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Effect of *Moringa oleifera* leaf powder and NPK fertilizer on soil properties and growth of pearl millet in Sudan savannah

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ABSTRACT

The soils of the savannah region are characterized by low soil fertility which poses a challenge for crop production. Farmers in this region rely on chemical fertilizers which are expensive and sometimes may have negative environmental consequences on soil fertility and crop yield. However, combining the Moringa leaf powder and chemical fertilizer can serve as the better alternative. A field experiment was carried out during the 2023 rainy season at the Dryland Teaching and Research farm of Usmanu Danfodiyo University Sokoto, Nigeria to evaluate the effect of moringa leaf powder and NPK fertilizer on selected soil properties and growth of Pearl millet (*Pennisetum glaucum* (L.) R. Br.). The experiment was conducted in a Randomized Complete Block Design (RCBD) with four treatments, namely Control (0 rate), NPK (60Kg N, 30 Kg P_2O_5, 30Kg K_2O ha^{-1}), Moringa leaf powder (5.0 Kgha^{-1}), and NPK (30Kg N, 15Kg P_2O_5, 15Kg K_2O ha^{-1}) + Moringa leaf powder (2.5 Kgha^{-1}). Soil samples were collected for laboratory analyses before and after the experiment to determine soil pH, organic carbon, total nitrogen, available phosphorus, exchangeable bases (calcium, magnesium, sodium and potassium), and cation exchange capacity (CEC). Plant growth parameters were evaluated. The results showed that the NPK+MLP treatment had the highest mean values for most of these soils and plant growth parameters (tiller count, plant height, and number of leaves), indicating a synergistic effect between these inputs compared to control, NPK and MLP alone. Therefore, the combined application of NPK and Moringa leaf powder can improve soil fertility and enhance millet growth in the study area.

Keywords: Growth; moringa; NPK; pearl millet; soil

INTRODUCTION

Pearl millet (*Pennisetum glaucum* (L.) R. Br.) belongs to the family poaceae, subfamily panicoideae, genus pennisetum and tribe paniceae (ICRISAT, 2006). It is one of the oldest food crops known to man and possibly first cereal grains to be used for domestic

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purposes (Railey, 2006). According to Chopra (2001), pearl millet is one of the most important dual-purpose crops and a staple food for millions of people in arid and semi-arid ecologies around the world. It is grown in areas where annual rainfall ranges from 200 to 800 mm spread over three to six months (Raemaekers, 2001). According to ICRISAT (2006) report, India is the largest producer of pearl millet in Asia, both in terms of area and production with an average productivity of 930 $Kgha^{-1}$. Nigeria uses millions of tons of pearl millet as staple food in many homes, especially among the poor, predominantly in Northern Nigeria (FAO, 2007). Pearl millet is a crop that requires nitrogen, phosphorus, and potassium, essential for its growth and productivity. Nitrogen is the most crucial nutrient for the growth of pearl millet, as it helps the plant efficiently use phosphorus and potassium (Singh, 2019). It is a key limiting factor in crop production and plays a crucial role in the synthesis of chlorophyll and amino acids, which contribute to protein building and plant growth (Sheoran *et al*., 2024). Nitrogen positively impacts pearl millet crops, such as growth attributes, panicle length and width, number of grains/panicle, grain weight, and ultimately, yield (Uppal *et al*., 2015). Phosphorus is crucial for the conversion of solar energy into chemical energy, influencing plant vigor, root growth, and product quality (Gemenet *et al*., 2016). Potassium is another primary nutrient that plays a vital role in the growth and development of pearl millet. It helps the plant withstand stress, and is involved in photosynthesis, protein synthesis, and more (Reddy *et al*., 2023). Zinc is another good micro element influencing the growth and yield of pearl millet positively as reported by Reddy *et al.* (2023).

