Influence of Yara fertilizer formulations on rice productivity in the Guinea savanna zone of Ghana

Abstract

Low soil fertility has been a major constraint to the increased and sustainable rice production in the Guinea savanna zone of Ghana. Studies were conducted in four locations to evaluate the yield of rice under different Yara fertilization regimes. The fields were laid out in a randomized complete block design with four replications for each treatment. Data were collected on grain yield and seed mass, and subjected to analysis of variance, with treatment means separated at 5% level of significance. Significant improvement in rice paddy yield was realized in all study locations due to the fertilizer treatments. Grain yield improvement of up to 4,280 kg/ha was realized. The best two performing treatments in improving rice grain yield were UNIK-L+AMI-L and ACT-L+AMI-L and ACT-L+URE-L, in descending order. At most locations, rice grain yield among the CropLiftBio foliar treatments was statistically similar. Application of ACT+URE and UNIK+ACT without CropLiftBio foliar supplementation consistently demonstrated lower rice grain yields compared to the other fertilizer treatments in all study locations. Rice grain mass was however, not significantly impacted by the fertilizer treatments at any of the study locations. From the results of this study, Actyva fertilizers used as basal appeared to be unsuitable for rice production in the savanna ecology of Ghana as these generally provided lower grain yields. For maximum grain yield of rice in the ecology, Yara UNIK 15 (NPK 15:15:15) fertilizer was the most recommended. The basal application of UNIK 15 at 125 kg/ha and topdressing with Amidas at 125 kg/ha with CropLiftBio foliar supplementation will provide better yields for farmers than applying Actyva as topdress.

Comment [i-[1]: Consistency of writing unit weight of grain production: ton/ha.

Comment [i-[2]: What is this described in the next section? Among other things, the content of nutrients.

Keywords: Yara fertilizer; Grain yield; Oryza sativa; Ghana; Savanna ecology.

1.0 INTRODUCTION

Rice is among the most important and widely consumed staple food in tropical Africa (FAO, 2020). In the savanna ecology of Ghana, rice is produced predominantly by smallholder, resource-poor farmers under rain-fed conditions (Kankam-Boadu et al., 2018). Sun et al. (2019)

reported that rice is most popular cereal crop in northern Ghana due to its high yield and low cost of production. However, the average yield of about 1.5 t/ha is below the achievable yields of up to 6 t/ha (Oppong-Abebrese et al., 2019. Soil fertility is crucial in increasing cereal crop yields, and low soil fertility and low application of external inputs are the major factors affecting productivity of rice, and these account for the low yield of the crop. Improving yields through increased productivity of the savanna soils can be achieved by external inputs of nutrients which are available mainly in the form of inorganic fertilizers.

Across the north of Ghana, the most sourced of inorganic fertilizers are commercial fertilizers, which farmers can easily access on the local market. The main limiting nutrients in the soils of the major maize growing areas in northern Ghana have been organic carbon (< 0.2 %), exchangeable potassium (< 10 mg/kg) (Abumere et al., 2019). For many decades, a one-cap-fits-all fertilizer recommendations have been made for rice and other crops in Ghana. Moreover, soil conditions are dynamic over the years and the old recommendations are not always efficient (e.g. Darma et al., 2020). Hence, the need to constantly update or make site-specific fertilizer recommendations for rice in the northern agroecological zone of Ghana.

Comment [i-[3]: It's more appropriate to plant rice, not corn.

Over the years, use of NPK fertilizers have been the primary means of nutrient replenishment. This is understandable as NPK remains the most important nutrients required for crop production (Abumere et al., 2019). Sole application of NPK has helped to increase rice yield significantly. However, some room remains for further yield increment. It has been postulated that the inclusion of secondary nutrients such as sulphur (S) and micro nutrients such as boron (B) and Zinc (Zn) in fertilizer blends could increase rice yields sharply, beyond levels achieved by use of sole NPK (Njoroge et al., 2018). This postulate has not been confirmed nor denied in savanna ecology of Ghana. In view of this, fertilizer blends/formulation in northern Ghana remains primarily of N, P and K which may be limiting possible yield increment through secondary and micro-nutrient inclusion. There is the need to study the growth and yield increment of fertilization through inclusion of secondary and micronutrient elements in fertilizer formulations.

