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

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Authors' contributions

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

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ABSTRACT

The primary objective of this multilocational study was to investigate the impact of NPKS granule and briquette fertilizers, on selected soil chemical properties and 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 kg ha^{-1}) + Granule Urea 217.2 kg ha^{-1}), T3 (Granule NPKS 10- 20-20-3 (600 kg ha^{-1}) + Granule Urea 87 kg ha^{-1} GrU), T4 (Granule NPKS 10- 20-20-3 (400 kg ha^{-1}) +

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Granule Urea 87 kg ha^{-1} GrU), T5 (Granule NPKS 10- 20-20-3 (400 kg ha^{-1}) + 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 application of Granular NPKS 10- 20-20-3 (400 kg ha^{-1}) + Granular Urea 87 kg ha^{-1} GrU) to maize produced significantly higher cob length and cob diameter 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 Nsapor and Atebubu respectively. Although the differences between treatments were not statistically significant, the result indicate a potential positive effect of T3 and T5 on grain yield (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.

1. INTRODUCTION

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 [1]. 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 [2]. 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 [3]. Farming practices such as monocropping, unsuitable land use regimes, nutrient, and insufficient nitrogen supplies are thought to have further depleted the soil [4]. 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 [5].

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 [6]. 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 [7,8]. 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 [9]. Another advantage of fertilizer briquettes is that they release nutrients slowly over time [5]. 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 [10]. 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 [11,12]. The improved N-use efficiency with the fertilizer briquette indicates lower N losses to water bodies and the atmosphere through leaching and volatilization [13]. In comparison to the split application of granular fertilizer sources, Adu-Gyamfi et al. [14] revealed that maize plants cultivated in Ghana's Savanna agroecological zones recovered N 77 percent 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 in combination with or without urea at different rates on maize yield and soil chemical properties.

2. MATERIALS AND METHODS

2.1 Description 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 neighboring 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 [1] legend as Eutric Nitosol. 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 experiment was conducted at Nsapor, a suburb of Berekum municipality of the Bono Region of Ghana. The major vegetation type is semi deciduous woodland with forested savannah in the municipality's northern and eastern corners. Nsapor agroecology supports a diverse ecosystem with tall grasses, and scattered trees like Shea (*Vitellaria paradoxa)*, African locust bean (*Parkia biglobosa*) and Baobab (*Adansonia digitata*), along with staple crops like Maize (*Zea mays*), Yam (*Dioscorea spp*.), Cassava (*Manihot esculenta*), and Groundnuts (*Arachis hypogaea*).

The soil at Nsapor is sandy clay, though fertile, is susceptible to erosion. The soil at Nsapor experimental site has been classified by FAO [1] legend as Rhodic Ferralsol. The area has a bimodal rainfall pattern characterized by major (April to July) and minor (September to November) rainy season, with annual rainfall ranging from 900 mm to 1200 mm. A four-month dry spell period between December and March is experienced.

Vegetation in Atebubu falls within the interior wooded savannah, heavily influenced by historical human activities.
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.

2.2 Soil 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 NPKS granular and briquette fertilizers were applied according to treatment and rate to each plot three (3) weeks after planting. The NPKS granular fertilizers were applied using the side placement method whereas the NPKS 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.

2.3 Soil 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.

2.4 Measured Soil Parameters

2.4.1 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.

2.4.2 Organic carbon determination

The wet combustion method of Walkley and Black [16] was used to determine the organic carbon content of the soil. Ten millilitres of 0.167 M potassium dichromate (K2Cr2O7) 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 K2Cr2O7 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.

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

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

$$OM = \frac{\text{Carbon x } 100}{58} \quad (2)$$

2.4.3 Total P determination in soil

Total P was determined by digesting 2 g of sieved soil with 25 mL of a mixture of concentrated HNO3 and 60% HClO4 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 [17]. 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 (NH4OH) 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:

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

2.4.4 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 H2SO4. 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 [18]. The % nitrogen was calculated as:

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

where

0.014 = milliequivalent of nitrogen

2.4.5 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.

$$P\ (\frac{\mathrm{mg}}{kg}) = \frac{(\mathrm{a}-\mathrm{b}) \times\ 20 \times 10 \times mcf}{w} \quad (5)$$

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 = final
volume of sample solution.

2.4.6 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:

$$\%K = \frac{(\mathrm{a}-\mathrm{b}) \times m}{factor} \quad (6)$$

Where

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

2.4.7 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:

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

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).

2.4.8 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 (NH4OAc 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.

2.4.9 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.

2.4.10 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.

2.4.11 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 [19].

2.5 Experimental 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^{-1}) + Granule Urea 217.2 kg ha^{-1}
T3	Granule NPKS 10- 20-20-3 (600 kg ha^{-1}) + Granule Urea 87 kg ha^{-1}GrU
T4	Granule NPKS 10- 20-20-3 (400 kg ha^{-1}) + Granule Urea 87 kg ha^{-1}GrU
T5	Granule NPKS 10- 20-20-3 (400 kg ha^{-1}) + 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)

2.6 Planting Material

The planting material used for the study was the Sanzal sima maize which was obtained from 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. The grain is flinty in texture, white, and with a normal grain type [15].