Moringa leaf powder comprises important nutrients that can improve plant growth and is derived from the leaves of the *Moringa oleifera* tree, this tree is also known as the drumstick tree or the miracle tree because of its numerous beneficial properties. Moringa leaf powder contains essential plant nutrients such as nitrogen, phosphorus, potassium, and calcium, making it a valuable organic fertilizer for plants (Leone *et al.*, 2016). According to Adebayo *et al.* (2021) moringa leaf powder as an organic fertilizer has the ability to improve soil health. Study by Adekiya *et al.* (2021), showed that the powder is an important organic material that helps in improving soil structure, texture, and water-holding capacity, it also contains beneficial microorganisms that help in breaking down organic matter and release nutrients in the soil, making them available for plant uptake. Moringa leaf powder has been found to increase plant growth and productivity. Studies by Ogunlaja *et al.* (2021) have shown that the nutrients in the moringa leaf powder are readily available for plant uptake, which promotes healthy plant growth, increases crop yields, and improves the quality of fruits and vegetables. Moringa leaf powder is also an environmentally friendly alternative to chemical fertilizers.

NPK is a chemically produced fertilizer that contains nitrogen, phosphorus, and potassium as primary nutrients. These nutrients are crucial for plant growth and are commonly lacking in soil. Nitrogen is the most significant nutrient in plant growth and accounts for about 78 % of the atmospheric air and approximately 2 % of the total weight of living organisms (USDA, 2019). Phosphorus is a crucial element in NPK fertilizer because it plays a critical role in plant growth and development. It is vital for root development, energy transfer, and photosynthesis in plants. Phosphorus also assists in the conversion of sunlight into energy for storage. Potassium is an important component of NPK fertilizers, which are widely used in agriculture to improve crop yields and nutrient uptake (NRC, 2000). According to Zhang *et al.* (2014), potassium is particularly critical for the development of root systems and the translocation of nutrients within plants. Potassium fertilization can increase the efficiency of water and nutrient use in crops, leading to improved productivity and yield. The NPK fertilizer combines the proportion of nitrogen, phosphorus and potassium in form of N, P_2O_5 and K_2O to provide essential nutrients to plants and promotes their growth, increasing crop yields and improving soil fertility (Garden, 2021). Therefore, this experiment was conducted to determine the effect of moringa leaf powder and NPK fertilizer on some selected soil properties and growth performance of millet.

MATERIALS AND METHODS

Experimental Site

The field experiment was conducted during the 2023 rainy season at Dry Land, Teaching and Research Farm, Usmanu Danfodiyo University, Sokoto, Nigeria. Sokoto State is located at Latitude $13^0$1' North, Longitude $5^0$15' East, and an elevation of 350 m above sea level (NIMET, 2022). The vegetation of the area is semi-arid, with an average annual rainfall of 655.85 mm and a relative humidity of 48.54 % between mid-May and early June and reaching its peak in August or September and an average temperature of 36°C. The dry season starts in mid-October and ends in April, while the coldest months are November to January, which is characterized by dry harmattan wind (NIMET, 2022).

Soil Sampling, Preparation and Laboratory Analysis

Soil samples of the experimental site were collected before the experiment using soil auger at a depth of 0–30 cm using simple random sampling technique. Soil samples were also collected per experimental plot after the end of the experiment. The representative soil sample collected was labeled, air dried, and stored in the laboratory. Standard methods were employed for soil parameter analyses, with Bouyoucos hydrometer methods as described by Gee and Bauder (1986) was used in determining particle size distribution, and the USDA textural triangle was used to establish soil textural classes. Soil pH was determined using a pH meter with a soil-water ratio of 1:1 as described by Thomas (1996), soil organic carbon (SOC) was determined using Walkey and Black's wet oxidation method as described by Nelson and Sommers (1975). Total nitrogen was determined using micro Kjehdahl digestion distillation methods. Available phosphorus (AP) was determined using the Bray-P No. 1 method as described by Jackson (1962). Exchangeable bases (Ca, Mg, K, and Na) were determined using atomic absorption spectrophotometers (AAS) as described by Kuo (1996), while cation exchange capacity (CEC) was determined using the ammonium acetate saturation method in pH 7 as described by Chapman (1965).

