EFFECT OF PRIMARY, SECONDARY AND MICRO NUTRIENTS ON MAIZE YIELD IN THE WENCHI MUNICIPALITY, GHANA

Abstract

One of the major constraints related to maize (*Zea mays* L.) productivity is low soil fertility related mainly to continuous cropping without replenishment of depleted nutrients. In view of this, this study sought to assess the effect of different combinations of primary and secondary nutrients on the yield of maize in the Wenchi Municipality in the Brong-Ahafo Region. Five treatments - Control (T1), NPK (T2), NPK + S + Mg + Ca+ B + Cu + Mo+ Zn (T3), Manure (T4) and T3 + Manure (T5) - were tested in a field experiment in a randomized complete block design (RCBD) with four replicates. The test crop was Lake 601 maize variety.

Data for the research was collected on total number of plants, stalkweight, hurst weight, cob weight, grain weight Nutrient Use Efficiency and Economic Viability. The data was analysed with analysis of variance (ANOVA) on all measured parameters and the results were presented in graphs. From the results gathered, it was realized that the application of NPK + Sec_MN had a more positive impact on dry shoot weight and grain weight.

The results obtained from the field experiment also indicated that it was more efficient to combine both NPK and secondary nutrients in maize production compared to applying the other treatments assessed in the study; such that, the combined effect gave more yield and subsequently generated more money (income).

Based on the results obtained in the research, it was recommended that; much attention should be given to T3 (NPK + Sec_MN). Possibly, different doses of this treatment should be further tested to know the actual extent at which the secondary nutrients and the NPK can be combined to give the maximum yield. Similar research should also be staged at a different location to know whether similar results would be obtained.

Keywords: Economic Viability, soil fertility, analysis of variance,*Zea mays*

1. Introduction

The most widely grown cereal in the world, maize (Zea mays L.) is significant economically because it may be used for a variety of purposes, including high-tech industries, animal feed, and human nourishment (FAO, 2014). Around the world, maize is widely farmed in temperate, subtropical, and tropical climates. The USA is the top producer (50.4%) with 361 million tonnes, followed by China and Brazil, out of the 1.04 billion tonnes of maize produced worldwide (FAO, 2014). "Africa generates about 77.7 million tonnes of which 10.8 m tonnes is from Nigeria, farmed from about 6 million ha arable area" (FAO, 2014, p. 1). Because of biotic, abiotic, and agricultural variables, maize yield is still regarded as poor despite its significance (Onasanya et al., 2009; Olaniyan, 2015). "The components of the primary abiotic factors contributing to the low yield in Africa include decreasing soil fertility and inadequate use of fertilisers, which results in severe soil minerals depletion" (Buresh et al, 1997). "Continuous growth of commodities on the same type of soil has resulted in the a greater amount of rapid decline in soil fertility" (Uzoh and et al, 2015).

It is a crop with a high yield that is climate-adaptable, making it a vital component of diets across the world (Burke et al, 2017). It provides food security for people in both rural and urban areas by acting as a cash crop and subsistence crop. Maize is an important source of vital nutrients in addition to being a significant source of calories. It has dietary fiber, carbs, and important minerals and vitamins including zinc, iron, and B vitamins (Zhang et al, 2016). When consumed in whole grain form, it promotes general health and wellbeing. In many economies, the core activity is the production and sale of maize. Farming maize boosts the agricultural industry, provides employment, and brings in money for farmers (Dong et al, 2016). Moreover, businesses dependent on maize, such those that prepare food and make animal feed, promote economic expansion. For many communities, maize has great cultural significance. It permeates rituals, cuisines, and customs. Corn has cross-cultural importance and is a symbol of identity for many different societies. It plays a crucial role in rites and festivities in several areas. Due to its adaptability and widespread distribution, maize is an essential commodity in international commerce (Brar et al, 2015). In addition to being consumed by humans, it is also used in industry and as animal feed. In areas vulnerable to food shortages or climate change, the capacity to store maize for long periods of time improves food security. The adaptability of maize is astonishing (Abate et al, 2015). A variety of products, such as cornmeal, cornflower, cornflour, and corn oil, may be made from it. It is the main component in a wide variety of recipes, including porridge, snacks, and bread and tortillas. One possible way to fight malnutrition is via biofortifying maize. In areas where maize is a staple grain, it helps to improve public health by increasing kinds of maize with increased nutritious content, especially protein and vitamin (Ha et al, 2015). In order to promote sustainable agricultural practises, maize is an essential component of crop rotation. It improves soil fertility, reduces insect infestations, and helps stop soil erosion. This supports agricultural ecosystems' long-term health. Scientific study on maize is very important (Hartmann et al, 2015). After being completely sequenced, its genome has shed light on molecular biology and genetics, which is advantageous for other crops in addition to maize. The development of novel cultivars with improved characteristics, such pest and drought tolerance, is facilitated by this study (Al-Naggar et al, 2015). Maize is an essential part of efforts to secure food security as the world's population grows. Its flexibility, diversity, and ability to feed cattle and people make it essential for meeting the dietary demands of a world that is growing faster than ever.