YARA Ghana Limited is an agro input company involved in the importation and sale of mineral fertilizers to improve agricultural production and income of farmers. Yara Ghana has recently introduced standard fertilizer formulations for cereal crop production, namely YaraMila Actyva (23N+10P+5K+2MgO+3S+0.3Zn), Unik-15 (15N+15P+15K+2.2S), YaraVita Croplift Bio

(8.5N+3.4P+6K+B+Cu+Mn+Mo+Zn), YaraVera Amidas (40N+5.6S) and YaraBela Sulfan (24N+6S). The comparative agronomic efficacy of these formulations within the different agro ecological zones in northern Ghana remains largely unknown. There is the need to compare the relative productivity of the fertilizer regimes to enable subsequent recommendation to the resource poor farmer for rice production in the ecology. This study sought to establish and compare the yields of rice obtained from treatments with the various YARA fertilizer formulations within the different agroecological zones of northern Ghana.

2.0 MATERIALS AND METHODS

2.1 Study sites

Comment [i-[4]: It is better to complement the chemical properties of the soil: pH, CEC, N-total, P available and total, K available and total, etc. Not only ecological traits.

The trial was conducted during the 2021 cropping season in farmers' farms in four locations, namely, Nyankpala, Walewale, Yendi and Damongo, in the northern Guinea savanna zone of Ghana. Generally, the savanna ecology is that of a tropical continental with a single rainy season, usually from May to October (and peaks around late August or early September), followed by an extended dry season (FAO, 2020; Tetteh et al., 2016).

The four locations for this study share ecological traits similar to the Guinea savanna ecological zone. However, there are some differences. Nyankpala is at an altitude of about 183 m above sea level and mean annual rainfall of about 1000 – 1300 mm. The area has a gentle undulating to flat terrain (Kumah, 2016). The area is largely characterized by low-lying areas of grassland with few spread perennial woody species. Some crops cultivated in this ecology include maize, rice, soybean and cowpea. Soils in this region are largely developed from voltaian shale and sandstone with texture being largely sandy loam to loamy sand (Yidana et al., 2011) and classified as a Ferric Luvisol. Yendi largely shares similar ecological traits with guinea savanna. On the other hand, unique traits include average annual rainfall which ranges between 1005 – 1150 mm. The area has a relatively flat terrain with gentle slopes. Soils here are developed over shale, usually shallow (15-30 cm) to very shallow (cultivated include maize, millet, rice, groundnuts, beans, sorghum and yam.

2.2 Land preparation, experimental design and treatments

At each location, stumps were initially removed from the fields to ease demarcation. Each field was disc-ploughed and harrowed (with a hoe) during the first week of July.

Comment [i-[5]: Please consider adding references: e.g. Darma et al. (2022).

2.3 Trial Protocols

The main purpose of the study was to evaluate the effect of the different YARA fertilizer formulations and application rates on the agronomic performance of rice across the four agroecological zones. The different fertilizer protocols evaluated for the crop are presented in Table 1 below:

Table 1: Protocols for rice trial, 2021 season

Treatments	**2 WAP**	**Beginning of tillering**	**At panicle initiation**
ACT-L+AMI-L	YaraMila Actyva @250kg/ha	CropLift Bio@ 2l/ha	YaraVera Amidas@125kg/ha
ACT-L+URE-L	YaraMila Actyva @250kg/ha	CropLift Bio@ 2l/ha	Urea@125kg/ha
UNIK-L+ACT-L	UNIK 15:15:15@250kg/ha	CropLift Bio@ 2l/ha	YaraMila Actyva @125kg/ha
UNIK-L+AMI-L	UNIK 15:15:15@250kg/ha	CropLift Bio@ 2l/ha	YaraVera Amidas@125kg/ha
UNIK-L+URE-L	UNIK 15:15:15@250kg/ha	CropLift Bio@ 2l/ha	Urea@125kg/ha
ACT+AMI	YaraMila Actyva @250kg/ha	No fertilizer	YaraVera Amidas@125kg/ha
ACT+URE	YaraMila Actyva @250kg/ha	No fertilizer	Urea@125kg/ha
UNIK+ACT	UNIK 15:15:15@250kg/ha	No fertilizer	YaraMila Actyva @125kg/ha
UNIK+AMI	UNIK 15:15:15@250kg/ha	No fertilizer	YaraVera Amidas@125kg/ha
UNIK+URE	UNIK 15:15:15@250kg/ha	No fertilizer	Urea@125kg/ha
CONTROL	No fertilizer	No fertilizer	No fertilizer

