Original Research Article

Effects of liquid organic fertilizer on soil chemistry, components and yields of maize

ABSTRACT

AIMS *:* The aim of this study is to help increase crop yields and soil fertility.

Location and duration of studies: the study takes place in the western part of Burkina Faso. It is based on the use of a liquid organic fertilizer on corn producers' plots. These are soil fertility data and corn agronomic data over three successive campaigns (2021, 2022 and 2023).

Methodology *:* 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.

Results : *R*esults 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%.

Conclusion : 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.

Key words : Maize, liquid organic fertilizer, mineral fertilizer, yields, soil characteristics, Burkina Faso

1. NTRODUCTION

Burkina Faso, like other countries, is facing the challenges of increasing agricultural production to meet the needs of the rapidly growing population, while preserving the environment (Kouakou, 2004). In addition, population growth coupled with unpredictable weather patterns and intensive farming are leading to continued degradation of cultivable land, resulting in low crop yields, in particular, cereals including maize. However, cereals play a very important role both in terms of production areas and human consumption (Anihouvi et al., 2016). Among cereals, maize is an important food in people's diets through its calorie and protein inputs in Africa (Macauley and Tabo, 2015). In Burkina Faso, it is ranked after millet and sorghum in terms of production and consumption areas (INSD, 2018).

However, it is one of the most mineral intensive crops requiring the use of fertile soils and good soil fertility management systems (Maltas et al., 2012). As a result, soil fertility degradation and decline are major constraints on productivity (Bationo et al., 2004). Thus, to cope with the drop in yields and increase maize productivity, the researchers have developed several technology

packages such as improved varieties, crop rotation (Koulibaly et al., 2016), introduction of legumes into rotations (Bado et al., 2012), crop residue management (Koulibaly et al., 2010; Ouattara et al., 2011; Abdou et al., 2016; Koulibaly et al., 2016 017), the combined use of mineral fertilizers and organic manure (Koulibaly et al., 2015; Akanza et al., 2016) and erosion control (Zougmoré, 2003). Despite these different techniques, which have been more or less applied for economic and social reasons, the decline in soil fertility and maize productivity still persists. Therefore, it is necessary to look at the issue and find other alternatives to solve the problem. However, for better management and improved soil fertility in a sustainable way, the use of liquid organic fertilizers protecting the soil's biological life is an optimal option. Satisfactory results have already been proven through the work of Tshimbombo et al., 2018 and Kotaix et al., 2019 on soil chemical properties, components and crop yields. In Burkina Faso, results from Zoungrana (2021) showed that liquid fertilizer improves the yield of Brachiaria and Mucuna in forage crops.
However, the finding is that these liquid organic fertilizers are still little used by producers in terms of their availability, their cost and the accessibility of the components used in their manufacture. It is therefore important to offer other liquid organic fertilizers that are cheaper and easy to manufacture from more available materials.
The aim of the study was to provide liquid organic fertilizer that was easy to produce and at a lower cost, with the aim of helping to increase maize yields.

2. METHODOLOGY

2.1. Study Area

The trial was conducted at the training and research center of NAZI Boni University in Bobo-Dioulasso, Burkina Faso, with geographical coordinates of longitude 3° 60' 160" west and latitude 12° 38' 169" north. The following figure shows the geographical location of the study site.

