Original Research Article

Effects of compost biomass using Mango (*Mangifera indica)* combined with popularized mineral manure on soil Chemical parameters and maize (*Zea mays* l.) yield in western Burkina Faso

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

ABSTRACT

Aims : To evaluate the effects of mango leaf compost and mineral manure on soil chemistry and maize yields.

Study Design: This study was conducted to assess the potential of compost derived from *Mangifera indica* biomass, combined with mineral manure, to enhance soil chemical properties and maize productivityin western Burkina Faso.

Place and Duration of Study: The study was conducted in Burkina Faso, over theInstitute of Environment and Agricultural Research, Farako-Bâ stationover twelve months.

Methodology:A Fisher block design was used, comprising four (4) replicates with five (5) treatments each. A single factor was studied, focusing onorgano-mineral fertilization at five (5) levels. T1: NPK (200 kg/ha) + Urea (150 kg/ha): GMF; T2: Compost (2.5 t/ha) + GMF; T3: Compost (5 t/ha) + GMF; T4: Compost (7.5 t/ha) + GMF and T5: Compost (10 t/ha) + GMF. Soil chemical and agronomic parameters of the maize were observed during the study.

Results: The results showed that the different treatments did not totally positively influence soil chemical parameters and maize plant growth. However, the best results in terms of soil chemical parameters were obtained for available assimilable phosphorus and potassium before planting, with respective averages of (6.65 mg/kg and 72.14 mg/kg) and after planting by T2 (5.66 mg/kg) and T5 (58.13 mg/kg) respectively. CEC was high in treatment T3 with 3.86 Cmolc.kg-1 and saturation rate (V) was high in treatment T5 with 3.86 Cmolc.kg-1 And the saturation rate (V) was high in the T5 treatment at 59.76%. Plant growth was high, with the height at 45 days after planting by T5 (91.14 cm) The manures applied had a significant impact on maize yields. The highest biomass and grain yields came from the T5 treatment (10 t/ha compost + GMF), with 5.8 t/ha and 3.7 t/ha respectively.

Conclusion: This study suggests that applying10 t/ha of compost + GMF to improve maize productivity in the western zone of Burkina Faso.It would be interesting to continue the study

in other agro-ecological zones of Burkina Faso in order to assess the impact of these fertilizers on the biological properties of the soil.

Keywords:*Mangifera indica* biomass, fertilizer, compost, soil, yield.

1. INTRODUCTION

In Burkina Faso, the agricultural sector remains one of the levers of the Burkinabe economy. It is essential forfood and nutrition security and contributes to more than 60% of the income of agricultural households[1].Maize is the most widely grown major food crop in sub-Saharan Africa [2]. Occupyingmore than 33 million hectares annually[2].In Burkina Faso, even though maize is grown in all regions of the country, its production varies from one region to another [3].In terms of production, maize ranks second,with an estimated production quantity of 143,085 tons and constitutes 20.6% of the land cultivated under cereals with a yield of 1920 kg/ha in 2015 [4].Indeed, high-yielding varieties reaching 5-6 tons/ha have been developed by research.Indeed, high-yielding varieties reaching 5-6 tons/ha have been developed by research. Despite this high yield potential, maize cultivation faces low productivity, due to physical and socio-economic problems that hinder production.One of these major problems is undoubtedly soil degradation, which has a direct impact on productivity.The nature of the soil and climatic condition (aggressive rainfall, severe winds and high temperatures) which are the causes of soil degradation. Faced with this major constraint, maize crop with high nutritional needs would require additional organic manure mineral to fertilizer and improve, thus increase soil productivity.However, it can be noted that for several reasons, this technology is insufficiently applied by producers.The adoption rate varies from one agricultural locality to another depending on the degree of supervision of producers, which is itself linked to the practice of cash crops, particularly cotton cultivation on farms [5].The general objective is to support soil fertility and maize productivity using compost derived from*Mangifera indica* biomass.

