Original Research Article

Effects of NPKS Granular and Briquette Fertilizers on Some Soil Chemical Properties and Yield Parameters of Maize (*Zea mays* L.)

Abstract

The primary objective of this multilocational study was to investigate the impact of NPKS granule and briquette fertilizers, on selected soil chemical propertiesand yield of maize.The treatments were made up of different rates of NPKS granules and briquette fertilizers namely: T1 (Control), T2 (Granule NPK 10- 20-20 (200 kgha^{-1}) + Granule Urea 217.2 kg/ha), T3 (Granule NPKS 10-20-20-3 (600 kg/ha) + Granule Urea 87 kg/haGrU), T4 (Granule NPKS 10-20-20-3 (400 kg/ha) + Granule Urea 87 kgha^{-1}GrU), T5 (Granule NPKS 10-20-20-3 (400 kg/ha) + No Urea), T6 (Briquette NPKS 10-20-20-3 (3 briquettes/hill) + Briquette Urea (2 briquettes/hill) and T7 (Briquette NPKS 10- 20-20-3 (3 briquettes/hill) + Briquette Urea (1 briquette/hill), were deployed in a randomized complete block design with four replications. Some soil chemical properties were assessed; pH, available phosphorus (P), exchangeable potassium (K), calcium (Ca), magnesium (Mg), cation exchange capacity (CEC), total nitrogen (N), and organic matter content. Findings revealed stable pH levels, low available P, and suboptimal exchangeable K levels in the soil, indicating that the treatment did not have any significant impact on the chemical properties of the soil. The cob length and cob diameter were significantly different ($P \leq 0.05$) among treatments compared with the control at only Atebubu. Total grain yield exhibited no significant differences ($P \geq 0.05$) among treatments at Atebubu and Nsapor respectively. Significant differences occurred in the 100-seed with T3 and T4 producing higher weights at both Atebubu and Nsapor. Although the differences were not statistically significant, these results indicate a potential positive effect of T3 and T5 on total grainyield (t/ha). The study highlights the influence of NPKS fertilizers in granule and briquette forms on soil chemical properties and maize yield, with the granules performing better than the briquette hence recommended.

Keywords: Inorganic fertilizer, NPK+S, Briquette, Granular, Maize, yield

1Introduction

Maize is an important cereal food crop of the world, and its consumption has risen tremendously, in recent years and millions of people around the world depend on it as an essential food (FAO, 2013). Maize is a good source of carbohydrates, vitamins A and B, protein, iron, and minerals when eaten as grain or as a snack or cereal. The demand for maize, especially white maize, is strong in Ghana and many other sub-Saharan African nations because of population growth and growing per capita consumption (FAOSTATS,2015). Furthermore, yellow maize has long served as the main feed source for the livestock sector, especially for poultry. Despite the numerous importance of maize, production of maize in terms of land size is high with low yield. This is because soils in Ghana are low in fertility.

Several reasons contribute to this underperformance, including soil nutrient deficits, soil physical restrictions, and poor crop management such as pest and disease control. Farming practices such as monocropping, unsuitable land use regimes, nutrient, and insufficient nitrogen supplies are thought to have further depleted the soil (Hengl *et al.*, 2017; Ebanyat *et al.*, 2018). It is important to apply external fertilizers to promote the growth and yield of crops, especially maize. Farmers in Ghana mostly apply granular inorganic fertilizer to their maize which is faced with the challenge of volatilization, leaching or runoffs. This has been a challenge for farmers for years and requires a solution for an increase in maize production and yield (Chen *et al.*, 2016).