2.4 Trial locations

The trials were conducted on-farm in four localities, namely Walewale, Yendi, Damongo and Nyankpala, representing the various agro-ecological zones in the north of Ghana. At each location, a total of three sites were selected for the trials on the three different crops. The site selection was based on the extent of cultivation of the target crops; the more extensive the cultivation of a given crop the higher the probability of inclusion in siting of the trials. Agricultural Extension Agents (AEAs) from the Ministry of Food and Agriculture (MoFA) operating within each zone were initially engaged to assist with the selection of farmers. The choice of fields selected depended on accessibility and proximity to the major road and willingness of the land owner to participate in the trial.

2.5 Land preparation and field layout

At all locations, each field was ploughed with a tractor and later manually leveled with a hoe. Stumps were initially removed from fields by the farmers to ease demarcation and ploughing. The dates of land preparation and field layout for the three crops in the various locations are shown in Table 5 below.

For each site, the fields were demarcated as a single factor experiment laid out in a Randomized Complete Block Design with three replicates for each treatment. Field sizes of 29 m x 19 m and plot sizes of 5 m x 4 m were covered. A 1 m and 2 m alleys were left between treatments in each block and between blocks, respectively.

2.6 Planting and application of fertilizer treatments

The AGRA rice variety used for planting at all sites. Planting was done between the first and third weeks of July, 2021. Planting was done at four seeds per hill and later thinned to the appropriate plant stands of 3 seedlings per hill after germination.

The broad-spectrum pre-emergence herbicide, Glyphader 480, was used to control the weeds in each field at planting. The basal fertilizer treatments were applied from two weeks after planting as indicated in the protocol.

2.7 Data collection and analysis

Sampling for yield data was done after manual harvest of the crops. The crop was harvested using sickle. Harvesting was done on plot bases. After harvesting, rice paddy were manually threshed on plot bases, and winnowed. Harvesting of plots were done separately in accordance with each treatment. Threshed grains were air dried to ~13% moisture content by weight. The weighed grains per plot were converted into weight per unit area (kg/ha).

Comment [i-[6]: Writing consistency of ton/ha.

The weight of 1000 grains of paddy were taken to investigate the effect of the nutrient regimes on grain mass.

All the yield data were analyzed using analysis of variance (ANOVA) in GenStat Statistical package 12th edition. The treatment means were separated and compared using the Least Significant Difference (LSD) at 5% level of probability.

3.0 RESULTS

3.1 Rice paddy yield

Rice paddy yield at Nyankpala was significantly affected (P<0.001) by the fertilization regimes (Table 2). Rice paddy yield ranged from 433 kg/ha in the unfertilized (control) plot to 4280 kg/ha in ACT-L+ACT-L. Yield among the fertilizer treatments without CropLiftBio application was not statistically different. Rice plants that received CropLiftBio foliar application gave significantly better yields than those without the foliar fertilizer. Among the foliar treatments, rice grain yield was statistically similar. Average yield increases over the control was 411% in ACT+URE and 888% and 152% in ACT-L+AMI-L.

Comment [i-[7]: The importance of the description of CropLiftBio so that it affects rice yields.

Rice paddy yield at Walewale was significantly affected (P<0.001) by the fertilization regimes. Grain yield ranged from 320 kg/ha in the unfertilized (control) plot to 4240 kg/ha in UNIK-L+AMI-L plot. All rice plots that received fertilization had significantly higher yields than that of the control (Table 3). Rice grain yield among the ACT+URE, UNIK+AMI, UNIK+URE, ACT+AMI and NPK+ACT treatments did not differ significantly. Grain yield among the CropLiftBio treatments were significantly higher than those with no CropLiftBio. Among the CropLiftBio treatments, ACT-L+AMI-L or NPK-L+AMI-L had the highest yield.

Rice grain yield at Damongo was significantly affected (P<0.001) by the fertilization regimes. Grain yield ranged from 440 kg/ha in the unfertilized (control) plot to 2440 kg/ha in ACT-L+AMI-L plot (Table 4). With the exception of ACT-L+URE-L, UNIK-L+AMI-L and ACT-L+AMI-L which had significantly higher yield, grain yield from the other fertilizer treatments was statistically similar. There was yield increment of at least 142% over the control.