2. MATERIAL ET METHODS

2.1. Study site description

Our study was conducted at the Institute of Environment and Agricultural Research ofFarako-Bâ agricultural research station, located along the Bobo-Banfora axis. According to [6] the geographical coordinates are 11°06' north latitude and 4°20' west longitude.With an altitude of 405 meters above sea level.The vegetation at Farako-Bâis characterized by a grassy to wooded savannah that is relativelydense in places [7].The soils of Farako-Bâ are mostly of the tropical ferruginous type [8]. The climate of the area isclassified as South Sudanian.In the last ten (10) years, 2018 was the rainiest year with 1303.8 mm in 70.

2.2. Material

The plant species used in the experiment was maize (Zea mays L.), specifically the Komsaya variety. This is a hybrid variety selected by Institute of Environment and Agricultural Researchwith a sowing-to-maturity cycle of 97 days and a potential yield of between 8 and 9.5 tonnes per hectare. The fertilizing material consisted of two types of manure (organic and mineral). These fertilizers used were one compost based on Mangifera indica biomass and the other with NPK-SB mineral fertilizer (14-18-18-6-1) and Urea (46%N).

2.3.Methods

ExperimentalDesign

The factor studied was fertilization, taken at 5 levels of variation. These levels constitutedthe treatments (Table 1). The experimental set-up is a Fisher block comprising five (05) treatments with four (04) repetitions. Each treatment represented one elementary plot (EP), a total of 20. The dimensions of the entire system are 44 m x 19 m, i.e. a total area of 836 m^2 and those of the elementary plots is 8 m x 4 m, i.e. 32 m2 each. The elementary plots and the blocks were spaced 1 m apart.

Table 1 : Treatments

Treatments	**Significations**	**Code**	**Quantity per plot**
Treatment 1	200 kg.ha^{-1} NPK + 150 kg.ha^{-1} Urea (**MF** : Minéral Fertiliser)	T1 :	640 g + 480 g
Treatment 2	2,5 t.ha^{-1}of compost + MF	T2 :	8 kg +640 g+480g
Treatment 3	5 t.ha^{-1}of compost + MF	T3 :	16 kg+640g+480 g
Treatment 4	7,5 t.ha^{-1}of compost + MF	T4 :	24kg +640g+480g
Treatment 5	10 t.ha^{-1}of compost + MF	T5 :	32 kg+640g+480g

Data collection

Plant height and corn yields

Plant height was randomly measure with a meter ruler from the base to the tip, each 15days after planting for three consecutive times from twelve (12) elementary plots. The days were 15th, 30th and 45th after sowing. The number of grains per ear, the weight of 1000 grains, biomass yield and the grain yield were determined by placing yield squares over 4 m^2 in each elementary plot. Biomass and grain yields were extrapolated to the hectare.

Determination of soil chemical parameters

Soil sampling

Soil soilsamples were collected before and after cultivation at a depth of 0-20 cm.Before crop establishment, a compositesoil sample was taken from the entire trial plot following the three-point diagonal pattern after cultivation, soil samples were taken from each elementary plot. Resulting in a totalof 21 composite samples were collected for laboratory analysis.

Chemical soil analysis

Soil analyses were carried out at the Soil-Water-Plant Laboratory of INERA Farako-Bâ. SoilpH was measured in a watersuspension using aglass electrode pH meter electrometric method [9]. Organic Carbon (C) was determined according tothe method by[10]. Total nitrogen (N) was measured by theKjeldalh method was used to determine the total nitrogen and the C/N ratio was determined from the results of the total carbon and total nitrogen analyses. Assimilable phosphorus (P)was determined according to the Bray I method [11]. Available potassium (K)was extracted with a solutionof oxalic acid ($H2C_2O_4$) and concentrated hydrochloric acid (HCl) solution. The solution is completed to 1 litre in a volumetric flask. The assay is carried out by a flame photometer (JENWAY, PFP7 Flame Photometer). Sum of exchangeable bases (S): this is the amount of useful ions (Ca^{++}, Mg^{++}, K^+, Na^+) in the soil. The values of the exchangeable bases were obtained through displacement by a thiourea silver solution $Ag(H_2CSNH)_2$ at 0.01 M and determined by spectrophotometry. Cation exchange capacity (CEC or T): It was made from the solution for extracting exchangeable bases. Saturation rate (V): it is the ratio of the sum of the exchangeable bases to the cation exchange capacity and corresponds to the percentage of the electronegative sites of the cation exchange capacity occupied by the exchangeable bases.