In Ghana, low soil fertility is acknowledged as the main obstacle to farming and food security. The majority of Ghana's soils lack adequate amounts of nitrogen (N) and phosphorus (P). Phosphorus shortage is a key crop production constraint in tropical agricultural systems soil (Mustonen et al., 2012). Phosphorus is the second most generally limiting component in soil after nitrogen (Balemi and Negisho, 2012). Phosphorus is a crucial macronutrient for plant development. Nutrient levels in the soil must be adjusted for the optimal yield of maize crops. Because of this, adding fertilisers to the soil to increase its natural fertility in order to maximise production has become necessary.Essential nutrients that are often deficient in soil, such as nitrogen (N), phosphorus (P), and potassium (K), are supplied by fertilisers. Fertilisers fill up the nutritional deficit that maize needs for proper development. Applying fertilisers provide increases maize yields significantly (Ranum et al, 2014). Using fertilisermaximises crop yields, which leads to more plentiful harvests to satisfy the rising demand for maize. In addition to increasing yield, fertilisers raise the calibre of maize that is produced. Being a vital component of maize growth, nitrogen aids in the development of the leaves and stem. Common nitrogen-based fertilisers include urea and ammonium nitrate. Phosphorus is essential for the growth of plants' roots and general structure. Common sources of phosphorus include superphosphate and triple superphosphate (Frenstein et al, 2022). In addition to its overall health, potassium helps maize withstand illnesses. A common fertiliser with a potassium base is muriate of potash. Although the use of fertilisers in maize growing has many advantages, overuse or misuse may have negative effects on the environment and the economy (Cairns et al 2013). A better-balanced nutrient supply is made possible by combining several fertiliser types, which lowers the possibility of nutrient imbalances in the soil (Ranum et al, 2014).

For many years, it has been suggested that alternate methods of applying fertiliser might maximise yields and improve the efficiency of nutrient use. According to several research (Ayodele and Omotosho, 2008; Adekayode and Ogunkoya, 2010; Isitekhale et al., 2013), "nitrogen (N), phosphorus (P), potassium (K), sulphur (S), and some trace elements in order to boost crop productivity" must be applied. For example, phosphorus (P) is, in most agricultural soils, the second most important nutrient required for plant development (Muhammad et al., 2015) and one of the most restrictive plant nutrients in crop yield (Akande et al., 2010). It is essential to several physiological processes that occur in developing and mature plants. It is related to plant enzymatic responses, which are necessary for mobile division, crucial for the production of seeds and fruits, impact grain quality, and can increase a plant's resilience to disease. Shanti et al (1997) highlighted that "Nitrogen (N) is a vital plant nutrient and a major determining factor required for maize production". It comprises 1-4 % of the dry matter of plants and is vital to their development. "Nitrogen is an essential part of protein and nucleic acids, and when N is inadequate, growth is reduced (Haque et al ,2001). Its availability to a sufficient degree throughout the growing season is essential to the most fruitful growth of maize. "It also mediates the utilisation of potassium, phosphorous, and additional nutrients in plants" . Bradley (1984) emphasised that plants lack nitrogen, they cannot properly use the ideal quantity of these elements in the soil. Thus, an excess or shortage of nitrogen can lower maize output. Being the most important cation in plant life, potassium is a basic nutrient. Enzyme stimulation, the production of proteins, the process of photosynthesis oxygen regulation, stomatal actions, power transmission, phloem transportation, cation-anion harmony, and resistance to stress are among the processes in which it is essential. Bashir (2012) added that preserving adequate plant K is, thereby, critical to successful plant growth".

