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Fertilizer Use Among Maize Farmers in Guinea Savannah Zone of Ghana: The Role of Topdressing Fertilizer

IFDC FERARI Research Report No. 9

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ABBREVIATIONS

FBO	Farmer-Based Organization
FERARI	Fertilizer Research and Responsible Implementation
FPG	Fertilizer Platform Ghana
FUE	Fertilizer Use Efficiency
GAP	Good Agronomic Practice
GoG	Government of Ghana
IFDC	International Fertilizer Development Center
MoFA	Ministry of Food and Agriculture
PFJ	Planting for Food and Jobs
SRI	Soil Research Institute
TFP	Total Factor Productivity
WUR	Wageningen University & Research

SUMMARY

Soil fertility management is key to improving crop yields and achieving food and nutritional security in Ghana. The sustainable use of inorganic fertilizers is therefore critical. The sharp rise in international fertilizer prices during the last quarter of 2021 has been a major drawback for fertilizer use at the local level. This has created a supply deficit of urea fertilizer in Ghana. As a stopgap, the Government of Ghana introduced ammonium sulfate into its subsidy program, even though the fertilizer is known for its acidification effects. This study evaluates the yields of farmers based on the fertilizer used for topdressing. A total of 369 farmers were interviewed, and physical yield cuts were done on 187 farms. The following are the major highlights of the study:

- Most of the farmers had access to extension services and reported positive returns on their yields. Less than half of the farmers (42%) belonged to a farmer-based organization (FBO). Although credit requests were low among farmers, credit access, especially in cash form, was high. Maize was largely cultivated under personal or family land tenure systems and, on average, 2.3 kilometers (km) away from the farmers' residence. Typical of northern Ghana, the cultivated lands were mostly flat. Most of the farmers hired tractor services in their land preparation. Nearly three-quarters of the farms were small-scale, with less than 2 hectares (ha) of cultivated land.
- Nearly four in every five farmers used preemergence weedicide. Only about 2% of the sampled farmers controlled weeds exclusively through manual weeding. About 57%, 18%, 15%, 6%, and 5% of the farmers used their own saved seeds, seeds bought from input shops, Ministry of Food and Agriculture (MoFA)-approved seeds, seeds from research institutions, and seeds obtained on the open market, respectively. Most farmers (63.4%) planted maize in July and harvested in October or November. The level of germination varied based on the source of seed, and except for those who used seeds bought from research institutions, farmers had to practice refilling to improve the plant density on their farms. From the data, more farmers who bought seeds from research institutions recorded higher yields than those using their own seeds; this claim was supported by the estimated yield.
- The major fertilizers used by maize farmers were NPK 15-15-15, NPK 23-10-5+2MgO+3S+0.3Zn, and ammonium sulfate. On average, a farmer applied 254.1 kg/ha of fertilizer to maize. About 34%, 25%, and 10% of the sampled farmers used ammonium sulfate, NPK compound or blend, and urea fertilizers for topdressing, respectively. Farmers applied their basal fertilizers within two to three-and-a-half weeks after planting and topdressing between four to seven-and-a-half weeks after basal fertilizer application. Most of the farmers, especially those using ammonium sulfate, bought their topdressing fertilizers at commercial price. Most farmers (89%) indicated that the use of fertilizer had improved their yields, and 83% indicated the increase in yield compensated for the cost of fertilizers used in maize production. Farmers adopted complementary good agronomic practices (GAPs), and generally, more than half (50%) practiced row planting, planting at recommended spacing, timely weed control, and use of preemergence weedicide; about 48% planted improved seed varieties; and less than 15% practiced minimum tillage, mulching, and use of organic fertilizers.
- The yield level from the 187 harvested (yield cut) farms ranged between 0.6 metric tons per hectare (mt/ha) to 5.2 mt/ha, and the average yield was 2.7 mt/ha. The yield level varied based on regional location and the type of fertilizer used for topdressing.

- ✓ In the North East Region, the average yield was 2.3 mt/ha. It was highest for farmers who used NPK fertilizers (2.5 mt/ha) for topdressing and lowest for farmers who used ammonium sulfate for topdressing (2.1 mt/ha).
- ✓ In the Northern Region, the average yield was 2.5 mt/ha. It was highest for farmers who used urea (2.8 mt/ha) for topdressing and lowest for those who used NPK compound or blended fertilizer (2.3 mt/ha) for topdressing.
- ✓ In the Upper West Region, the average yield was 3.1 mt/ha. It was highest for farmers who did not do topdressing (3.3 mt/ha) and lowest for farmers who used ammonium sulfate for topdressing (3.0 mt/ha).
- ✓ Small-scale farmers had an average yield of 2.7 mt/ha, while medium/large-scale farmers had an average yield of 2.9 mt/ha, although the former used more fertilizer (277.4 kg/ha) than the latter (200.2 kg/ha).

- Regarding the source of seed planted, farmers who used seeds from research institutions had the highest average yield of 3.2 mt/ha and farmers who used their own saved seeds or seeds from MoFA had the lowest average yield of 2.6 mt/ha. Regarding GAPs, farmers who did mulching or minimum tillage had significantly higher yields than farmers who did not.
- The fertilizer use efficiency (FUE) among the farmers averaged 14.8 kg of grain/kg of fertilizer. There were, however, variations based on the socioeconomic characteristics and GAPs adopted by the farmers. Most importantly, own land cultivation, medium/large-scale cultivation, cultivation of farmlands closer to homes, and mulching improved FUE.
- In addition to the promotion of fertilizer use under the subsidy program, farmers must be continuously sensitized or trained on GAPs, particularly mulching, for sustainable maize production.

CHAPTER 1: INTRODUCTION

Soil fertility management remains an important aspect in meeting the food needs of the rising population in sub-Saharan Africa in general and Ghana in particular. The continued cultivation of the soil has led to persistent nutrient depletion. In Ghana, about 12% of households (3.6 million people) are food insecure, reaching as high as 23% in the Savannah and Upper West regions, 31% in the Northern Region, 33% in the North East Region, and 49% in the Upper East Region (FAO and WFP, 2021). This means that food production must be improved to put Ghana on the right path toward a hunger-free society. The persistent gaps between observed and potential/achievable yields for staple crops of the country are attributable to several factors, including declining soil fertility and changing climate. The low yields have also affected the incomes of rural dwellers, making poverty persistent in these areas. Therefore, improving the productivity of the soils could provide productivity gains and transform the rural economies. An important step to restore the fertility of the soils is through the application of fertilizers, either organic or inorganic. Due to the low and declining soil fertility, use of inorganic fertilizers is unavoidable in Ghana if yields must increase to meet the rising food and nutritional security needs of the country. At the sub-Saharan regional level, the minimum input requirement for maize production must rise more than the expected rise in maize production levels to meet the 2050 food and nutrition security projections (ten Berge et al., 2019).

Considering the need to improve cereal crop production, the Government of Ghana has implemented fertilizer subsidy programs since 2008, primarily aimed at enhancing the use of fertilizers for improved productivity. Largely, this has been successful in increasing fertilizer usage. But the impacts of the rising fertilizer applications on crop yields remain questionable. For instance, the FUE of farmers was found to be significantly low at an average 2.7 kg maize grains per kilogram of nitrogen applied: 2.8 kg/kg and 2.4 kg/kg for farmers who used subsidized and commercially priced fertilizers, respectively (Adzawla et al., 2021a). The implication is that the use of fertilizers does not translate into a significant increase in actual yields. It is uneconomical, inefficient, and environmentally unsustainable to continue increasing nutrient application without correcting the low yield response to the nutrients (ten Berge et al., 2019). This raises many questions including the appropriateness of fertilizer use practices adopted by the farmers, such as the use of the right fertilizer types. Nonetheless, the low nutrient efficiencies do not underscore the importance of fertilizer in crop production in countries such as Ghana.

Fertilizer application is generally done as basal and topdressing. While basal application is done before or shortly after planting, topdressing is done as a second fertilizer application after basal application and during the initial developmental stage of the crop. In Ghana, basal application on cereals like maize is recommended to be done within two weeks after planting and topdressing six weeks after planting. Because of the high leaching capacity of nitrogen despite its significant importance in soil fertility, topdressing with a nitrogen fertilizer improves its availability and the performance of crops. The Government of Ghana’s Planting for Food and Jobs (PFJ) program provides subsidies for blended fertilizers as basal fertilizers and urea as topdressing fertilizer for cereal crops. However, in 2021, international fertilizer prices skyrocketed, especially for urea, affecting fertilizer availability for the local farmers. As a stopgap measure, the government, through the Ministry of Food and Agriculture (MoFA) proceeded to include ammonium sulfate in its subsidized fertilizer list to enable farmers to topdress their cultivated farmlands. The use of ammonium sulfate is already high among farmers, and efforts to reduce its use are being advocated due to its acidification effect on soils. Therefore, it is important to understand whether the stopgap measure could be justified at least on yield grounds. As this fertilizer contains sulfur, which was previously found to favorably impact yield (Bua et al., 2020), it was hypothesized that top-dressing with ammonium sulfate might result in higher yields than urea. A key approach to the implementation of the FERARI project is to take actions or implement activities based on evidence and to provide practical and justifiable policy recommendations that can help improve yield at farm level and increase households' income. Therefore, a comprehensive analysis is necessary.

Maize remains an important crop in Ghana's food basket, as it represents over half the total cereal production. Almost every Ghanaian household consumes maize, and it is cultivated by most staple crop producers in the country. It plays a significant role in the food and income security of households. The use of inorganic fertilizers for maize production is higher than for most other staple crops. In addition, maize is a major crop under consideration by the FERARI project. Against these backdrops, evidence on maize production and how yields can be bettered is crucial. In this study, the impact of the type of fertilizer used for topdressing on the farmers' yield will be analyzed. We hypothesize that topdressing with ammonium sulfate leads to an increase in maize yield over topdressing with other fertilizer types (urea or NPK compound/blends).

CHAPTER 2: METHODOLOGY

The study was conducted in the Guinea Savannah region of Ghana, specifically the Northern, North East and Upper West regions of Ghana. The zone is located in the northern part of the country that characteristically has higher temperatures and lower rainfall relative to the southern zone. Although unimodal, rainfall plays a significant role in the livelihood of households in the agroecological zone since most depend on rainfed agriculture for their needs. The study was conducted in the Guinea Savannah zone only because the announcement for the inclusion of ammonium sulfate among subsidized fertilizers under the PFJ program happened during the production period of 2021 and farmers in the Transitional zone had already applied or purchased the fertilizers they intended to use for topdressing under the major cropping season. But this came at a time when farmers in the Guinea Savannah zone were still making such purchasing decisions. Figure 1 shows the locations of the sampled farms and households.