The use of fertilizers either granular or briquette form is highly needed to replenish nutrients taken out from the soil by harvested crops and to supplement more nutrients to boost yield (Khojely et al., 2018). Fertilizer briquettes are made by compressing organic or inorganic fertilizers into a solid form and are designed to provide nutrients to plants while also being easy to transport and store (Sharna *et al.*, 2021; Bhattacharya and Singh, 2017). Unlike granular fertilizer, which can be messy and difficult to handle, briquettes can be easily transported in bags or containers and stored in a dry, cool place until they are needed. This makes them an ideal choice for farmers or gardeners who need to apply fertilizer to a large area (Kozicki, 2022). Another advantage of fertilizer briquettes is that they release nutrients slowly over time (Chen *et al.*, 2016). When a briquette is applied to soil, it gradually breaks down and releases nutrients into the soil, providing a steady source of nutrients to plants over an extended period. This slow release also helps to prevent the fertilizer from leaching out of the soil and into nearby water sources, which can be harmful to the environment. Rice yields were increased by 25 % to 50 % with the application of the fertilizer briquette compared with commercial granular fertilizer in Vietnam and Cambodia (IFDC, 2007). In Bangladesh, the rice yield was enhanced by 25–35 %, while expenditure on commercial fertilizer was decreased by 24–32 % when the fertilizer briquette was used (Gaihre *et al.*, 2017; Huda *et al.*, 2016). The improved N-use efficiency with the fertilizer briquette indicates lower N losses to water bodies and the atmosphere through leaching and volatilization (Gaihre *et al.*, 2015). In comparison to the split application of granular fertilizer sources, Adu-Gyamfi *et al.* (2019) revealed that maize plants cultivated in Ghana's Savanna agroecological zones recovered N 77 per cent of the applied fertilizer to boost maize production by N 30 per cent with the use of fertilizer briquettes.Understanding the differential effects of these fertilizer forms on soil chemical properties, as well as maize yield, is vital for developing sustainable and efficient fertilizer management strategies. By addressing these research gaps, this study aims to provide valuable insights and practical recommendations to enhance agricultural productivity and ensure sustainable crop production systems. There is a need for the cultivation of maize with high yield and sustainable soil nutrient. This study seeks to examine the effect of NPKS granules and briquette on maize yield and soil chemical properties.

2Materials and methods

2.1Description of Study Areas

The multilocational experiment was conducted at Atebubu and Nsapor during the major rainy season from April to August 2022. Atebubu, situated in the central woodland savanna of the Bono East Region, underwent ecological transitions attributed to human activities like charcoal manufacture and annual bushfires. The municipality shares boundaries with neighbouring districts, further complicating its environmental dynamics. Atebubu's soil composition ranges from fine sandy loams to clayey loams, posing drainage challenges.The soil at Atebubu experimental site has been classified by FAO (2013) legend as EutricNitosol. The climate, a modified wet semi-equatorial type, displays two rainy seasons with annual rainfall ranging between 1.400 mm to 1.800 mm.

The second experimental site, Nsapor-Berekum, located in the Guinea savanna zone of the Bono Region, presents a mix of trees and grasses. Nsapor sandy clay soil, though fertile, is susceptible to erosion. The soil at Nsapor experimental site has been classified by FAO (2013) legend as Rhodic Ferralsol. The climate is characterized by distinct wet (April to October) and dry (November to March) seasons, with annual rainfall ranging from 900 mm to 1.200 mm.

Vegetation in Atebubu falls within the interior wooded savannah, heavily influenced by historical human activities. In contrast, the Nsapor Guinea savanna zone supports a diverse ecosystem with tall grasses, and scattered trees like shea, dawadawa, and baobab, along with staple crops like maize, yam, cassava, and groundnuts.

Climate-wise, Atebubu experiences a tropical continental or interior savanna climate with two rainy seasons and an annual rainfall between 1.400 mm to 1.800 mm. Nsapor climate is a tropical savanna, featuring distinct wet and dry seasons with an average rainfall of 1.200 to 1.500 mm during the rainy season and little to no rainfall in the dry season.

2.2Land preparation, Field layout and Fertilization

The land was prepared by clearing the weeds and removal of stumps followed immediately by lining and pegging to prepare the plots for sowing of maize seeds.

The experimental field was then divided into four (4) blocks; each block measured 41 m x 5m with a spacing of 2 m between blocks and 1.0 m spacing between plots of each block. The total field area was 41 m x 26 m (1066 m^2).

The NPKSgranular and briquette fertilizers were applied according to treatment and rate to each plot three (3) weeks after planting. The NPKS granule fertilizers were applied using the side placement method whereas theNPKS briquettes fertilizers were applied one and two briquettes per hill using a dibber and a hand fork.Urea was also applied seven weeks after planting using the side placement method and according to the rate specified.

2.3Planting

Each experimental plot had plant spacing of 40cm within rows and 75 cm between rows. The maize variety known as Sanzal Sima was obtained from the International Fertilizer Development Centre (IFDC). Three (3) seeds were sown per hill and later thinned to two (2) seedlings per hole.

2.4Soil sampling and Analysis

A total of 28 undisturbed soil samples were taken from each plot with a core sampler of 5 cm internal diameter and a height of 10 cm from each plot. These samples were used for the determination of bulk density, total porosity, and particle density. Other disturbed soil samples were also collected randomly from 0 - 20 cm soil depth on each plot for the determination of particle size and chemical properties.

2.5Some soil parameters measured

Soil pH

Soil pH was determined using a pH glass electrometer. Ten grams (10 g) of the soil sample was weighed into a 50 ml beaker and 25 ml of distilled water (1:2.5 soil: water) was added. The solid-liquid mixture was then stirred several times for 30 min and allowed to stand for the suspended clay to settle out. Using a standard solution of pH 4.0 and 7.0, the pH meter was standardized. The standardized electrode was then inserted into the supernatant of the suspension to measure the pH of the soil sample.