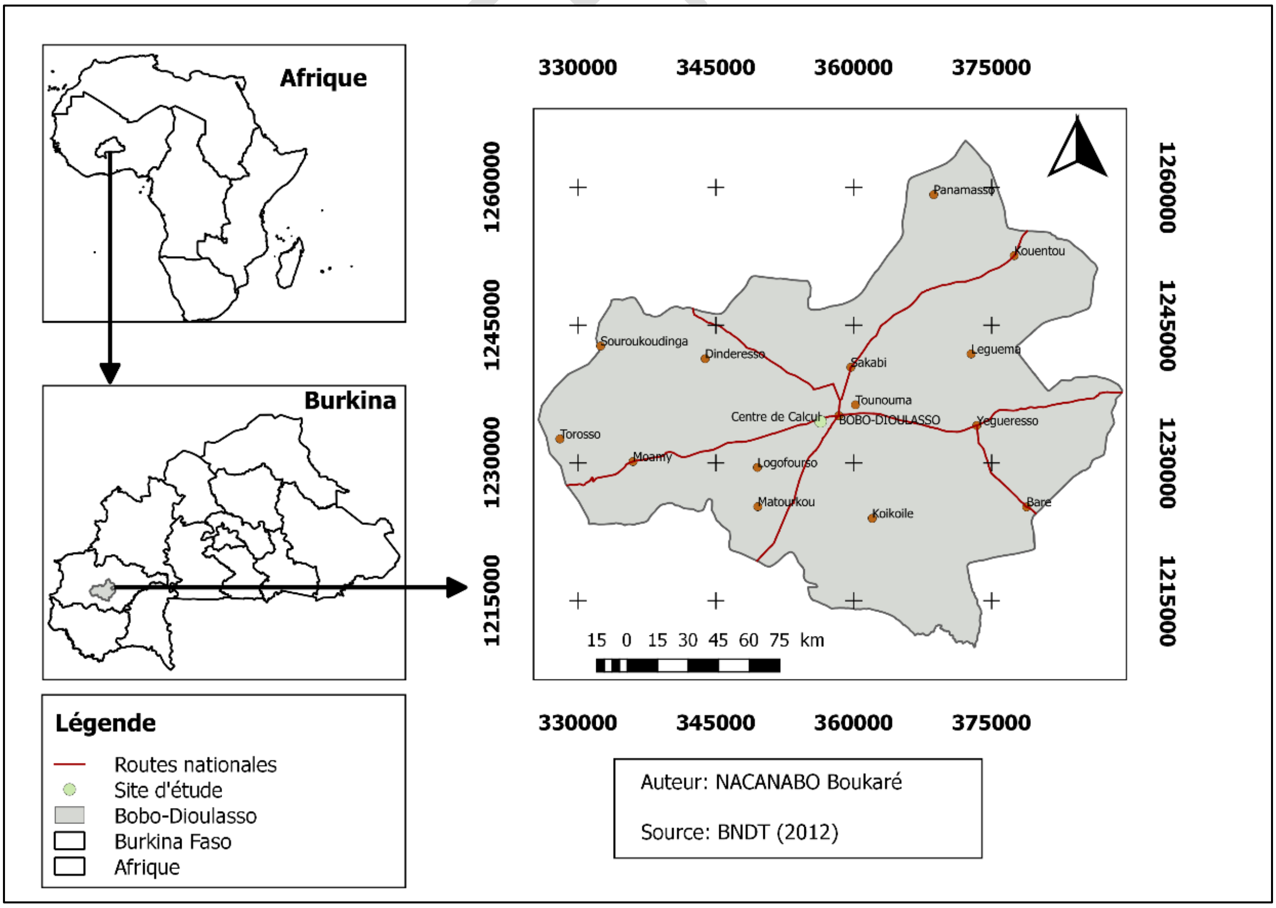

Figure 1: Study Site Location Map

2.2. Preparation of liquid fertilizer

The liquid organic fertilizer was prepared from cowpea flour, neem leaves and cow dung at a rate of 1 kg for each component. Then 1 liter of cow urine and 1/4 kg of brown sugar were added. Finally, the water is supplied in the proportions of volume which is 10 liters. The concentrated solution was stored in a drum for 10 days before being filtered. For the liquid fertilizer to be applied, we diluted 1 liter of the concentrated solution with 100 liters of water as recommended by the NGO Educational Hungers of Organization (ECHO).

2.3. Experimental device

The experimental device was a completely randomized block with 5 treatments with 3 repetitions or blocks. Each block contained 10 feet of corn.
The treatments were as follows:
T0: no fertilizer input
T1: input of liquid organic fertilizer
T2: provision of mineral fertilizer at the recommended dose
T3: Intake of liquid organic fertilizer + mineral fertilizer at recommended dose
T4: addition of liquid organic fertilizer + ½ mineral fertilizer at recommended dose.

2.4.Establishment and maintenance of the culture

A semi-manual was made at the rate of two grains per packet. A marriage was made at 10 DBS to leave 1 seedlings per stake. Maintenance of the crop consisted of mineral fertilizers and liquid organic fertilizer. NPK mineral fertilizers (15-15-15) and urea 46% were applied at doses of 200 and 150 kg/ha, respectively. As regards liquid fertilizer, it was applied at a dose of 0.35 l/pouch. Water was provided every other day and as needed.