In the meanwhile, it is impossible to ignore the essential micronutrients that the plant needs. Micronutrients like zinc have a range of functions, from extremely basic to quite complicated processes. "Zn plays a very important role in plant metabolism by influencing the activities of hydrogenase and carbonic anhydrase and stabilisation of ribosomal proteins" (Tisdale, 1984, p. 1). Marschner (1995) argued that"Zinc activates the plant enzymes by carbohydrate metabolism, maintaining the integrity of cellular membranes, protein synthesis and regulation of auxin synthesis". Additionally, Cakmak, 2000 stated, "Zn is required for regulation and maintenance of the gene expression to induce tolerance of environmental stresses in plants." Additionally, according to Xia et al. (2004), "nitrogen integrated with zinc improved plant height and yield in maize." According to Adetunji and Adepetu (1989), "Sulphur has additionally grown as an important yield-limiting determinant in many soils." After N, P, and K, it is identified as the fourth main nutrient. It has a crucial role in the production of the amino acid's methionine and cysteine, which are important components of proteins and helpful in secondary metabolism. According to Choudhary and Das (1996), " sulphur has a beneficial effect by lowering soil pH and improving physical condition of the soil". "Increasing level of S progressively enhanced the average total N uptake by maize and this increase in N uptake may be attributed to increase in N content of plant and dry matters yield due to increasing S levels" as stated by (Jaliya et al., 2012 As stated by Ray and Mughogho (2000), "S is a secondary nutrient taken up by most grain crops in amount namely 10 to 30 kg ha–1". Kumawat identified the "synergistic effect of applied P and S" (2004). "In mung and wheat, an antagonistic relationship between P and S was observed." "This interaction influences the absorption of sulphur, in form of sulphate in the soil" (Islam et al., 2006) and in maize (Muhammad et al., 2015). (1991, Adetunji). A comprehensive programme for soil fertility must take into account every macro- and micronutrient that is essential for the growth and development of maize (Zea mays L.).

Micronutrient (Zn, Mn, Cu, Fe, and B) deficiencies are less common because of smaller crop removal amounts and generally adequate soil supply in most maize-producing regions where the soil pH is maintained between 6.0 and 7.0. However, maize macronutrient requirements must be taken into consideration on a seasonal basis." (Rego et al, 2007). But since 2000, the price of maize grain has increased significantly, reaching a record high of 16 kg-1 on average at one point in 2017, with prices even reaching 18 kg-1 in some months. Due to these documented high maize costs, many producers have turned to other products, such foliar micronutrient fertilisers, in an attempt to increase production. Previous studies have shown that environmental factors such as natural matter, pH, temperature, moisture, and aeration affect how maize production responds to micronutrient functions. The need for crop nutrients has also grown as a result of the significant genetic advancements that have enhanced maize yields. Accurate knowledge of nutrition absorption, partitioning, and elimination might help determine the best utility timing and rates to combat variability and increase the likelihood of a high-quality yield response. This study aims to ascertain the impact of various combinations of primary, secondary, and micronutrients on the maize yield characteristics in light of this.

2. Materials and methods

2.1 Study Area

The study was conducted in the Brong-Ahafo Region's Wenchi Municipality from August to December of 2020. Situated among latitudes 7° 30' and 8° 05' North and longitudes 2° 15' West and 1° 55' East, the municipality is situated in the western part of the Brong-Ahafo Region. Its total land area is 1,145 rectangular kilometres, and its borders are shared by Techiman Municipal to the west, Tain District to the east, Kintampo South District to the northwest, and Sunyani Municipal to the south. The average temperature in the municipality is typically high—about 24.5 °C. 30.9 (°C) is the average maximum temperature, while 21.2 (°C) is the average low. April through February are the freshest months. There are two distinct seasons in the municipality: the wet and dry seasons. Timber species like (*Miliciaexcelsa), (Entandrophragmacylindricum), (Triplochitonscleroxylon), and (Khayaivorensis*), are observed in locations such as Nwoase.