Organic carbon determination

The wet combustion method of Walkley and Black (1934) was used to determine the organic carbon content of the soil. Ten millimetres of 0.167 M potassium dichromate ($K_2Cr_2O_7$) solution and 20 ml concentrated sulphuric acid (H_2SO_4) were added to a 1g soil sample (which had been sieved through a 0.5 mm sieve) in an Erlenmeyer flask. The flask was then swirled to ensure full contact of the soil with the solution after which it was allowed to stand for 30 mins. The unreduced $K_2Cr_2O_7$ remaining in the solution after the oxidation of the oxidizable organic material in the soil sample was titrated against 0.2 N ferrous ammonium sulfate solution after adding 5 ml of orthophosphoric acid and 2 ml of barium diphenylamine sulfate indicator.

$$\% \textbf{ Organic Carbon } = \frac{(\textbf{Blank} - \textbf{ titre value})\textbf{ x 1.33 x 0.003x 100}}{\textbf{weight of soil}(\textbf{g})} \qquad \textbf{(1)}$$

Carbon = 58 % of organic matter. Therefore, organic matter is determined by;

$$\boldsymbol{OM} = \frac{\textbf{Carbon x 100}}{\textbf{58}} \qquad \textbf{(2)}$$

Total P determination in soil

Total P was determined by digesting 2 g of sieved soil with 25 ml of a mixture of concentrated HNO_3 and 60 % $HClO_4$ prepared in a ratio of 2:3. The solution was heated on a digestion rack until the solution became colourless. The digest was cooled, diluted, and filtered through a Whatman filter paper No. 42 into a 250 ml volumetric flask and made to cool. Phosphorus in the filtrate was determined using the molybdate-ascorbic acid method of Watanabe and Olsen (1965). Suitable aliquots of the filtrate were taken (in duplicate) into 50 ml volumetric flasks containing distilled water. The pH was adjusted using a P-nitrophenol indicator and neutralized with a few drops of 4 M ammonium hydroxide (NH_4OH) until the solution turned yellow. The solution was diluted to about 40 ml with distilled water after which 8 ml of reagent B was added and made to volume with more distilled water. The solution was mixed thoroughly by shaking and allowed to stand for 15 minutes for the colour to stabilize. A blank was prepared with distilled water and 8 ml of reagent B. The method was calibrated using a 25 mg/L standard P solution in the same manner as above. The intensity of the blue colour was measured using the Philips PU 8620 spectrophotometer at a wavelength of 712 nm. P was calculated using the formula:

$$\mathbf{P} = \frac{(\mathbf{Sp.Reading} - \mathbf{Blank}) \times \mathbf{Vol.of\ extractant}}{\mathbf{Vol.of\ aliquot} \times \mathbf{weight\ of\ soil}} \tag{3}$$

Total nitrogen determination

Half of a gram (0.5 g) of air-dried soil was weighed into a 250 ml Kjeldahl flask and a tablet of digestion accelerator, selenium catalyst, was added followed by 5 ml of concentrated H_2SO_4. The mixture was digested until the digest became clear. The flask was then cooled, and its content was transferred into a 100 ml volumetric flask with distilled water and quantitatively made up to volume. A 5 ml aliquot of the digest was taken into a Markham distillation apparatus. Five ml of 40 % NaOH solution was added to the aliquot and the mixture was distilled. The distillate was collected in 5 ml of 2 % boric acid. Three drops of a mixed indicator containing methyl red and methylene blue were added to the distillate in a 50 ml Erlenmeyer flask and then titrated against 0.01M HCl acid solution (Bremner, 1965). The % nitrogen was calculated as:

$$\%\mathbf{N} = \frac{\mathbf{Molarity\ of\ HCl\ x\ Titre\ value} \times \mathbf{0.014} \times \mathbf{volume\ of\ extractant}}{\mathbf{Weight\ of\ soil\ sample\ x\ volume\ of\ aliquot}} \times \mathbf{100} \tag{4}$$

where 0.014 = milliequivalent of nitrogen

Available P determination

Soil-available phosphorus was determined using the Bray P1 method (Olsen and Sommers, 1982). Two grams of air-dried soil was weighed into a 50 ml shaking bottle. Twenty millilitres (20) ml of Bray^{-1} solution was added as an extracting agent and the mixture was shaken for ten minutes and then filtered through Whatman No. 42 filter paper. Ten millilitres (10 ml) of the filtrate were pipetted into a 25 ml volumetric flask and 1 ml each of molybdate reagent and reducing agent was added for colour development. The absorbance was measured at 660nm wavelength on a spectronic 21D spectrophotometer. The concentration of P was obtained from a standard curve.

$$\boldsymbol{P}\left(\frac{\mathbf{mg}}{\boldsymbol{kg}}\right)=\frac{(\mathbf{a}-\mathbf{b})\times\ \mathbf{20}\times\mathbf{10}\times\boldsymbol{mcf}}{\boldsymbol{w}} \qquad \textbf{(5)}$$

Where: a= mg/1 P in sample extract, b = mg/l P in blank, w = sample weight in gram,mcf = moisture correction factor, 20 = volume of extracting solution, 10 = finalvolume of sample solution.