2.5.Measured agronomic parameters

Observations were made on a sample of ten (10) plants randomly selected from each elementary plot while avoiding the border effects, and concerned the diameter of the stem at the collar and the height of the plants at the 30th, 45th, 60th and 75th DBS. The grain yield of the useful plot was obtained after drying in the sun to reach a moisture content of 14%. To do this, a sample was taken and tested using a humidimeter. The grains were then freed of all the impurities by valving and sorting. The yield was determined from the formula:

$$Grain\ yield = \frac{Grain\ weight(g) * 10000m^2}{Elemental\ parcel\ useful\ area * 1000g}$$

2.6.Methods of soil analysis

Soil samples were taken before, during and at harvest. They were dried, crushed and sieved using a sieve of 2 and 0.5 mm to be subjected to chemical analyzes in the Sol-Eau-Plante laboratory of the IN.E.R.A Farako-Bâ.
Soil analyzes were performed on the following parameters: pHeau, Organic Carbon, Total N, P and K, and Cation Exchange Capacity (CEC).
The pHeau measurement is made by the electronic method using a glass electrode pH meter in a suspension with water in a soil/solution ratio of 1/2.5 (1 g of soil per 2.5 ml of water) according to the AFNOR NF ISO 10-390 standard. The total organic carbon was determined by oxidation under hot conditions (135° C. for 1 h) in an acid medium with potassium dichromate according to standard NF ISO 14-235. The determination of N-total was carried out by mineralization and distillation through the Kjeldahl method according to the AFNOR ISO

11-261 standard. For P-total, soil samples were first mineralized hot with a H2SO4-SeH2O2 mixture. Subsequently, the P-total was determined in the mineralizates using an automatic colorimeter SKALAR (Segmented flow analyzer, model SAN plus 4000-02, Skalar Hollande). K-total was determined using a flame photometer (JENCONS. PFP 7, Jenway LTD, Felsted, England).

2.7.Data processing and analysis

The data collected was entered and processed with the Microsoft Excel 2013 spreadsheet. The statistical analyzes were carried out with the software R version 3.6.2. A normality test was carried out and, depending on the result, the variables were subjected either to a non-parametric test (Kruskal-Wallis test) or a parametric test (ANOVA test). The comparison of the means for ANOVA was made by the Tukey test. The significance level for all tests was 0.05.

3. RESULTS

3.1.Effects of different fertilizers on soil chemical parameters

Statistical analysis revealed a significant difference between treatments at all sampling periods except 30 DBS ($p=0.19$). High means were seen with T1 treatment at the first three sampling points of 30 DBS, 45 DBS and 60 DBS. The values of T1 at these periods are respectively 6.37; 6.76 and 6.73. For the period 75 DBS, the largest value (6.71) was observed with the T0 treatment. At harvest (80 DBS), treatments T0 and T1 have the same value which is 6.75. At harvest and whatever the treatment, the pH values are higher than the initial soil (Table 1).
Table II shows the effect of the different treatments on soil carbon. Statistical analyzes revealed a significant difference between treatments at all sampling dates except the flowering stage (60 days after sowing) where the probability is 0.145. T4 treatment at all time points except 60 DBS where statistical analysis did not reveal any significant difference. At harvest (80 DBS), all fertilizer treatments had higher carbon values compared to the T0 control.
The effect of fertilizers on total soil nitrogen is presented in Table III. Analysis of variance at the 5% cut-off revealed a significant difference between treatments regardless of sampling period. The high percentage means were recorded in the T4 treatment at all sampling periods with the respective values 0.149; 0.132; 0.122; 0.126 and 0.144 for 30, 45, 60, 75 and 80 DBS.
Table IV presents the results of the input of the various fertilizing products on the total phosphorus of the soil. Analyzes of variance at the 5% cut-off revealed a significant difference between treatments at all sampling periods except 60 DBS (Table IV). At 30, 45 and 75 DBS, mean values are higher with T3 treatment of 513; 487 and 410.33 mg/kg, respectively. At the 60 DBS period, the T2 treatment had the highest value (423.33 mg/kg). At harvest (80 DBS), the highest mean is noted with the T1 treatment (410.66 mg/kg). The mean total phosphorus content was higher in fertilizer treatments compared to control treatments regardless of sampling date.