2.2 Experimental treatments

Five (5) treatments were tested in a field experiment as listed below:

- ✓ T1= Control
- ✓ T2= NPK
- ✓ T3= NPK + S + Mg + Ca+ B + Cu + Mo+ Zn
- ✓ T4= Manure (containing N, P_2O_5, K_2O, Ca, Mg, Fe, Zn, Pb, Ni and Cd)
- ✓ T5= T3 + Manure

2.3 Experimental layout/design and crop establishment

Before plots were defined and delineated, the experiment site was physically cleared, ploughed, and weeded. Four repetitions of a randomised complete block design (RCBD) were used to arrange the five-by-five-meter plots. reaching stop treatment drifts reaching neighbouring plots, alleys of 1.0 m and 2.0 m, respectively, were left between plots and duplicates. Lake 601 was the maize variety used as a test crop. Each hill had two maize seeds planted at a distance of 75 by 50 cm, at a depth of around 3-5 cm. To prevent weeds from growing in the fields, weeding was done by hand with a hoe. Point placement was employed in all fertiliser treatments to save nutrients for efficient plant utilisation.

The primary nutrients (NPK) were administered in different amounts: urea was used for N, triple superphosphate was used for P, and muriate of potash was used for K. Two weeks after planting, half of the N (60 kg/ha) was treated as urea, and the other half (30 kg/ha) was applied six weeks later. Two weeks following planting, full amounts of potassium (60 kg K2O/ha) and phosphorus (60 kg P2O5/ha) were applied as triple superphosphate and muriate of potash, respectively. 6000 kg of manure ,cow dung were spread out each hectare. 2.5 kg of zinc sulphate (ZnSO4) was sprayed per hectare. Kieserite was used to apply sulphur (S) and magnesium (Mg) at rates of 6 kg S/ha and 7.5 kg MgO/ha, respectively. Nitrabor, or calcium (Ca), was administered at a rate of 10 kg CaO/ha. Additionally, 1.5 kg B/ha of Nitibor, a type of borate, was treated.

2.4 Data collection

Data for the research was collected after harvesting. Specifically, data were collected on the following;

i. ***Total number of plants:***The total number of plants on each plot (per treatment) were counted and noted.

ii. ***Stalk weight (kg):***After harvesting, 20 stalks from each plot (per treatment) were picked, dried and weighed.

iii. ***Hurst weight (kg):***Theweight for all harvested plants (per treatment) was weighed.

iv. ***Cob weight (kg):***This was achieved after dehusking the maize. Afterwards, the cobs were weighed for each experimental plot (per treatment).

v. ***Grain weight (kg):*** Selected plants within the middle row of each plot were used. After harvesting, the grains are removed from the cobs and dried to a moisture level of 13 %. Afterwards, the seeds are weighed per plot and recorded.

vi. ***Agronomic efficiency:***This will be determine using the formulae, NUE= $\Delta Y/\Delta Q$; where ΔY = change in yield increase and ΔQ = change in qa

vii. ***ost Ratio (EBCR):***This will be determined using the formulae, EV = ΔY (p)/C; where ΔY = change in yield increase; p = price of the produce at harvest / kg and C = cost of fertilizer used.

2.5 Statistical analysis

Data was analysed using the Statistical Packages for Social Scientist (SPSS) vs 26.The analysis of variance (ANOVA) was performed on all measured parameters. Means for each parameter were separated by the least significant difference (LSD) method at 5 % level of significance.

3. Results

3.1 Dry shoot weight

There was high significant difference (P < 0.05) among the individual treatments with respect to their effect on the dry shoot weight. Specifically, T3 (NPK + Sec_MN) recorded the highest (3.875) dry shoot weight followed by T2 (2.76), T5 (2.7), T4 (2.61) and T1 (2.53) as illustrated in Figure 1.