Plant Collection, Preparation and Laboratory Analysis

The plant leaves were collected at the University Fadama Teaching and Research Farm Sokoto State, Nigeria. The leaves were harvested green, air-dried under shade and milled into powder through 1 mm sieve, they were stored in well-dried black plastic containers inside the storeroom at room temperature of 25°C. Dried powdered Moringa leaves were assessed for dry matter, crude protein, crude fat, ash, calcium, magnesium, potassium, phosphorus and sodium using the AOAC (2005) procedure.

Treatments and Experimental Design

The treatment consists of NPK Fertilizer (60Kg N, 30 Kg P_2O_5, 30Kg K_2O ha^{-1}), Moringa leaf powder (5.0 $Kgha^{-1}$) alone, combination of NPK Fertilizer (30Kg N, 15Kg P_2O_5, 15Kg K_20 ha^{-1}) and Moringa leaf powder (2.5 $Kgha^{-1}$) and control (where no Fertilizer or Moringa leaf powder) were applied. The treatments were arranged in a Randomized Complete Block Design (RCBD), replicated three times.

Crop Husbandry and Agronomic Practice

The land was cleared after initiation of rainfall and the experiment was laid on a 3 x 3 m plot with 0.5 m and 1 m between plots and blocks respectively, total plot size 108 m^2 of 12 plots with each plot measure 3 x 3 m (9 m^2). All agronomic practices (sowing, supplying, thinning, weeding, disease, pest control etc.) were carried out as at when due.

Treatment Application

Nitrogen (N), phosphorus (P_2O_5), and potassium (K_2O) fertilizer was applied using recommended rate of 60Kg N, 30Kg P_2O_5, 30Kg K_2O ha^{-1} Using NPK 15:15:15. 30Kg N, 30 Kg P_2O_5, 30Kg K_2O ha^{-1} was applied at sowing and second application was done 6 weeks after sowing using urea (46%) N at the rate of 30Kg Nha^{-1} (Pramila and Shukla, 2020). Moringa leaf powder was applied at the rate of 5.0 $Kgha^{-1}$ at sowing (Ebido *et al.*, 2014).

Data Collection

Data on soil properties were collected before and after the experiment and the following growth parameters were considered:

Stand Establishment Count: The Stand Establishment Count (SEC) was taken at 2 weeks after sowing.

Tiller Count: Tiller which is an extra shoot growing from the base of the plant was taken from the net plot area (3 plants) at 3weeks after sowing.

Plant Height (cm): Plant height was measured from 3 randomly selected plants from the net plot using a meter rule from the base to the tip of the plant, periodically from 3, 6 and 9 weeks after sowing.

Number of Leaves: Number of leaves of the selected plant from the net was counted at 3, 6 and 9 weeks after sowing.

Data Analysis

Data obtained from the experiment were subjected to analysis of variance (ANOVA) using SPSS version 22 and the treatment means were separated using LSD (least significance difference) at 5% level of significance.

RESULTS

Physical and Chemical Properties of Soil before the Experiments

The result of the physical and chemical properties of the soil before the experiment is presented in Table 1. The result shows that the soil was slightly acidic with a pH value of 6.02. Based on Esu (1991) ratings, the soils were low in organic carbon, total nitrogen, available phosphorus, exchangeable calcium, potassium and sodium and also low in CEC with values of 4.0 g/kg, 0.4 g/kg, 0.44 g/kg, 0.5 cmol/kg, 0.06 cmol/kg 0.06 cmol/kg and CEC 2.40 cmol/kg respectively. However, exchangeable magnesium was medium (0.57

cmol/kg). The particle size distribution showed that the soil was dominated by sand separates (92.75%) followed by clay (5.29%) and silt (1.96%), while the textural classification indicated that the soil was sand in nature.