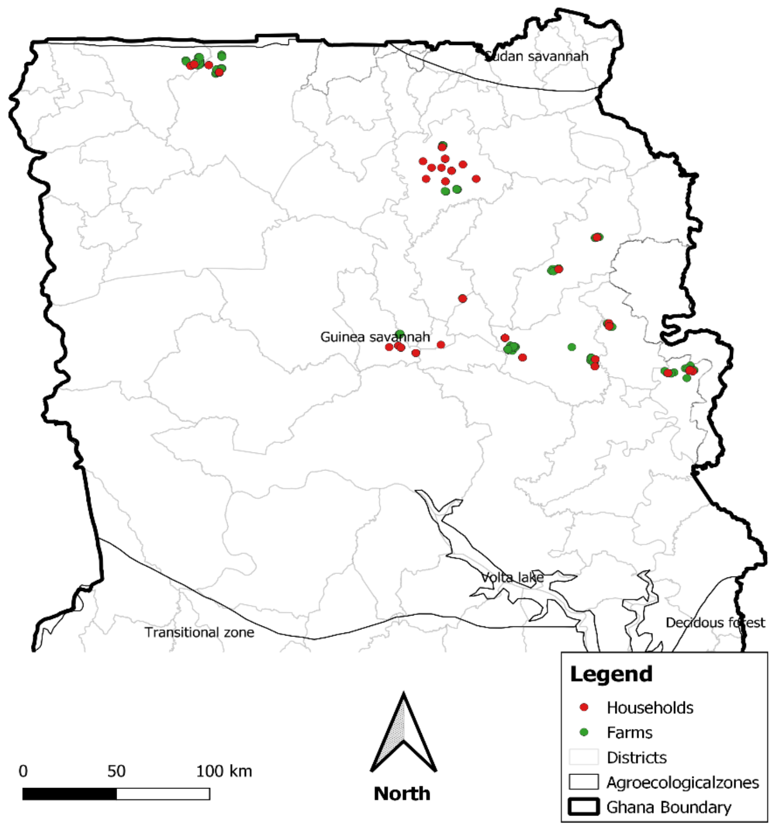

Figure 1.   Locations of the Sampled Farms and Households

The announcement of the inclusion of ammonium sulfate in the fertilizer subsidy program of Ghana triggered the sampling of the farmers. Farmers were profiled during the production period based on the topdressing fertilizer used or intended to be used by the farmers. The profiling revealed low urea use among the farmers. At harvest, the profiled farmers who had not harvested their farms at the time were contacted for farm harvesting. Also, farmers who were not profiled but used fertilizers were also contacted and sampled. The design was to interview an equal proportion of farmers who used urea, ammonium sulfate, and NPK compound or blended fertilizers as topdressing fertilizers on their maize farms. However, the data collection process dictates that an unequal distribution be sampled. Experienced yield cut technicians went to the farms of the selected farmers to harvest and measure the yield and biomass on three quadrants with a 2 x 2 meter (m) dimension. In all, 187 farms were harvested.

In addition to the yield cuts, the socioeconomic and production data on the farmers were gathered through face-to-face interviews. A total of 182 farmers whose farms were not harvested were also interviewed to increase the representativeness of the sample. Therefore, a total of 369 farmers were interviewed. For methodological verification, the recall yields of both the yield cut and non-yield cut farmers were recorded subsequently.

Four main steps were followed to determine the yield of the farmers:

1. The harvest from each farm was done on three spots measuring 2 x 2 m (i.e., 4 m^2), totaling 12 m^2.[1]
2. The weight of the harvested output (cobs with grains) was taken and extrapolated (i.e., the observed weight was multiplied by 10,000 and the result was divided by 4). This gave the measurement in kilograms per hectare (kg/ha).
3. A shelling percentage of 80 (80%) was applied to the weight at harvest to determine the weight of the grains (i.e., grain weight is equal to the product of 0.80 and weight of cob with grain from step 2).
4. The moisture content of the grains was taken for each sample using a moisture meter and was used to correct the grain yield (i.e., grain yield with moisture minus moisture content in the grain to get dry matter grain yield [kg/ha]). The moisture content of the grains averaged 14.2% (standard deviation of 3.3%), with a minimum and maximum of 8.9% and 25.1%, respectively.
5. The average yield from the three spots are recorded as the observed yield of the farmer.

[1] Refer to Appendix 1 for the descriptive statistics of yields at each quadrant.

CHAPTER 3: RESULTS AND DISCUSSION

3.1 Socioeconomic Characteristics of Farmers

3.1.1 FBO Membership

Figure 2 shows the percentage distribution of farmers based on their membership in an FBO and the impact of membership on crop production. About 42% of the farmers belonged to an FBO. Among the FBO members, about 83% indicated that their membership in an FBO led to an improvement in their maize production. However, about 17% of FBO members indicated FBO membership had no effect on their maize production levels. The results suggest that the FBO membership made positive gains on maize production for the majority. Mostly, an FBO serves as a platform for farmers to share information and provide production assistance to each other. While it is important that farmers are encouraged to join or form associations, other stakeholders in the agriculture sector must help the farmer groups to function well and to deliver on crop production improvement goals.

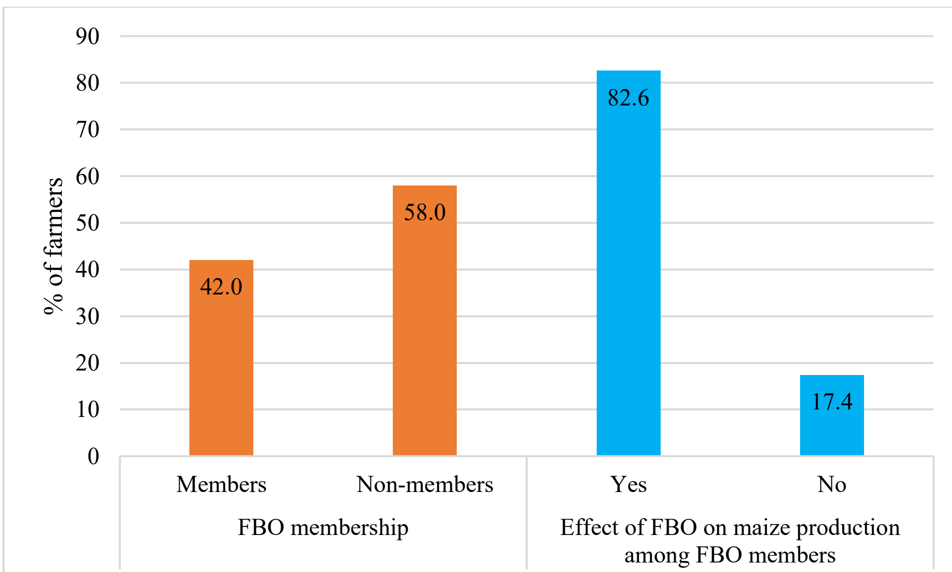

Figure 2. FBO Membership and Its Effect on Maize Production

3.1.2 Access to Extension Services

Extension service delivery is an integral part of improving crop production. As shown in Figure 3, about 60% of the farmers had access to extension services. Among these farmers, 96% expressed that their access to extension services had influenced their maize production positively. The percentage of the farmers who had no access to extension services (40%) was reasonably high considering the role of extension service delivery on crop production. Thus, MoFA and other non-governmental organizations in the agriculture sector should work to ensure that farmers are given the needed agricultural information and technical support. Extension service should particularly be provided to the farmers, since nearly all of those who received the services indicated it had helped improve their maize production. However, the estimated data revealed that, although farmers perceived that extension services increased yield, the yield difference was insignificant. The extension services received by the farmers were largely related to proper planting, appropriate use of fertilizers and other agrochemicals, climate information (particularly rainfall), conservation agriculture and zero tillage, other GAPs, and general farm management. Details on the actual impact of extension contact on yield and FUE are discussed in Section 3.8.4.

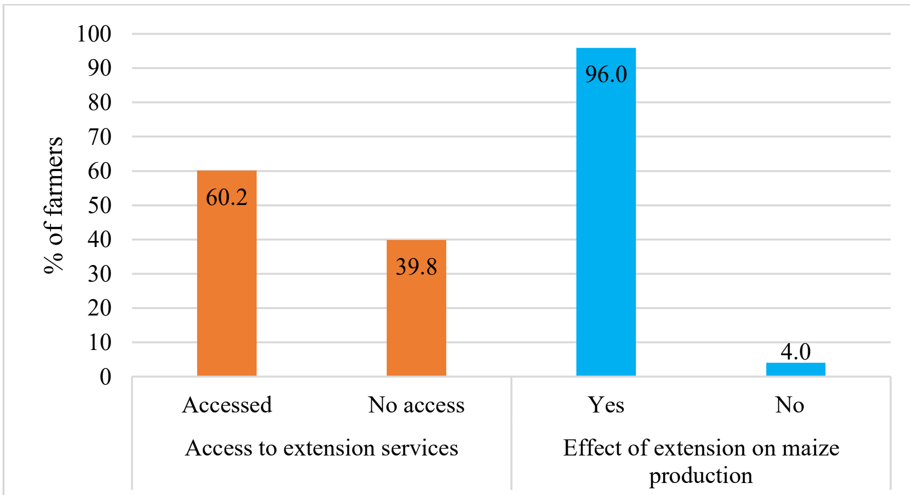

Figure 3. Access to Extension Services and Its Effect on Maize Production

3.1.3 Access to Credit

Table 1 shows the information on access to credit among the farmers. The highest proportion of the farmers did not apply for credit to support their crop production. This means that most farmers relied on their personal funds for maize production. Among the 43% of the farmers who applied for credit, only one of them was not granted the request. Also, only one farmer who applied for credit did not receive the exact amount requested. The majority of the farmers received cash credit. The implication is that the problem of low credit access among farmers may not necessarily be due to a failure by credit providers to lend to the farmers, but largely due to the lack of desire of the farmers to apply for the credit or the lack of collateral that prevents them from applying. Farmers who received input credits often had contractual arrangements with the input providers or marketers to obtain inputs, particularly fertilizer and herbicides, during the production period. After harvesting, the farmers repaid with the number of bags of harvested maize equivalent to the total cost of such credited inputs received by the farmer.

Table 1. Access to Credit among Farmers

Response	Frequency	Percentage
Application for credit		
Yes	158	42.8
No	211	57.2
Access to credit		
Yes	157	99.4
No	1	0.6
Received amount requested		
Yes	156	99.4
No	1	0.6
Form of credit		
Cash	100	63.3
Input/in-kind	51	32.3
Both	7	4.4

3.2 Land Tenure and Land Preparation

3.2.1 Source of Cultivated Land

Figure 4 shows the land tenure systems under which maize was produced. Most of the sampled farmers cultivated maize on their own farmlands, and about one in every four farmers cultivated maize on family land. The use of communal or leased land was very low among the maize farmers. The land tenure system is important, as it may have implications on the soil fertility investment decisions made by the farmers. Considering the dominant use of own or family land, it is most likely that the farmers would be willing to invest in not only short-term fertility management strategies, but also long-term strategies that could make their soil continually productive. A previous report (Adzawla et al., 2021b) also showed that the use of personal or family land is common among farmers.

