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# PROFITABILITY OF MAIZE PRODUCTION IN THE NORTHERN REGION OF GHANA

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**ABSTRACT**

On-farm research on profitability of maize (*Zea mays,* L.) production in the Northern Region of Ghana was conducted in five districts during 2014 and 2015 cropping seasons. Research fields were laid out in a Randomized Complete Block Design with 16 treatments and three replications. Treatments consisted of control ($T_1$), synthetic fertilizer treatments alone ($T_2$, $T_3$, $T_4$, $T_5$, $T_{10}$, $T_{11}$, $T_{12}$, and $T_{13}$), synthetic fertilizers and poultry manure treatments ($T_6$, $T_7$, $T_8$, $T_9$, $T_{14}$, and $T_{15}$), and $T_{16}$ (only Sulphate of Ammonia as topdressing). Combined application of poultry manure and synthetic fertilizer recorded significantly ($P<0.05$) higher maize grain yields. Application of synthetic fertilizers alone was not financially profitable but application of 187.5 kg of 23-10-05 NPK + 125 kg Sulphate of Ammonia + 4000 kg of poultry manure per hectare resulted in highest profitability ratio of 4.79. Combining poultry manure and synthetic fertilizers will ensure sustainable maize production and environmental sustainability in the Northern region of Ghana.



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## INTRODUCTION

Maize (*Zea mays* L.) is the third most important crop after wheat and rice, widely cultivated in tropics, sub-tropics and temperate regions to almost all the conditions of irrigated to semiarid of the world. It however, grows best under sub-tropical conditions of 21°C to 28°C and about 600 – 1200 mm of rain (Pandey and Chadha, 2008). In Ghana, maize is the most important staple and food security crop and it accounts for more than 50% of total cereal production and the second important commodity crop in the country after cocoa (MoFA, 2011a). It is cultivated in all agro-ecological zones of Ghana but grows best in deep and well-drained loamy soils (MoFA, 2005). Of all the major food crops grown in 2011, maize occupied the largest proportion of 24.9% in terms of total area cultivated (MoFA, 2011a). Smallholder farmers produce 90% of maize in Ghana (AGRA, 2016). Maize has wider uses than any other cereal (CSIR-SARI, 2011).

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The bulk of maize produced in Ghana is consumed in every household and it is arguably the most important crop for cash and food security because every household in Ghana consumes it. It is estimated that 85% of all maize grown in Ghana is consumed by humans and the remaining 15% is used for the animal feed preparation (mainly poultry) (Angelucci, 2012). It contributes about 20% of calories to the Ghanaian diet (Braimoh and Vlek, 2006). In 2000, the per capita consumption of maize in Ghana was estimated at 42.5 kg (MoFA, 2000) and in 2011 at 43.8 kg/capita (MoFA, 2011a) whilst the national consumption of maize was projected at 943,000 MT in 2006 (SRID, 2007). Industrially, maize provides raw materials for food industry world over. Maize is used in manufacturing corn starch, glucose, corn syrup, dextrin, food sweeteners, alcoholic beverages, and corn oil and used in the preparation of lubricants, soaps, salad oil, and fuel (Pandey and Chadha, 2008; Rouf *et al*., 2016). The fibrous stalks are also used for making paper, yarn, and a light packing material. Artificial fibers with tensile strength and wool-like properties are also prepared from the protein, and *zein* present in maize (Pandey and Chadha, 2008). Maize is noted to be a heavy nutrient feeder and has been found to respond well to higher fertilizer application, particularly nitrogenous in

Northern Ghana (CSIR-SARI, 2011). For decades (since 1960s), however, the recommended rate of chemical fertilizer application for maize production in Ghana has been basal application of 250 kg/ha of NPK 15-15-15 compound fertilizer and topdressing with 250 kg/ha of sulphate of ammonia (Ragasa *et al*., 2013; MoFA, 2005). Even though soil fertility and climatic conditions have since changed in Ghana particularly in the Northern region, the recommended fertilizer rates for maize cultivation has not been revised. Moreover, increasing fertilizer prices and economic considerations have forced farmers to adopt various types and combinations of fertilizers to produce maize in this part of Ghana. It is therefore not surprising that fertilizer use in Ghana is low. In Ghana, fertilizer use is estimated at 7.2 kg/ha (IFDC, 2012). Limited physical access to fertilizers and the high prices have been identified as major constraints to the use of fertilizers (IFDC, 2012; Larson and Frisvold, 1996). Application of low rates of N is noted to negatively affect photosynthesis and transpiration rates thereby reducing crop yields (Ashraf *et al*., 2016). On the other hand, droughts during the growing season frequently lead to total maize crop failures when this stress coincides with the drought-sensitive crop growth development periods like the tasseling (Benneh, 1993). This has been confirmed by Baba *et al*. (2013) who reported increasingly severe yield losses of maize as a result of droughty conditions. The occurrence is as a result of lower biomass (dry matter) production resulting from slower early growth of maize under water stress conditions (Schittenhelm, 2010). There is, therefore, the need to adopt crop management practices that help to conserve soil moisture and make efficient use of applied nutrients to ensure higher maize growth and productivity in the Northern region of Ghana.

At the Africa Fertilizer summit in 2006, a call for increasing the use of fertilizers from the current average of 8 kg/ha was made to raise agricultural production (IFDC, 2006). It was argued that if Sub-Saharan Africa is to feed its population, there is the need to increase agricultural production through adoption of improved technologies like the use of fertilizers. Although synthetic fertilizers may help in increasing maize yields, their application could lead to harmful soil and environmental consequences besides increasing the production cost due to the high cost of fertilizers (Dadarwal *et al*., 2009; Ranjan *et al*., 2013). Moreover, adoption and continuous application of fertilizers by farmers is dependent on the profitability of such practices and technologies to them. According to Baba *et al*. (2013), however, unless farmers in the Northern Region of Ghana ameliorated their soils, maize production was not profitable and sustainable with chemical fertilizers.