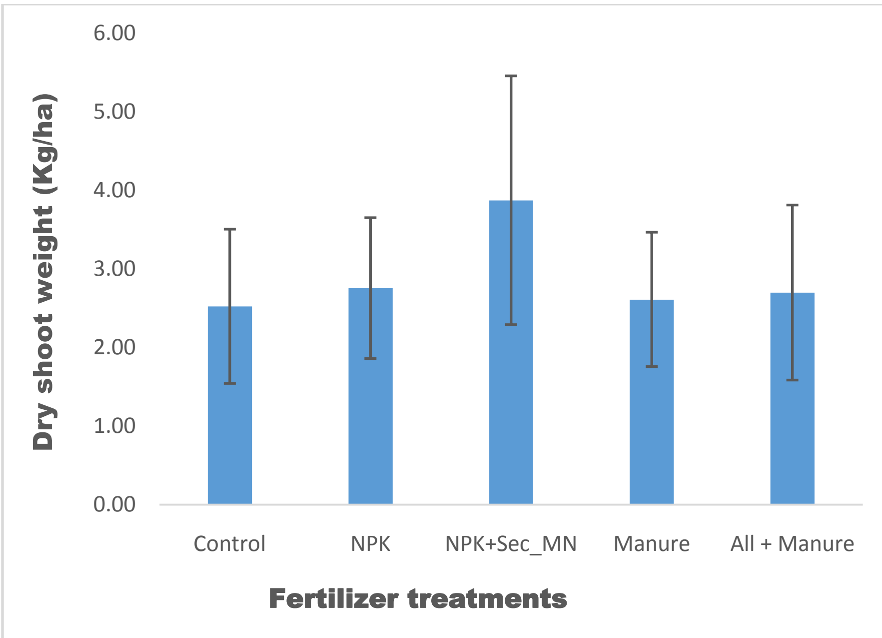

Figure 1: Effect of the treatments on dry shoot weight

3.2 Grain weight

With respect to the grain weight, there was a significant difference (P < 0.05) among the individual treatments. The highest (7.17) grain weight was recorded by T3 (NPK + Sec_MN) with the least (1.72) being recorded by T1 (Control). The other treatments recorded 4.75, 4.60 and 5.61 for T2 (NPK), T4 (Manure) and T5 (All + Manure) respectively (Figure 2).

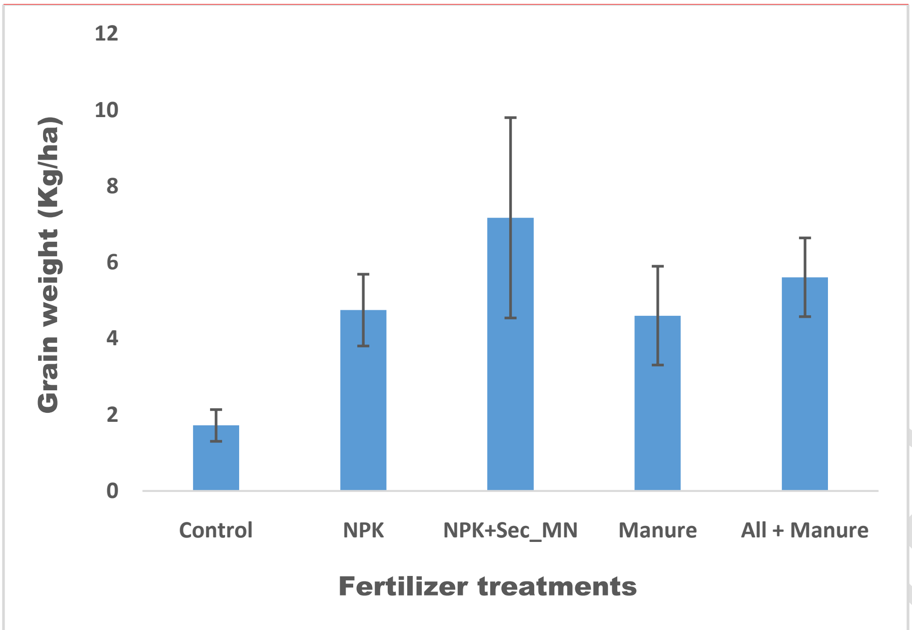

Figure 2: Effect of the treatments on grain weight

3.3 Agronomic efficiency

The research also looked at the Agronomic efficiency of the individual treatments. The control treatment (T1) was used as a common ground (basis) to judge the efficiency of the other treatments (T2, T3, T4 and T5). From the analysis, Duncan's multiple range test for T1, T2, T3, T4 and T5 were 1722, 4935, 7172, 4604 and 7172 respectively. Using the table (from Appendix 1) as the basis for calculation, NUE = $\Delta Y/\Delta Q$; where ΔY = change in yield increase and ΔQ = change in quantity of fertilizer used. The results revealed no significant difference ($P > 0.05$) among the individual treatments with respect to their agronomic efficiency. Generally, T3 (NPK + Sec_nutrients) recorded the highest efficiency (24.5 ± 12.47) compared to the other treatments. This was because, on average, for every 1kg of NPK and secondary nutrients applied, 24.5 ± 12.47 kg maize was realized. The implication of this results is that it is more efficient to combine both NPK and secondary nutrients in maize production compared to the other treatments.