Table 1: Physical and chemical properties of soil before the experiment

Parameter	Mean value
Sand %	92.75
Silt %	1.96
Clay %	5.29
Textural class	Sand
pH (H_2O) 1:1	6.02
Organic Carbon (g/kg)	4.00
Total Nitrogen (g/kg)	0.40
Available Phosphorus (mg/kg)	0.44
Exchangeable bases	
Exchangeable Calcium (cmol/kg)	0.52
Exchangeable Magnesium (cmol/kg)	0.57
Exchangeable Sodium (cmol/kg)	0.06
Exchangeable Potassium (cmol/kg)	0.06
CEC (cmol/kg)	2.40

Mineral Contents of Dried Moringa (*M. oleifera*) Leaves

The result of the mineral contents of dried moringa (*M. oleifera*) leaves is presented in Table 2. The result shows that the dried leaves of Moringa had a moisture content of 9.60 %, crude protein content of 30.10 %, fat of 6.57 %, and ash of 8.09 %. Calcium had the highest mean value of 3.63% followed by potassium 1.58%, magnesium 0.48 %, phosphorus 0.29 % and sodium had the least mean value of 0.17 %.

Table 2: Mineral contents of dried Moringa (*M. oleifera*) leaf

Parameter	Mean value
Moisture %	9.60
Crude protein %	30.10
Fat %	6.57
Ash %	8.09
Calcium %	3.63
Phosphorus %	0.29
Magnesium %	0.48
Potassium %	1.58
Sodium %	0.17

Effect of Moringa Leaf Powder and NPK Fertilizer Application on Physical and Chemical Properties of Soil

Soil pH: The result (Table 3) shows that there was an increase in pH as influenced by different treatments. There was significant difference ($P<0.05$) in the soil pH between the treatments. The combination of NPK+MLP recorded the highest pH mean value of 6.21, followed by sole NPK and MLP with the same mean value of 6.13, CK recorded the least mean value of 6.10.

Organic Carbon: The result (Table 3) shows an increase in soil organic carbon at different treatments which was significant (P≤0.05) between the treatments, NPK+MLP had the highest mean value of (6.47 g/kg) followed by NPK and MLP (4.60 g/kg and 4.67 g/kg) respectively, while the control recorded the least mean value (4.33 g/kg).

Soil Total Nitrogen: The result (Table 3) shows that the treatments had a significant effect (P≤0.05) on the soil total nitrogen. The combination of NPK+MLP gave the highest value of 0.51 g/kg, followed by MLP 0.48 g/kg, and NPK 0.47 g/kg, while control (CK) recorded the least mean value of 0.36 g/kg.

Available Phosphorus: The result (Table 3) shows that the treatment had a significant effect (P≤0.05), and the combination of NPK+MLP gave the highest mean value of 0.58 g/kg, followed by MLP 0.54 g/kg, NPK 0.46 g/kg, and CK recorded the least mean value of 0.42 g/kg.

The result in Table 3 shows an increase in exchangeable calcium in the MLP level treatment (0.60 cmol/kg) as compared to the NPK (0.48 cmol/kg), NPK+MLP (0.33 cmol/kg) and control (0.45 cmol/kg) treatment. However, this increase is not significant (P≥0.05) among the treatments.

Exchangeable Magnesium result in Table 3 shows that the treatments had significant effect (P≤0.05) on the soil exchangeable magnesium, thus NPK+MLP had the highest mean value of 0.88 cmol/kg, followed by NKP with a mean value of 0.63 cmol/kg, MLP with a mean value of 0.68 cmol/kg, and CK with a mean value of 0.65 cmol/kg.

Exchangeable sodium levels also increased in the NPK treatment (0.16 cmol/kg) as compared to the control (0.13 cmol/kg), MLP (0.12 cmol/kg) and NPK+MLP (0.09 cmol/kg) treatment. However, this increase is not significant (P≥0.05) among the treatments.

Exchangeable Potassium: The result (Table 3) shows there was an increase in exchangeable potassium of the different treatments. This increase was significant (P≤0.05) and the combination of NPK+MLP had the highest mean value of 0.08 cmol/kg, followed by NPK with mean values of 0.06 cmol/kg, MLP and CK with mean values of 0.04 cmol/kg, respectively.