Meanwhile, organic manures have been found to supply plant nutrients and improve soil health due to buildup of organic matter and beneficial microbes (Singh *et al*., 2016). Unfortunately, no field studies have been conducted in recent years to investigate the profitability of the current recommended fertilizer rate and other rates as well as combination of synthetic fertilizers and poultry manure for maize production in Northern Ghana to guide fertilizer and nutrient management application decisions. The main objective of the present study was therefore to investigate the profitability of maize production in the Northern Region of Ghana based on the current recommended fertilizer rate for maize production and other rates and combinations of synthetic and poultry manure in the Region.

## MATERIALS AND METHODS

A multi-location on-farm farmer participatory research was conducted in the Northern Region of Ghana in five districts namely Central Gonja, East Gonja, Zabzugu, Tatale and West Mamprusiduring 2014 and 2015 cropping seasons. The specific locations of the study in the districts were Kanpong, Adamupe, Mognegu, Bidribombe and Bugyakura, respectively. Three hundred and seventy-two farmers comprising of 254 males (68.3%) and 118 females (31.7%) participated in the research from the five locations. The research fields were laid out in a Randomized Complete Block Design with 16 treatments in three replications at each location. The plot size was 12 m long and 6 m wide, and were separated by 1 m alley with intra-block distance of 2 m. The maize seeds were planted at 80 cm x 40 cm and thinned to two plants per hill to achieve a plant population of about 62,500 plants per hectare. During both years, sixteen treatments ($T_1$, ………, $T_{16}$) (Table 2) were applied at each of the five locations. The treatments were selected for the investigation based on the common maize production and fertilizer application practices of farmers in the Northern region and also based on the recommended fertilizer rates for maize production in Ghana.

Chemical analysis of the soil (0-30 cm) was conducted at the start of the experiment at the laboratory of the Soil Research Institute, Kwadaso, Kumasi using chromic acid oxidation method for organic carbon (Walkley and Black, 1934), Bray's method for available P (FAO, 2008), neutral ammonium acetate of 1 M with the help of a flame photometer to determine available and exchangeable K (Toth and Prince, 1949), Kjedahl method for total N, exchangeable Ca and Mg were determined by the EDTA titration method (Cheng and Bray, 1951), and soil pH using a calibrated pH meter of two buffer solutions (FAO, 2008).

Land preparation was done by ploughing, followed by spraying the field with Sarosate [a.i glyphosate 360 g/l in the form of 480 g/l isopylamine salt of soluble liquid (SL)] to kill any surviving weeds on the field; and alligator 400 Emulsified Concentrate (EC) (a.i. Pendimethaline 400 g/l; EC) as pre-emergence herbicide immediately after planting. Poultry manure was evenly spread on treatment plots that included application of poultry and thoroughly incorporated into the soil with a hoe, seven days before planting. Three seeds were planted in rows using a dibbler and seedlings thinned to two plants per hill before fertilizer application. The planting distance was 80 x 40 cm. In both years, planting was done under rain-fed conditions. Manual weeding was done before top dressing ($2^{nd}$ fertilizer application) when weeds appeared. This helped to loosen the soil and to earthen up around the base of the plants. Weeds that appeared subsequently were hand-picked as and when necessary. Compound fertilizers (NPK) were applied within the first two weeks after planting depending on the available soilmoisture condition. Application of sulphate of ammonia as topdressing was done 4 weeks after planting. Yield data was collected from the five central rows of each plot at physiological maturity. Number of crops harvested from the five central rows were counted and recorded.

The value to cost ratios and profitability of maize production were calculated for each fertilizer treatment for each season. To make these calculations, prices were collected for:

- Costs of fertilizers, weedicides, seeds, ploughing, and labor for each cropping season at actual, not subsidized, local market prices.
- Market prices of maize at harvest time (December), when prices are generally lowest.
- Peak produce prices occurring later in the year (June), which is usually the latest period the surplus crop is sold for farming activities.

Prices were quoted in Ghana cedis at an exchange rate of US $1 to GH₵ 4.00. The unsubsidized input costs from the local market and the crop prices between harvest and at peak from the regional (Tamale) market were obtained from the database of Esoko Ghana and used to calculate the value to cost ratios (VCRs) as a first indicator of acceptability of investment. The VCRs were calculated at three (3) levels viz:

Total Value Cost Ratio (VCR) using the following formula:

$$VCR_{Total} = \frac{B}{A}$$

where B (GH¢) is the total crop production cost of all treatments including control; A (GH¢) is the value of the crop harvested (Gross Income).

Location Value Cost Ratio using the following formula:

$$VCR_{Location} = \frac{Br}{Ar}$$

where Br (GH¢) is the total crop production cost at the various locations using the current recommended fertilizer rates; Ar (GH¢) is the value of the crop harvested (Gross Income) from the various locations using the current recommended rate of fertilizer.

Treatment Value Cost Ratio (Profitability) using the formula:

$$VCR_{Treatment} = \frac{Y-YC}{X}$$

where Y (GH¢) is the value of the crop harvested in intervention (treatment) plots; Yc (GH¢) is the value of the crop harvested in control plots, X (GH¢) is the cost of intervention inputs (fertilizers and manure). The cost of producing each extra ton of maize above that produced in the control was also calculated. Marginal rates of returns of the treatments were also computed. Dominance analysis was also conducted to identify most superior treatment (CIMMYT, 1988). Statistical analysis was done using Minitab v16.2.4.4 statistical package employing a two-sample t-test procedure. Mean grain yield was adjusted for by number of plants harvested, number of cobs harvested, cob diameter, cob length, and plant height at harvest.