3.4 Economic Viability (EV)

Economic viability (EV) is an important index used to evaluate the likely profitability of a practice or product. In this research, the individual treatments were assessed to know their economic implications when adopted. Like in the NUE, the control treatment (T1) was used as a common ground (basis) to judge the profitability in using the other treatments (T2, T3, T4 and T5). The results revealed that there was no significant difference ($P > 0.05$) among the individual treatments with respect to their economic viability (EV). However, T3 (NPK + Sec_nutrients) proved to be more economically feasible (GH¢ 9.2 ± 4.7). The implication of this results is that for every 1 kg of T3 (NPK + Sec_nutrients) that was used, an amount of GH¢ 9.2 ± 4.7 will be realized. This was the highest compare to T2 (GH¢ 6.1 ± 2.0), T4 (GH¢ 2.5 ± 1.2) and T5 (GH¢ 2.2 ± 0.8). See ap

3.5 Discussion

3.5.1 Effect of NPK + Sec_MN on the performance of maize

Based on the collected data, it was determined that the majority of the study's parameters were more positively impacted by the use of NPK + Sec_MN. In comparison to the other treatments, NPK + Sec_MN demonstrated very encouraging results in terms of its impact on stalk weight, hurst weight, cob weight, and grain weight. Nutrient optimisation is one of the main benefits of combining NPK fertilisers with secondary micronutrients such as iron (Fe), manganese (Mn), copper (Cu), and zinc (Zn). Specific nutritional needs for different development stages of maize plants exist. While secondary micronutrients provide the plant's demands for micronutrients,

The addition of secondary nutrients to NPK may have contributed to T3's exceptional performance (NPK + Sec_MN). In a similar vein, a number of studies have demonstrated that in order to increase agricultural yield, several nutritional elements including nitrogen (N), phosphorus (P), potassium (K), sulphur (S), and certain trace (secondary) elements must be applied (Ayodele and Omotosho, 2008; Adekayode and Ogunkoya, 2010). In contrast to traditional fertilisation, which lacks micronutrients, the application of micronutrients in conjunction with macronutrients boosted both the yield and the absorption of nutrients (Bakry et al. 2009; Singh et al. 2009; Azhar, 2011). A similar claim was also made by Isitekhale et al. (2013). Similarly, Tisdale (1984) documented the importance of certain secondary nutrients on maize yield. Marschner (1995) and Cakmak (2000) also emphasised the critical role that secondary nutrients like zinc and sulphur play in the maintenance and control of gene expression, which is necessary to promote plant tolerance to environmental challenges (Cakmak, 2000).
According to Xia et al. (2004), the integration of nitrogen and zinc increased maize plant height and yield. Adetunji and Adepetu (1989) corroborated the significance of S for plant growth. Choudhary and Das (1996), who found that S has positive effects via reducing soil pH and enhancing soil physical conditions, provide more credence to this claim. According to Muthukumararaja and Sriramachandrasekharan et al. (2012), applying NPK together with micronutrients greatly enhanced the soil's availability of both applied and native macro- and micronutrients, increasing maize grain production. According to Kumar et al. (2012), zinc (Zn) is regarded as another significant secondary nutrient that is necessary for plant development. Zinc deficiency disrupts the development of both male and female reproductive organs as well as the pollination process, according to Brown et al. (1993). It is necessary for several enzymes and is crucial for the transcription of DNA (Kumar et al., 2012). Zinc has other roles in plant cells, such as catalysing oxidation, which is essential for the conversion of carbohydrates, and affecting the synthesis of chemicals that promote growth, such as auxins and chlorophyll (Mamatha, 2007).

Hnamteet al (2016) argued that NPK fertilisers provide the fundamental nutrients required for plant growth. Improving nutrient absorption efficiency is mostly dependent on micronutrients. Remisonet al (2014) added that in maize, manganese (Mn) is essential for nitrogen metabolism and photosynthesis. These micronutrient deficiencies may impair nutrient absorption, lowering the health and production of plantsRop et al (2015) added that when NPK and secondary micronutrients are combined, nutrient absorption is maximised and overall plant performance is improved. For photosynthesis to occur, the synthesis of chlorophyll requires the elements iron (Fe) and manganese (Mn). Chukwukaet al (2015) emphasized that ore efficient photosynthesis results in higher plant development and growth. Fertilisers NPK + Sec_MN cause maize plants to photosynthesize at higher rates, which leads to healthier, more robust growth. Gulet al (2015) stated that there are certain secondary micronutrients that help a plant resist environmental stressors and illness.Onwudiwe et al (2015) observed that micronutrients such as zinc (Zn) and copper (Cu) may strengthen a maize plant's defences. When maize plants get enough of these nutrients, they are more resilient to environmental stresses and show greater resistance to disease (Heuchan,2018).