Determination of available potassium (K)

The flame photometric method by the Soil Science Society of Ghana (2009) was used. Appropriate aliquots of standard samples digest and blank were taken. K-emission in an air-propane flame at 768 nm wavelength was measured. The concentration of K was calculated as:

$$\%\boldsymbol{K}=\frac{(\mathbf{a}-\mathbf{b})\times\boldsymbol{m}}{\boldsymbol{factor}} \qquad \textbf{(6)}$$

Where a = measured mgK/ ml in samples, b = measured mgK/ml in blank, m = moisture correction factor, $factor=\frac{200}{\text{Dilute factor}}$

Cation exchange capacity

Weigh 2.5 g of soil into an extraction bottle. 40 ml of 1.0 M ammonium acetate solution at pH 7.0 was added to the soil in the extraction bottle. The contents were shaken in a tabletop shaker at 180 RPM for 5 minutes to ensure thorough mixing and exchange of cations between the soil and the ammonium ions in the solution. Then, the mixture was poured into leachate tubes.

The leachate tubes were arranged in a centrifuge machine and centrifuged for 5 minutes at 4000 RPM. This step is to separate the soil particles from the solution. The supernatant (liquid) was carefully removed from the tubes, leaving the soil particles at the bottom. Any non-adsorbed

NH4+ ions were washed off by adding and washing with methanol. This step ensures that only cations held by the soil's cation exchange sites are considered for CEC determination. After washing, the NH4+-saturated soil was leached four times with acidified 1.0 M KCl. This step replaces the adsorbed ammonium ions with potassium ions from the KCl solution. Collect the KCl filtrate after each leaching step.

The Ammonium ion concentration (mol/L) in the KCl filtrate was measured using an ELIT 9808 ion analyzer. The CEC of the soil was calculated in cmol/kg based on the ammonium ion concentration in the KCl filtrate and the amount of soil used in the extraction bottle. The formula for calculating CEC can be expressed as:

$$\boldsymbol{CEC = \frac{(C1 - C2) \times V \times 1000}{w}} \quad \textbf{(7)}$$

Where:

CEC is the cation exchange capacity in cmol/kg.C1 is the initial concentration of ammonium ions in the ammonium acetate solution before it comes into contact with the soil (mol/L).C2 is the final concentration of ammonium ions in the KCl filtrate after leaching with 1.0 M KCl (mol/L).V is the volume of KCl filtrate used (L).W is the weight of the soil sample used (kg).

Exchangeable bases

Ten grams of the soil sample were weighed into a 200 ml centrifuge tube and 100 ml of 1 N neutral ammonium acetate (NH_4OAc at pH 7.0) solution was added. The suspension was shaken for 1 hour and filtered through a Whatman No. 42 filter paper. Suitable aliquots of the extract were used for the determination of exchangeable cations.

Exchangeable calcium and magnesium

An aliquot of 10 ml of the extract was taken into a conical flask and 10 ml of 10 % KOH and 1 ml of methylamine were added. Three drops of KCN solution and a few crystals of Cal-red indicator were added. The mixture was then titrated with 0.2 N EDTA using Eriochrome Black T (EBT) as an indicator.

Exchangeable Magnesium (Mg^{2+})

Ten ml of the extract was transferred into a conical flask and titrated with EDTA using Cal-red as an indicator. Exchangeable Mg was estimated by difference. Exchangeable potassium and sodium were determined by flame photometry.

Exchangeable acidity

Twenty-five ml of 1 M KCl was added to 10 g of soil sample in a 250 ml conical flask. The content was mixed by swirling and then allowed to stand for 30 min. The suspension was filtered through a Whatman No. 42 filter paper into a volumetric flask. The soil was consecutively leached with five (batches of 25 ml 1 M KCl to a total volume of about 150 ml. Four drops of phenolphthalein were added to the leachate and titrated against 0.1M NaOH to the first permanent pink endpoint. Potassium chloride extractable exchangeable acidity was calculated C mol kg^{-1}KCl acidity = (ml NaOH sample - ml NaOH blank) x M x 100 / Sample weight) where M is the Molarity of NaOH. For the estimation of Al^{3+} and H^{+}, the titre for NaOH was recorded; 10 ml NaF was added to the NaOH and titrated with 0.1M HCl until the pink colour disappeared. The solution was then allowed to stand for about 30 min and additional HCl was added to the clear endpoint (Thomas, 1982).