## RESULTS

**Soil analysis:** Results of the soil analysis at the five locations as presented in Table 2 indicated that the soils at the various sites are largely sandy loam except at Kanpong that falls in the loamy soil characterization. The soils at the locations showed significant ($P< 0.01$) differences in respect of all the soil properties analyzed except for exchangeable K ($P = 0.579$) and exchangeable Na ($P = 0.718$). The pH of the soils ranged from moderately acidic at Adamupe to slightly acidic at Mognegu and neutral at Kanpong, Bugyakura, and Bidribombe (Soil Research Institute, 2015).

**Grain yield:** All the treatments that included poultry manure ($T_6$, $T_7$, $T_8$, $T_9$, $T_{14}$, and $T_{15}$) produced significantly ($P < 0.0001$) higher grain yield than the rest of the treatments without poultry manure (Table 3). The pooled results indicated that$T_6$ produced the highest grain yield (2591.85 kg/ha) whilst $T_{10}$ recorded the least grain yield of 1887.87 kg/ha. Consistently, $T_6$, was statistically at par ($P > 0.05$) with $T_7$, $T_8$, $T_9$, and $T_{14}$ which also included poultry manure.

**Economic analysis of maize production:** The economic analysis was conducted to understand the cost components of labor and fertilizer use and its profitability in maize production. The economic analysis indicated that the cost of fertilizers and manures constituted between 9% and 22% depending on the treatment applied. Additionally, the analysis indicated that labor cost constituted between 27% and 32% of the total production cost depending on the location. Furthermore, as the total cost of fertilizer and manure reduced due to the type of combinations and quantities applied leading to reduction in the total production cost, the percentage of the labor cost increased up to 60% as in the case of the control where no fertilizer was applied.

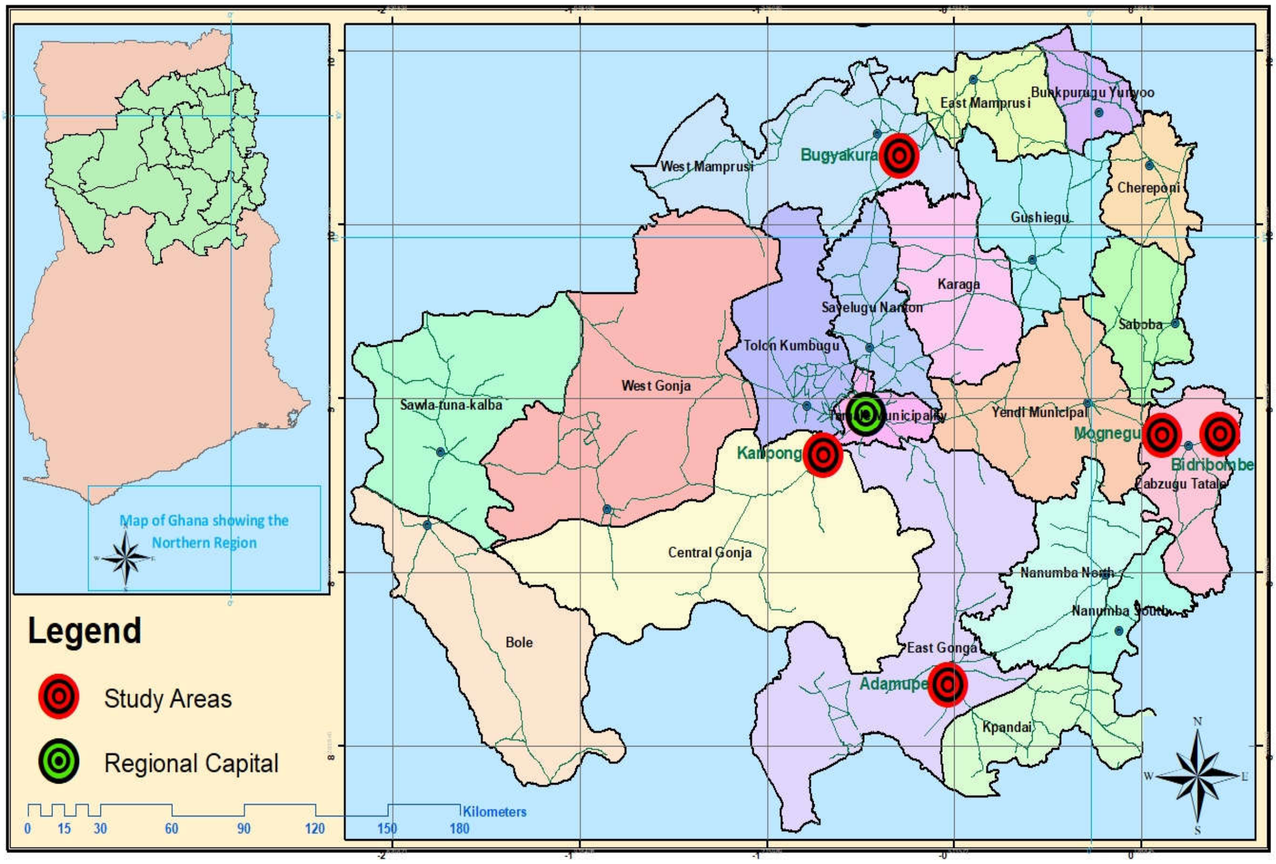
**Total value cost ratio (VCR):** The total value cost ratio (VCR) of all the treatments at harvest (in December) and during the lean (June) periods was greater than 1 (Figure 1). The control ($T_1$) significantly and consistently recorded the highest total VCR (Figures 1 and 2). The current recommended fertilizer rate ($T_5$) recorded the lowest total VCR between the harvest and the lean periods (Figure 2).