2.7 Sowing

Each experimental plot had plant spacing of 40 cm within rows and 75 cm between rows. Maize seeds were sown at a depth of 4 to 6 cm and three (3) seeds were sown per hill. Ten (10) days later seedlings were thinned to two (2) plants per hole. Seedling emergence of maize was observed by four (4) days after sowing and eight days later vacant holes were refilled. Each experimental plot measured 5 m x 5 m. Each plot had six (6) rows with twenty-four (24) plants per row. The total number of plants per experimental plot was one hundred and forty-four (144).

2.8 Agronomic Practices

Ungerminated seeds on individual plots were replaced eight days after sowing. Weed control was carried out by using hand cultivation with hoe and hand-pulling methods fourteen days after sowing. Further weed control was done every two weeks using the same weed control method. Occurrence of pests and diseases were regularly monitored by visit to experimental site to assess their severity. The insect pests were controlled using Emaster insecticide with *Emamectin benzoate* as active ingredient at a rate of 10 - 20 ml per 15 litre knapsack sprayer.
The NPKS granular and briquette fertilizers and were applied according to treatment and rate to each plot three (3) weeks after planting. The NPKS granular fertilizers were applied using the side placement method whereas the NPKS 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.

2.9 Data Collection

The total number of maize plants from the 3 m x 3 m area within the four central rows per plot was harvested. Data were collected on yield and yield components.

2.10 Measured Yield Parameters

The following yield parameters were measured; cob diameter, cob length, 100-seed weight and grain yield (t/ha).

2.11 Cob Length and Diameter

The five cobs randomly selected from the five tagged plants per plot were measured for their length from the base to the tip of the cob with a meter rule and the mean was recorded. The diameter of five randomly selected cobs per plot after harvest and dehusking was also measured from the widest part using the digital vernier caliper and the mean recorded.

2.12 100-Seed Weight

A hundred seeds were randomly taken from each plot after shelling of cobs and weighed with an electronic weighing scale and the mean was recorded.

2.13 Grain Yield Per Plot

Cobs from the 3 m x 3 m area per plot were shelled after harvest and grains removed by manual means, sun-dried to constant moisture of 14^{0} C. The dried grains were then weighed with an electronic weighing scale and their grain yields per plot were estimated in t/ha.

3. RESULTS AND DISCUSSION

3.1 Effect 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 1. The pH values were slightly acidic, with both Atebubu and Nsapor having 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 Atebubu and Nsapor. Calcium and magnesium 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 1). The pH of the treatment remained slightly acidic and moderately acidic in T4 across both locations. 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. [20] and Liu et al. [21] who reported that the application of mineral fertilizers decreased soil pH.

Total nitrogen remained the same throughout the treatments except T7 which recorded a higher total nitrogen of 0.2% after harvest. Available P levels have increased across all treatments and locations except T6 which records the 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. 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. The losses may be due to the acidic nature of the soil since. The tendency of the applied P being adsorbed in the colloidal phase was high in soils with higher acidity and P is reduced when the soils acidity shifts to the neutral region [22].

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).

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. 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

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

Table 2. Climatic data for 2022 minor rainy season for Atebubu

Months	Rainfall (mm)	Temp (Max)°C	Temp (Min)°C	Humidity (%) 15.00hr	Wind speed (m/s)
April	170	34.2	22.7	23.8	4.6
May	273	32.0	21.9	22.8	4.5
June	210	30.1	21.3	21.7	4.1
July	114	31.5	28.9	21.1	4.7
August	142	33.5	29.5	21.5	3.6
Total	909				

(Ghana Meteorological Agency – Atebubu, 2021, 2022)

Table 3. Climatic data for 2022 minor rainy season for Nsapor

Months	Rainfall (mm)	Temp (Max)°C	Temp (Min)°C	Humidity (%) 15.00hr	Wind speed (m/s)
April	230	34.5	22.3	23.5	4.3
May	277	32.3	21.7	22.3	4.2
June	218	31.9	21.6	22.7	4.4
July	116	30.5	22.4	22.5	4.1
August	139	30.8	24.8	22.9	4.5
Total	980				

(Ghana Meteorological Agency – Nsapor, 2021, 2022)

Table 4. 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^{-1} + 217.2kg ha^{-1}U	13.55 ab	12.53	4.42 a	4.63
Gr (10- 20-20-3 NPKS) 600 kg ha^{-1}+ 87kg ha^{-1}U	14.35 a	13.03	4.45 a	4.71
Gr (10- 20-20-3 NPKS) 400 kg ha^{-1}+ 87kg ha^{-1}U	14.58 a	12.95	4.53 a	4.72
Gr (10- 20-20-3 NPKS) 400 kg ha^{-1}+ 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**

Table 5. Effect of NPKS fertilizer granules and briquettes on 100- seed weight and yield (t/ha) at Atebubu and Nsapor