2.6Yield Parameters of Maize Measured

The following parameters were also measured; cob diameter and length per plot, dry 100-seed weight per plot, and grain yield per plot.

Cob length and diameter

The cobs of the five tagged plants were measured for their length with a metre rule and recorded.

100-seed weight

A hundred seeds were taken from each plot was weighed with an electronic weighing scale and recorded.

Grain yield per plot

Grains from each plot were removed by manual means and sun-dried to constant moisture. The dried grains were then weighed with an electronic weighing scale and their grain yields per plot were estimated.

2.7Experimental Design and Treatment

The experimental design used for the two studies was Randomized Complete Block Design (RCBD), each having seven treatments. Each treatment was replicated four times. The treatments used for the study were:

T1	No Fertilizer (Control)
T2	Granule NPK 10-20-20 (200 kg/ha) + Granule Urea 217.2 kg/ha
T3	Granule NPKS 10-20-20-3 (600 kg/ha) + Granule Urea 87 kg/haGrU
T4	Granule NPKS 10- 0-20-3 (400 kg/ha) + Granule Urea 87 kg/haGrU
T5	Granule NPKS 10-20-20-3 (400 kg/ha) + No Urea
T6	Briquette NPKS 10-20-20-3 (3 briquettes/hill) + Briquette Urea (2 briquettes/hill)
T7	Briquette NPKS 10-20-20-3 (3 briquettes/hill) + Briquette Urea (1 briquette/hill)

2.8Planting material

The planting material used for the study was the Sanzal sima maize which was obtained from the International Fertilizer Development Center (IFDC). The Sanzal sima maize variety is white and was chosen because it is resistant to most maize diseases, drought tolerant, adapted to local growing conditions and matures within 110 days after planting.

2.9Data Collection

The total number of plants from the 3 m x 3 m area within the four central rows per plot was harvested. Cobs were shelled after harvesting and grains were sun-dried to a constant moisture content of 10 ^{o}C.The dried grains were then weighed with an electronic weighing scale and the grain weight per plot was estimated in kilogram per hectare. Grain yield was estimated from forty plants from the two middle rows per plot. Cobs were shelled after harvesting and grains were sun-dried to a constant moisture content of 14 ^{o}C. The dried grains were then weighed with an electronic weighing scale and the grain yield was estimated in tons per hectare.

3Results

3.1Effect of Amendments on Soil Chemical Property

The initial soil chemical properties provided valuable insights into the nutrient status and characteristics of the soil at the two locations, Atebubu and Nsapor as shown in Table 2**Error! Reference source not found.**. The pH values were slightly acidic, with both Atebubuand Nsaporhaving an initial pH of 6.2 compared. Total nitrogen (N) was low (0.1) at both locations. The available phosphorus (P) levels were low (8.0 ppm) in both locations, and the exchangeable potassium (K) levels were also low (0.2) at Atebubuand Nsapor. Calcium andmagnesium levels were generally low, highlighting potential deficiencies in these nutrients.

After harvest, the amended plots showed an increase in some nutrient levels and a decrease in some while some remained the same as compared with the control treatment (Table 2).The pH of the treatment remained slightly acidic and moderately acidic in T4 across both locations. Total nitrogen remained the same throughout the treatments except T7 which recorded a higher total nitrogen of 0.2%.Available P levels have increased across all treatments and locations except T6 which recordsthe lowest phosphorus level of 7.3 ppm, indicating that the fertilizer treatments did not greatly impact the phosphorus availability of that treatment. Exchangeable K levels varied but did not show consistent patterns across treatments. However, it is noteworthy that granule NPK and briquette NPKS treatments generally resulted in slightly higher exchangeable K levels compared to the control.

Base saturation, Exchangeable Acid (H + Al), Calcium, and magnesium levels did not show substantial changes after the application of fertilizer treatments. The cation exchange capacity (CEC) values were relatively consistent across treatments and locations, with slight increases observed in the fertilized treatments compared to the control except for T4 which recorded less

CEC compared with the initial record.Organic matter content did not show significant differences among the treatments.