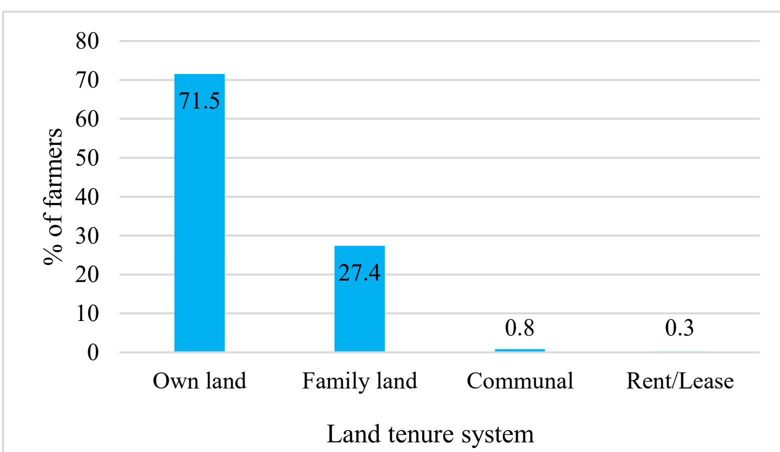

Figure 4. Sources of Land for Maize Production

3.2.2 Cultivation of Same Land in Previous Cropping Season

Table 2 shows the percentage distribution of farmers cultivating their farmlands in the previous cropping season and to which crop such lands were cultivated. Only 13 (3.5%) farmers cultivated new land, while the remainder continued to cultivate on the same piece of land. About 43% of the farmers grew maize following a maize crop, while 26% cultivated soybean. About one-third of the farmers cultivated other crops such as millet or vegetables in the previous year. The continued cultivation of maize on the same farmland may affect the level and pattern of nutrient depletion in the soil, since the same nutrients are being taken up by the crops at similar depths and levels over the cropping periods. The impact of the cultivation of the farmland in the previous season on maize yield and FUE is discussed in Section 3.8.4.

Table 2. Continuous Land Cultivation

Response	Frequency	Percentage
Cultivated same farmland		
No	13	3.5
Yes	356	96.5
Crop cultivated on same farmland		
Maize	153	43.0
Rice	1	0.3
Soybean	93	26.1
Other crops	109	30.6

3.2.3 Nature of Farmland and Land Preparation Methods

The majority of farmers (86.7%) expressed that their farmlands were flat, while the remaining farmers said their farmlands had a gentle to medium slope. The nature of the farmland is important, as it partially determines the level of water retention. It may also have an implication on the ease of carrying out farm activities, such as weeding. The highly cultivated flat land means that some water would remain on the farm and there would be less runoff, thereby reducing the leaching of soil nutrients. The results also show that the majority of the farmers prepared their farmlands through tractor plowing, while only a few used chemical sprays or slash and burn. The frequent tractor plowing has become a major practice among farmers in northern Ghana. Due to the low availability of tractors, access to tractors or tractor services has become a major challenge that results in a delay in planting of seeds.

Table 3. Nature of Cultivated Farmlands

Response	Frequency	Percentage
Nature of farmland		
Flat	320	86.7
Gentle slope	41	11.1
Medium slope	8	2.2
Method of land preparation		
Tractor plow	340	92.1
Chemical spray	23	6.2
Slash and burn	6	1.6

3.2.4 Distance from Home to the Farmlands

The distance from farmers' homes to the cultivated maize farmlands is shown in Table 4. From the data, a farmer traveled 2.3 km on average from home to the farm, with a range of 1-25 km. Over 90% of farmers traveled no farther than 5 km to their farms. Only one farmer had a farm more than 20 km away from home. The short distance from the homes to the farms for the majority of farmers may suggest that these farmers do not travel long distances, which can have an effect on their movement and lessen their tiredness. The major means of transport to the farms included the bicycles, motorbikes, and on foot.

Table 4. Distance from Home to Maize Farms

Distance (km)	Frequency	Percentage
1-5	341	92.4
5-10	14	3.8
11-15	13	3.5
16-20	0	0.0
21-25	1	0.3
Total	369	100.0

3.2.5 Scale of Production

Table 5 details the percentage distribution of the scale of maize production among the farmers. The majority of the farmers cultivated land of 2 ha or less. The average farm area cultivated by the small-scale producers was 0.9 ha, while medium- to large-scale farmers cultivated an average area of 3.6 ha. Overall, the mean cultivated area of the entire sample was 1.6 ha. This is lower than previous studies, which revealed a mean maize cultivated area of 2.2 ha for the 2019 cropping season (Adzawla, 2021b) and 2.0 for the 2020 cropping season (Adzawla et al., 2021c). In terms of classification by scale of production, the observed 74% of small-scale proportion is comparable to the 70% estimated by Adzawla et al. (2021c). The low mean cultivated area observed in this survey relative to the previous ones is due to the exclusion of the Transitional zone, where farm sizes are observed to be higher. Thus, the average of 1.6 ha is reasonable for the Guinea Savannah zone.

Table 5. Scale of Maize Production

Scale	Frequency	Percentage	Mean	Std. Dev.
Small-scale	273	74.0	0.9	0.4
Medium/large-scale	96	26.0	3.6	3.1

3.3 Weed Management

3.3.1 Method of Weed Control

Table 6 shows the methods and frequencies of weed control by the farmers. Most of the farmers (79.1%) used preemergence weedicides on their maize farms. These preemergence chemicals are used on the farms before the weeds emerge. Thus, just after planting, the farmers spray their farms with preemergence weedicide. Most of the farmers used only herbicides in controlling weeds on their farms and about 37% of them used both herbicides and manual weeding. The rising availability and awareness of farmers on various herbicides explains the low exclusive manual (use of hoes and cutlasses) weed control by the farmers. Overall, most of the farmers (69%) practiced weed control twice on their farms, while one farmer practiced weed control as many as five times.

Table 6. Methods and Frequency of Weed Control

Response	Frequency	Percentage
Use of preemergence weedicides		
No	77	20.9
Yes	292	79.1
Method of weed control after planting		
Manual weeding only	7	1.9
Herbicides only	224	60.7
Both	138	37.4
Number of times of weed control		
1	58	15.7
2	255	69.1
3	50	13.6
4	5	1.4
5	1	0.3

3.3.2 Perception of Farmers on the Effectiveness of Weed Control

Overall, about 94% of the farmers indicated they had adequately controlled weeds on their maize farms (Figure 5). Surprisingly, all seven farmers who did exclusive manual weeding (Table 6) indicated they had effectively controlled weeds on their farms (Figure 6). However, some of the farmers indicated that although they controlled weeds on their farms adequately, sometimes this is done a bit late. This raises questions about the timing of weed control by the farmers.

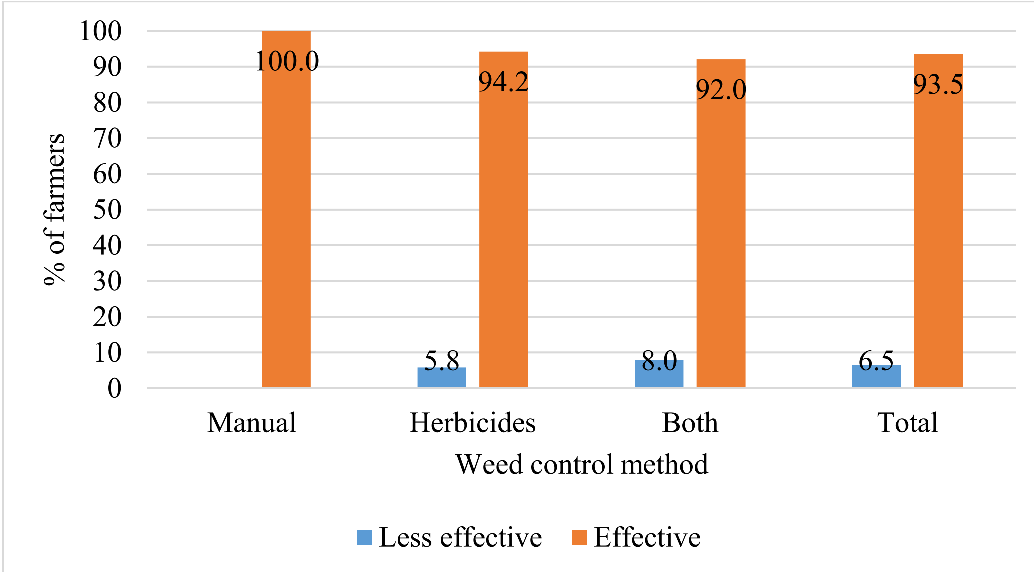

Figure 5. Effectiveness of Weed Control Methods

3.4 Seeds Used for Maize Production

3.4.1 Sources of Seed

Table 7 shows the major sources of maize seed planted by the farmers. More than half of the sampled farmers (57.2%) used their own saved seeds, and the remaining 42.8% bought the seeds from various sources, including the open market, input shops, MoFA offices, and research institutions. This suggests a high use of local seeds among the farmers.

Table 7. Sources of Maize Seed

Source	Frequency	Percentage
Own saved seed	211	57.2
Open market	17	4.6
Input shop	65	17.6
MoFA	54	14.6
Research institute	22	6.0

3.4.2 Maturity Period of Seed Varieties Used

Figure 6 shows the planting and harvesting periods of the farmers. The majority of the farmers planted their maize in July, followed by June. The harvesting of maize was done by most of the farmers in October, followed by November. It is often recommended that maize be planted in late May to June in the Guinea Savannah zone and up to July in the Sudan Savannah zone. However, due to the changing rainfall pattern, especially the onset of the rains, farmers continue to respond appropriately by changing their planting period. This explains the high percentage of farmers planting maize in July.

The duration from planting to harvesting of maize by individual farmers and the distribution is shown in Figure 7. This shows that the majority of the farmers planted maize seed varieties that took four months to mature. About one in every four farmers planted varieties that matured at three months.

