

Effect of Fertilizers on the Productivity of Maize (*Zea mays* L.) Cultivated in the Zinder Region (Niger Republic)

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Abstract

Maize constitutes one of the most important crops in Niger's fight for food security, and it is cultivated in all regions of the country. However, maize cultivation is declining due to low soil fertility. This study focused on evaluating the impact of fertilizers on maize plant production in Zinder. The fertilizer effect was evaluated based on 21 quantitative and 9 qualitative descriptors proposed by IBPGR and CIMMYT 1991. The experiment was conducted during the rainy season in the experimental domain of Université André Salifou following randomized complete block designs with three repetitions. Seven fertilizer treatments, including two organic, two mineral, two combinations of fertilizers, and a control treatment, were applied. The analysis shows that fertilizers had positive effects on the earliness and productivity of the selected variety. The best yield of dry corn cob (7480 kg/ha) was recorded on organic fertilizer of composted poultry manure, which is equal to 4.8 times that obtained with the control (1561 kg/ha), followed by the mineral fertilizer NPK combined with composted cow dung with 6395.231 kg/ha. Therefore, the use of fertilizers could be an appropriate alternative to overcome the negative consequences of yield declines in the corn production system in the Zinder region.

Keywords

Maze, Organic Fertilizer, Mineral Fertilizers, Productivity, Zinder

1. Introduction

Agriculture in the Sahel faces many problems, such as soil depletion, which leads to low crop productivity and remains the most alarming threat [1] [2]. Located in the heart of the Sahel, Niger has a relatively undiversified economy that is largely dependent on agriculture. Like in other Sahelian countries, land degradation in Niger results in a decrease in soil fertility and low agricultural production, although the fact that agriculture is the main economic activity in the country, employing nearly 80% of the rural population [3]. This drop in productivity concerns several crops, including maize (*Zea mays* L.)

Maize is a cereal plant of the Poaceae family, producing grains and haulms widely used in sub-Saharan Africa [4]. It is an annual plant with almost no tillering [5] cultivated worldwide on more than 130 million hectares, with an estimated yield of 5.71 tonnes/ha in 2022 [6]. This yield is estimated at 2.22 tonnes/ha in Africa and 678 kg/ha in Niger [6]. In sub-Saharan Africa, maize grains are the basis for human food and also serve as raw material in several industries, and the residues are used for animal feed [7]. The maize plant plays an essential role in food security in Niger.

In Niger, corn is consumed grilled or after being transformed into flour to make dough or local couscous [8]. The deficit of agricultural products during the 2023 campaign led in 2024 to a steep rise in corn prices in sub-Saharan Africa in general and in Niger in particular [9]. According to the same authors, the kg of corn, which in previous years was between 100 FCFA and 150 FCFA, reached nearly 400 FCFA in 2024. Consequently, it is essential to create the conditions to increase the production of this commodity in sub-Saharan Africa in general and in Niger in particular. Furthermore, the use of fertilizers on improved varieties could contribute further to improving agricultural production in the context of advanced land degradation. Indeed, agricultural activity is only profitable with considerable nutrient inputs [10]. Researchers, namely Mukengere [11], Useni [12], Li [13], Nyembo [14], Koulibaly [15], Coulibaly [16], and Bakayoko [17] have shown that the contribution of organic manure (from chickens, cows), mineral fertilizers or the combination of the two fertilizers make it possible to improve the above-ground and below-ground biomass, the weight of grains per ear and the grain yield of corn.

However, beyond 1100 kg/ha of mineral fertilizers, corn grain yield decreases [18]. In addition, the timing of basal and maintenance fertilization can improve corncob weight [19]. The uncontrolled use of all these fertilizers can have negative repercussions on the environment and human health; hence, it is important to know when, in what form, and in what quantity to provide fertilizing elements [20]-[22].

Today, few studies have been conducted in the Zinder region on the development of appropriate maize cultivation techniques to boost its productivity. Thus, to promote and popularize its cultivation in rural areas, this study aims at finding the best fertilizer to improve the productivity of the “Maka” maize variety in the

Zinder region in Niger Republic.

2. Materials and Methods

2.1. Description of Study Area

The study was conducted at the Experimental site of the Faculty of Sciences of André Salifou University (UAS), located 13° 48'N latitude and 8° 59'E (Zinder region in Niger Republic) in the 2022/23 rainy season. The area is characterized by low rainfall, with 350 - 450 mm of annual rainfall mean, peaking in July and August. The dominant soil type of the site is sandy-clayey. The mean annual temperature ranges between 21.6°C to 35.51°C.

