), who showed that liquid organic fertilizer applied alone at increasing rates improves growth and yield compared to an absolute control.

4 CONCLUSION

From the various results obtained at the conclusion of the study, it is clear, first of all, that the liquid organic fertilizer applied alone has a high content of carbon, total nitrogen, total phosphorus, total potassium and CEC compared to the control. It therefore helps improve soil chemical properties. Furthermore, the two treatments T3 and T4 which combined liquid organic fertilizer with mineral fertilizer had no effect on the diameter and height of the corn plants compared to the control and the single-input treatments (T1 and T2). Finally, the liquid organic fertilizer had a positive effect on grain yield compared to the control and the T3 treatment. However, the yield was low compared to T2 and T4.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

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Disclosure of conflict of interest

The authors declare that there are no conflicts of interest.

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