Cation Exchange Capacity: The result (Table 3) shows there was an increase in exchangeable cation exchange capacity of the different treatments. The increase was significant (P≤0.05) on the soil exchangeable cation exchange capacity; NPK+MLP had the highest mean value of 7.20 cmol/kg, followed by NPK and MLP with mean values of 4.60 cmol/kg, and 6.53 respectively and CK had the least mean values of 4.07 cmol/kg.

Effect of Moringa Leaf Powder and NPK Fertilizer Application on Plant Growth

Stand Establishment Count: The result of stand establishment count presented in Table 4 indicated that there was increase in stand establishment count in the combined treatment NPL+MLP (85.0) as compared to the control (79.0). However, this increase was not significant (P≥ 0.05).

Tiller Count: The results of tiller count presented in table 4 indicated that there was significant difference (P≤0.05) between the treatments with regards to tiller count. The values ranged from 1.0 to 5.0. NPK, MLP, and NPK + MLP recorded the highest mean tiller count, while CK recorded the least mean tiller count at 3 weeks after sowing.

Plant Height: The results of plant height presented in table 4 indicated that, there was significant ($P \leq 0.05$) difference in the plant height between the treatments. The combination of NPK+MLP had the highest mean plant height of 16.33 cm, and CK recorded the lowest mean of plant height of 8.70 cm at 3 weeks after sowing. Again, at 6 WAS, NPK+MLP had the highest of plant height of 41.24 cm, and CK recorded the lowest mean plant height of 15.53 cm. Also, NPK+MLP gave the highest plant height of 100.50 cm, and CK recorded the lowest plant height of 36.57 cm at 9 WAS.

Number of Leaves: The results presented in table 4 indicated that, there was significant ($P \leq 0.05$) difference in the number of leaves between the treatments observed. The combination of NPK+MLP has the highest mean number of leaves (7.0), and CK recorded the lowest number of leaves (2.0) at 3 weeks after sowing. This increase differed both at 6 and 9 WAS between the treatments.

Table 3: Effect of moringa leaf powder and NPK fertilizer application on selected chemical properties of soil after the experiment

Treatment	Soil pH	OC (g/kg)	TN (g/kg)	AP (g/kg)	Ca (cmol/kg)	Mg (cmol/kg)	Na (cmol/kg)	K (cmol/kg)	CEC (cmol/kg)
CK	6.10^{c}	4.33^{c}	0.36^{b}	0.42^{b}	0.45	0.65^{b}	0.13	0.04^{b}	4.07^{b}
NPK	6.13^{b}	4.60^{b}	0.47^{a}	0.46^{ab}	0.48	0.63^{b}	0.16	0.06^{ab}	4.60^{b}
MLP	6.13^{b}	4.67^{b}	0.48^{a}	0.54^{ab}	0.60	0.68^{b}	0.12	0.04^{b}	6.53^{a}
NPK+MLP	6.21^{a}	6.47^{a}	0.51^{a}	0.58^{a}	0.33	0.88^{a}	0.09	0.08^{a}	7.20^{a}
S.E±	0.02	0.54	0.20	0.03	0.06	0.04	0.01	0.01	0.41
P. Value	0.01	0.54	0.02	0.01	0.49	0.05	0.26	0.01	0.00
Significance	*	*	*	*	NS	*	NS	*	*

Mean in a column followed by similar letter (s) are not significantly different at 5% level of significance using least significant difference (LSD). * = Significant, NS = Not significant. CK= Control, NPK= NPK fertilizer, MLP= Moringa leaf powder, NPK + MLP= NPK fertilizer + Moringa leaf powder.