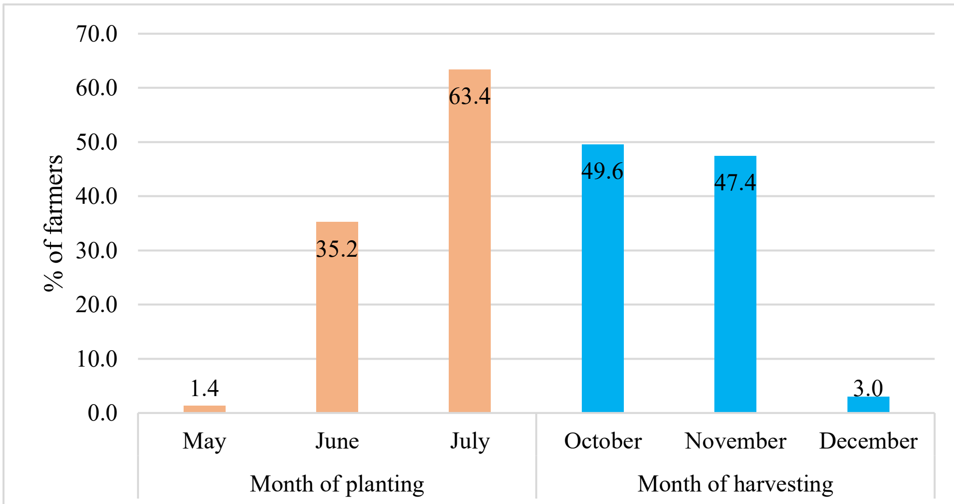

Figure 6. Months of Planting and Harvesting Maize

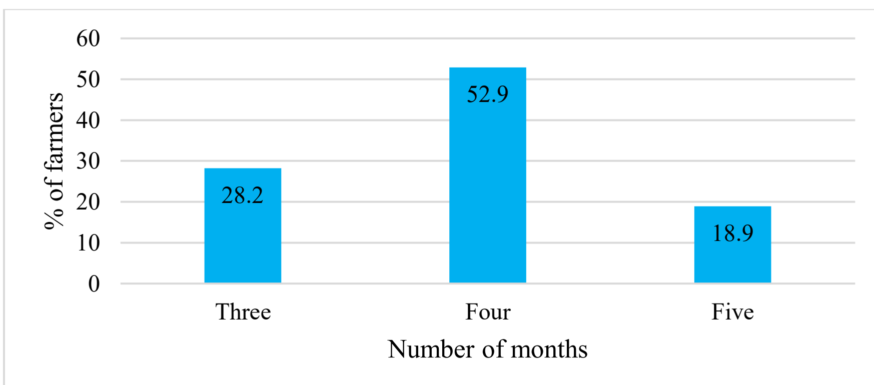

Figure 7. Maturity of Seed Varieties Planted

3.4.3 Level of Seed Germination

The farmers provided an assessment on the level of germination of seeds planted. About 91% of the farmers indicated that their seeds germinated very well, and they did not do any refilling of seeds (Figure 8). This was specifically highest for farmers who used seeds they bought from research institutions, as none of them practiced refilling. The results suggest that there was a low germination rate for their own saved seeds and seeds from the open market, since no germination test is done for such seeds before sowing. Farmers must be sensitized to the need to obtain seeds from the right sources to improve the germination rate and, ultimately, crop yields.

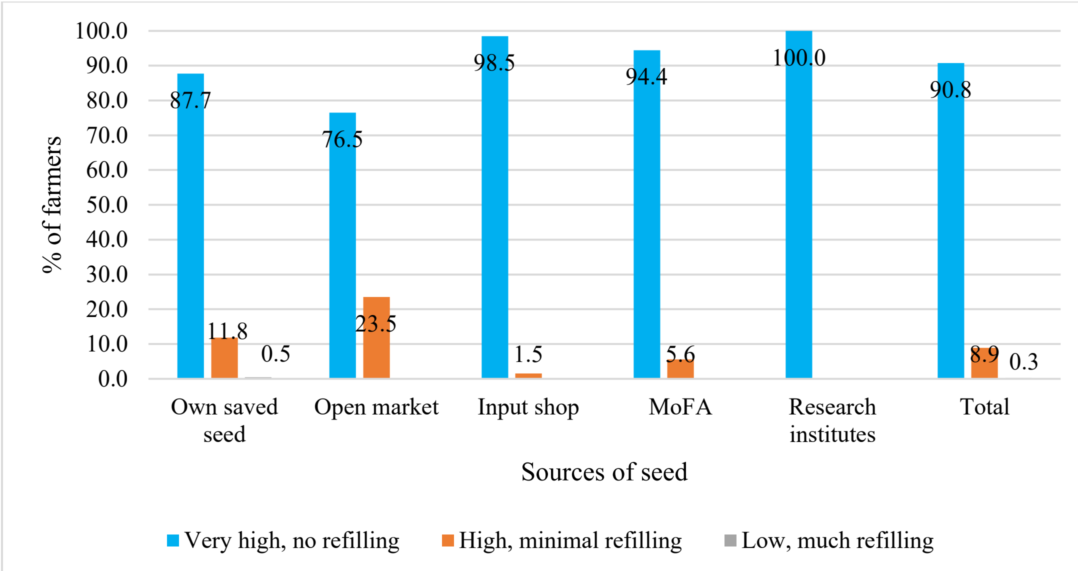

Figure 8. *Level of Seed Germination by Source of Seed*

3.4.4 Yield Assessment Based on Bought Seeds

The farmers who used seeds other than their own compared the yields from the current seeds to those of their own used in previous years. As shown in Figure 9, most of the farmers who used seeds from research institutions perceived that yields were much higher than when they had used their own saved seeds. The same was true for farmers who used seeds bought from MoFA and input shops. However, farmers perceived yields with seeds from the open market to be lower than yields from using their own saved seeds, which is justifiable since such open market seeds are largely intended for subsistence only.

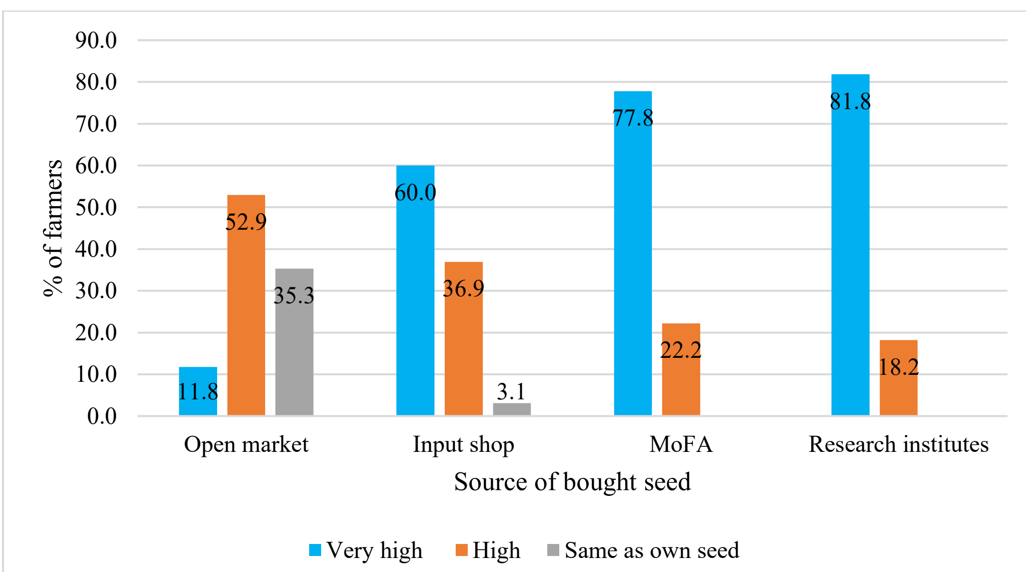

Figure 9. *Yield Assessment based on Source of Seed*

3.4.5 Source of Seeds for the Next Season

Figure 10 shows whether farmers intended to use the seeds from the same source in subsequent production seasons. Most farmers, except those who used seeds from the open market, indicated they will use seeds from the same source in the next season. Specifically, about 93% of farmers who used seeds bought from MoFA offices indicated they would buy the same seeds for the 2022 production. This may be because, in addition to the high yields as reported in Figure 8, such seeds are subsidized by the government, hence a lower cost to the farmers. It is surprising that, although most of the farmers who used seeds bought from research institutions indicated having very high yields (Figure 9), about 32% plan to change to a different source of seed. This could be due to cost implications, since seeds sold at the research institutions are relatively more expensive than those in the input shops.

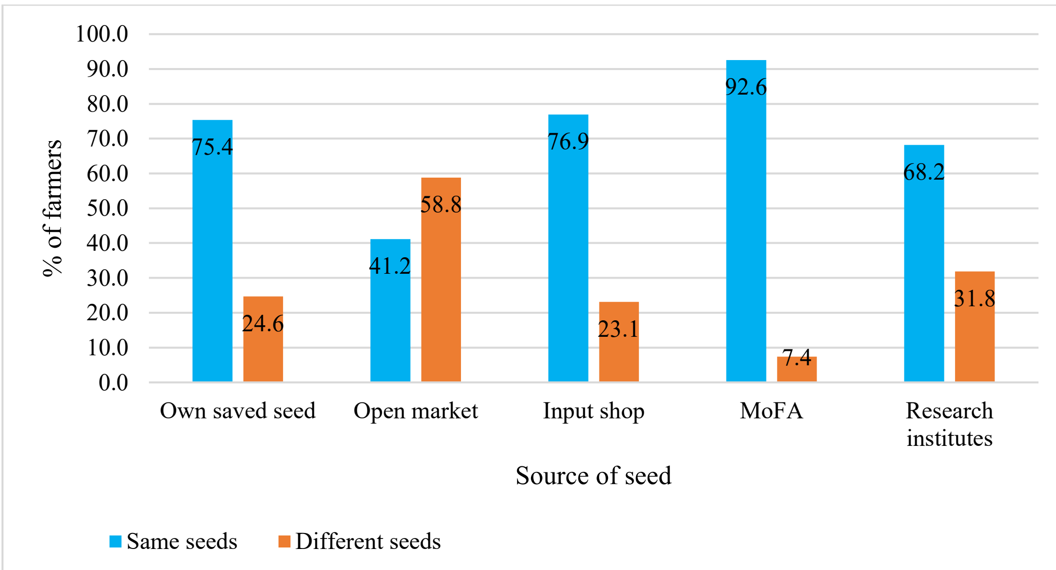

Figure 10. Source of Seed for the Next Season

3.5 Labor Analysis in Maize Production

3.5.1 Perceptions on Labor Availability and Cost

Table 8 shows the perceptions of the farmers on the availability and cost of labor for maize production. About 89% of the farmers held that there adequate labor was always available to them. However, the remaining 11% indicated inadequate available labor. The implication is that such farmers must reduce their cultivated area to supply adequate labor for their farms. An earlier result shows that inadequacy of manpower is a major challenge to about 37% of maize farmers (Adzawla., 2021c).