Table V shows the effect of different fertilizers on total soil potassium. Statistical results show that there is a significant difference between treatments at 30 DBS with a probability ($p=0.026$) in contrast to other dates. On the other hand, variations are observed between treatments. At 30 days, the T3 treatment recorded the high mean with a value of 717.69 mg/kg. For 45 DBS, T0 is high at 652.44 mg/kg.
Statistical analyzes revealed a very significant difference at the 5% cut-off between treatments at all time periods (Table VI). In the samples taken at 45 and 75 DBS, the high means are recorded with T4 (10.04 and 59.58 cmol/kg). For 60 and 80 DBS, the highest values are found with T2 (10.92 and 10.23 cmol/kg). As for the 30 DBS date, it is T3 which records a high CEC with the value of 10.83 cmol/kg.On notes that the treatments which received fertilizers showed a greater cationic exchange capacity (CEC) than the control treatment.

Table I: Effect of treatments on soil pH-water

Treatments	pH-water				
	30 DBS	**45 DBS**	**60 DBS**	**75 DBS**	**80 DBS**
Starting 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 input; **T1**: liquid organic fertilizer input; **T2**: recommended dose of mineral fertilizer input; **T3**: liquid organic fertilizer input + recommended dose of mineral fertilizer; **T4**: recommended dose of liquid organic fertilizer + ½ recommended dose of mineral fertilizer.
*significant probability value. **highly significant probability value.

Table II: Effect of treatments on average soil organic carbon content

Treatments	Organic carbon (%)				
	30 DBS	**45 DBS**	**60 DBS**	**75 DBS**	**80 DBS**
Starting 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**

Table III: Effect of treatments on average total nitrogen content in soil

Treatments	Total nitrogen (%)				
	30 DBS	**45 DBS**	**60 DBS**	**75 DBS**	**80 DBS**
Starting 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***

Table IV: Effect of treatments on average total phosphorus content in soil

Treatments	**Total phosphorus (mg/kg)**				
	30 DBS	**45 DBS**	**60 DBS**	**75 DBS**	**80 DBS**
Starting 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*

Table V: Effect of treatments on average total potassium content in soil

Treatments	**Total potassium (mg/kg)**				
	30 DBS	**45 DBS**	**60 DBS**	**75 DBS**	**80 DBS**
Starting soil	636.13±48.93abc	636.13±48.93	636.13 48.93a	636.13 48.93	636.13 48.93
T0	635.43±1.21bc	652.44±28.25	538.26±48.93	489.33±48.93	538.27±0.00
T1	603.51±28.24c	554.58±28.24	505.64±28.25	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±28.25	603.51±56.49	652.44±74.74
T4	717.69±28.24ab	619.82±56.50	554.58±28.24	554.57±56.50	554.57±56.50
Probability	0.026*	0.199	0.055	0.084	0.056

Table VI: Effect of treatments on soil cation exchange capacity

Treatments	**CEC (cmol/kg)**				
	30 DBS	**45 DBS**	**60 DBS**	**75 DBS**	**80 DBS**

Starting 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**

3.2.Effects of Treatments on Maize Diameter and Height

Figures 2 and 3 show the effect of the different treatments on the diameter and height of the plants at different stages of measurement, respectively. The different treatments do not show significant differences at the threshold of 5% whatever the measurement date (FIG. 2). In stage 6 to 7 sheets (30 DBS), the high average diameter was observed in T1 with a value of 14.54 mm. For stages 8 to 10 leaves, flowering and maturity, the T2 treatment has the highest average diameters which are respectively 16.02, 16.85 mm and 16.35 mm.
The mean heights measured within the treatments at different stages are given in FIG. 3. Statistical analysis does not reveal any significant difference between treatments at any stage of measurement. However, slight variations in height were noted between treatments for all stages.