**Value cost ratio of maize production at different locations:** With the application of $T_5$, the current recommended rate of fertilizer (250 kg/ha NPK and 250 kg/ha Sulphate of ammonia) for maize production, the pooled VCR at the various locations ranged between 1.0 and 1.9 (Figure 3). Kanpong consistently recorded the highest VCRs. This was followed by Adamupe, Mognegu, Bugyakura and Bidribombe, respectively. Delaying the sale of the produce till June increased the VCR by 40% to 60%.

**Profitability of applied treatments:** The profitability of the treatments that included poultry manure ($T_6$, $T_7$, $T_8$, $T_9$, $T_{14}$, and $T_{15}$) ranged from 1.01 to 2.44 in 2015 and between 1.79 and 4.79 in 2014 compared with the control ($T_1$). Consistently, the integrated treatments ($T_6$, $T_7$, $T_8$, $T_9$, $T_{14}$, and $T_{15}$) recorded profitability ratios greater than 1 (Figures 4 and 5). $T_8$ consistently and significantly recorded the highest ratio in both 2014 and 2015 cropping seasons whilst $T_{16}$ recorded negative and the lowest VCRs in both years (Figures 4 and 5). Generally, treatments that involved application of only synthetic fertilizers recorded less than 1, negative, or the lowest ratios (Figures 4 and 5). The results showed that investment in fertilizer application for maize production in the Northern region without addition of poultry manure was generally not profitable.

## DISCUSSION

**Soil Analysis:** Analysis of the soils at the various locations indicated that the soils vary significantly from one another in terms of their properties.




**Map 1.Map of the research area**

**Table 1. Description of the research treatments and their nutrient equivalents**

| Treatment code | Treatment description (kg/ha) | Nutrient equivalent (kg/ha) | | |
|---|---|---|---|---|
| | | N | $P_2O_5$ | $K_2O$ |
| $T_1$ | Control - No fertilization | 0 | 0 | 0 |
| $T_2$ | 250 kg of 23-10-5 + 125 kg of S/A | 84 | 25 | 13 |
| $T_3$ | 250 kg of 23-10-5 + 250 kg of S/A | 110 | 25 | 13 |
| $T_4$ | 250 kg of 15-15-15 + 125 kg of S/A | 64 | 38 | 38 |
| $T_5$ | 250 kg of 15-15-15 + 250 kg of S/A | 90 | 38 | 38 |
| $T_6$ | 250 kg of 23-10-5 + 125 kg of S/A + 4000 kg Poultry manure | 230 | 78 | 39 |
| $T_7$ | 250 kg of 15-15-15 + 125 kg of S/A + 4000 kg Poultry manure | 210 | 90 | 64 |
| $T_8$ | 187.5 kg of 23-10-5 + 125 kg of S/A + 4000 kg Poultry manure | 216 | 72 | 36 |
| $T_9$ | 187.5 kg of 15-15-15 + 125 kg of S/A + 4000 kg Poultry manure | 201 | 81 | 55 |
| $T_{10}$ | 125 kg of 23-10-5 + 125 kg of S/A | 55 | 13 | 6 |
| $T_{11}$ | 125 kg of 23-10-5 + 125 kg of 23N-10P-5K | 58 | 25 | 13 |
| $T_{12}$ | 250 kg of 23-10-5 + 125 kg of 23N-10P-5K | 86 | 38 | 19 |
| $T_{13}$ | 125 kg of 15-15-15 + 125 kg of S/A | 45 | 19 | 19 |
| $T_{14}$ | 125 kg of 23-10-5 + 125 kg of S/A + 4000 kg Poultry manure | 201 | 65 | 33 |
| $T_{15}$ | 125 kg of 15-15-15 + 125 kg of S/A + 4000 kg Poultry manure | 201 | 72 | 45 |
| $T_{16}$ | 125 kg of S/A only | 26 | 0 | 0 |

S/A = Sulphate of Ammonia N= Nitrogen P = Phosphorus K = Potassium

Poultry manure composition = 3.66% N: 1.32% P: 0.66% K

$T_5$ is the current recommended fertilizer rate for maize production in Northern Ghana

**Table 2. Soil characteristics of research locations**

| Location | Soil type | Soil pH | Organic Matter (%) | Total Nitrogen (%) | Available P (ppm) | Exchangeable Bases (cmol/kg) | | | | ECEC | Base Saturation | Exch. Acidity |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | K | Ca | Mg | Na | | | |
| Bidribombe | Sandy loam | 6.55 b | 1.69 ab | 0.09 b | 4.73 b | 0.15 a | 4.11 a | 1.69 a | 0.10 a | 6.15 b | 98.30 a | 0.10 d |
| Mognegu | Sandy loam | 6.38 c | 1.84 a | 0.10 a | 5.53 b | 0.21 a | 4.47 a | 1.95 a | 0.11 a | 6.92 a | 97.24 b | 0.19 a |
| Kanpong | Loam | 6.73 a | 1.15 c | 0.07 c | 4.81 b | 0.20 a | 2.97 b | 1.27 b | 0.13 a | 4.69 c | 97.16 b | 0.13 c |
| Adamupe | Sandy loam | 5.94 d | 1.64 b | 0.08 b | 6.69 a | 0.20 a | 2.31 c | 1.69 a | 0.12 a | 4.48 c | 96.27 c | 0.16 b |
| Bugyakura | Sandy loam | 6.56 b | 1.14 c | 0.07 c | 3.23 c | 0.13 a | 3.45 b | 1.06 b | 0.07 a | 4.88 c | 96.17 c | 0.17 ab |
| *P- Value* | - | 0.000 | 0.000 | 0.000 | 0.000 | 0.579 | 0.000 | 0.000 | 0.718 | 0.000 | 0.000 | 0.000 |