Regarding cost, about 83% of the farmers indicated that they could afford the cost of labor at all times. This means that the current cost of labor is not a major challenge to many farmers. Consistently, most of the farmers (61.5%) indicated that both the cost and availability of labor had no effect on their yield since they can invest in the required labor at the prevailing costs. These farmers indicated that, because they had enough labor, farm activities were able to be performed on time, the workload of individuals working on the farm was reduced, and the accuracy and speed of farm activities was higher. The 38.5% of farmers who indicated that labor unavailability and cost had negatively influenced their production through poor weed control, delay in performing farm activities such as weeding and harvesting, ineffective farm activities, and general inability to effectively manage the farms. Some indicated that they had abandoned portions of the cultivated areas to manage the remainder with the available labor.

Table 8. Perceptions on Availability and Cost of Labor

Response	Frequency	Percentage
Availability of adequate labor always		
Yes, adequately available	327	88.6
No, inadequately available	42	11.4
Ability to always afford labor cost		
Yes, able to afford	307	83.2
No, unable to afford	62	16.8
Effect of cost/unavailability of labor on yield		
Negative effect	142	38.5
No negative effect	227	61.5

3.5.2 Perceptions on the Stage of Maize Production in Which Labor Demand is High

Figure 11 shows the farm activities for which labor is less accessible to the farmers. The highest percentage of the farmers indicated that labor is often less accessible during land preparation and during fertilizer application. The low accessibility of labor during land preparation is mainly due to low accessibility of tractor services for plowing land on time. Because of the few tractors in the regions, farmers must wait for days before they are able to access the services. The low accessibility of labor during periods of fertilizer application by the farmers can hamper timely and appropriate fertilizer application. Because weed control periods vary more by farm, it is justifiable that farmers may not demand labor at the same time to control their weeds, hence reducing the competition for labor at such periods.

Figure 11. Stage of Maize Production at which Labor Demand is Highest

3.6 Fertilizer Application Among Maize Farmers

3.6.1 Types of Fertilizer Used in Maize Production

Table 9 shows the various fertilizers used by farmers. Some farmers used more than one fertilizer; hence, the percentage distribution of each fertilizer type was computed over the total sample of farmers. Most farmers used NPK 23-10-5+2MgO+3S+0.3Zn, NPK 15-15-15, or ammonium sulfate. A previous study showed that these were the major fertilizers used for maize production in the 2020 cropping season (Adzawla et al., 2021c). Although NPK 15-20-20+0.7Zn is one of the fertilizers promoted for cereal production under the PFJ program, only two farmers used it. Also, the use of NPK 11-22-21+5S+0.7Zn+0.5B is low among the farmers. Except for NPK 15-15-15, all other fertilizer types were under the government's fertilizer subsidy program. Ammonium sulfate was only introduced into the fertilizer subsidy program during the 2021 production period. This was a stopgap measure in response to international fertilizer price hikes in the last quarter of 2021, which reduced the local supply of urea fertilizer to the farmers.

In terms of quantity applied, farmers applied an average of 257.3 kg/ha of fertilizer to maize in the 2021 cropping season. The few farmers who used NPK 12-30-17+0.4Zn fertilizer applied 278.0 kg/ha, and those who used NPK 15-20-20+0.7Zn applied 247.1 kg/ha. Considering that urea and ammonium sulfate are topdressing fertilizers, the average quantities applied were 127.8 kg/ha and 130.9 kg/ha, respectively. The data from Table 10 shows that some farmers used more than one fertilizer type. Therefore, the average amount fertilizer applied by the 369 farmers was 254.1 kg/ha.

Table 9. Types of Fertilizers Used in Maize Production

Fertilizer Type	Users		Quantity Applied (kg/ha)			
	Freq.	%	Mean	Std. Dev.	Min	Max
NPK 15-15-15	116	31.4	187.7	126.6	10.5	741.3
NPK 15-20-20+0.7Zn	2	0.5	247.1	0.0	247.1	247.1
NPK 12-30-17+0.4Zn	4	1.1	278.0	228.4	61.8	556.0
NPK 20-10-10+3S	29	7.9	213.4	150.7	41.2	617.8
NPK 25-10-10+6S+3MgO+0.3Zn	16	4.3	195.9	108.1	24.7	370.7
NPK 11-22-21+5S+0.7Zn+0.5B	3	0.8	135.9	98.1	61.8	247.1
NPK 23-10-5+2MgO+3S+0.3Zn	175	47.4	204.7	162.1	16.5	741.3
Urea	61	16.5	127.8	81.1	6.2	370.7
Ammonium sulfate	143	38.8	130.9	99.1	14.8	494.2
Average total fertilizer applied	**369**	**100.0**	**254.1**	**181.7**	**6.2**	**741.3**

NB: The same min and max values for NPK 15-20-20+0.7Zn does not suggest equal bags used by the farmer. The yield by fertilizer type is presented in Appendix 2. (This result should be interpreted with caution because most farmers used a combination of these fertilizers.)

3.6.2 Fertilizer Application Periods

Table 10 shows the various fertilizers applied as basal and topdressing as well as the timing of their application. The farmers mostly applied the first fertilizer between two and four weeks after planting. Farmers who applied NPK 12-30-17+0.4Zn did so earlier, while those who used ammonium sulfate applied it later than other fertilizer types. Farmers who used urea or ammonium sulfate as basal fertilizer tended to mix it with NPK fertilizer before application or did not apply any other fertilizer, only the single dose application. Farmers who used urea for topdressing applied it at about four weeks after basal application, while those who used sulfate of ammonia for top-dressing applied at about five weeks after basal application. Except for those using NPK 11-22-21+5S+0.7Zn+0.5B, farmers who used other compound fertilizers for topdressing applied them within four weeks after basal fertilizer application. These results imply that, on average, the sampled farmers applied their basal and topdressing fertilizers later than the recommended two and six weeks, respectively.

Table 10.　Time of Fertilizer Application

Variable	Obs.	Mean	Std. Dev.	Min	Max
Time of basal application: # of weeks after planting					
NPK 15-15-15	115	2.9	1.0	2	8
NPK 15-20-20+0.7Zn	2	2.5	0.7	2	3
NPK 12-30-17+0.4Zn	3	2.3	0.6	2	3
NPK 20-10-10 3S	29	3.1	1.5	1	6
NPK 25-10-10+6S+3MgO+0.3Zn	15	3.2	1.6	1	7
NPK 11-22-21+ 5S+0.7Zn+0.5B	3	2.7	0.6	2	3
NPK 23-10-5+2MgO+3S+0.3Zn	165	3.2	1.3	2	8
Urea	30	3.2	1.6	2	6
Ammonium sulfate	51	3.5	1.6	2	7
Time of topdressing application: # of weeks after basal application					
NPK 15-15-15	56	4.3	2.3	2	9
NPK 20-10-10+3S	6	4.3	2.3	2	8
NPK 25-10-10+6S+3MgO+0.3Zn	5	4.4	1.5	3	7
NPK 11-22-21+5S+0.7Zn+0.5B	2	7.5	0.7	7	8
NPK 23-10-5+2MgO+3S+0.3Zn	77	3.9	1.8	2	8
Urea	38	3.9	1.3	2	7
Ammonium sulfate	125	4.9	1.7	2	8

3.6.3 Category of Farmers Based on Fertilizers Used for Topdressing

The farmers were categorized based on the type of fertilizer used for topdressing. Table 11 shows 33.9% of the farmers used ammonium sulfate for topdressing, while only 10.3% used urea. About 31% of the farmers did not apply a topdressing, while 25% used an NPK compound or blended fertilizer for top-dressing. It is important to note that the farmers were not selected from a random sample. A deliberate effort was made to interview an equal number of farmers under each category. However, few farmers used urea, leading to the inability to obtain an adequate number of urea users. Farmers who used ammonium sulfate mentioned that it enhances tasseling, produces large cobs, and gives higher yields; it helps the maize crop to grow faster and form stronger stems; gives heavier grain weight; it was available and relatively affordable; and the farmers have used such fertilizers over the years and are convinced of its effectiveness in maize production. The users of NPK compounds or blended fertilizers for top-dressing used these because of their availability, the farmer's trust them; very poor soils that require more NPK; and it makes the crop healthier and improves yield. The main reason given for top-dressing with urea was that it leads to faster growth, big cobs, and higher yields.

To introduce some randomness in topdressing fertilizer, the farmers were asked to indicate their preferred topdressing fertilizer, irrespective of what had been used. The highest percentage of the farmers preferred ammonium sulfate and, surprisingly, more maize farmers preferred NPK fertilizers over urea for top-dressing.

Table 11. Topdressing Fertilizer

Fertilizer Type	Frequency	Percentage
Topdressing fertilizer used		
None of those listed	114	30.9
NPK fertilizer	92	24.9
Urea	38	10.3
Ammonium sulfate	125	33.9
Preferred topdressing fertilizer		
None of those listed	11	3.0
NPK fertilizer	125	33.9
Urea	70	19.0
Ammonium sulfate	163	44.2

3.6.4 Fertilizer Price Types

The fertilizers used by the farmers were bought either at subsidized or commercial prices. Figure 12 shows the majority of the farmers who applied a topdressing bought such fertilizer at commercial prices. This is especially high for ammonium sulfate users but is justifiable, considering that it only became subsidized in 2021, by which time some farmers had already bought the fertilizer at a commercial price. The results suggest that access to subsidized fertilizers is low among the farmers.