2.2. Experimental Materials and Design

The material used is an improved variety of corn, locally called “Maka”, obtained from the National Institute of Agronomic Research of Niger (INRAN/Zinder).

The experimental design is a complete randomized block with three repetitions and two factors: the variety in large plots and the fertilizer in small plots and at seven levels. The repetitions are 3 m apart and each elementary plot of 2.75 m² (2.75 m*1 m) is 1 m apart from the other. Each plot is composed of 16 pockets arranged in lines of 0.75 m and the pockets are 0.2 m apart. The treatments are composed of a Control treatment (T0; without any fertilizer input), a treatment with well-composted poultry manure (T1; 7 tons/ha), a treatment with NPK mineral fertilizer (T2; 0.3 tons/ha), a treatment with poultry manure mixed with composted cow dung (T3; 7 tons/ha), a treatment with mineral fertilizer Urea (T4; 0.2 tons/ha), a treatment with NPK mixed with composted cow dung (T5; 0.15 tons/ha and 3.5 tons/ha respectively) and a treatment with composted cow dung (T6; 7 tons/ha). All these fertilizers were weighed before application using a high-precision balance to the order of a centigram.

The plots are plowed before sowing. Sowing was done by hand due to three grains per pocket, placed at a depth of about 5 cm after a 30 mm rain in June. The plants were thinned to one plant per pocket with a density of 66,666 plants/ha. 3 weeding sessions were carried out respectively on the 14th, 30th, and 45th day after sowing, and the spreading of fertilizers was carried out after sowing in three fractions, namely the 15th, 30th, and 45th days after sowing (DAS). A phytosanitary treatment with the anti-caterpillar insecticide was carried out on the 38th DAS at the time of female flowering.

2.3. Data Collection and Analysis

All of the pockets were measured, and the measurements focused on the agronomic and morphological parameters of corn. The quantitative and qualitative descriptors used are respectively, those proposed by [23] and [24]. These are germination test or emergence percentage; Male flowering; Female flowering; Maturity; Number of leaves; Leaf length; Leaf width; Stem diameter; Plant height; cob insertion height; Number of nodes; Number of cobs per plant; cob length; cob

diameter; Number of rows per cob; Number of grains per row; Dry cob weight; Weight of 100 grains; Panicle length and Number of branches per panicle. A sample of three leaves and one cob per plant taken at random were measured in order to calculate their average.

Analysis of variance (ANOVA) was used with Minitab 18 trial version 8.1 software to compare means. Principal component analysis (PCA) was performed with R software version 4.1.0 [25] to assess the influence of fertilizers.

3. Results

3.1. Agronomic Characters

The grains germinated at the same time in all treatments (Table 1). 100% appearance of male and female flowers was observed at treatment level T1 with an average value of 37 days after sowing (DAS) with a difference of 7 days less than the control treatment T0 (Table 1). The time of grain maturity was early recorded with treatments T1 and T2, respectively 66 and 67 DAS, moderately recorded in T3, T4, and T5 with all 69 DAS, and late recorded in treatment T0 and T6, respectively 71 and 72 DAS (Table 1). Also, the highest dry cob yield was obtained at T1 with 7.48 t/ha, followed by T5 with 6.4 t/ha, while the control treatment T0 recorded 1.56 t/ha as the lowest dry ear yield (Table 1).

Table 1. Analysis of the effects of fertilizers on agronomic characters.

Treatment	FloM (JAS)		FloFe (JAS)		Matu (JAS)		Rnd
	Moy	E.typ	Moy	E.typ	Moy	E.typ	Rendement en ha
T0	43.08 ^a	3.332	48.25 ^a	3.6	71.85 ^a	2.432	1.56 ^d
T1	37.35 ^d	1.828	40.68 ^d	1.98	66.68 ^d	1.776	7.48 ^a
T2	38.08 ^{cd}	2.112	42.37 ^c	2.15	68.25 ^c	1.48	5.62 ^b
T3	38.52 ^c	2.414	42.56 ^c	2.592	69.22 ^b	3.005	6 ^b
T4	38.54 ^c	2.269	42.16 ^c	2.177	69.14 ^b	2.154	5.45 ^b
T5	38.22 ^{cd}	1.905	42.25 ^c	1.874	69.29 ^b	2.192	6.39 ^{ab}
T6	41.16 ^b	3.309	45.29 ^b	3.274	71.62 ^a	2.059	4.25 ^c
P	0.000		0.000		0.000		000
S	***		***		***		***