Means that do not share a letter are significantly different

**Table 3. Effect of Treatments on grain yield**

| Treatment code | Grain Yield + SEM* (kg/ha) | | | |
|---|---|---|---|---|
| | pooled 2014 & 2015 | 2014 | 2015 | % variation in grain yield (kg/ha) |
| $T_1$ | $2118 \pm 91.59^{bc}$ | $1693 \pm 137.74^{de}$ | $1967 \pm 136.73^{cdef}$ | 16.18 |
| $T_2$ | $2003 \pm 68.74^{c}$ | $1981 \pm 111.42^{cde}$ | $2020 \pm 99.31^{def}$ | 1.97 |
| $T_3$ | $2144 \pm 68.89^{bc}$ | $2043 \pm 107.15^{bcde}$ | $2186 \pm 100.43^{bcdef}$ | 7 |
| $T_4$ | $1954 \pm 68.64^{c}$ | $1866 \pm 105.04^{cde}$ | $1965 \pm 99.99^{ef}$ | 5.31 |
| $T_5$ | $1991 \pm 68.55^{c}$ | $2041 \pm 105.74^{bcde}$ | $1961 \pm 99.73^{ef}$ | -3.92 |
| $T_6$ | $2592 \pm 71.58^{a}$ | $2668 \pm 107.85^{a}$ | $2766 \pm 104.37^{a}$ | 3.67 |
| $T_7$ | $2444 \pm 72.40^{ab}$ | $2543 \pm 109.65^{ab}$ | $2512 \pm 108.04^{abcd}$ | -1.22 |
| $T_8$ | $2559 \pm 71.85^{a}$ | $2650 \pm 110.95^{a}$ | $2656 \pm 106.57^{ab}$ | 0.23 |
| $T_9$ | $2413 \pm 71.30^{ab}$ | $2533 \pm 107.32^{ab}$ | $2526 \pm 104.67^{abc}$ | -0.28 |
| $T_{10}$ | $1888 \pm 69.11^{c}$ | $1875 \pm 107.14^{cde}$ | $1947 \pm 99.79^{ef}$ | 3.84 |
| $T_{11}$ | $1925 \pm 68.70^{c}$ | $1825 \pm 104.76^{de}$ | $1986 \pm 99.54^{ef}$ | 8.82 |
| $T_{12}$ | $2147 \pm 68.80^{bc}$ | $2225 \pm 106.20^{abcd}$ | $2132 \pm 99.90^{cdef}$ | 4.18 |
| $T_{13}$ | $1927 \pm 68.62^{c}$ | $1893 \pm 106.93^{cde}$ | $1839 \pm 100.39^{f}$ | -2.85 |
| $T_{14}$ | $2367 \pm 69.70^{ab}$ | $2357 \pm 106.48^{abc}$ | $2422 \pm 101.08^{abcde}$ | 2.78 |
| $T_{15}$ | $2154 \pm 68.92^{bc}$ | $2187 \pm 107.50^{abcde}$ | $2224 \pm 100.65^{bcdef}$ | 1.69 |
| $T_{16}$ | $1920 \pm 72.22^{c}$ | $1660 \pm 114.18^{e}$ | $1941 \pm 119.50^{cdef}$ | 16.93 |
| P-value | 0 | 0 | 0 | |
| n | 30 | 15 | 15 | |

Values are least square means adjusted for by number of plants harvested, number of cobs harvested, cob diameter, cob length, and plant height at harvest. Means that do not share a letter within a column are significantly different * SEM = Standard Error of the Means