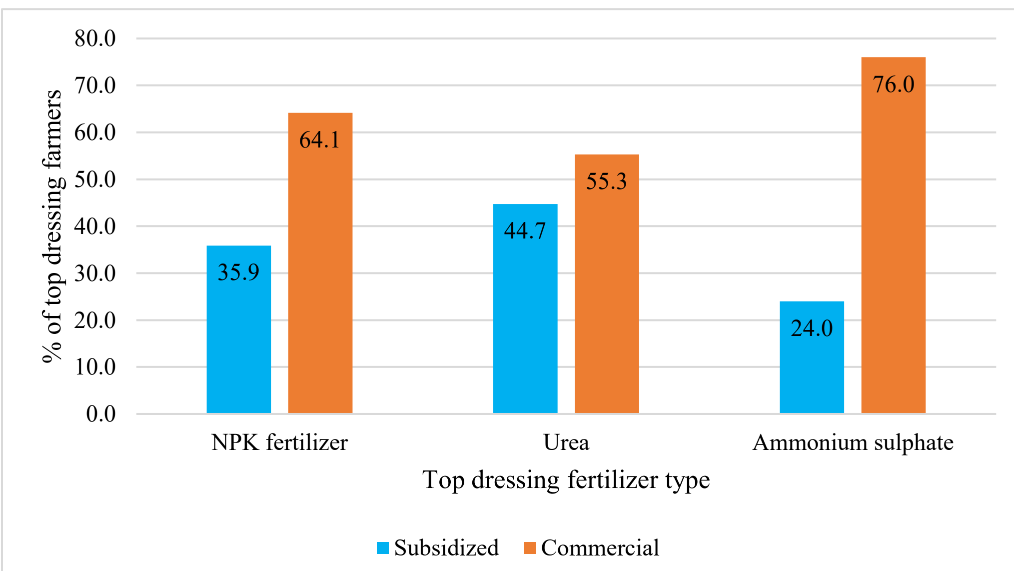

Figure 12. Price at which Farmers Bought Topdressing Fertilizers

3.6.5 4R Nutrient Stewardship

The farmers were asked for specific information on the nutrient principles of fertilizer usage. Table 12 shows that most of the farmers were aware of the recommended fertilizer types for maize production and indicated using the same. But other farmers indicated not using the recommended fertilizers for maize even though they were aware of such fertilizers. While about 62% of the farmers indicated awareness of the recommended rate of fertilizer for maize, only about 38% of the farmers indicated applying the recommendation. This is supported by the results in Table 9. The majority of the farmers had no knowledge of the best method of fertilizer application; hence, only a few indicated applying fertilizers through the right method. Also, while a little over half of the farmers had knowledge on the appropriate time to apply fertilizers, only about 40% indicated applying fertilizers at the recommended time. The results generally suggest that most of the farmers did not apply fertilizers through the recommended method, time, or rate. Most farmers indicated using the recommended fertilizers because these fertilizers are promoted under the government's PFJ program, which has been highly publicized in the country. On the other hand, most farmers did not apply fertilizers at the recommended time because the application time sometimes coincides with unfavorable weather conditions, for instance, no rain (especially during application time for urea), or because of the lack of timely availability of fertilizers. Farmers also cited a lack of labor and generally time-consuming fertilizer application through deep placement or drilling, while the unavailability of fertilizer and a lack of funds affected the rate of fertilizer used by the farmers.

Table 12. 4R Nutrient Stewardship

	Farmers Awareness of Fertilizer Application Practice		Adoption of Fertilizer Application Practice	
Principle	**Freq.**	**%**	**Freq.**	**%**
Right type				
Yes	319	86.5	286	77.5
No	50	13.6	83	22.5
Right rate				
Yes	227	61.5	141	38.2
No	142	38.5	228	61.8
Right method				
Yes	184	49.9	115	31.2
No	185	50.1	254	68.8
Right time				
Yes	193	52.3	149	40.4
No	176	47.7	220	59.6

3.6.6 Perceptions on the Effects of Fertilizer on Crop Yield

The farmers were asked if they thought the fertilizers applied were enough to give them the maximum yield expected. Table 13 shows that about 89% of the farmers indicated using enough fertilizers to guarantee maximum yields. This means that, provided other farm activities are properly done, most of the farmers expected to obtain maximum yields from their farms. About 87% of the farmers also indicated that the cost invested in fertilizer use was compensated by the high yield due to fertilizer application. Thus, the farmers held that, with higher yields under fertilizer application, they were able to sell more outputs, which could at least cover the cost of the fertilizers used.

Table 13. Perceptions on the Effects of Fertilizer on Yield

Response	Frequency	Percentage
Obtained maximum yield due to fertilizer application?		
Yes	328	88.9
No	41	11.1
Can yield increment compensate for fertilizer cost?		
Yes	286	87.2
No	42	12.8

3.7 Adoption of Good Agronomic Practices

Table 14 outlines the various GAPs adopted by the farmers. The GAPs practiced by the majority of the farmers were row planting, recommended spacing, and timely weed control through preemergence weedicide application or weeding when weeds were at an early stage. Improved seeds were used by 48% of the farmers. The use of mulching and organic fertilizers was low among the farmers. The planting of maize in rows helps the farmers to carry out other farm activities, such as weed control and fertilizer application effectively. It also facilitates the planting of maize using the recommended spacing, which ensures appropriate plant density and efficient use of resources.

Table 14. Adoption of GAPs

	Practiced		Not practiced	
GAPs	Freq.	%	Freq.	%
Row planting	330	89.4	39	10.6
Planting with recommended spacing	249	67.5	120	32.5
Improved seed varieties	177	48.0	192	52.0
Weeding/spraying weeds when they are young	351	95.1	18	4.9
Organic fertilizer	55	14.9	314	85.1
Bunding	1	0.3	368	99.7
Mulching	43	11.7	326	88.4
Minimum tillage	18	4.9	351	95.1
Preemergence weedicide application	204	55.3	165	44.7

3.8 Yield Cut

3.8.1 Observed Yield Based on the Type of Topdressing Fertilizer

Table 15 shows the maize yield of farmers obtained through direct yield cut. This involved only 187 farmers from the sample. The analysis was based on the region of the farmer and the type of fertilizer used for topdressing. The mean yields are shown in Figure 13. The results revealed that there was a difference in the mean yields of farmers based on their location and the type of topdressing fertilizer appears to have had different impacts based on the regional location of the farmers. Generally, maize yields were lowest in the North East region and highest in the Upper West region. There was less difference in yield between the North East and Northern regions.

Previous reports have also shown that maize yields are higher in the Upper West region and farmers in this region exhibit characteristics that can help improve maize production in the Guinea Savannah zone (Adzawla et al., 2021a; Adzawla et al., 2021b).

In the North East, farmers who used ammonium sulfate for topdressing had the lowest yield and those who used NPK fertilizers for topdressing had the highest yield. For the Northern region, farmers who used urea for topdressing had the highest average yields: 387.2 kg/ha more than the average yield of farmers who used ammonium sulfate for topdressing. Although the average yield for farmers who used urea for topdressing in Upper West region was higher than the average for farmers who used ammonium sulfate, they are both less than the average yield of farmers who did not apply topdressing. Expectedly, farmers who did no topdressing in all regions used a lower quantity of fertilizer than the farmers who did apply topdressing. The average yield for farmers in the Upper West region, irrespective of the topdressing fertilizer, was above the average pooled yield (2,728.2 kg/ha) of the sampled farmers and the averages for the different categories of farmers in the Northern and North East regions.

Table 15. Yield (kg/ha) of Farmers under Yield Cut[a]

		Yield (kg/ha)				Fertilizer (kg/ha)
Type of Farmer	**N**	**Mean**	**Std. Dev.**	**Min**	**Max**	**Mean**
North East						
No topdressing users	6	2,441.2	1,328.8	627.6	3,938.9	112.4
NPK fertilizer users	3	2,524.2	1,112.8	1,260.1	3,356.2	304.8
Urea users	1	2,218.6	NA	2,218.6	2,218.6	308.9
Ammonium sulfate users	7	2,073.7	778.9	1,376.0	3,334.0	303.2
Total	***17***	***2,291.4***	***986.8***	***627.6***	***3,938.9***	***236.5***
Northern						
No topdressing users	35	2,524.2	704.0	1,075.3	3,722.1	145.6
NPK fertilizer users	23	2,329.6	709.8	960.1	3,544.6	233.0
Urea users	8	2,835.2	739.6	1,561.9	4,009.2	333.7
Ammonium sulfate users	23	2,448.0	843.7	1,230.2	4,870.0	225.5
Total	***89***	***2,482.2***	***746.5***	***960.1***	***4,870.0***	***205.9***
Upper West						
No topdressing users	19	3,305.0	718.8	2,153.8	4,763.3	221.7
NPK fertilizer users	23	3,096.5	1,064.2	964.4	5,178.1	492.2
Urea users	4	3,107.2	767.1	1,965.4	3,587.2	483.9
Ammonium sulfate users	35	2,967.6	955.2	734.3	4,793.1	461.9
Total	***81***	***3,090.3***	***924.7***	***734.3***	***5,178.1***	***414.7***

a. The limitation is that we do not have data on the separate quantities for basal and topdressing applications.

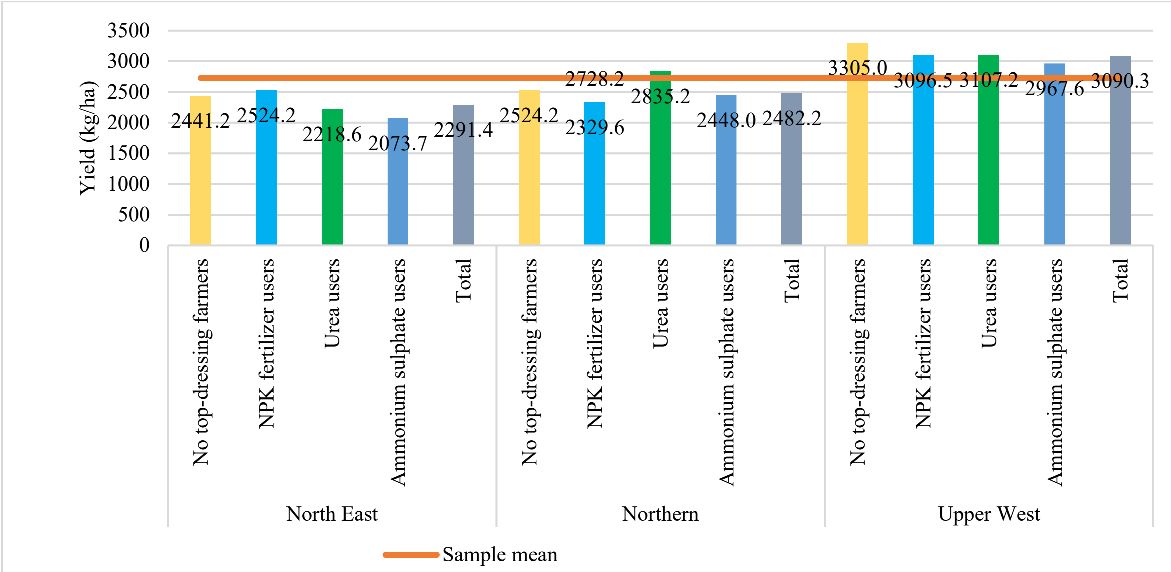

Figure 13. Mean Yield Values (kg/ha) by Region and Type of Topdressing Fertilizer

3.8.2 Yield Distribution by the Source of Seed

Table 16 shows the yield of farmers based on the source of seed planted. The average yield for farmers who bought their seeds from research institutions (3,212.7 kg/ha) was higher than for farmers using other seed sources. This means that the farmers who used seeds from research institutions had about 587 kg/ha on average more than the average 2,625.9 kg/ha obtained by farmers who used their own saved seeds. The second highest average yield was for farmers who used seeds bought from an input shop. This was about 286 kg/ha more than the average for those using their own saved seed but about 305 kg/ha less than the average for farmers who used seeds from research institutions. It is unclear why the average yield for farmers who used seeds obtained from MoFA had a similar average yield as those who used their own seeds. The test statistics also show that observed mean differences are statistically insignificant.