Rice paddy yield at Yendi was significantly affected (P<0.001) by the fertilization regimes (Table 5). Grain yield ranged from 3787 kg/ha in UNIK-L+AMI-L to 1467 kg/ha in the unfertilized (control) plot. With the exception of UNIK+URE, all the rice plots that received fertilization had significantly higher yields than that of the control. Grain yield obtained from ACT-L+URE-L or ACT-L+AMI-L was similar to those from the other fertilizer treatments with no CropLiftBio. Average yield increases of 39% and 158% over the control were recorded from the UNIK+URE and UNIK-L+AMI-L treatments, respectively.

Table 2: Effect of YARA fertilization regimes on rice grain yield at Nyankpala, 2021 cropping season.

Comment [i-[8]: Provide a column for the Table.

Fertilization regimes	Grain yield (kg/ha)
CONTROL	433 a
ACT+URE	2213 b
UNIK+AMI	2213 b
ACT+AMI	2360 b
UNIK+URE	2387 b
UNIK+ACT	2680 b
UNIK-L+URE-L	3673 c
UNIK-L+ACT-L	3787 c
ACT-L+URE-L	4027 c
UNIK-L+AMI-L	4107 c
ACT-l+AMI-L	4280 c

LSD (0.05) = 657.5; P<0.001

~~**Figure**~~ **Tabel 3:** Effect of YARA fertilization regimes on rice grain yield at Walewale, 2021 cropping season.

Comment [i-[9]: Provide a column for the Table. It's not a "Image", but rather a "Table".

Fertilization regimes	Grain yield (kg/ha)
CONTROL	320 a
ACT+URE	2120 b
UNIK+AMI	2240 b

UNIK+URE	2320 b
ACT+AMI	2573 b
UNIK+ACT	2627 b
UNIK-L+ACT-L	3440 c
ACT-L+URE-L	3507 c
UNIK-L+URE-L	3560 c
ACT-l+AMI-L	3867 cd
UNIK-L+AMI-L	4240 d

LSD (0.05) = 539.6; P<0.001

Table 4: Effect of YARA fertilization regimes on rice grain yield at Damongo, 2020 cropping season.

Comment [i-[10]]: Provide a column for the Table.

Fertilization regimes	Grain yield (kg/ha)
CONTROL	440 a
ACT+URE	1067 ab
UNIK+ACT	1173 b
UNIK+AMI	1200 b
ACT+AMI	1600 bc
UNIK+URE	1707 bcd
UNIK-L+ACT-L	1747 bcd
UNIK-L+URE-L	1813 bcd
ACT-L+URE-L	2027 cd
UNIK-L+AMI-L	2147 cd
ACT-L+AMI-L	2440 d

LSD (0.05) = 695.1; P<0.001

Table 5: Effect of YARA fertilization regimes on rice grain yield at Yendi, 2021 cropping season.

Comment [i-[11]]: Provide a column for the Table.

Fertilization regimes	Grain yield (kg/ha)
CONTROL	1467 a
UNIK+URE	2040 ab
UNIK+ACT	2640 bc

UNIK+AMI	2693 bc
ACT-L+URE-L	2880 bcd
ACT-l+AMI-L	2933 bcd
ACT+URE	2960 bcd
ACT+AMI	3027 cd
UNIK-L+ACT-L	3667 d
UNIK-L+URE-L	3733 d
UNIK-L+AMI-L	3787 d

LSD (0.05) = 860.6; P<0.001

3.2 Rice grain weight

The results on seed weight however showed that the fertilization regimes had no significant effect on rice 1000 seed weight at Nyankpala (P=0.14) (Table 6), even though the highest seed weight (25.50 g) was recorded from UNIK-L+AMI-L while the lowest (24.63 g) was recorded from the control (Table 6).

The fertilization regimes had no significant effect on rice 1000 seed weight at Walewale (P=0.95). The highest seed weight (27.53 g) was recorded from UNIK+URE while the lowest (26.80 g) was recorded from ACT-L+AMI-L (Table 7).

The fertilization regimes had no significant effect on rice 1000 seed weight at Damongo (P=0.44). The highest seed weight (27.53 g) was recorded from NPK+URE while the lowest (26.80 g) was recorded from ACT-L+AMI-L (Table 8).