Statistically equal with the Fisher method; S: Significance at the 5% threshold; NS: Not significant; ***: Very highly significant; T0: Control; T1: Composted poultry manure; T2: NPK 15-15-15; T3: Composted poultry manure + Composted cow dung; T4: Urea; T5: NPK + Composted cow dung; T6: Composted cow dung; P: Probability; E.typ: Standard deviation; FloM: Mean days of 100% male flowering; FloFe: Mean days of 100% female flowering; Matu: Mean day of 100% maturity.

3.2. Quantitative Morphological Characters

Unlike plant height (Hp), leaf length (Lfe), leaf width (lfe), and number of leaves (Nbrfe), the mean value of stem diameter gradually increased from 30th to 50th DAS and decreased at maturity (Table 2). Treatments T2, T1, and T5 gave the

highest plant heights at maturity with respective mean values of 259.02 cm, 257.98 cm, and 252.46 cm, while the lowest values were obtained with treatment T0 and T6 with respectively 172.27 cm and 230.21 cm (**Table 2**). The highest values of the number of stem nodes, number of leaves, length, and width of the leaf are recorded at the level of treatments T1, T4, and T5, while the lowest values are recorded with the control (**Table 2**). Treatment T1 has the highest number of panicle branches (19.09) and the highest value of panicle length (41.44 cm; **Table 2**).

The height of the stem and that of insertion of the first cob, the number of ears per plant, the length and diameter of the ear, the weight of the ear, the number of rows per ear, the number of grains per row, the number of grains per ear and the weight of 100 grains are different from one treatment to another. Indeed, with the exception of the height of insertion of the first ear, the average values obtained with treatment T1 are all higher than those obtained with the other treatments. The highest averages recorded after treatment T1 of the NbrE, PE, and P100Gr were recorded with treatment T5, respectively 2.02 g, 279 g, and 22.29 g (**Table 2**). The greatest height (89.09 cm) of insertion of the first ear was recorded with treatment T2 (**Table 2**). For all the variables, the lowest values were recorded at the level of the control treatment T0 (**Table 2**).

Table 2. Analysis of the effects of fertilizers on quantitative morphological characters.

	Traitement	T0	T1	T2	T3	T4	T5	T6	P	S
NbrN	Moy	10.97 ^d	13.06 ^a	12.47 ^{bc}	12.12 ^c	12.85 ^{ab}	12.70 ^{ab}	12.14 ^c	0.000	***
	E.typ	1.139	0.976	1.01	0.981	0.945	0.849	1.01		
Nbrfe	Moy	12 ^e	14.25 ^a	13.64 ^{bc}	13.43 ^{cd}	13.95 ^{ab}	14.08 ^a	13.18 ^d	0.000	***
	E.typ	0.851	1	1.041	0.987	1.01	1.048	0.938		
Lfe (cm)	Moy	77.83 ^d	93.33 ^a	88.99 ^b	87.30 ^b	93.53 ^a	89.33 ^b	84.36 ^c	0.000	***
	E.typ	5.999	6.746	5.676	6.085	7.29	5.691	4.226		
lfe (cm)	Moy	7.020 ^e	9.16 ^a	8.60 ^{bc}	8.23 ^d	8.91 ^{ab}	8.22 ^d	8.31 ^{cd}	0.000	***
	E.typ	0.4976	0.76	0.803	0.947	0.792	0.971	0.749		
DT (mm)	Moy	21.66 ^d	30.76 ^b	30.44 ^b	29.99 ^b	32.01 ^a	31.04 ^{ab}	28.09 ^c	0.000	***
	E.typ	3.523	3.014	3.45	3.098	2.352	2.127	2.509		
Hp (cm)	Moy	172.27 ^e	257.98 ^a	259.02 ^a	241.63 ^c	248.52 ^{bc}	252.46 ^{ab}	230.21 ^d	0.000	***
	E.typ	24.1	17.93	22.51	22.98	25.34	20.96	26.48		
HIE (cm)	Moy	59.86 ^e	84.7 ^{ab}	89.09 ^a	77.58 ^{bc}	76.2 ^c	85.55 ^a	67.97 ^d	0.000	***
	E.typ	17.79	17.06	24.93	16.68	15.96	22.77	15.2		
NbrBPa	Moy	13.47 ^d	19.08 ^a	16.29 ^{bc}	15.93 ^{bc}	16.95 ^{bc}	17.56 ^{ab}	15.18 ^{cd}	0.000	***
	E.typ	3.759	5.335	3.853	3.905	3.957	5.214	4.783		