Table 16. Yield (kg/ha) Distribution by the Source of Seed

Source of Seed	Freq.	Mean	Std. Dev.	Min	Max
Own saved seed	97	2,625.9	939.0	627.6	5,178.1
Open market	11	2,889.8	864.4	1,781.7	4,793.1
Input shop	47	2,907.6	899.4	964.4	4,870.0
MoFA	28	2,648.8	827.4	1,155.1	4,009.2
Research institutes	4	3,212.7	421.1	2,646.1	3,647.3
All sampled farmers	***187***	***2,728.2***	***904.8***	***627.6***	***5,178.1***

Note: F-statistics (1.21).

3.8.3 Yield Distribution by GAPs Adopted

The yield distribution based on the GAPs adopted is presented in Table 17. This shows that farmers who practiced GAPs other than row planting had higher yields; this was statistically significant for those who practiced mulching and minimum tillage. Farmers who practiced mulching had 676 kg/ha more production than those who did not. Mulching involves the covering of soil surface, especially around the plants, with crop residue. This is important in soil moisture conservation and water usage by crops. Farmers who practiced minimum tillage (disc harrowing by animals or no tillage) also produced 1 mt/ha more maize than those who plowed by tractor. Minimum tillage involves less destruction to the physical properties of the soil. Generally, the yields varied greatly for farmers who did not mulch and those who did plowing by tractor. Like mulching, minimum tillage also enhances the moisture content of the soil and minimizes soil erosion that carries away soil nutrients. However, considering that disc plowing is becoming a major land preparation method among farmers in the Guinea Savannah zone, it is important that policymakers, especially MoFA and research institutions such as the Soil Research Institute (SRI), look in detail at how plowing should be done to maintain or improve the soil health for crop production.

Buah et al. (2017) observed from experimental data in the Guinea Savannah zone that maize yield under no tillage is 51-68% more than the yield under tillage. Although a significant difference was not found in this study, it is important that farmers control weeds on their farms before the weeds overgrow and plant their farms using recommended spacing in order to obtain higher yields. The low average yield for fields planted in rows is surprising since row planting is expected to enhance the performance of farm activities, including weeding and fertilizer application. However, this could be due to the high standard deviation (yield difference) among these farmers. Also, most of the farmers who did not plant in rows were from the Upper West region, where yields are generally high.

Table 17. Yield (kg/ha) Distribution by GAPs Adopted

GAP	Adoption	Freq.	Mean	Std. Dev.	Min.	Max.	T-Value
Row planting	No	12	3,025.6	806.4	2,035.7	4,763.3	-1.18
	Yes	175	2,707.8	909.7	627.6	5,178.1	
Recommended spacing	No	52	2,696.6	963.3	958.7	5,178.1	0.30
	Yes	135	2,740.4	884.7	627.6	4,870.0	
Mulching	No	179	2,699.3	912.3	627.6	5,178.1	2.09**
	Yes	8	3,375.4	300.6	3022.5	3,796.8	
Minimum tillage*	No	184	2,709.7	899.9	627.6	5,178.1	2.22**
	Yes	3	3,864.5	262.5	3642.5	4,154.3	
Timely weed control	No	7	2,547.8	1,169.0	960.1	3,938.9	0.54
	Yes	180	2,735.2	896.4	627.6	5,178.1	

**The opposite of minimum tillage is plowing with a tractor.*

The fertilizer use efficiency (FUE) was proxied by total factor productivity (TFP), which was obtained from dividing the measured yield by the total fertilizer applied by the farmer. On average, the FUE among the sampled farmers was 14.8 kg/kg. Figure 14 shows that farmers who adopted any GAP except mulching had a lower FUE. This was largely because farmers also used lower quantities of fertilizer than those who did not practice mulching. The quantity of fertilizer applied and the FUE did not vary much due to the practice of minimum tillage. However, the standard deviation of the FUE for farmers who plowed with a tractor was more than twice that of the farmers who practiced minimum tillage.

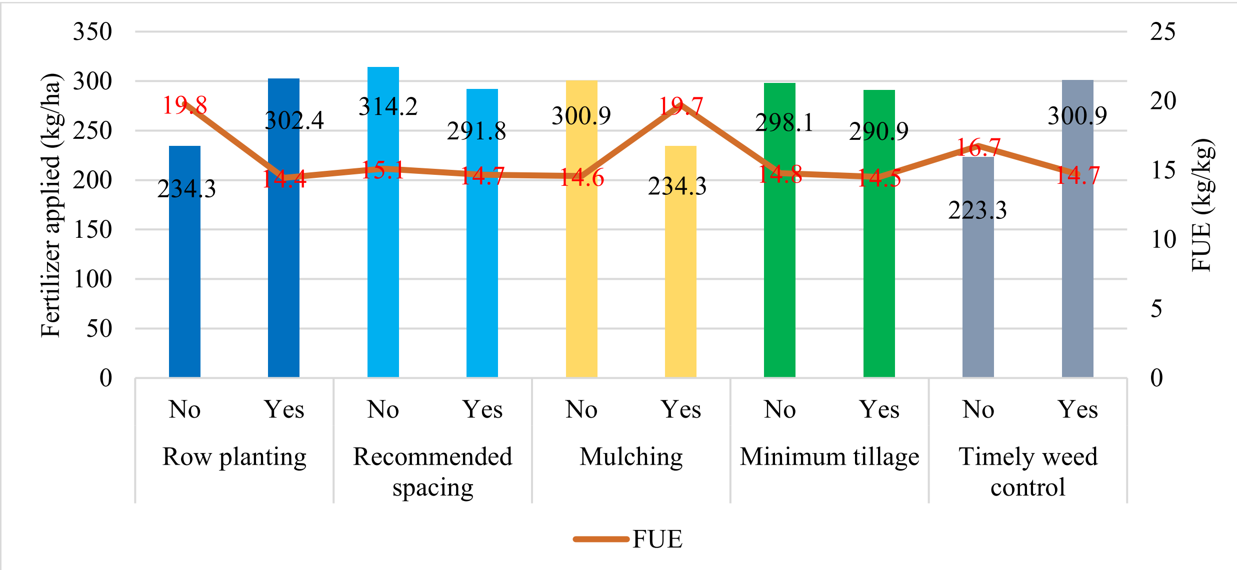

Figure 14. Fertilizer Applied (kg/ha) and FUE (kg grain /kg fertilizer) by GAP

3.8.4 Fertilizer Use and Yield Distribution by Socioeconomic Characteristics

This section provides the distribution of fertilizer used (Figure 15), the estimated yields (Figures 15 and 16), and FUE (Figure 16) by the socioeconomic characteristics of the farmers.

- Farmers who received extension services used 307.2 kg/ha fertilizer and had an average yield of 2,760.4 kg/ha, while those who received no extension services used 278.1 kg/ha fertilizer and had an average yield of 2,658.5 kg/ha. Farmers with no access to extension services had a higher FUE than those who did (Figure 16). However, these three differences were statistically insignificant.
- Farmers who accessed credit used 307.2 kg/ha fertilizer and had an average yield of 2,804.0 kg/ha, while those who did not access credit used 278.1 kg/ha fertilizer and had an average yield of 2,665.1 kg/ha (Figure 16). The FUE for farmers who accessed credit was only 0.2 kg/kg higher than those who did not access credit. While the difference in fertilizer use was significantly different, the differences in the estimated yield and FUE were insignificant. Farmers who received credit in cash form used 298.4 kg of fertilizer and had an average yield of 2,987.2 kg/ha. Those who received input/in-kind credit used as much as 391.8 kg/ha of fertilizer and had an average yield of 2,588.1 kg/ha. Farmers who received both cash and in-kind credit used an average 268.7 kg/ha of fertilizer and had an average yield of 2,108.7 kg/ha. Therefore, FUE was highest for those who received cash credit. The fertilizer use among farmers who received in-kind credit was higher than those who received cash credit because they used the cash credit for only fertilizer purchases but also other inputs and farm activities. It is possible the conditions on the cash credit forced farmers to effectively manage their farms for higher yield.

- There was no significant difference in the fertilizer use, yield, or FUE of farmers based on their FBO membership. While those who belonged to an FBO used 294.9 kg/ha of fertilizer and had an average yield of 2,713.1 kg/ha, those who were not a member of an FBO applied an average fertilizer rate of 300.3 kg/ha and had an average yield of 2,739.3 kg/ha. On average, FBO members had 1 kg/kg FUE more than the non-FBO members.
- Farmers who used their own land applied an average 277.4 kg/ha of fertilizer and had a maize yield of 2,681.3 kg/ha. Those who used family land applied 342.5 kg/ha of fertilizer and had an average yield of 2,821.4 kg/ha. The single farmer who used rented/leased land applied 487.7 kg/ha of fertilizer and had a yield of 3,614.9 kg/ha. The FUE was highest for farmers who cultivated their own land and lowest for the farmer who cultivated rented land.
- Small-scale farmers applied 313.4 kg/ha fertilizer had an average yield of 2,699.5 kg/ha, while medium/large-scale farmers applied 259 kg/ha fertilizer and had an average yield of 2,852.9 kg/ha. The medium/large-scale farmers had about twice the FUE of the smallholder farmers (Figure 16). While the fertilizer and FUE differences were statistically significant, the yield difference was not. The implication is that the scale of production does not really play a significant role in influencing the yield level among the farmers, but medium/large-scale farmers end up using their fertilizers more efficiently.
- Distance from home to farm had a significant impact on fertilizer application but an insignificant effect on yield. Farmers who had farms at over 5 km from their homes applied 407.7 kg/ha of fertilizer on average and had an average yield of 2,717.8 kg/ha, while those who had farms no more than 5 km from their homes applied 295.4 kg/ha of fertilizer and had an average yield of 2,717.8 kg/ha. Farmers who cultivated lands not more than 5 km from home had a higher FUE (Figure 16).
- Farmers who did not cultivate their farmland in the previous season used 311.2 kg/ha of fertilizer and had an average yield of 2,718.7 kg/ha. Those who cultivated their farmland to maize in the previous season applied 248.8 kg/ha of fertilizer and had an average yield of 2,719.4 kg/ha. Those who cultivated their farmland in the previous season with soybean applied 265.6 kg/ha of fertilizer and had an average yield of 2,774.2 kg/ha. It was surprising that farmers who did not cultivate their farmland in the previous season not only applied more fertilizer to their maize but also had a lower FUE. The FUE was higher for farmers who cultivated their farmland to maize in the previous season.