Rice 1000 seed weight was not significantly affected by the fertilization regimes at Yendi (P<0.43), even though the highest seed weight (26.97 g) was recorded from UNIK+URE while the lowest (26.13 g) was recorded from the control (Table 9).

Table 6: Effect of YARA fertilization regimes on rice 1000 grain weight at Nyankpala, 2021 cropping season.

Comment [i-[12]: Provide a column for the Table.

Fertilization regimes	100 Seed weight (g)
ACT-L+URE-L	24.63 a
UNIK-L+URE-L	24.67 a

UNIK+AMI	24.73 a
ACT+AMI	24.80 a
ACT+URE	25.30 a
UNIK-L+ACT-L	25.33 a
CONTROL	25.37 a
UNIK+ACT	25.40 a
ACT-l+AMI-L	25.50 a
UNIK+URE	25.50 a
UNIK-L+AMI-L	25.50 a

LSD (0.05) = 0.82; P=0.14

Table 7: Effect of YARA fertilization regimes on rice 1000 grain weight at Walewale, 2021 cropping season.

Comment [i-[13]: Provide a column for the Table.

Fertilization regimes	100 Seed weight (g)
ACT-L+AMI-L	26.80 a
ACT+AMI	27.13 a
UNIK-L+ACT-L	27.13 a
UNIK+ACT	27.20 a
UNIK-L+URE-L	27.30 a
CONTROL	27.33 a
ACT-L+URE-L	27.37 a
UNIK-L+AMI-L	27.37 a
UNIK+AMI	27.40 a
ACT+URE	27.47 a
UNIK+URE	27.53 a

LSD (0.05) = 1.01; P=0.95

Table 8: Effect of YARA fertilization regimes on rice 1000 grain weight at Damongo, 2021 cropping season.

Comment [i-[14]: Provide a column for the Table.

Fertilization regimes	100 Seed weight (g)
UNIK+AMI	26.13 a
ACT-l+AMI-L	26.37 a

ACT+AMI	26.47 a
ACT-L+URE-L	26.53 a
UNIK-L+AMI-L	26.57 a
UNIK+ACT	26.73 a
UNIK-L+URE-L	26.90 a
UNIK-L+ACT-L	26.93 a
CONTROL	26.97 a
UNIK+URE	26.97 a
ACT+URE	27.10 a

LSD (0.05) = 0.87; P=0.44

Table 9: Effect of YARA fertilization regimes on rice 1000 grain weight at Yendi, 2021 cropping season.

Comment [i-[15]: Provide a column for the Table.

Fertilization regimes	100 Seed weight (g)
ACT-L+URE-L	26.13 a
UNIK+AMI	26.47 a
ACT+AMI	26.47 a
UNIK-L+AMI-L	26.57 a
UNIK-L+URE-L	26.57 a
ACT-l+AMI-L	26.70 a
CONTROL	26.73 a
UNIK+ACT	26.73 a
ACT+URE	26.87 a
UNIK-L+ACT-L	26.93 a
UNIK+URE	26.97 a

LSD (0.05) = 0.79; P=0.61

4.0 DISCUSSION

Results from this study have demonstrated that availability of adequate nutrients could improve growth and yield parameters of rice in the study locations. The higher paddy yield obtained from UNIK-L+AMI-L treatment could be due to the action of NPK, Urea and Sulphur in that fertilizer regime. This NPK product (also called T15 or UNIK 15), is composed of NPK 15-15-15 fertilizer, and every granule of T15 contains total N, P, K nutrition. Yara T15 products include a balance of nitrate and ammonium nitrogen, making the products significantly more effective than urea of ammonium-based fertilizers per unit of nitrogen. This formulation is known to dissolve quickly and evenly when in contact with the soil in humid conditions or after a night's dew. In dry climates, the higher solubility of the products helps nutrients reach the roots where limited soil moisture is available. In tropical climates nutrients move rapidly into the soil, avoiding potential for soil surface run-off due to heavy rain, and thus, promoting rice growth and productivity.