Table 4: Effect of moringa leaf powder and NPK fertilizer application on growth parameters of millet

Treatment	SEC	Tiller Count	Plant Height (cm)			Leaves Number		
	(2 WAS)	(3 WAS)	3 WAS	6 WAS	9 WAS	3 WAS	6 WAS	9 WAS
CK	79.0	1.0^{b}	8.70^{b}	15.53^{c}	36.57^{b}	2.0^{c}	5.0^{b}	6.0^{b}
NPK	85.0	4.0^{a}	11.33^{ab}	25.86^{bc}	63.56a^{b}	4.0^{b}	8.0^{a}	8.0^{ab}
MLP	83.0	5.0^{a}	13.33^{ab}	36.26^{ab}	81.25^{a}	6.0^{ab}	10.0^{a}	10.0^{ab}
NPK+MLP	85.0	5.0^{a}	16.33^{a}	41.24^{a}	100.50^{a}	7.0^{a}	9.00^{a}	11.0^{a}
S.E.±	2.20	0.58	1.08	3.53	8.70	0.47	0.62	0.44
P. Value	0.83	0.01	0.05	0.02	0.03	0.03	0.05	0.03
Significance	Ns	*	*	*	*	*	*	*

Mean in a column followed by similar letter (s) are not significantly different at 5% level of significance using least significant difference (LSD). * = Significant, ns = Not significant. CK= Control, NPK= NPK fertilizer, MLP= Moringa leaf powder, NPK + MLP= NPK fertilizer + Moringa leaf powder.

DISCUSSION

The result on the soil pH shows that there was an increase in pH at the different treatments. This indicated significant ($P \leq 0.05$) difference in the soil pH between the treatments. The mean values obtained for CK, NPK, MLP, and NPK+MLP were slightly acidic based on the rating of Esu (1991). This result agrees with the observation of Mengistu and Fekadu (2019), who reported that combined application of NPK fertilizer and Moringa leaf powder resulted in a higher increase in soil pH compared to the individual applications, indicating potential synergistic effects between these treatments. The values obtained for the soil organic carbon in CK, NPK, MLP, and NPK+MLP were low (<10) based on the rating by Esu (1991). The report in this study disagrees with the findings of Nguyen *et al.* (2018), who reported that the use of NPK fertilizer significantly decreased soil organic carbon (SOC) levels compared to the control (no fertilizer) and moringa leaf powder treatments. The lower values in the rating could be due to the high nitrogen content in NPK fertilizer, which may have led to increase in microbial decomposition of organic matter, resulting in a net loss of soil organic carbon (SOC). Despite the significant ($P \leq 0.05$) difference obtained in the values for the soil total nitrogen between the treatments. The values obtained for CK, NPK, MLP, and NPK+MLP were low based on the rating by Esu (1991). This is in conformity with the findings of Olatunji *et al.* (2012), who reported that combining NPK and Moringa leaf powder tends to increase soil nitrogen. Additionally, this could also be due to enhanced release and mineralization of nutrients from added organic amendment as well as the synergistic effect of the NPK on organic manure, as noted by Adeniyan and Ojeniyi (2005). Agber and Obi (2012) noted that organic matter (such as leaf and manure addition) contains a reasonable amount of N that will raise the productivity of the soil and increase the yield of crops. Similarly, Available phosphorus increased at different treatment compared to the control value, indicating significant ($P \leq 0.05$) difference between treatments, whereas the values obtained for all treatments were also low based on Esu's (1991) rating. This finding commemorates with the study conducted by Rai *et al*. (2019), who reported that the application of NPK+MLP significantly increased the available phosphorus in soil compared to the control treatment. There was an increase in exchangeable calcium in the MLP treatment as compared to the control, whereas applying NPK or NPK+MLP showed no significant ($P \geq 0.05$) difference among the treatment. Nevertheless, all values obtained by the treatments are low based on the standard rating (Esu 1991). Although, calcium is typically not limited in most agricultural soils due its widespread availability in most agricultural soils and many natural sources, such as limestone and gypsum, which are commonly used to adjust soil pH levels (Singh and Singh, 2019). For the exchangeable magnesium, an increase was found at different treatments. Despite the significant ($P \leq 0.05$) difference on the soil exchangeable magnesium, the values obtained by treatments were medium based on the Esu (1991) ratings. This aligns with the study conducted by Singh and Singh (2018), who reported that the use of NPK fertilizers and Moringa leaf powder can enhance magnesium availability and uptake by plants, leading to improved plant health and productivity. Exchangeable sodium in the NPK treatment increased as compared to the control and whereas application of MLP or NPK+MLP showed no significant difference ($P \geq 0.05$) among the treatments on soil exchangeable sodium. The values obtained by in all the treatments were medium based on the standard ratings (Esu 1991). This finding agrees with the study of Kutmanoglu and Yildirimoglu (2019), who reported that high sodium levels in soils can temper with the negative impacts on plant productivity and soil health. Exchangeable potassium was significant (P≤0.05) as influenced by different treatments compared to the value obtained before the experiment. NPK+MLP had the highest mean value, followed by NPK and CK having same mean value respectively. All the values obtained are low based on the standard rating (Esu 1991). The findings were in agreement with the work of Rai *et al.* (2019), who reported that NPK fertilizers and Moringa leaf powder increase available K in the soil compared to NPK fertilizers alone, indicating a synergistic effect between these sources on soil potassium availability. Similarly, significant (P≤0.05) difference was observed in cation exchange capacity as affected by different treatments compared to the initial value obtained before the experiment. NPK+MLP had the highest mean value, followed by NPK and MLP, and while CK had the least mean value. The values obtained fall within the low to medium fertility class (Esu 1991). Tropical soils, as described by Fitzpatrick (1980), are characterized by low to medium CEC values because of the abundance of kaolinite clay, which contributes barely to the CEC of the soils. The organic matter of the soil was also low and may have an effect on the overall CEC of the soil. (Brady and Weil, 1996).