Continued

Lpa (cm)	Moy	33.06 ^c	41.44 ^a	38.53 ^b	39.05 ^{ab}	38.06 ^b	38.06 ^b	37.95 ^b	0.000	***
	E.typ	5.831	6.418	7.93	5.43	6.435	6.156	4.673		
NbrE	Moy	1.041 ^c	2.25 ^a	1.77 ^{bcd}	2.02 ^{ab}	1.68 ^{cd}	1.89 ^{bc}	1.58 ^d	0.000	***
	E.typ	0.2019	0.812	0.6601	0.6681	0.719	0.722	0.5392		
LE (cm)	Moy	14.76 ^d	19.99 ^a	18.78 ^b	17.75 ^c	19.15 ^b	19.21 ^{ab}	17.75 ^c	0.000	***
	E.typ	1.068	2.498	1.871	2.234	2.071	1.632	2.103		
DE (mm)	Moy	32.49 ^c	49.44 ^a	46.08 ^{bc}	43.90 ^d	46.27 ^{bc}	46.68 ^b	44.91 ^{cd}	0.000	***
	E.typ	3.029	4.028	3.804	3.416	3.777	3.694	2.904		
NbrR	Moy	13.20 ^d	18.33 ^a	16.56 ^{bc}	15.81 ^c	17.06 ^b	17.08 ^b	16.22 ^{bc}	0.000	***
	E.typ	1.75	2.355	2.072	1.841	2.206	2.916	2.013		
NbrGrR	Moy	22.27 ^c	38.89 ^a	36.43 ^b	34.20 ^c	37.43 ^{ab}	38.72 ^a	32.20 ^d	0.000	***
	E.typ	3.375	3.888	4.037	4.182	4.021	3.63	4.968		
P (g)	Moy	70.26 ^c	336.6 ^a	252.9 ^c	270.2 ^{bc}	245.3 ^c	287.8 ^b	191.62 ^d	0.000	***
	E.typ	16.02	87.3	91.4	90.4	86.9	91.5	66.3		
P100Gr (g)	Moy	15.47 ^c	23.04 ^a	21.79 ^{bc}	22.29 ^{ab}	21.11 ^c	21.19 ^{bc}	18.75 ^d	0.000	***
	E.typ	2.761	2.627	2.898	3.13	2.688	2.742	3.114		

For each character, the values with the same letters are statically equal with the Fisher method; S: Significance at the 5% threshold; ***: Very highly significant; T0: Control; T1: Composted poultry manure; T2: NPK 15-15-15; T3: Composted poultry manure + Composted cow dung; T4: Urea; T5: NPK + Composted cow dung; T6: Composted cow dung; P: Probability; E.typ: Standard deviation; Avg: Mean; NbrN: Number of nodes; Nbrf: Number of leaves; Lfe: Leaf length; lfe: Leaf width; DT: Stem diameter; HP: Plant height; NbrBPa: Number of branches per panicle; Lpa: Panicle length; NbrE: Number of spikes; LE: Spike length; DE: Spike diameter; NbrR: Number of rows; NbrGrR: Number of grains per row; PEtot: Total weight of dry ear; P100gr: Weight of 100 grains.

3.3. Effect of Fertilizers on Corn Production

The principal component analysis (PCA) shows that the first two components absorb 67.87% of the total variability of the information (Figure 1). Axis 1 alone explains more than 57.42% of the total variation observed. The PCA results show that all treatments are different from the control treatment T0 (Figure 1). Considering the first plane, the treatments are organized into 4 distinct groups: group 1 consisting of treatment T0 on the far left of axis 1, followed by group 2 consisting of treatment T6 on the left of the origin on axis 1, group 3 consisting of treatment T2, T4 and T5 on the right of the origin on axis 1 and group 4 consisting of treatment T1 on the far right of axis 1. The first four groups are distinguished from each other by axis 1 and group 5, consisting of treatment T3 is distinguished from the rest by axis 2. Furthermore, considering Figure 2, we note that groups 1 and 2 (treatment T0 and T6) are characterized by late male (FloM) and female (FloF)

flowering unlike the other treatments. Group 4 is much more characterized by ear length (LE); the number of grains per row (NbrGrR); fresh ear weight (Pefrai); ear diameter (ED); stem diameter (SD); total dry ear weight (PEtot) and plant height (HP) than group 3.