3.5.2 Assessment of Nutrient Use Efficiency (NUE) and Economic Viability (EV) as affected by different nutrients (and nutrient combinations).

Given the advantages of applying fertiliser to soils for the development of sustainable food crops, it is desirable to have information on fertiliser availability and usage in order to boost food production (Adekayode and Ogunkoya, 2010). The end result of several yield-contributing factors, including as physiological processes and morphological changes that occur in plants during growth and development phases, is grain yield. The farmer's income is likewise determined by the same factor. The cost of applying fertiliser must be compared to the value of the yield it produces in order to determine if it is profitable. The field experiment's results showed that combining secondary nutrients with NPK was a more efficient way to produce maize than using NPK alone (Chukwuka et al, 2015). This combined impact increased yield, which in turn increased revenue. Using this technique, Morris et al. (2007) and Kelly (2006) investigated the profitability of fertiliser in SSA.

Morris et al. (2007) discovered that while fertiliser is often lucrative for West African maize farmers, fewer than half of Ghanaian maize farmers use it. They attributed this to the fact that the majority of farmers base their decisions about applying fertiliser on profitability. Therefore, the very poor returns that maize farmers receive after harvest may be attributed to their low fertiliser application (particularly NPK). The maize plant's ability to develop vegetatively and produce biologically depends largely on its ability to consume micro and macrochemical ingredients (Ehsanullah et al., 2015). It follows that applying fertilisers containing the essential components that maize plants need results in a significant rise in biological yield and an improvement in revenue levels. As the findings of the current study demonstrate, it would be reasonable to propose that the addition of secondary nutrients will have a significant impact. According to a prior study, adding elemental S to soil at a rate of 0.5 g S kg-1 reduced soil pH from 7.03 to 6.29 and greatly enhanced magnesium and zinc availability, which raised overall yield by 45% (Karimizarchi et al., 2014).

4. Conclusions

Although the application of NPK alone had a substantial increase on the yield and yield parameters of maize, it was the combined application of the secondary nutrients and NPK that made the difference in the research.

The findings showed that the combine effect of secondary nutrients (S + Mg + Ca + B + Cu + Mo + Zn) and NPK had a very positive impact on the stalk weight, weight, cob weight and grain weight. In almost all the parameters assessed, the control treatment proved the need for the application of fertilizer to obtain maximum yield.

Based on the results obtained in the research, it is recommended that:

i. With the combination of the secondary nutrients and NPK giving more promising results compared to the other treatments, the research recommends that much attention should be given to this particular treatment. Possibly, different doses of this treatment should also be analysed to know the actual extent at which the secondary nutrients and the NPK can be combined to give the maximum yield.

ii. Also, similar research should be staged at a different location to know whether similar results would be obtained. This is because soil and climatic conditions can as well affect plants' ability to effectively absorb and utilize available nutrients. By implication, the research sought to know whether the performance of T3 (NPK + Sec_MN) was not soil or climatic bound.

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Appendices

Appendix 1: Amount and cost of fertilizers used in the field experiment

utrient	Product	Nutrient content	Rate to applied (Kg/ha)	Total product to applied (kg/ha)	Total bags/ha	Unit price/bag (ghc)	Total amount (ghc)/ha	Total product to applied on 100m2 in grams	Total to ap 25 m gram
itrogen	Urea	46%N	90	196	3.9	110	429	1960 split 1/3 and 2/3	490 s and 1
hosphorus	Triple superphosphate	48%P2O5	60	130	2.6	130	338	1300	325
otassium	Muriate of potash	60%K2O	60	100	2	120	240	1000	250
ulfur and nagnesium	Kieserite	20%S and 25%Mgo	6S and 7.5 MgO	30	0.6	85	51	300	75
alcium	Nitrabor	25%CaO	10	40	0.8	80	64	400	100
oron	Etibor	15%B	1.5	10	0.18	200	36	100	25
inc	ZnSO4	36%Zn	2.5	7	0.28	80	22.4	70	17.5
opper and olybdenum	Croplift	0.1%Cu and 0.003%Mo	Foliar application (2.5 Cu and 2.5 Mo	2.5	2.5	23	57.5	25ml	6.25
otal				515.5			1237.9		