Statistical analysis of the data

Data wererecorded inMicrosoft Excel 2016andsubjected to an analysis of variance (ANOVA) using the GenStat edition 12.1, 2009 version. Comparison and separation of means were performed with the Student Newman-Keuls test (SNK) at the 5% significance level.

3. RESULTS AND DISCUSSION

3.1. RESULTS

Effects of fertilisers on soil chemistry.

The effects of treatments on pH, organic carbon, nitrogen, C/N ratio, assimilable phosphorus, and available potassium before and after cultivation are presented

The chemical characteristics of the soils collected before and after cultivation are presented according to the treatments in (Table 2).Generally, the statistical analysis showedno significant variation between pre- and post-cultivation treatments for water pH, total organic Carbon, total nitrogen and C/N ratios. On the other hand, there are significant variations in the assimilable Phosphorus and Potassium available. The pH of the soils taken before cultivation and after cultivation show that the soils of the site are acidic with a pH between (5.04-5.30). Organic carbon and nitrogen levels in soils taken before and after cultivation remain low overall, regardless of the treatment. The C/N ratios of soils before and after cultivation are between 9.75 and 10.52. The available Phosphorus and Potassium contents of soils sampled before cultivation are 6.65 mg/kg and 72.14 mg/kg higher respectively than post-cultivation levels. In addition, the assimilable Phosphorus content of the T2 treatment (2.5 t/ha Compost + FV) increased by 7% compared to that of the T1 control (200 kg/ha NPK + 150 kg/ha Urea). On the other hand, in soils from the T4 (7.5 t/ha Compost + FV) and T5 (10 t/ha Compost + FV) treatments, the assimilable Phosphorus contents decreased by 20% compared to the control (T1). As for the available potassium, a 5% increase was achieved in the soils of the T5 and T3 treatments compared to the control soil (T1). The lowest available Potassium content was noted with the control treatment (T1). For the other parameters (pH, total organic Carbon, total nitrogen and C/N ratio), compost treatments do not differ statistically from MF.

Table 2. Soil chemical characteristics (pH, C, N, C/N, P, K) as a function of treatments.

Traitements	**pH**	**C (%)**	**N-total (%)**	**C/N**	**Phosphorus (mg/kg)**	**Potassium (mg/kg)**
Before cultivation	5.04±0.17	0.32±0.02	0.03±0.02	9.75±5.23	6.65a±0.44	72.14a±4.79
T1	5.25±0.13	0.39±0.06	0.04±0.01	9.92±0.24	4.95b±0.52	52.19b±3.87
T2	5.30±0.12	0.47±0.08	0.05±0.01	9.86±0.30	5.66ab±0.99	54.19b±7.62
T3	5.20±0.22	0.46±0.07	0.04±0.01	10.52±0.36	4.06b±0.91	57.99b±9.39
T4	5.26±0.13	0.42±0.05	0.04±0.01	10.47±0.35	3.28c±0.49	54.19b±7.42
T5	5.30±0.23	0.40±0.05	0.04±0.00	10.39±0.59	3.28c±0.64	58.13b±6.34
Pr >F	***0.137***	***0.526***	***0.441***	***0.132***	***0.027***	***0.046***
Signification	***NS***	***NS***	***NS***	***NS***	***S***	***S***

Legend: *NS: non-significant, s: significant. The values assigned by the same letter(s) in the same column are not statistically different at the 5% significance level according to the Student-Newman-Keuls test.*

Effects of treatments on exchangeable bases, sum of exchangeable bases, cation exchange capacity, and saturation rate before and after soil sampling.