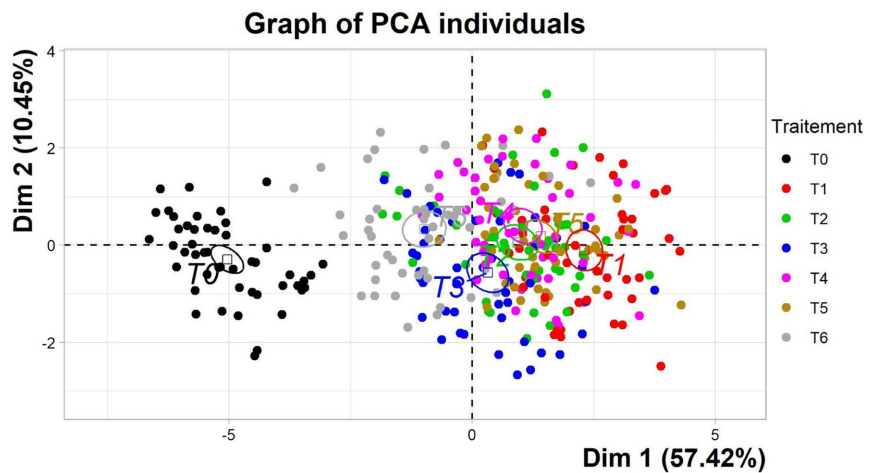


Figure 1. Organization of treatment groups based on their similarity.

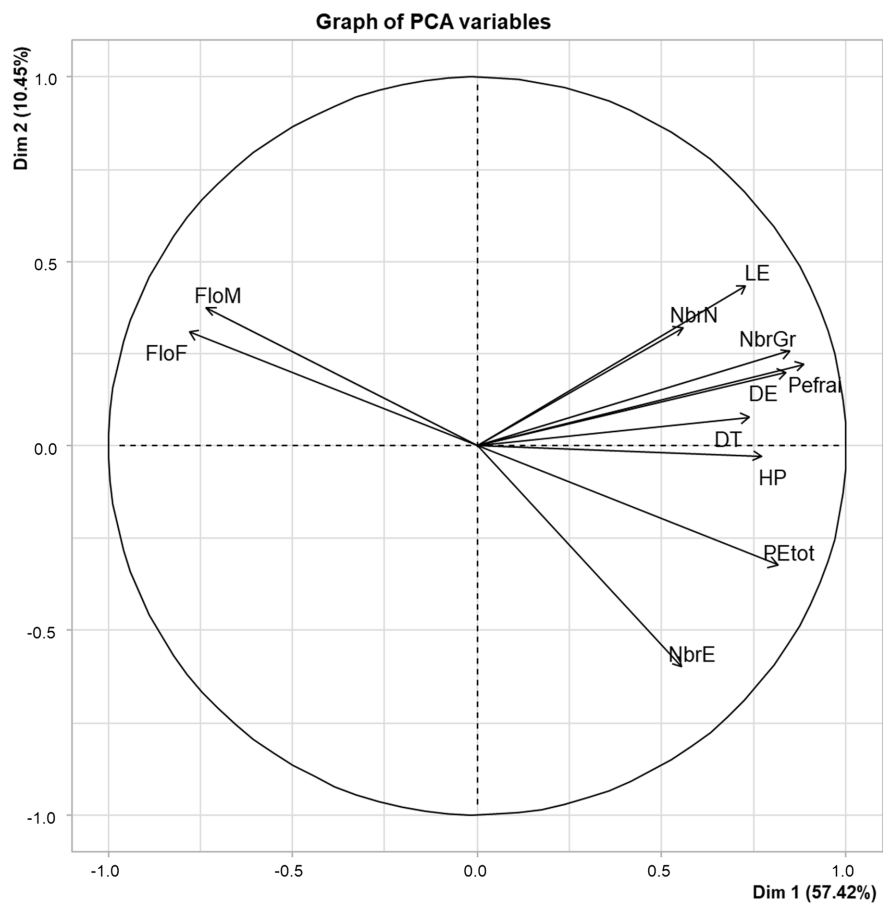


Figure 2. Contribution of the characteristics to the building of the first two components of the PCA.