Table 1: Final Soil Chemical Properties at Atebubu and Nsapor

	Initial		**T1**		**T2**		**T3**		**T4**		**T5**		**T6**		**T7**	
	Ateb	**Nsap**	**Ateb**	**Nsap**	**Ateb**	**Nsap**	**Ateb**	**Nsap**	**Ateb**	**Nsap**	**Ateb**	**Nsap**	**Ateb**	**Nsap**	**Ateb**	**Nsap**
pH	6.2	6.2	6.3	6.3	6.3	6.3	6.3	6.3	5.8	5.8	6.3	6.3	6.3	6.3	6.4	6.4
% TN	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2
% OC	0.6	0.6	1.0	1.0	0.8	0.8	0.2	0.2	0.6	0.6	0.7	0.7	0.9	0.9	2.2	2.2
% OM	1.1	1.1	1.8	1.8	1.4	1.4	0.4	0.4	1.1	1.1	1.2	1.2	1.5	1.5	3.7	3.7
P ppm	8.0	8.0	11.5	11.5	17.7	17.7	17.1	17.1	15.1	15.1	9.5	9.5	7.3	7.3	10.0	10.0
Ca cmol/kg	3.4	3.4	3.4	3.4	3.4	3.4	3.6	3.6	1.9	1.9	3.0	3.0	3.9	3.9	3.9	3.9
Mg cmol/kg	1.7	1.7	1.7	1.7	2.1	2.1	1.5	1.5	1.5	1.5	1.9	1.9	1.7	1.7	1.7	1.7
K cmol/kg	0.2	0.2	0.3	0.3	0.4	0.4	0.2	0.2	0.4	0.4	0.3	0.3	0.3	0.3	0.2	0.2
Na cmol/kg	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TEB cmol/kg	5.4	5.4	5.5	5.5	5.9	5.9	5.3	5.3	3.9	3.9	5.3	5.3	5.8	5.8	5.8	5.8
Ex. Acid (H + Al)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.3	0.3	0.1	0.1	0.1	0.1	0.1	0.1
ECEC	5.5	5.5	5.6	5.6	6.0	6.0	5.4	5.4	4.1	4.1	5.4	5.4	5.9	5.9	5.9	5.9
% B.S	98.2	98.2	98.2	98.2	98.3	98.3	98.2	98.2	93.9	93.9	98.1	98.1	98.3	98.3	98.3	98.3

3.2Yield and yield components of maize

Cob length

From table 2, there was a significant difference ($P \leq 0.05$) in cob length at Atebubu but there is no significant difference ($P \geq 0.05$) at Nsapor. Granule NPKS 10-20-20-3 (400 kg/ha) + Granule Urea 217 g/plot recorded the longest cob length, followed by Granule NPKS 10-20-20-3 (400 kg/ha) + No Urea. The Control recorded the shortest cobs length. The means with the same letters are not significantly different from each other ($P \leq 0.05$).

Cob diameter

From **Error! Reference source not found.**, there was a significant difference ($P \leq 0.05$) in cob diameter at Atebubu but there is no significant difference ($P \geq 0.05$) at Nsapor. At Atebubu, Granule NPKS 10-20-20-3 (400 kg/ha) + Granule Urea 217 g/plot recorded the highest cob diameter, followed by Granule NPKS 10-20-20-3 (400 kg/ha) + No Urea. The Control recorded the shortest cobs diameter. The means with the same letters are not significantly different from each other ($P \leq 0.05$).

Table 2: Effect of NPKS fertilizer granules and briquettes on Cob length and Cob diameter

Treatment	Cob length(cm)		Cob diameter(cm)	
	Atebubu	Nsapor	Atebubu	Nsapor
No Fertilizer (Control)	11.18 b	12.55	4.06 b	4.53
Gr (10-20-20 NPK) 200 kg/ha + 217.2kg/haU	13.55 ab	12.53	4.42 a	4.63
Gr (10-20-20-3 NPKS) 600 kg/ha+ 87kg/haU	14.35 a	13.03	4.45 a	4.71
Gr (10-20-20-3 NPKS) 400 kg/ha+ 87kg/haU	14.58 a	12.95	4.53 a	4.72
Gr (10-20-20-3 NPKS) 400 kg/ha+ No Urea	14.55 a	12.50	4.52 a	4.61
Briq (10-20-20-3 NPKS) 3briq + 2briqU	14.03 a	13.53	4.34 ab	4.72
Briq (10-20-20-3 NPKS) 3briq + 1briqU	12.85 ab	12.75	4.37 ab	4.41
HSD ($P \leq 0.05$)	**2.8**	**NS**	**0.32**	**NS**
CV (%)	**8.84**	**6.03**	**3.17**	**3.89**

100 seed weight

From table 3, there was a significant difference ($P \leq 0.05$) in the 100 seed weights at Atebubu and Nsapor. Granule NPKS 10-20-20-3 (400 kg/ha) + Granule Urea 217 g/plot recording the highest weight in Atebubu while Granule NPKS 10-20-20-3 (1500 g/plot) + Granule Urea 217 g/plot recorded the highest in Nsapor. The Control recorded the lowest 100 seed weight in both locations. Means with the same letters are not significantly different from each other ($P\leq0.05$).