The results of the exchangeable bases, the sum of the exchangeable bases, cation exchange capacity and the saturation rate are presented in (Table 3). Analysis of variance showed no significant differences between pre- and post-cropping soils in terms of exchangeable bases and sum of exchangeable bases. On the other hand, there are significant variations between the soils of the plots before and after cultivation, with regard to the CEC and the saturation rate (V). Thus, the CEC and saturation rate contents of the plots before cultivation are lower than those of the soils from the plots after cultivation. The CEC rates of soils from the T3 (5 t/ha Compost + MF) and T2 (2.5 t/ha Compost + MF) treatments increased by 18% and 4% respectively compared to those from the T1 control soil (200 kg/ha NPK + 150 kg/ha Urea). The saturation rate from the soil of the T5 treatment (10 t/ha Compost + MF) increased by 16% and that from the soil of the T4 treatment (7.5 t/ha Compost + MF)it increased by 6%. In contrast, a 2% decrease in saturation rate was observed in the T2 treatment soil compared to the T1 control soil.

Table 3. The exchangeable bases, the sum of the exchangeable bases, the cation exchange capacity and the saturation rate according to the treatments.

Treatments	**Ca^{2+} (cmol$_c$ kg^{-1})**	**Mg^{2+} (cmol$_c$ kg^{-1})**	**Na^{+} (cmol$_c$ kg^{-1})**	**S (cmol$_c$ kg^{-1})**	**CEC (cmol$_c$ kg^{-1})**	**V (%)**
Beforecultivation	0.78±0.13	0.30±0.10	0.05±0.02	1.25±0.16	2.11b±0.46	45.50b±7.75
T1	0.67±0.11	0.33±0.07	0.02±0.01	1.14±0.15	2.69b±0.84	42.95b±6.80
T2	0.67±0.30	0.29±0.04	0.06±0.02	1.15±0.25	2.89b±0.47	40.92b±8.12
T3	0.77±0.21	0.39±0.07	0.05±0.01	1.34±0.23	3.86a±0.15	43.06b±9.07
T4	0.67±0.35	0.39±0.09	0.05±0.02	1.22±0.11	2.51b±0.20	48.12b±7.28
T5	0.73±0.52	0.41±0.08	0.05±0.01	1.33±0.14	2.43b±0.47	59.76a±8.12
Pr >F	***0.989***	***0.901***	***0.478***	***0.989***	***0.047***	***0.048***
Signification	***NS***	***NS***	***NS***	***NS***	***S***	***S***

Legend: *NS: non-significant, s: significant. The values assigned by the same letter(s) in the same column are not statistically different at the 5% significance level according to the Student-Newman-Keuls test. T1: 200 kg/ha of NPK + 150 kg/ha of Urea; T2: 2.5 t/ha of Compost + MF; T3: 5 t/ha of Compost + MF; T4: 7.5 t/ha of Compost + MF; T5: 10 t/ha of Compost + MF.*

Effect of treatments on the height of maize plants at the 15th, 30th and 45th DAS.

The changes of the average height of maize plants according tothe treatments at the 15th, 30th and 45th DAS is visible through the (Figure 1). Statistical analysis of variance revealed no significant variation between treatments in general at the 15th and 30th DAS. In contrast to the 45th DAS, there was a significant variation. Thus, the highest average heights were found in the T5 and T2 treatments with values of 91.14 cm and 83.95 cm compared to the control treatment which recorded the lowest average height with a value of 75.48 cm.