4. Discussion

The result of the variance analysis shows that fertilizers significantly affect most of the agronomic traits studied. Comparing the mean values, all treatments gave a higher result than the control treatment (T0, without fertilizer). This result confirms that of [26], who observed differences in the durations of the vegetative and reproductive phases for four types of fertilizer. It emerges from this experiment that agronomic parameters such as male and female flowering and maturity studied at the level of composted poultry manure (T1) gave the best results for precocity. In addition, the best yield in dry corn cobs was obtained with treatment T1, with a yield greater than 7 tons per hectare. Treatment T1 and T5, respectively made it possible to obtain 4.8 and 4.2 times the yield obtained by the control. The same observation was made by [26], who shows that organic manure based on chicken droppings improves corn yield compared to the control treatment. In addition, the combination of composted cow dung with NPK made it possible to obtain 4.2 times the yield obtained with the control treatment. This result confirms that of [11], who also shows that the combination of organic and mineral fertilizers creates the best production conditions.

The results show that vegetative growth parameters such as plant height, stem collar diameter and number of leaves, leaf length and width at 35th DAS, 50th DAS, and maturity have different values between treatments and gave greater growth to treatment T1. This finding could be explained by the availability of mineral elements, including nitrogen, phosphorus, and potassium, in organic fertilizers based on poultry droppings for crop growth and development [27]. These results corroborate those of [22], who show that treatments based on poultry droppings have significant repeated and residual effects on soil chemical parameters and that repeated application of poultry droppings still induces significant differences, including the highest N, P, and K contents. Also, plots treated with mineral manures or in combination with organic fertilizer gave a yield significantly different from unfertilized plots. This is due to the fact that the major nutrients in mineral fertilizers are substances that are readily assimilated by the plant. Kiari [28] notes that in the Maradi and Dosso regions, the use of NPK in sorrel cultivation favorably increased the leaf and grain yield of the latter.

Comparison of the mean stem diameter value showed that the mean values at maturity slightly decreased compared to those at the 35th and 50th DAS. This has already been reported by [26] in their study on “The effect of four types of fertilizers on the growth and productivity of two maize genotypes”, whereby they found that the mean values of collar diameter of plants treated with any fertilizer remain statistically equivalent from 85th to 92nd DAS.

As for the vegetative parameters, the contribution of poultry manures with or without the addition of mineral fertilizers significantly influenced all the yield parameters. The number of ears per plant, the number of grain rows per ear, the weight of grains per ear, the weight of 100 grains, and the grain yield were significantly affected by the contribution of fertilizers. The highest averages in number

of ears, the weight of ears, and the weight of 100 grains were obtained with the treatment in composted poultry manure T1, followed by T5, which is a combination of cow dung plus NPK. These results could be due to the fact that the phosphorus (P) contained in these manures promotes fertilization, fruiting, and grain formation. Similar results were reported by [29], according to which the contributions of composted poultry manure and NPK during the rainy and dry seasons on the cultivation of three okra varieties had positive effects on the growth and the production variables of the plants.

The principal component analysis carried out on the agronomic and morphological characteristics shows that treatment T1, followed by treatment T5 of group 3 are clearly far from the control treatment T0. This analysis also confirms that treatment T1 is clearly the best compared to the others. This result corroborates that of [26], which shows that organic manure based on chicken droppings improves corn productivity compared to the control treatment.

5. Conclusion

The results of the study have shown that the treatment with composted poultry manure (T1) increases corn production. This treatment is the best for corn production. In addition, the combination of composted cow dung mixed with composted poultry manure (T5) and the combination of composted cow dung mixed with NPK (T3) also made it possible to obtain good yields of dry corn cobs. Finally, it appears from the study that the three treatments, including composted poultry manure (T1), the combination of composted cow dung with composted poultry manure (T5), and the combination of composted cow dung mixed with NPK (T3), are recommended to farmers in order to improve corn production and reduce environmental pollution following the use of mineral fertilizers.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

- [1] Poss, R., Fardeau, J.C. and Saragoni, H. (1996) Sustainable Agriculture in the Tropics: The Case of Potassium under Maize Cropping in Togo. *Nutrient Cycling in Agroecosystems*, **46**, 205-213. <https://doi.org/10.1007/bf00420555>
- [2] Saïdou, A., Kossou, D., Acakpo, C., Richards, P. and Kuyper, W.T. (2012) Effets des pratiques paysannes d'application d'engrais et des types d'utilisation des terres sur le rendement ultérieur du maïs et l'absorption des nutriments dans le centre du Bénin. *International Journal of Biological and Chemical Sciences*, **6**, 363-376
- [3] Banque mondiale (2023) Transformer le système agroalimentaire Nigérien© Banque mondiale. 71.
- [4] Barro, A., Sangare, M., Coulibaly, K., Koutou, M. and Diallo, M.A. (2016) Etude des modalités d'association maïs/niébé dans les villages de Koumbia et Gomêlédougou en zone cotonnière de l'ouest du Burkina Fasso. *Sciences Naturelles et Appliquées*, **2**, page.