The results on the growth parameters of the plant indicated that there was an increase in stand establishment count in the combined treatment NPL+MLP (85.0) as compared to the control (79.0). However, this increase was not significant (P≥ 0.05) between the treatments. This finding aligns with the study conducted by Oyebade *et al.* (2019), who reported that the number of stand establishment counts was not significantly different among the treatments which was likely due to the fact that millet is not highly responsive to nutrient inputs during the early stages of growth. Instead, nutrient requirements for millet are primarily met during the vegetative and reproductive stages, rather than during seedling establishment. As regard to the tiller count, all the treatments recorded highest mean with the exception of the control, recording the least mean tiller count at 6WAS. This is in conformity with the findings of Singh *et al.* (2017), who reported that both treatments (NPK and MLP) significantly increased the number of tillers per plant compared to the control (no fertilizer). Findings by ICRISAT (2005) also reported that tillering is very important in millet because crops are often grown at low plant populations under semi-arid conditions and can contribute 50 % of the total yield of millet under rain-fed conditions. Combined application of NPK+MLP had the highest plant height of 100.50 cm, and while CK recorded the lowest plant height of 36.57cm, both at 9WAS. This is in line with the study conducted by Sadiq *et al.* (2018), who reported that both NPK fertilizer and Moringa leaf powder significantly increased plant height. Similarly in the number of leaves, the combined application of NPK+MLP recorded the highest number of leaves (11), while CK recorded the lowest number (6) at 9WAS. This is in conformity with the findings of Oyebanjo and Olatunde (2018), where millet plants treated with both NPK fertilizer and Moringa leaf powder had significantly higher numbers of leaves compared to the control that received no fertilizer.

CONCLUSION

The combination of MLP and NPK significantly improved soil properties and plant growth parameters in millet cultivation. The results showed that the treatments led to significant increases in pH, total nitrogen, available phosphorus, exchangeable magnesium, exchangeable potassium, and cation exchange capacity compared to the control, as well as an increase in plant growth parameters such as plant height, number of tillers, and leaf number. However, the combined application of NPK+MLP showed better performance in respect to several parameters on growth and soil chemical properties compared to the sole application of fertilizer or moringa leaf powder alone.

Based on the findings in this research, farmers should consider incorporating NPK fertilizer and Moringa leaf powder as soil amendments in millet cultivation to improve soil properties and promote millet growth. Also, the optimal dosage and application methods for these treatments should be determined through further research to maximize their benefits while minimizing their costs.

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