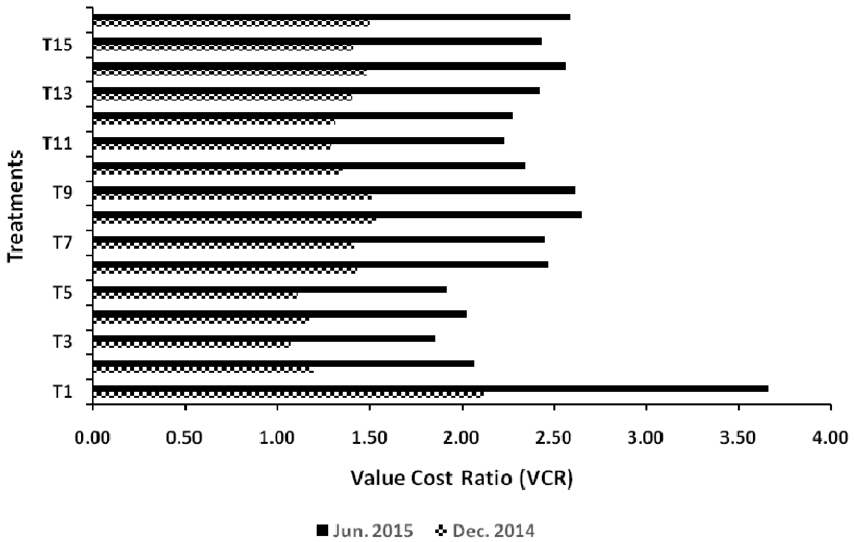



**Figure 1. Total value cost ratio for 2014 maize production**

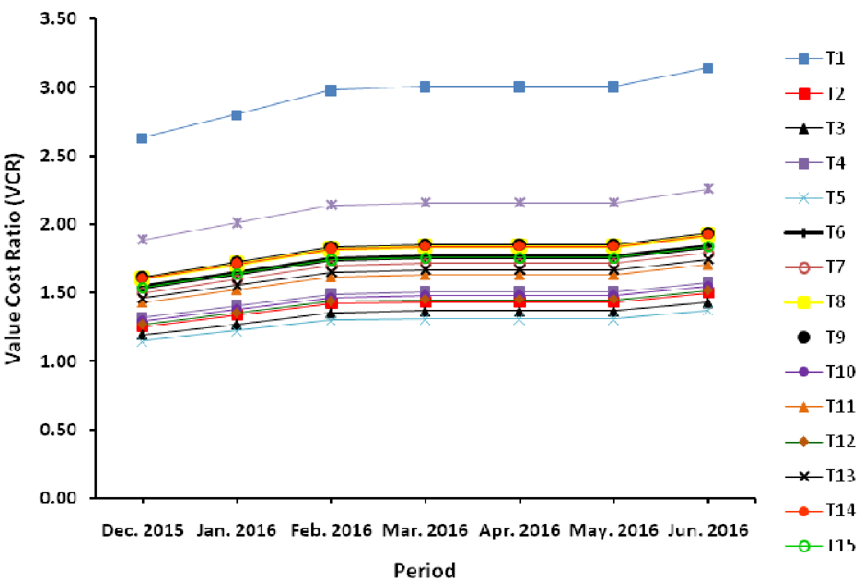



**Figure 2. Total value cost ratio trend analysis for 2015**

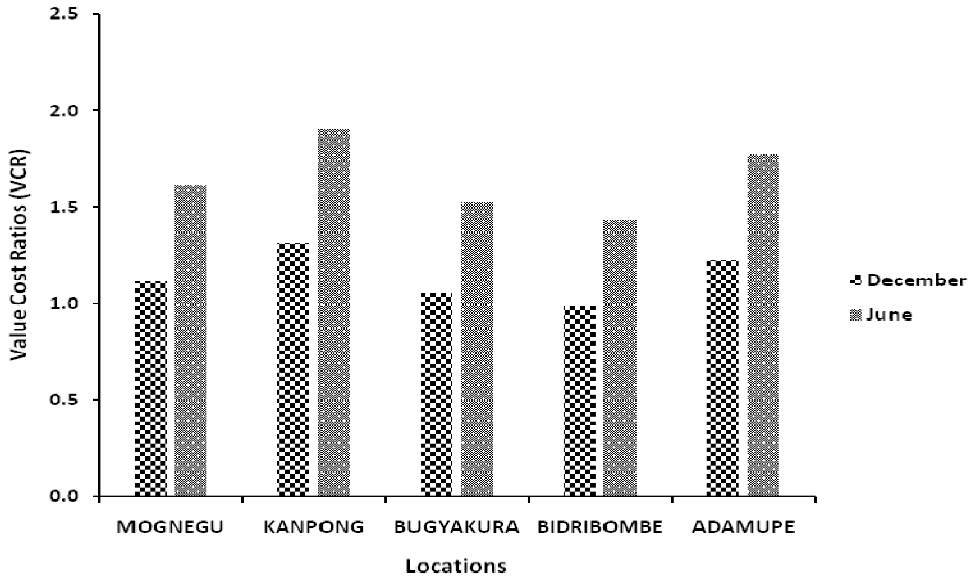



**Figure 3. Pooled Value Cost Ratios from different locations in Northern Region**

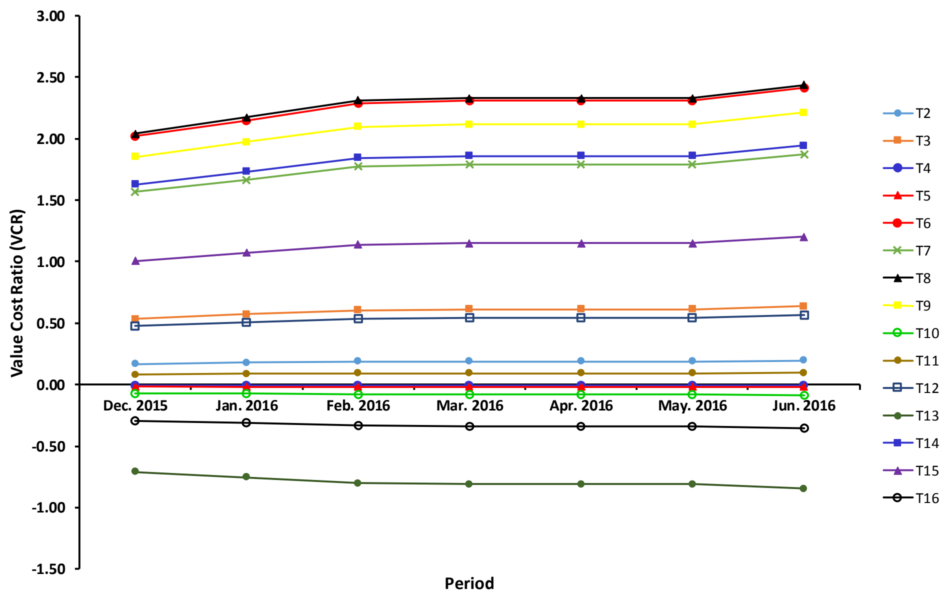



**Figure 4. Trend analysis of treatments profitability for 2015 maize production**

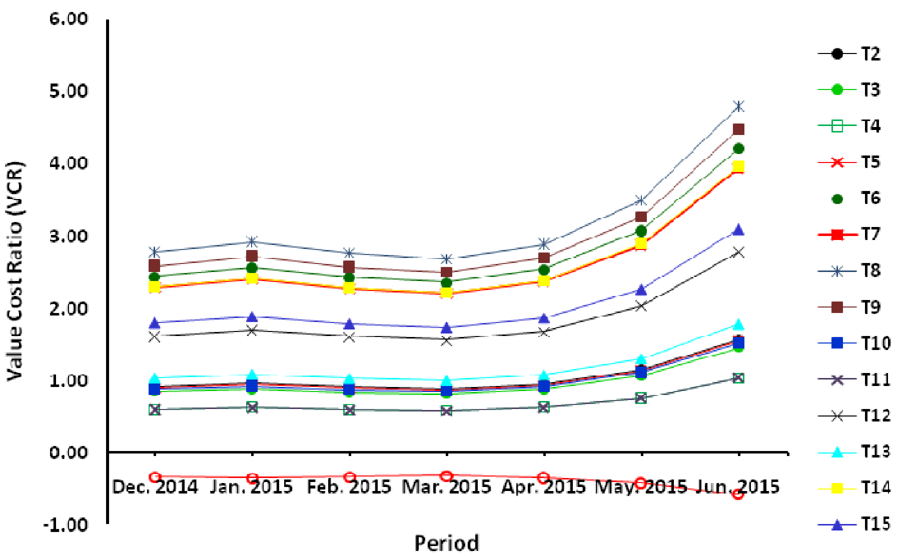



**Figure 5. Trend analysis of treatments profitability for 2014 maize production**

This means that application of the same nutrient management practices at all the locations will not yield the same results. Fertilizer recommendation and nutrient management practices should, therefore, be location specific. The sandy nature of the soils with low organic matter content at the locations means that the soils would generally be susceptible to leaching and nutrient loss and will not sustain crop production without proper soil management practices. The pH of the soils at all the locations ranging between 5.94 and 6.73 indicates that the soils are mildly acidic, which can support cultivation of many crops. This is because plants generally prefer soils that have pH close to either side of neutrality as most nutrients are available in the pH range of 5.5 – 6.5 (FAO, 2008). The pH range recorded will also promote soil microbial population and activity. The relatively low soil pH of the soils at Adamupe (5.94) and Mognegu (6.38) as compared to the values at Kanpong, Bugyakura, and Bidribombe could be attributed to leaching of bases and continuous application of sulphate of ammonia at the two sites in previous cropping seasons. According to NARS (1993), application of ammonium sulphate fertilizer tends to leave a slight acidic residue after the cropping season in most of the soils in the Guinea Savannah Agro-ecological Zone (GSAZ). The soil pH and organic matter content of the soils at the research locations are within the ranges reported by MoFA (2011b). The percent total N content (0.07 – 0.10) of the soils at the locations being higher than the reported range (0.02-0.05) for soils in the Northern region is attributable to favorable pH recorded at the sites which promotes microbial activities and ensures nutrient availability. This means that the fertility status of the soils at the locations are higher than the reported. Generally, Mognegu recorded the highest values in most of the soil properties analyzed (organic matter, N, K, Mg, and ECEC) and second to Adamupe in the case of P. It can, therefore, be concluded that Mognegu is the most fertile site and is expected to support improved crop growth and yield than the other sites *ceteris paribus*.

**Grain yield:** Generally, the maize grain yields was influenced significantly by the various treatments of the synthetic and organic fertilization. The consistently lower grain yields recorded by $T_1$ (control – no fertilization) and $T_{16}$ (application of 125 kg Sulphate of Ammonia only) is attributed to inadequate nutrition. Nutrient deficiencies have been reported to cause changes in physiological and biochemical processes that result in growth retardation, delayed development as well as qualitative and quantitative