- [5] Marchand, J., Berthaud, J., Clerget, B., Dintinger, J., Reynaud, B. and Dzido J. (1997) Les maïs dans l'amélioration des plantes tropicales. CIRAD, ORSTOM, 401-228.
- [6] FAOSTAT (2022) Perspectives de l'alimentation. Bulletin de la FAO sur l'offre et la demande de céréales. <https://www.fao.org/worldfoodsituation//fr>
- [7] Boone, P., Stathacos, C.J.D. and Wanzie, R.L. (2008) Évaluation sous-régionale de la chaîne de valeurs du maïs, rapport technique ATP n°1. Projet ATP, Abt Associates Inc Accra-Ghana.
- [8] Moussa, A.A., Salako, V.K., Gbemavo, D.S.J.C., Zaman-Allah, M., Kakaï, R.G. and Bakasso, Y. (2018) Performances agro-morphologiques des variétés locales et améliorées de maïs au sud-ouest du Niger. *African Crop Science Journal*, **26**, 157-173. <https://doi.org/10.4314/acsj.v26i2.1>
- [9] Afrique Verte International (2024) Bulletin d'information sur la sécurité alimentaire au sahel.
- [10] Yannick, U., Minerve, C., John, T., Emmanuel, M., Prisca, K., François, N., *et al.* (2013) Utilisation des déchets humains recyclés pour l'augmentation de la production du maïs (*Zea mays* L.) sur un ferralsol du sud-est de la RD Congo. *Journal of Applied Biosciences*, **66**, 5070-5081. <https://doi.org/10.4314/jab.v66i0.95005>
- [11] Mukengere, B.E. (2010) Evaluation de l'efficacité d'usage des engrais dans les sols dégradés du Sud-Kivu sur la culture du maïs et du haricot. Cas du groupement de Burhale. Master's Thesis, Université Evangélique en Afrique.
- [12] Useni, S.Y., Baboy, L.L., Nyembo, K.L. and Mpundu, M.M. (2012) Effets des apports combinés de biodéchets et de fertilisants inorganiques sur le rendement de trois variétés de *Zea mays* L. cultivées dans la région de Lubumbashi. *Journal of Applied Biosciences*, **54**, 3935-3943.
- [13] Li, X.H., Han, X.Z., Li, H.B., Song, C., Yan, J. and Liang, Y. (2012) Soil Chemical and Biological Properties Affected by 21-Year Application of Composted Manure with Chemical Fertilizers in a Chinese Mollisol. *Canadian Journal of Soil Science*, **92**, 419-428. <https://doi.org/10.4141/cjss2010-046>
- [14] Luciens, M., Yannick, U., Dieudonné, C., Dieudonné, K., Yambayamba, K., Michel, M., *et al.* (2014) Amélioration des propriétés physiques et chimiques du sol sous l'apport combiné des biodéchets et des engrais minéraux et influence sur le comportement du maïs (*Zea mays* L. variété Unilu). *Journal of Applied Biosciences*, **74**, 6121-6130. <https://doi.org/10.4314/jab.v74i1.7>
- [15] Koulibaly, B., Dakuo, D., Ouattara, A., Traore, O., Lompo, F., Zombre, P.N. and Yao Kouame A. (2015) Effets de l'association du compost et de la fumure minérale sur la productivité d'un système de culture à base de cotonnier et de maïs au Burkina Faso. *Tropicultura*, **33**, 125-134.
- [16] Koulibaly, D., Sissoko, F., Doumbia, S., Ba, A. and Dembele, A. (2017) Evaluation de l'effet de la fertilisation minérale sur la production de variétés améliorées de maïs et le disponible fourrager en zone cotonnière du mali-sud (mali). *Agronomie Africaine*, **29**, 109-117.
- [17] Bakayoko, S., Abobi, A.H.D., Konate, Z. and Toure, N.U. (2019) Effets comparés de la bouse de bovins séchée et de la sciure de bois sur la croissance et le rendement du maïs (*Zea mays* L.). *Agronomie Africaine*, **8**, 63-72.
- [18] Nyembo, K.L., Useni, S.Y., Mpundu, M.M., Bugeme, M.D., Kasongo, L.E. and Baboy, L.L. (2012) Effets des apports des doses variées de fertilisants inorganiques (NPKS et Urée) sur le rendement et la rentabilité économique de nouvelles variétés de *Zea mays* L. à Lubumbashi, Sud-Est de la RD Congo. *Journal of Applied Biosciences*, **59**, 4286-4296.