Yield (t/ha)

From Table 3, there was no significant difference ($P \geq 0.05$) in the yield (t/ha) at Atebubu and Nsapor. Granule NPKS 10-20-20-3 (1500 g/plot) + Granule Urea 217 g/plot recording the highest weight in Atebubu while Granule NPKS 10-20-20-3 (400 kg/ha) + No Urea recorded the highest in Nsapor. The control recorded the lowest yieldat both locations. Means with the same letters are not significantly different from each other ($P\leq0.05$).

Table 3: Effect of NPKS fertilizer granules and briquettes on 100 seed weight and yield (t/ha) at Atebubu and Nsapor.

Treatment	100-seed weight (g)		Yield(t/ha)	
	Atebubu	Nsapor	Atebubu	Nsapor
No Fertilizer (Control)	28.75 c	29.25 b	1.65	1.91
Gr (10-20-20 NPK) 200 kg/ha + 217.2kg/haU	29.50 bc	29.75 ab	1.93	2.21
Gr (10-20-20-3 NPKS) 600 kg/ha+ 87kg/haU	30.25 ab	31.25 a	2.38	2.08
Gr (10-20-20-3 NPKS) 400 kg/ha+ 87kg/haU	31.00 a	30.00 ab	2.10	2.01
Gr (10-20-20-3 NPKS) 400 kg/ha+ No Urea	30.75 ab	30.25 ab	2.30	2.31
Briq (10-20-20-3 NPKS) 3briq + 2briqU	30.50 ab	30.00 ab	2.10	2.13
Briq (10 20-20-3 NPKS) 3briq + 1briqU	29.50 bc	30.75 ab	1.65	1.96
HSD ($P \leq 0.05$)	**1.38**	**1.76**	**NS**	**NS**
CV (%)	**1.97**	**2.5**	**18.82**	**15.59**

4Discussion

In this study, the effects of different NPK+S fertilizer treatments, including granule and briquette forms, on some soil chemical properties, and the yield of maize were investigated. The initial soil chemical properties were evaluated before planting, and the soil properties were reassessed after the harvest for each treatment.

Effects of Fertilizer Treatments on Soil Chemical Properties

After the harvest, the fertilizer treatments did not significantly alter the pH values compared to the control treatment but rather decreased in T4. The pH of most treatments has slightly increased. However, it is important to note that the pH values for most treatments were slightly below the optimal range for most crops, indicating a slightly acidic soil environment. Adjustments in soil management practices, such as lime application, may be necessary to optimize pH levels for improved crop growth and nutrient availability.

This is not in agreement with Agegnehu et al. (2016) and Liu et al. (2010) who reported that the application of mineral fertilizers decreased soil pH.

There was no significant difference in residual soil NPKS and concentrations among the treatments in either location (Table 1). This suggests that most of the granular NPKS applied at high rates that were not taken up by the plants did not accumulate in the soil; instead, it was lost from the soil, possibly through leaching and/or surface runoff. In the case of briquettes, they are probably not dissolved on time for plant uptake. The soil at the Nsapor experimental site was sandy-loam and with low organic matter content (Table 1), therefore the propensity of NPKS leaching from the soil was high and could account for a large portion of NPKS losses from the soil, considering locational differences and the form of NPKS fertilizer(Table 1).

Considering the crop to be grown, which is maize, these initial soil chemical properties can have significant impacts on maize crop growth and yield. Low levels of available phosphorus along with acidic soil conditions, can limit maize growth and productivity. However, the high levels of calcium and iron in Atebubu soil may favour maize growth and yield, while the high CEC in Atebubuhas helped retain nutrients in the soil.

The available phosphorus (P) content in the soil after harvesthas increased ranging from 7.3-17.7 ppm. This suggests that the application of different fertilizer formulations substantially increase the availability of phosphorus in the soil across all treatment which helps the crop in photosynthesis and general growth and yield.

The exchangeable potassium (K) levels in the soil were consistent across all treatments. This indicates a deficiency of available potassium, which is an essential nutrient for plant growth and development. The results highlight the need for targeted potassium supplementation through the use of potassium-rich fertilizers or potassium-specific soil amendments to overcome this limitation and promote optimal crop performance.

These concentrations suggest that the soil provided sufficient iron and magnesium to meet the nutrient requirements of the maize crop.