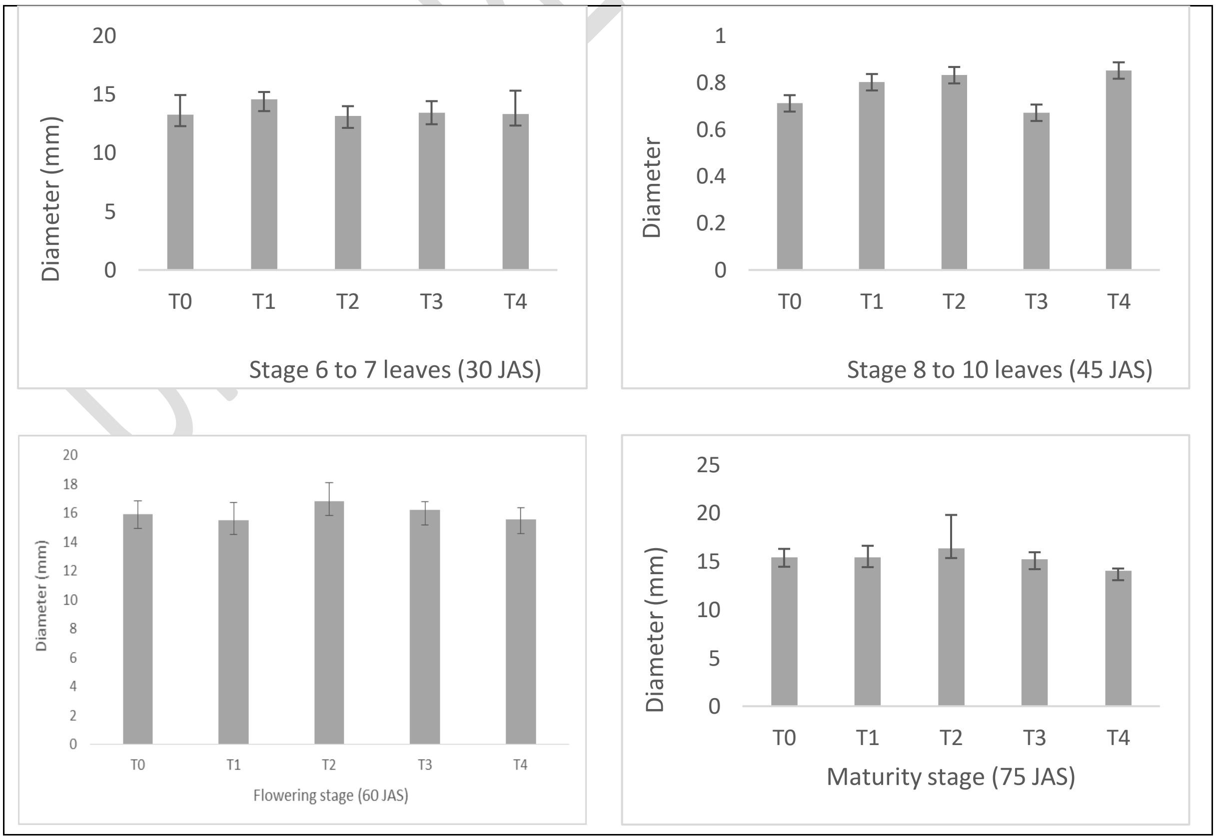

Figure 2: Effect of treatments on rod diameter

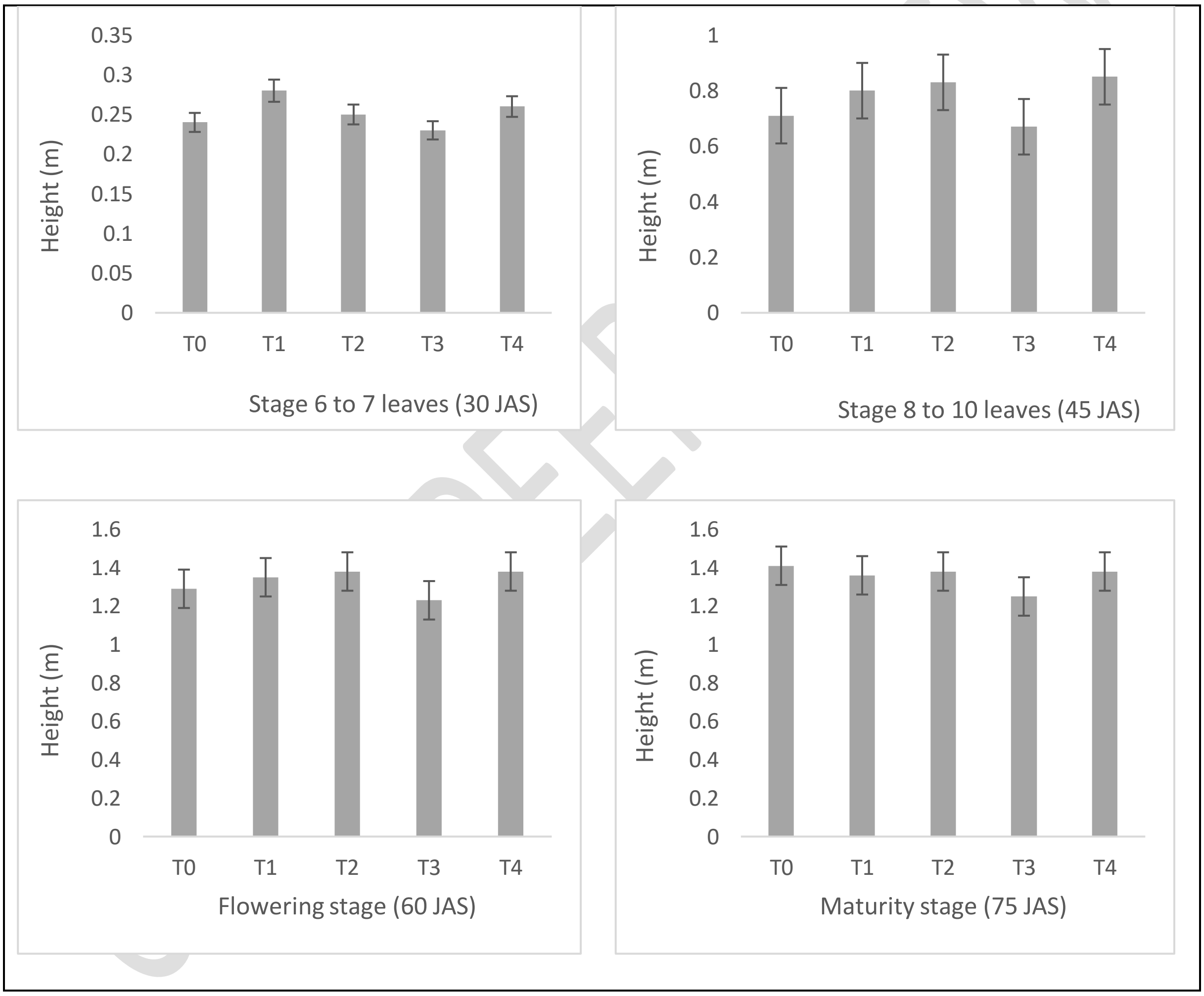

Figure 3: Mean height of the stem depending on treatments

3.3.Effects of treatments on maize grain yield

The effect of the treatments on maize grain yield is shown in Figure 4. Statistical analysis revealed a significant difference between treatments at the 5% threshold for grain yield p(0.049). The best grain yield was obtained with treatment T4 (1983.23 kg/ha) followed by treatments T2 (1834.9 kg/ha), T1 (1723.43 kg/ha) and T3 (1557.12 kg/ha). The lowest yield was attributed to the control treatment (1024.03 kg/ha).

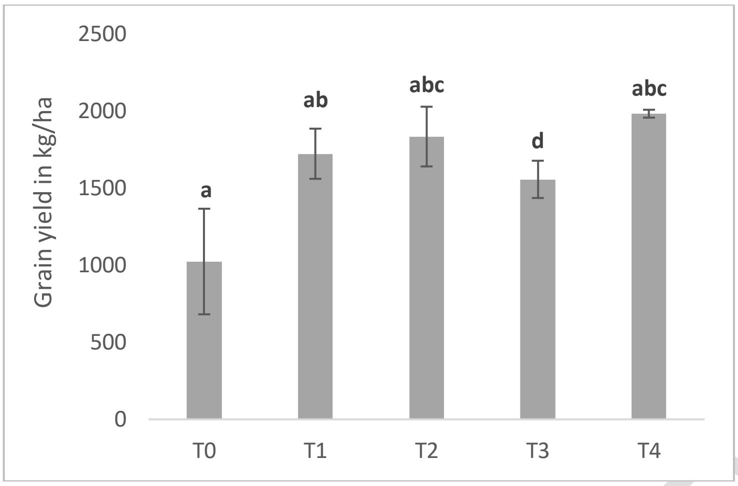

Figure 4: Effect of different treatments on grain yield

4. DISCUSSION

4.1.Effects of different treatments on soil chemical parameters

Soil analysis included pHeau, organic carbon, total nitrogen, total phosphorus, total potassium and CEC.

The treatment effect was significant on soil water pH at all sampling times, except 30 DBS. At the level of the first three dates and at the harvest (80 DBS), the T1 treatment which received only the liquid organic fertilizer exhibited the high averages. This can be explained on the one hand by the pH value (6,98) of the applied liquid fertilizer which tends to be neutral. Moreover, chemical fertilizers contribute to soil acidification, which renders mineral elements inaccessible to plants. The decrease in pH in treatments that received chemical fertilizers indicates an acidifying effect of these fertilizers on the soil in Po and Tiébélé in Burkina Faso (Nignan, 2017). The same observation was made by Uyo and Elemo (2000) on the soils of Nigeria. At 75 DBS, the control (T0) records the high value). This is certainly due to interactions between plants and soil that create imbalances in its chemical parameters.