- [19] Ilunga, T.H., Banza, M.J., Lukusa, M.L., Mukunto, K.I., Malonga, H.L., Kanyenga, L.A., et al. (2019) Influence du moment d'application du NPK sur la croissance et le rendement du maïs (*Zea mays* L.) installé sur un ferralsol. *Journal of Applied Biosciences*, **127**, 12794-12803. <https://doi.org/10.4314/jab.v127i1.4>
- [20] Isfan, D., Zizka, J., D'Avignon, A. and Deschênes, M. (1995) Relationships between Nitrogen Rate, Plant Nitrogen Concentration, Yield and Residual Soil Nitrate-Nitrogen in Silage Corn. *Communications in Soil Science and Plant Analysis*, **26**, 2531-2557. <https://doi.org/10.1080/00103629509369466>
- [21] Kidinda, L., Kiluba, K.J., Tshipama, T.D., Kilumba, K.M., Mpoyo, M.G., Langunu, S., Muteba, K.M. and Nyembo, K.L. (2015) Mise en évidence des doses de fertilisants minéraux à appliquer aux nouvelles variétés de maïs introduites dans la région de Lubumbashi (RD Congo). *International Journal of Innovation and Applied Studies*, **12**, 96-10.
- [22] Gomgnimbou, A.P.K., Bandaogo, A.A., Kalifa, C., Sanon, A., Ouattara, S. and Nacro, H.B. (2019) Effets à court terme de l'application des fientes de volaille sur le rendement du maïs (*Zea mays* L.) et les caractéristiques chimiques d'un sol ferrallitique dans la zone sud-soudanienne du Burkina Faso. *International Journal of Biological and Chemical Sciences*, **13**, 2041-2052. <https://doi.org/10.4314/ijbcs.v13i4.11>
- [23] IPGRI (1991) Descriptors for Maize. CIM-MYT.
- [24] CIMMYT (1991) CIMMYT 1989/1990, réalités et tendances: Potentiel maïsicole de l'Afrique Subsaharienne, 71.
- [25] R Core Team (2021) R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna. <https://www.R-project.org>
- [26] Siene, L.A.C., Doumbouya, M., Traore, M.S., Conde, M., N'guettia, T.V.F. and Kone, M. (2020) Effet de quatre types de fertilisants sur la croissance et la productivité de deux génotypes de maïs (*Zea mays* L.) en cas d'un semis tardif à Korhogo au Centre-Nord de la Côte d'Ivoire. *International Journal of Biological and Chemical Sciences*, **14**, 55-68. <https://doi.org/10.4314/ijbcs.v14i1.6>
- [27] Muyayabantu, G.M., Kadiata, B.D. and Nkongolo, K.K. (2012) Response of Maize to Different Organic and Inorganic Fertilization Regimes in Monocrop and Intercrop Systems in a Sub-Saharan Africa Region. *Journal of Soil Science and Environmental Management*, **3**, 42-48.
- [28] Kiari, B.K.K., Daouda, A.K.T., Inoussa, M.M., Moussa, M., Sanoussi, A.T.T. and Bakasso, Y. (2021) Effet de NPK (15-15-15) sur la production des écotypes d'oseille des Guinée (*Hibiscus sabdariffa* L.) au Niger. *Revue Marocaine des Sciences Agronomiques et vétérinaires*, **9**, 705-709.
- [29] Abdou, R., Halilou, A.I., Zango, O., Agbo So, T.K., Yahaya, M.I. and Bakasso, Y. (2022) Effet des fertilisants sur la productivité de trois variétés de gombo (*Abelmoschus esculentus* L. Moench.) de la région de Zinder (Niger). *International Journal of Biological and Chemical Sciences*, **16**, 378-389. <https://doi.org/10.4314/ijbcs.v16i1.32>