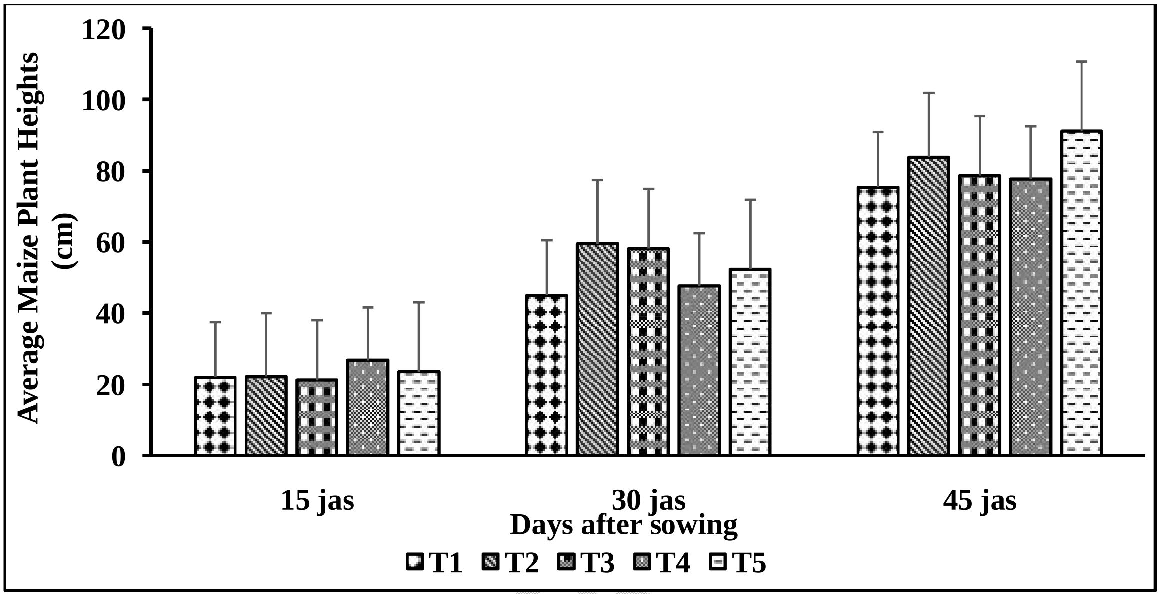

Figure 1: Average height of maize plants as a function of treatments at the 15th, 30th and 45th DAS.

3.2. Effect of treatments on the number of kernels per ear and on the weight of 1000 kernels

The number of grains per ear and the weight of 1000 grains were determined as shown in Table 4.Statistical analysis of variance revealed a significant variation between the different treatments in general for the number of grains per ear as well as for the weight of 1000 grains.

The highestnumber of grains per ear were obtained in the T5 treatment (10 t/ha of Compost + FV) with 438 grains/ear compared to the T1 control (200 kg/ha of NPK + 150 kg/ha of Urea) with 328.8 grains/ear. The same observation was observed with the weight of 1000 grains. The highest weight of 1000 grains comes from the T5 treatment with 248 g. On the other hand, the lowest weight of 1000 grains comes from the T1 control treatment with 221.8 g.

Table 4. Average number of grains per ear and the average weight of 1000 grains depending on the treatments.

Treatments	**Number of grains/ear**	**1000 grains weight (g)**
T1	328.8b±127.04	221.8b±9.77
T2	436.5a±116.22	235.2ab±16.98
T3	389.5b±74.25	222.3b±20.02
T4	433.8a±114.58	232.3ab±22.74
T5	438.0a±98.74	248.0a±20.94
Probability	***0.042***	***0.049***
Signification	***S***	***S***

Legend: Means followed by the same letter in the same column are not significantly different at P = 0.05. S: Meaning.