The total nitrogen (N) content in the soil varied among treatments, ranging from 0.05 % to 0.09 % (Table 1). These levels suggest that the different fertilizer treatments had a variable impact on the soil's nitrogen content. The treatment involving the briquette formulation with 0.2 % total nitrogen showed the highest concentration, indicating successful nitrogen retention. This highlights the effectiveness of the briquette formulation in providing a sustained release of nitrogen over time.

The increase in organic carbon (% OC) and organic matter (% OM) in both locations, notably in treatments T2, T4, T6, and T7, is of significant importance. Organic carbon and organic matter are essential components that contribute to soil structure, water retention, and nutrient cycling. The positive trend in these parameters suggests that these specific treatments have enhanced the organic content of the soil, potentially improving soil fertility and resilience.

The cation concentrations (Ca, Mg, K, Na cmol/kg) provide insights into the soil's nutrient status and its ability to support plant growth. The diverse responses to treatments underscore the importance of considering multiple nutrient elements in agricultural management practices. Understanding the dynamics of cation exchange capacity (TEB cmol/kg) further elucidates the soil's capacity to retain essential nutrients, contributing to the broader picture of soil fertility.

The data on exchangeable acidity (Ex. Acid) and effective cation exchange capacity (ECEC) offer information about the soil's buffering capacity and its ability to resist changes in pH. Stable exchangeable acidity levels suggest that the treatments have not induced significant alterations in soil acidity. The variations in ECEC highlight the complex interplay of soil components and treatment effects on the soil's overall nutrient-holding capacity.

The high and consistent base saturation levels (% B.S) in both locations indicate a predominantly stable proportion of exchangeable bases in the soil. Maintaining an optimal base saturation is critical for ensuring the availability of essential nutrients. The data underscores the importance of monitoring base saturation as part of a comprehensive soil fertility management strategy.

Effects of Fertilizer Treatments on Yield Parameters

Significant differences were observed in cob length at Atebubu, indicating that the various NPKS fertilizer treatments had an impact on this parameter. However, no significant difference was found at Nsapor. The treatments with Granule NPKS 10-20-20-3 (1500 g/plot) + Granule Urea 217 g/plot and Granule NPKS 10-20-20-3 (1000 g/plot) + No Urea resulted in longer cob lengths compared to the control treatment. These findings suggest that these treatments have provided enough nutrients for plant growth and storage of sugar.

Similar to cob length, significant differences were observed in cob diameter at Atebubu but not at Nsapor. The treatments with Granule NPKS 10-20-20-3 (1500 g/plot) + Granule Urea 217 g/plot and Granule NPKS 10-20-20-3 (500g/plot) + Granule Urea 543g/plot resulted in larger cob diameters compared to the control treatment. These results indicate that the fertilizer combinations above have the potential to enhance cob diameter.

Significant differences were found in the 100 seed weights at both Atebubu and Nsapor, indicating that the fertilizer treatments influenced seed weight. The treatments with Granule NPKS 10-20-20-3 (1000 g/plot) + Granule Urea 217 g/plot and Granule NPKS 10-20-20-3 (1500 g/plot) + Granule Urea 217 g/plot resulted in higher 100 seed weights compared to the control treatment. These findings suggest that the fertilizer treatments had a positive impact on seed development and weight at both locations which agrees with Adu-Gyamfi, et al. (2019), who found out that one-time application of multi-nutrient fertilizer briquettes increased maize seed weight and grain yields.

No significant difference was observed in the yield at both Atebubu and Nsapor. However, the treatments with Granule NPKS 10-20-20-3 (1500 g/plot) + Granule Urea 217 g/plot and Granule NPKS 10-20-20-3 (1000 g/plot) + No Urea resulted in relatively higher yield compared to the control treatment. Although the differences were not statistically significant, these results indicate a potential positive effect of Granule NPKS 10-20-20-3 (1500 g/plot) + Granule Urea 217 g/plot and Granule NPKS 10-20-20-3 (1000 g/plot) + No Urea on total grain yield.

5Conclusions

The results of this study suggest that the applied granule and briquette NPKS fertilizer treatments had limited effects on the chemical properties. The changes observed in pH, available P, exchangeable K, calcium, magnesium, boron, copper levels were minimal which indicates that the crop utilized the nutrients, and some could be lost through leaching and run-offs in the case of the granule. The briquettes on the other hand might not be readily available at critical stages for the plant since they could not easily break down. The briquettes have a smaller surface area for soil adsorption and root uptake.

It is recommended to conduct long-term studies to observe the potential cumulative effects of fertilizer treatments on soil properties and crop productivity. These may include planting on the land after harvest to observe the long-term effect of the briquettes.

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