Statistical analyzes revealed a significant difference between treatments at all sampling dates except flowering stage (60 DBS) on organic carbon. The T4 treatment benefiting from liquid fertilizer plus half of the recommended dose of mineral manure achieved the high carbon contents. This is justified by the combined effect of fertilizers. The small amount of chemical fertilizer probably did not have a negative effect on soil biology, all of which resulted in normal mineralization of organic matter by releasing carbon. The application of liquid fertilizer plus half of the mineral manure had a positive effect on the improvement of carbon during and at the end of the season, thus showing a significant difference between treatments. On the other hand, at 60 DBS, the control (without fertilizer input) obtained the highest average. This result could be explained by the richness of the initial soil in carbon and also the introduction of a crop can lead to an improvement in the soil's chemical characteristics through the release of carbon-rich root exudates.

For total nitrogen, the results of the statistical analysis showed a significant difference between treatments at all sampling periods. T4 treatment yielded the highest nitrogen levels at all time points. The likely explanation for these results would be low doses of NPK and Urea, which did not significantly affect pH. However, pH is a determining factor in the availability of nutrients. We can also think of the combination of the two fertilizers. A small amount of mineral fertilizer will quickly solubilize with liquid fertilizer and immediately pass into the soil solution.

This reflects the effectiveness of the combination of liquid organic fertilizer and half of the mineral fertilizer at the recommended dose.
Examination of the results obtained with total phosphorus revealed a significant difference between treatments at all periods except 60 DBS. Indeed, in the first two samples (30 DBS, 45 DBS) and in the penultimate sample (75 DBS), the high total phosphorus contents were observed with T3. This result is related to the high content of major elements in mineral fertilizers and also the combination (liquid fertilizer and recommended dose of mineral fertilizers) which is expected to provide more. Segda et al. (2013) showed in Bagré that mineral fertilization (in NPK) increases phosphorus content. At the 60 DBS period, the T2 treatment exhibits the highest value which is probably due to its low pH (6.31) compared with the other treatments. This has certainly reduced the export of phosphorus from plants. At that time, however, the crop was at the flowering stage where the need for water and mineral elements is high. As for the harvest (80 DBS), the high average is observed with T1. This is justified by the frequency of liquid fertilizer input which has led to phosphorus accumulation in the soil. Moreover, plants do not need enough minerals at maturity to function. The T1 performance observed at harvest confirms that liquid fertilizer improves the phosphorus level in soil.
In our total potassium study, we found that the statistical results do not show any significant difference between treatments at all sampling periods except 30 DBS. Indeed, at 60 DBS and 75 DBS, the high averages are obtained with the initial soil. This could be linked to soil fertility, because it's a forest soil with a high soil organic matter content. The decrease in the potassium content at the level of the treatments is obviously linked to the sampling by the plants with regard to its role in the growth and development of the culture. As a reminder, potassium improves the plant's water regime and increases its tolerance to drought, frost and salinity (FAO, 2003). It increases the response of the plant to phosphorus and reduces its lignification, thus increasing the risks of pouring (Lanyon and Smith, 1985). On the other hand, at 30 DBS and at harvest (80 DBS), the T3 treatment records the high potassium values. This is probably justified by the effect of the input of the mineral fertilizer which took place five days before the sampling. As regards 45 DBS, T0 shows the high total potassium content. This is certainly related to its pH (6.60) which is higher than the others and conducive to microbial life ensuring the decomposition of organic matter followed by the release of nutrients into the soil.
For the CEC, statistical analyzes revealed a very significant difference at the 5% cut-off between treatments at all periods. Indeed, all the treatments improved the CEC of the soil compared with the control. In the samples taken at 45 DBS and 75 DBS, the high averages are recorded with T4. These results could be explained by the high level of soil organic matter in this treatment. At these different periods, 45 and 75 DBS, the value of the CEC is 2.35 and 2.24 respectively. They are high compared to other treatments. However, organic matter influences the ability to exchange through charge fixation. This is consistent with Lompo (2005), which showed that organic matter increases the capacity for cation exchange. As regards 60 DBS and the harvest, the highest values are observed with T2. This could be related to the effect of the mineral fertilizer in terms of its mineral input.