Also, T15's nitrophosphate production process gives the formulation a unique combination of polyphosphates and orthophosphates. These forms give greater availability of soluble phosphate to the rice plant over a wide range of soil types. oreover, Amidas is made up of 40 N + 5.6 S. This is an improved Urea with Suphur fertilizer Yara Amidas is a unique granular fertilizer that is 100% soluble and very efficient. The product contains nitrogen and sulphate sulphur that is totally available to the rice crops in an ideal N:S ratio of 7:1. The nitrogen is mostly available in the urea form, making it ideal for rice growth, yield and productivity especially in the relatively poor soils of northern Ghana. Furthermore, the sulphur content of Amidas improves nitrogen efficiency from urea by reducing nitrogen volatilisation losses by up to 35% on low pH soils; a property that is generally lacking in our conventional physical blends of urea and ammonium sulphate. Less nutrient losses and the balanced nitrogen and sulphur supply from Amidas fomulation could ensure consistently high yields of quality paddy with minimum environmental impact (Olowookere et al. 2017; Daphade et al., 2019; Yigermal et al. 2019).

On the other hand, Urea (46% N) is a formulation from anhydrous ammonia (NH_3) with high nitrogen (N) analysis of 46% compared to all known N fertilizers. It is made available to the plant after contact with moisture within 48hours of application which is best achieved through soil incorporation. Urea is generally applied alone and is the fertilizer of choice when only N is needed in a fertilizer program. This may explain its inability to compete favorably with Amidas as a top-dress fertilizer as revealed in this study.

5.0 CONCLUSION AND RECOMMENDATIONS

Comment [i-[16]: At the end of the paragraph, the authors should highlight the limitations of the study, so that it becomes a practical implication and theoretical contribution to support the motivation of future studies.

Based on the results obtained, the following conclusions were made:

1. Significant improvement in rice paddy yield was realized in all study locations due to the fertilizer treatments. Grain yield improvement ranged from 4,280 kg/ha in Nyankpala to 2,440 kg/ha in Damongo.
2. The best two performing treatments in improving rice grain yield in both Nyankpala and Damongo were UNIK-L+AMI-L and ACT-L+AMI-L and ACT-LURE-L, in descending order.
3. At most locations, rice grain yield among the CropLiftBio foliar treatments was statistically similar.
4. Application of ACT+URE and UNIK+ACT without CropLiftBio foliar supplementation consistently demonstrated lower rice grain yields compared to the other fertilizer treatments in all study locations.
5. Rice paddy weight was however, not significantly impacted by the fertilizer treatments at any of the study locations.

Based on the conclusions raised, the following recommendations were made:

1. From the results of this study, Actyva fertilizers used as basal appear to be unsuitable for rice production in the savanna ecology of Ghana as these generally provided lower grain yields.
2. For maximum grain yield of rice in the ecology, Yara UNIK 15 (NPK 15:15:15) fertilizer is the most recommended. The basal application of UNIK 15 at 125 kg/ha and topdressing with Amidas at 125 kg/ha with CropLiftBio foliar supplementation will provide better yields for farmers than applying Actyva as topdress.
3. Where Amidas becomes unavailable, however, Urea (46 N) may be used as alternative topdressing product for moderate yield.
4. There is the need to investigate the efficacy of adding UNIK 15, or including Sulfan as possible topdress alternatives for rice production in the ecology.
5. For the smallholder situation where, double application may be a challenge, there is need to consider the efficacy of fertilizing rice with UNIK 15 alone at recommended rate, without any topdress application.

Competing interest

Authors have no conflict of interests

Acknowledgements

YARA Ghana Limited provided funding for the research.

REFERENCES

Comment [i-[17]: There are still references such as journals, which do not include numbers (series) and doi links/urls.