yield reduction (Saxena and Diwakar, 2012). This was observed in the field as the $T_1$ plants looked stunted with yellowish coloration, an indication of nitrogen deficiency. Nitrogen is important for the synthesis of protein and nucleic acid and an essential constituent of other compounds needed for plant growth processes such as chlorophyll and many enzymatic processes (Gallais and Hirel, 2004). It affects growth negatively when it is sub-optimal (Hague *et al*., 2001). Even though $T_{16}$ appeared better than $T_1$, both effects were statistically similar. This demonstrates that application of 125 kg/ha of S/A to maize at the latter growth stage was inadequate and uneconomical. It further implies that adequate and timely application of nutrients is critical to ensure good plant growth and yield and that delayed application could cause nutrient deficiencies and irreversible damage. The result is consistent with CSIR-SARI (1996) and NARS (1993) who reported that maize grain yields in the GSAZ of Ghana are low and uneconomical when cultivated without fertilizers. The consistently higher grain yields recorded by the application 250 kg/ha 23-10-05-NPK and 125 kg/ha Sulphate of Ammonia ($T_2$) as compared to the same rate of 15-15-15 NPK plus the sulphate of ammonia ($T_4$) can partly be explained by the higher levels of N in 23-10-05 NPK than 15-15-15 NPK that resulted in greener coloration and chlorophyll development in the maize crops and therefore higher production of assimilates which eventually resulted in higher grain yield. The significantly improved grain yields recorded by treatments that included poultry manure ($T_6$, $T_7$, $T_8$, $T_9$, $T_{14}$, and $T_{15}$) could be attributed to the ability of the treatments to match soil nutrient availability with crop demand to satisfy various growth and development stages (Graham *et al*., 2017) and the general soil fertility improvement. The improved yields of the integrated poultry manure and synthetic fertilizer fields can be attributed to the additional and balanced plant nutrients supplied and ameliorating effects of the poultry manure which helped to increase number of cobs per plant. The poultry manure supplied additional macro and micro nutrients which improved crop growth, stover yield, and general crop performance. The poultry manure could have also assisted in improving the soil physical conditions by acting as a binding agent that helped in binding the soil particles and improving in water retention, aeration, and nutrient availability. This contributed to better performance even in 2015 when total rainfall was low. Elsewhere, other researchers (Johnson, 1985, Li *et al*., 2009; Prado and Claudio, 2000; Sojkaand Entry, 2000) who demonstrated with various soil amendments observed improved yields and productivity of various crops under water-stressed conditions. The findings corroborates the observation by Kumar and Chopra (2014), Das *et al*. (2004) and Chatha *et al*. (2002) that increased application of organic and synthetic fertilizers in developing countries could enhance the environment and increase crop yields. The findings also agree with the view expressed by Baba *et al*. (2013) that unless farmers in the GSAZ of Ghana ameliorated their soils, maize production was not profitable and sustainable.