4.2.Effects of treatments on maize diameter and height

For the diameter, the results of our different treatments do not show significant differences at the threshold of 5% at all the periods of measurements. However, there is a slight variation between treatments from one period to the next. In stage 6 to 7 sheets (30 DBS), the high average diameter was observed in T1 with a value of 14.54 mm. This may be justified by the fact that the nutrients contained in the liquid fertilizer are immediately available for the plants. Yahaya (2009) showed that in urine (components of liquid organic fertilizer) nutrients exist in ionic form and are readily absorbed by plants. As for stages 8 to 10 leaves, flowering and maturity, the T2 treatment exhibits the highest average diameters which are respectively 16.02, 16.85 mm and 16.35 mm. This would be justified by the high input of nutrients contained in chemical fertilizers.
Regarding height, statistical analysis shows that treatments did not affect the mean height of plants at all stages of measurement. However, there were varying degrees of variation

between treatments at each stage. This is the case for stage 6 to 7 leaves (30 DBS) where the highest value is observed with the T1 treatment with an average of 0.28 m. This could be explained by the efficiency of the liquid fertilizer in terms of its nutrient content and its pH favorable to the mobility of mineral elements. There is also its soluble state which facilitates the removal of mineral elements compared to those granules which will undergo a mineralization phase in order to enter the solution of the soil to be assimilated by the plants. As a result, plants are able to draw nutrients in time and this has an immediate impact on their growth and development. This is consistent with Zoungrana (2021), which showed that when liquid organic fertilizer is added on the same day as the mineral, the effect of liquid organic fertilizer will be more immediately noticeable on maize plants compared to mineral fertilizer. As for stage 8 to 10 sheets (45 DBS), the T4 treatment exhibits the most important value which is 0.85 m. This result can be justified by two hypotheses, namely, on the one hand, the low dose of mineral fertilizer which did not have a negative effect on the soil pH. Anything that hasn't blocked the availability of mineral elements to plants, so that they can grow rapidly compared to other treatments. Another hypothesis is that there has been a better interaction between liquid and low-dose mineral fertilizers that produce good plant growth. This finding is inconsistent with the Tshimbombo et al., (2018) study conducted in Congo, which found that liquid organic fertilizer (D.I.GROW) has a better influence on corn height compared to liquid fertilizer combined at half the recommended dose of mineral fertilizers. This difference is explained by the fact that this fertilizer contains all the ionic elements. It also has plant growth hormones. The flowering stage and maturity, the T2 and T4 treatment have the same average height with a value of 1.38 m. This is probably due to the richness of the soils in certain parameters in these treatments of total nitrogen. The specific case of T2 may be due to the dose of mineral fertilizers. Siri (2015) had demonstrated that there is a strong correlation between the growth rates of mineral fertilizers and yield.

4.3.Effects of treatments on maize yield

ANOVA found a significant difference ($p = 0.049$) between the different grain yield treatments. The T4 treatment gave the best grain yield. This could be justified by the availability and quantity of major element, in particular potassium, present in the soil. Potassium, however, is involved in the increase in grain size and weight. This is at odds with that of Tshimbombo et al. (2018), which showed that the input of mineral fertilizers only yields better grain yield compared to liquid organic fertilizer alone, as well as the combination of liquid fertilizer plus half of the recommended mineral fertilizers.
The yield of T1 is greater than that of the absolute control. This reflects the effectiveness of liquid organic fertilizer in improving crop yields. This is consistent with Supriyono et al. (2022), which showed that liquid organic fertilizer applied alone and in increasing doses improves growth and yield compared to an absolute control.

5. CONCLUSION AND APPLICATION OF RESULTS

From the various results obtained at the end of the study, it is firstly apparent that the liquid organic fertilizer applied alone has a high content of carbon, total nitrogen, total phosphorus, total potassium and CEC compared with the control. It therefore favors an improvement in the chemical parameters of the soil. Next, the two treatments T3 and T4, combining liquid organic fertilizer mineral fumure, had no effect on the diameter and height of the maize plants compared with the control and the single intakes (T1 and T2). Finally, liquid organic fertilizer had a positive effect on grain yield compared to the control and T3 treatment. On the other hand, the yield was low compared with T2 and T4.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

The authors hereby declare that NO generative AI technologies such as large language models (ChatGPT, COPILOT, etc.) and text-image generators were used during writing or edition of this manuscript.

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