1. Abumere, V.I., O. A. Dada, A. G. Adebayo, F. R. Kutu, and A. O. Togun (2019). Different Rates of Chicken Manure and NPK 15-15-15 Enhanced Performance of Sunflower (Helianthus annuus L.) on Ferruginous Soil. International Journal of Agronomy 2019. http https://doi.org/10.1155/2019/3580562.
2. Ceyhan, E., Onder, M., Ozturk, O., Marmankaya, M., Hamurcu, M., Gezgin, S. (2008). Effects of application of boron on yields, yield component and oil content of sunflower in boron-deficient calcareous soils. African Journal of Biotechnology 7(no?), 2854-2861. doi?
3. Daphade, S.T., G. R. Hanwate, Gourkhede, P. H. (2019). Influence of Zn, Fe and B Applications on Nutrient Availability in Soil at Critical Growth Stages of Maize (*Zea mays*) in Vertisol of Marathawada Region of Maharashtra, India. International Journal of Current Microbiology and Applied Sciences, 8(no?), 206-212. doi?
4. Darma, S., Lestari, D., Darma, D.C. (2022). The productivity of wineries – An empirical in Moldova. Journal of Agriculture and Crops, 8(1), 50-58. https://doi.org/10.32861/jac.81.50.58.
5. Darma, S, Hakim, Y.P., Kurniawan, E., Darma, D.C., Suparjo, S. (2022). Understanding market behavior on corn commodity: Phenomenon at year end. Asian Journal of Agriculture and Rural Development, 12(2), 53–64. https://doi.org/10.55493/5005.v12i2.4434
~~4.~~6. Fismes, J., P.C. Vong, A. Guckert, Frossard, E. (2000). Influence of sulfur on apparent N-use efficiency, yield and quality of oilseed rape (*Brassica napus* L.) grown on a calcareous soil. European Journal of Agronomy, 12(no.?), 127–141, doi?. and others !
~~5.~~7. Irfan, M., Abbas, M., Shah, J.A., Depar, N., Memon. M.Y., Sial, N. A. (2019). Interactive effect of phosphorus and boron on plant growth, nutrient accumulation and grain yield of wheat grown on calcareous soil. Eurosian Journal of Soil Science 8 (1), 17-26.

~~6.~~8. Kankam-Boadu I., Joseph Sarkodie-Addo and Francis Kweku Amagloh (2018). Profitability of maize production in the northern region of Ghana. International Journal of Development 2(1):3-10.

~~7.~~9. Kihara, J., Sileshi, G.W., Nziguheba, G., M. Kinyua, Zingore, S., Sommer R. (2017). Application of secondary nutrients and micronutrients increases crop yields in sub-Saharan Africa. Agronomy for Sustainable Development 37 (25):5-12.

~~8.~~10. Lisuma, J., Semoka, J., Sem, E. (2016). Maize Yield Response and Nutrient Uptake after Micronutrient Application on a Volcanic Soil. Agronomy Journal 98 (2), 402-406.

~~9.~~11. MacCarthy D., Samuel G Adiku, Bright S Freduah, Alpha Y Kamara, Stephen Narh & Alhassan L Abdulai (2017). Evaluating maize yield variability and gaps in two agroecologies in northern Ghana using a crop simulation model, South African Journal of Plant and Soil,

~~10.~~12. Njoroge, R., Abigael N. Otinga, John R. Okalebo, Mary Pepela and Roel Merckx (2018). Maize (Zea mays L.) Response to Secondary and Micronutrients for Profitable N, P and K Fertilizer Use in Poorly Responsive Soils. Agronomy 8(4), 49-59

~~11.~~13. Olowookere, B.T., Oyerinde, A.A. and Malgwi, W.B., (2017). Influence of Nitrogen and Micronutrient Fertilizer Blends on Growth and Yield of Maize Varieties. Journal of Agriculture Food and Development 3,1-6.

~~12.~~14. Oppong-Abebrese, S., Alex Yeboah, Wilson Dogbe, Paul Kofi Ayirebi Dartey, Richard Akromah, Vernon Edward Gracen, Samuel Kwame Offei, and Eric Yirenkyi Danquah (2019). Evaluation of Yield, Reaction to Diseases, and Grain Physical Attributes of Some Introduced Rice Hybrids in Ghana. International Journal of Agronomy (2019). doi.org/10.1155/2019/3926765

~~13.~~15. Qahar, A., Ahmad, B. (2016). Effect of nitrogen and sulphur on maize hybrids yield and post harvest soil nitrogen and sulphur. Sarhad Journal of Agriculture 32 (3), 239-251.

~~14.~~16. Rudani, L., Vishal, P., Kalavati, P. (2018). The importance of zinc in plant growth- a review. International Research Journal of Natural and Applied Sciences 5 (2), 38-48.

~~15.~~17. Tahir, M., Ali, A., Khalid, F., Naeem, M., Fiaz, N., Waseem, M. (2012). Effect of foliar applied boron application on growth, yield and quality of maize (*Zea mays* L.). Pakistan journal of scientific and industrial research 55(3), 117-121.

~~16.~~18. Yigermal, H., Nakachew, K., Assefa, F. (2019). Effect of integrated nutrient application on phonological, vegetative growth and yield-related parameters of maize in Ethiopia: A review. Cogent Food and Agriculture 5 (1): doi.org/10.1080/23311932.2019.1567998.