Treatment	100-seed weight (g)		Grain 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^{-1} + 217.2kg ha^{-1}U	29.50 bc	29.75 ab	1.93	2.21
Gr (10- 20-20-3 NPKS) 600 kg ha^{-1}+ 87kg ha^{-1}U	30.25 ab	31.25 a	2.38	2.08
Gr (10- 20-20-3 NPKS) 400 kg ha^{-1}+ 87kg ha^{-1}U	31.00 a	30.00 ab	2.10	2.01
Gr (10- 20-20-3 NPKS) 400 kg ha^{-1}+ 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**

along with acidic soil conditions, can limit maize growth and productivity. However, the high levels of calcium and magnesium in Atebubu and Nsapor soil may favour maize growth and yield, while the moderate CEC in Atebubu has helped retain nutrients in the soil.

3.2 Climatic Conditions at the Experimental Sites

The study locations were carefully selected based on variations in the soil at the experimental sites according to FAO/UNESCO system of classification although the organic matter content and the climatic conditions are similar. The climatic condition at the experimental sites is shown in Tables 2 and 3.

3.3 Yield and Yield Components of Maize

3.3.1 Cob length

From Table 4, there was a significant difference ($P \leq 0.05$) between treatments in cob length at Atebubu but there was no significant difference ($P \geq 0.05$) between treatments in cob length at Nsapor.

Granule NPKS 10- 20-20-3 (400 kg ha^{-1}) + Granule Urea 87 kg ha^{-1} recorded the longest cob length, followed by Granule NPKS 10- 20-20-3 (400 kg ha^{-1}) + No Urea. The Control recorded the shortest cobs length. The significant differences among treatments in cob length at Atebubu, indicate that the different NPKS fertilizer treatments had an impact on cob length. This could be attributed to availability of the granular NPKS fertilizer for the crops uptake under these treatments and this agrees with Adu-Gyamfi, et al. [14]. The non-significant differences among treatments at Nsapor could be due to the fact that the treatments were similar.

3.3.2 Cob diameter

From Table 4, there were significant differences ($P \leq 0.05$) between treatments in cob diameter at Atebubu whereas no significant difference ($P \geq 0.05$) exists between treatment at Nsapor. At Atebubu, Granule NPKS 10- 20-20-3 (400 kg ha^{-1}) + Granule Urea 87 kg ha^{-1} recorded the widest cob diameter, followed by Granule NPKS 10- 20-20-3 (400 kg ha^{-1}) + No Urea. The Control recorded the shortest cob diameter. This result shows that the fertilizer combinations have the potential to enhance cob diameter which agrees with Keteku and Terapongtanakorn [23].

3.3.3 100- seed weight

From Table 5, there were significant differences ($P \leq 0.05$) between treatments in 100-seed weight at Atebubu and Nsapor. Granule NPKS 10- 20-20-3 (400 kg ha^{-1}) + Granule Urea 87 kg ha^{-1} recorded the heaviest hundred seed weight in Atebubu while Granule NPKS 10- 20-20-3 (600 kg ha^{-1}) + Granule Urea 87 kg ha^{-1} recorded the heaviest hundred seed weight at Nsapor. Both treatments however were not significantly different from Briquette (10- 20-20-3 NPKS) 3briq + 2briq Urea. The Control recorded the least 100- seed weight across both locations. 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. [14], who found out that one-time application of multi-nutrient fertilizer briquettes increased maize seed weight.

3.3.4 Grain Yield (t/ha)

From Table 5, the grain yield ranged between (1.65 - 2.38 t ha^{-1}) and (1.91- 2.31 t ha^{-1}) at Atebubu and Nsapor respectively although there were no significant differences ($P \geq 0.05$) between treatments in grain yield.These results showed that the maize grain yield was below the national achievable yield of approximately 6.0 t ha^{-1} in Ghana [24,25]. The low grain yield in this current study could be attributed to slow release of nutrients to plants [5], especially in Briquette (10- 20-20-3 NPKS) 3briq + 1briq Urea, and also probably due to the delay in application of granule and briquette fertilizers to maize. The application of granule and briquette fertilizer and their combination with or without Urea at different rates was done at 3 weeks after planting which might have affected the vegetative growth, delayed the reproductive phase and hence affected grain yield. According to Amali and Namo [26] early application of fertilizer hastened tasseling and silking (reproductive phase), and enhances leaf-growth, thus making enough assimilates available to be transferred to the sink (grains) at a later stage of the crop growth which is translated into higher yield.

4. CONCLUSIONS

The results of this study suggest that the applied granule and briquette NPKS fertilizer treatments had limited effects on the soil 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 nutrient 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.

Meanwhile, the study showed that the application of Granule NPKS 10- 20-20-3 (400 kg ha^{-1}) + Granule Urea 87 kg ha^{-1} to maize enhanced cob length, cob diameter and hundred seed weight.

This study recommends that farmers should apply Granule NPKS 10- 20-20-3 (400 kg ha^{-1}) + Granule Urea 87 kg ha^{-1} to their maize to improve cob quality. There is the need 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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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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