**Economic analysis of maize production:** The range of 9 - 22% fertilizer cost estimated in respect of the total cost of maize production in the study is in agreement with the near 22% fertilizer cost for maize production reported by YARA (2012). This cost appears high and can inhibit adoption of fertilizer in maize production by resource-poor rural farmers. Therefore, to make the fertilizer cost affordable and thereby increase adoption, there is the need for social interventions like provision of subsidies on fertilizers or encourage local production of fertilizers to minimize the cost of fertilizers to farmers. The labor cost ranging from 27% to 32% of the total production cost means that labor is an important cost component in maize production in the Northern Region of Ghana. In the region, labor is employed in planting, weeding and weedicide application, fertilizer application, harvesting, and shelling. The labor cost percentage recorded was marginally higher than the 25% labor cost reported in Bangladesh by Moniruzzaman *et al*. (2009). The findings indicate that farmers in the Northern Region can increase profitability of maize production by reducing substantially the use of hired labor on their farms.

**Total value cost ratio (VCR):** The total VCR ranging from 1.07 to 3.66 is an indication that investment in production of maize in the Northern Region can bring between 7% and 266% return on investment. The finding is consistent with Moniruzzaman *et al*. (2009) who reported benefit cost ratio of between 1.58 and 2.85. The significantly higher VCR recorded by the control ($T_1$) was attributable to the low production cost because no fertilizer or manure was applied and not because $T_1$ out-yielded the other treatments. To improve the VCR of maize production, therefore, efficient production technologies must be applied to reduce the production cost whilst increasing the productivity.

**Value cost ratio for recommended fertilizer rate:** The VCR for maize production with application of the recommended fertilizer rate of 250 kg/ha NPK and 250 kg/ha Sulphate of Ammonia ($T_5$) at all the locations was mostly positive and greater than 1, an indication that maize production in the Northern Region with the current recommended fertilizer rates will bring positive return on investment. The greatest return of 30% to 90% recorded at Kanpong implies that Kanpong has a comparative advantage for maize production when the current fertilizer rate is applied. This is attributable to the comparatively high yield and relatively low production cost resulting from its proximity to the regional capital. The 40% to 60% increase in the VCR from December to June was as a result of the increase in produce market price from the harvest period till June. The low VCR recorded at harvest was due to the low maize market price recorded during the harvest period than later in the season (Angelucci, 2012) due toavailability of new maize at harvest. This means that farmers could increase their profitability by about 60% if they were able to delay sale of their produce till June. This is because maize tended to be available in the market after harvesting than during the lean period. Selling maize at harvest will therefore lead to low profitability and income. Unfortunately, this period tend to coincide with the Christmas festivities and re-opening of schools where parents are required to provide new clothing, food for the festivities, pay school fees, purchase learning materials for their wards, and meet other immediate expenses compelling farmers to sell their produce at the low price instead of storing and selling during the lean periods when the prices are high. Access to low interest credit to farmers will help farmers to delay selling their produce to attain attractive market price.

**Profitability of applied treatments:** The high VCRs (1.01 to 2.04) in 2015 and between 1.79 and 4.79 in 2014 recorded by the integrated treatments ($T_6$, $T_7$, $T_8$, $T_9$, $T_{14}$, $T_{15}$) demonstrates the superior profitability of the integrated nutrient management practices over the application of synthetic fertilizers alone which recorded less than 1 or negative profit. This means that application of the chemical fertilizers alone is not financially rewarding and sustainable. The profitability ratios recorded by the integrated treatments compare favorably with the 2.7 value-cost ratio of fertilizer use in maize production reported by FAO (2005). Among the integrated treatments, however, $T_8$ was outstanding with a profitability ratio of up to 4.79. This implies that $T_8$ was dominant economically. The performance of the integrated treatments means that their application for maize production in the Northern region will ensure sustainable maize production and increase farmers' economic fortunes. This is because not only did they produce higher grain yields and proved to be superior economically, but the addition of the organic manure will also help to improve the soil structure. The higher ratios in 2014 compared with the 2015 values is attributed to the favorable weather conditions during 2014 and the corresponding higher productivity compared with the latter.

## Conclusion

The integrated treatments ($T_6$, $T_7$, $T_8$, $T_9$, $T_{14}$, and $T_{15}$) produced significantly higher grain yields than treatments that involved application of only synthetic fertilizers. Although synthetic fertilizers alone increased maize yields above the control, rates above the current recommended fertilizer rate for maize production in the Northern Region of Ghana did not yield profitable return on investments except when the synthetic fertilizer rates were combined with 4000kg/ha of poultry manure. Optimum grain yield and highest profitability ratio of 4.79 was achieved through the application of 187.5 kg of 23-10-05 NPK + 125 kg Sulphate of Ammonia + 4000kg of poultry manure per hectare ($T_8$). Therefore, to achieve optimum maize yields and guarantee income profitability to farmers and sustain soil health, farmers in the Northern Region of Ghana should combine synthetic fertilizers with poultry manure in maize production.

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