3.3. Effect of treatments on biomass and grain yields

Average biomass and grain yield values were assessed as shown in Table5. Analysis of variance showed a significant variation between treatments for both biomass and grain yield. The highest biomass and grain yields come from the T5 treatment with 5812 kg/ha and 3706 kg/ha respectively. The lowest biomass yield comes from the T1 control treatment with an average of 3031 kg/ha. As well as the lowest grain yield (2804 kg/ha).

Table 5: Average biomass and grain yield as a function of treatments.

Treatments	**Biomass yield (kg/ha)**	**Grain yield(Kg.ha^{-1})**
T1	3031c±108.53	2804b±160.05
T2	4906ab±195.49	2926b±197.98
T3	3875b±105.19	2838b±57.108
T4	4969ab±194.35	2950b±127,92
T5	5812a±153.59	3706a±267,32
Probability	***0.039***	***0.033***
Signification	***S***	***S***

Legend: Means followed by the same letter in the same column are not significantly different at P = 0.05. S: Meaning.

3.2. DISCUSSION

Effects of fertilisers on soil chemistry.

Effects of treatments on pH, organic C, nitrogen, C/N ratios, assimilable P and available K before and after culture.

No significant changes were reported in water pH, organic carbon, total nitrogen and C/N ratios. Analysis of the soils sampled before and after cultivation showed that the pH of our site is acidic (5.04 ≤ pH≤ 5.30).This acidity is due to the nature of the soil but also to the accumulation of certain chemicals (pesticides, inorganic fertilizers) used over several years in the soil of the site. The work of [12] showed that the use of inorganic fertilizers and pesticides causes a decrease in soil pH.The low level of organic carbon and nitrogen could be explained by the decrease in the accumulation of organic matter but also by tillage which leads to a loss of nitrogen through mineralization, leaching and water erosion [13].The soil's C/N ratio, ranging from 9.75 to 10.52, is low and reflects strongmineralization of the organic matter in the soil according to BUNASOLS standards. For [14], a C/N ratio between 8 and 12 is an optimal ratio and a sign of good microbial activity and a good balance between humification and mineralization.The high levels of Pass and K available in the soil before cultivation compared to those in the soils after cultivation and the 20% decrease in the available phosphorus in the T4 and T5 treatments, would be due to the fact that the maize plants were able to take up a necessary quantity of these elements in the soil after cultivation and in these treatments.[15]also observed low levels of assimilable and total phosphorus in the soil under rhizospheric influence due to the uptake of bioavailable forms by the roots.This may also be linked to the fixation of phosphorus in the soil by other elements and to the low mineralisation due to a deficiency of organic matter and/or the unfavourable pH of the environment.Then, the 7% increase in assimilable P in T2 treatment and the 5% increase in K available in T5 and T3 treatments; would be explained by the combined action of organo-mineral fertilization in these treatments.Also, this could be linked to the role of organic amendments in improving the physicochemical properties of the soil through an increase in its exchange capacity [16]. The lowest available K content noted by the control treatment (T1) would be justified by the addition of exclusively mineral fertiliser.

Effects of treatments on exchangeable bases, sum of exchangeable bases, cation exchange capacity, and saturation rate before and after culture.

The results obtained after analysis show that the exchangeable bases and the sum of the exchangeable bases before and after cultivation are low overall. Also, these results show that the different fertilizers applied were not remarkable on these different parameters.This could be due to the non-restitution of organic waste to compensate for losses due to mineralization, resulting in a rapid decrease in soil organic matter and a decrease in exchangeable base contents, cation exchange capacity, acidification and an increase in exchangeable aluminum content [17].The high levels of CEC in the T3 (18%) and T2 (4%) treatments could be justified by the effect of compost associated or not with mineral fertilizers on the chemical parameters of organic matter, calcium and magnesium, similar to the previous results found by several authors [18]with different organic fertilizers.Indeed, with compost, the level of organic carbon, biological activity, soil moisture as well as nitrogen, phosphorus, potassium, magnesium and calcium in the soil increases [19].The saturation rate increased by 16% in the treatment that received 10 t/ha of Compost + FMV and by 6% in the treatment that received 7.5 t/ha of Compost + FMV and this increase in these treatments confirms the ability of the compost enriched with mango leaf to restore the fertility of the soils of the study through its nutrient richness.This would come from the activity of fungi trapped in this compost which is an activator of the microbial activity of the soil. These results are in agreement with those of the authors [20], who showed the ability of compost to restore the properties of acidic soils in the Democratic Republic of Congo (DRC).The low saturation rate recorded by the treatment that received 2.5 t/ha of Compost + FMV is linked to the low amount of calcium and magnesium in this treatment.

Effect of treatments on maize plant height.

This height performance of maize plants from the T3 (5$t.ha^{-1}$of compost + FMV) and T5 (10 $t.ha^{-1}$ of compost + FMV) treatments could be justified by the availability of mineral elements and the improvement of the physicochemical properties of the soil due to the combination of organic and mineral fertilisation.These results are consistent with those of [21] who showed that organic matter retains nutrients on the surface while mineral fertilizer alone accelerates their vertical migration.The poor height performance of maize plants from the T1 treatment (200 kg/ha NPK + 150 kg/ha of Urea) is justified by the exclusive contribution of mineral fertiliser to the soil.This situation could result in a lack of available resources, in particular mineral elements, which are the main factors limiting agricultural production in the dry tropics [22].

Effects of treatments on corn yield components

The analysis of results showed that the different fertilizers applied may have had a positive impact on the maize yield components. Indeed, these different components of maize yield have generally increased with the doses of 10 t/ha of compost + FMV.This result could be due to the effect of the dose of organic manure combined with mineral fertiliser, which was able to release a necessary amount of nutrient thus promoting good maize productivity.This is what is maintained ([23]and [24]) when they stipulate that nutrients (N P K) are very accessible to plants, thus ensuring a good diet for the plant and allowing the best yields to be obtained in most cases. They attribute this to a high demand for mineral elements (especially N and P).Our results are similar to those obtained by [25] and [26]who state that decomposed litter could be a nutrient source for maize plants.In addition, this increase in yield could be linked to the presence of less lignified material in this compost, which reflects the availability of free organic matter for corn plants [27].These results corroborate those obtained by [25] who found that potassium (K) stimulates the constitution of the nutrient reserve; Nitrogen is involved in the main yield determination processes, and phosphorus could accelerate seed planting and seed maturation.Our results are also in line with those of [28] who found that the best rice yields are obtained by organo-mineral fertilizations.However, the lowest yield components were reported by the treatment which received exclusively popularized mineral manure (200 kg/ha of NPK + 150 kg/ha of Urea). This would be justified by the low level of soil fertility in this treatment.

4. CONCLUSION

The objective of this study was to evaluate the effects of mango biomass compost combined with standard mineral fertilizer on soil chemical parameters and maize yields in western Burkina Faso.The aim is to contribute to the improvement of soil chemical properties and maize productivity. It appears that the fertilization applied did not have much effect on the chemical parameters of the soil and on the growth of the maize plants.Nevertheless, there was a significant improvement with the assimilable P, the available K, the CEC, the saturation rate and the height of the plants at the 45th JAS. Thus, the best results in terms of soil chemical parameters and plant growth were achieved with the T3 (5 t/ha compost + FMV) and T5 (10 t/ha compost + FMV) treatments.As for the yield components, our results showed that the different fertilizers applied were beneficial. Indeed, these different components have generally increased with the dose of 10 t/ha of compost + FMV (T5).However, the lowest yield components were reported by the treatment that received 200 kg/ha NPK + 150 kg/ha Urea (T1). We can therefore say that the combination of organo-mineral fertilisers makes it possible to increase the productivity of maize and to partly improve soil fertility.It would be interesting to continue the study in other agro-ecological zones of Burkina Faso in order to assess the impact of these fertilizers on the biological properties of the soil.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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