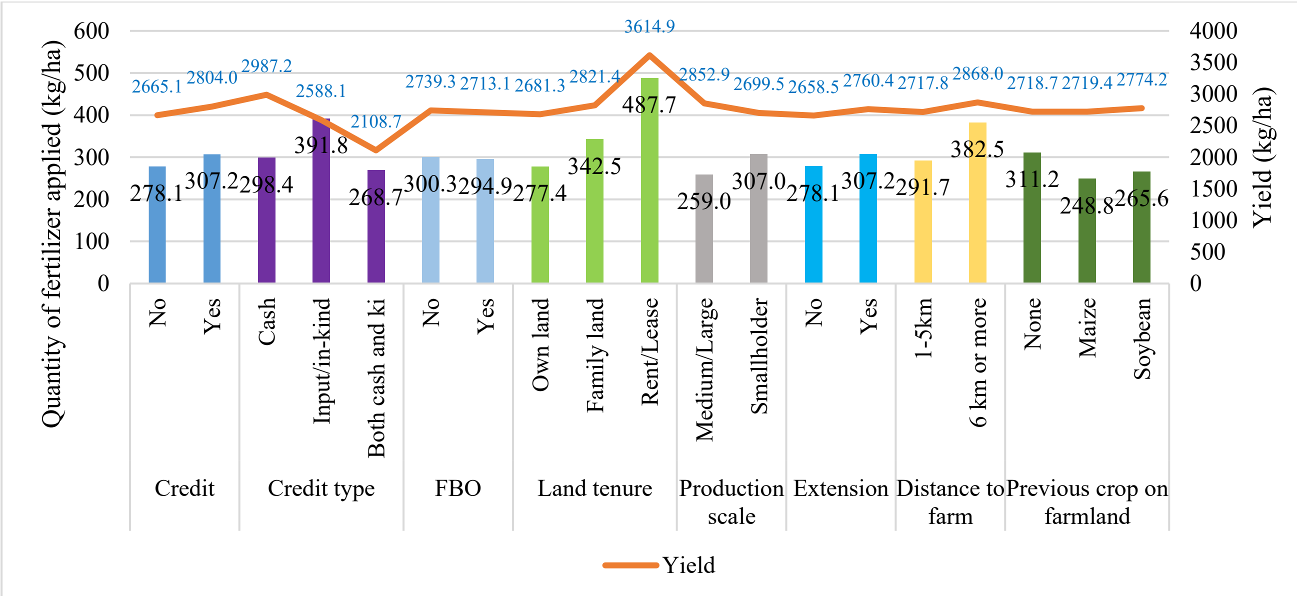

Figure 15. Quantity of Fertilizer Applied and Estimated Yield by Socioeconomic Characteristic

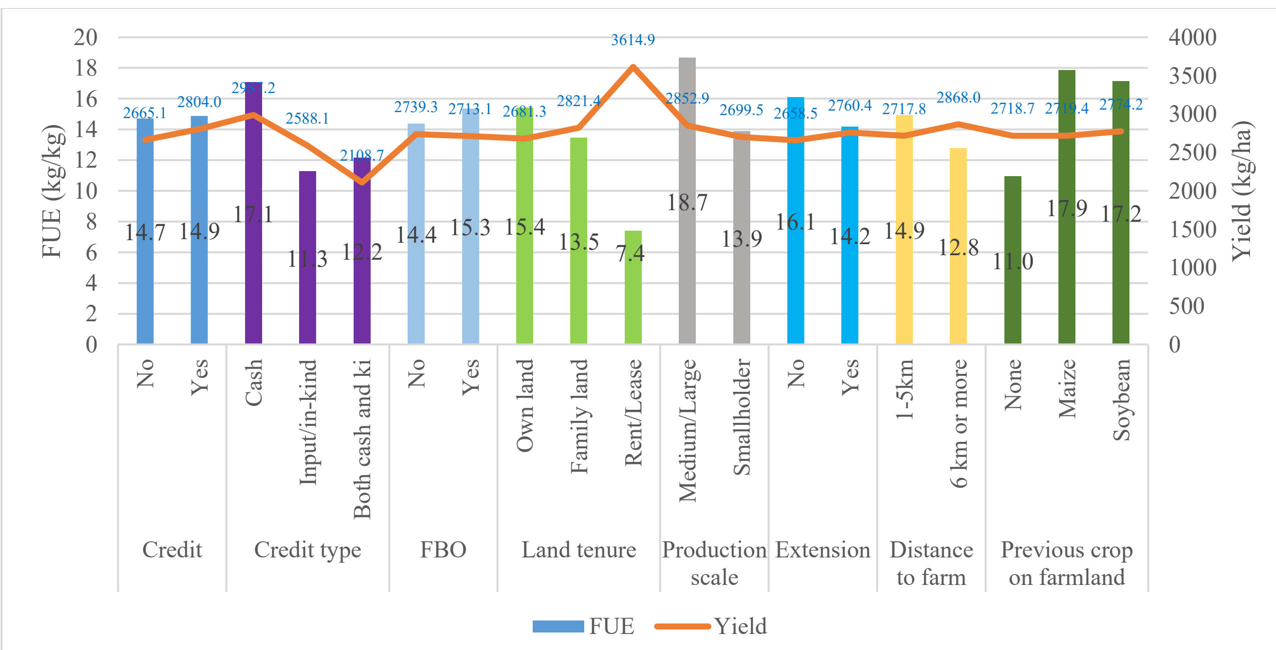

Figure 16. Fertilizer Use Efficiency and Estimated Yield by Socioeconomic Characteristic

CHAPTER 4: CONCLUSIONS

Declining soil fertility is a major constraint to food security. For a country like Ghana, the role of fertilizer in crop production is indispensable. To eliminate the cost limitations on farmers, the Government of Ghana has implemented fertilizer subsidy programs since 2008. It is important that appropriate fertilizers and application procedures are followed. A number of different fertilizers have been subsidized and urea is recommended and subsidized for topdressing. However, in the 2021 production season, the Government of Ghana added ammonium sulfate to the list of subsidized fertilizers under the Planting for Food and Jobs (PFJ) program. Although this goes against the gains made in moving away from the use of ammonium sulfate to urea application, the latter fertilizer continues to be used by many farmers in Ghana. An important question is how justified is the decision to subsidize ammonium sulfate. This report highlights the impact of using different fertilizer types for topdressing on maize yields.

Among the subsidized fertilizers, NPK 23-10-5+2MgO+3S+0.3Zn and ammonium sulfate were used by most farmers. NPK 15-15-15 continued to be used by many farmers. Overall, a farmer in the sample applied an average of 254.1 kg/ha of fertilizer to maize, which is lower than the recommended application rate. Ammonium sulfate, NPK compound or blend, and urea were used for topdressing by 34%, 25%, and 10% of the farmers, respectively. It is also worrying that some of the farmers indicated not applying the fertilizers at the right time. From 187 yield cuts, maize yields ranged from 627.6 kg/ha to 5,178.1 kg/ha and averaged 2,728.3 kg/ha. The yields differed based on the type of fertilizer used for topdressing and regional location. Details are summarized in the following bullets.

- Overall, topdressing with ammonium sulfate did not increase maize yields. Therefore, this report failed to accept the hypothesis that topdressing with ammonium sulfate increases yield more than topdressing with other fertilizers.
- In the North East Region, the average yield was 2.3 mt/ha. It was highest for farmers who used NPK fertilizers (2.5 mt/ha) for topdressing and lowest for farmers used ammonium sulfate (2.1 mt/ha) for topdressing.
- In the Northern Region, the average yield was 2.5 mt/ha. It was highest for farmers who used urea (2.8 mt/ha) for topdressing and lowest for farmers who used NPK compound or blended fertilizer (2.3 mt/ha) for topdressing.
- In the Upper West Region, the average yield was 3.1 mt/ha. It was highest for farmers who applied no topdressing (3.3 mt/ha) and lowest for farmers who used ammonium sulfate for topdressing (3.0 mt/ha).
- Small-scale farmers had an average yield of 2.7 mt/ha, while medium/large-scale farmers had an average yield of 2.9 mt/ha, even though small-scale farmers applied more fertilizer per hectare (300.7 kg/ha) than the medium/large-scale farmers (259.0 kg/ha).
- Farmers who used seeds from research institutions had the highest average yield of 3.2 mt/ha, and farmers who used their own saved seeds or seeds from MoFA had the lowest average yield of 2.6 mt/ha. Mulching and minimum tillage had significantly positive effects on yields.

- On average, the FUE among the farmers was 14.8 kg/kg. This was higher for farmers who practiced mulching than those who did not, but those who did minimum tillage had a lower FUE than those who plowed their land with a tractor.
- FUE also differed by the socioeconomic characteristics of the farmer. Access to credit, especially input/in-kind credit, increased fertilizer application rate, but cash credit increased FUE. Although access to extension services led to slightly higher fertilizer application rates, it did not translate into a higher FUE. The cultivation of rented land and distant farmlands increased fertilizer application rate but not FUE.
- Although the promotion of higher fertilizer application is necessary for improving soil fertility and crop production, measures such as farmer education and continuous sensitization on efficient farm management to improve FUE must be given prime attention, since this is the only way maize production can be sustainable.

CHAPTER 5: REFERENCE

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APPENDICES

Appendix 1. Yield Distribution at Each Quadrant

Quadrant	Mean	Std. Dev.	Min	Max
First	2660.2	1049.8	269.7	6015.0
Second	2695.9	1054.8	425.0	6233.1
Third	2828.5	1090.8	680.0	6037.1
Average	*2728.2*	*904.8*	*627.6*	*5178.1*

Appendix 2. Descriptive Statistics of Yield by Fertilizer Type

Fertilizer Type	N	Yield (kg/ha)			
		Mean	Std. Dev.	Min	Max
NPK 15-15-15	55	2,515.5	1,054.8	627.6	4,870.0
NPK 15-20-20+0.7Zn	2	2,881.1	1,295.0	1,965.4	3,796.8
NPK 12-30-17+0.4Zn	4	2,278.5	960.2	1,724.3	3,715.8
NPK 20-10-10+3S	18	3,234.6	557.8	2,132.8	4,430.1
NPK 25-10-10+6S+3MgO+0.3Zn	7	2,499.2	290.3	1,921.5	2,807.7
NPK 11-22-21+5S+0.7Zn+0.5B	1	3,662.7	.	3,662.7	3,662.7
NPK 23-10-5+2MgO+3S+0.3Zn	82	2,800.6	890.1	960.1	5,178.1
Urea	18	2,660.3	849.0	1,260.1	4,009.2
Ammonium sulfate	75	2,704.3	828.0	1,230.2	4,870.0

Yield by fertilizer type is indicative only and should be interpreted with caution because most farmers used a combination of fertilizers.

FERARI

FERTILIZER RESEARCH & RESPONSIBLE IMPLEMENTATION

FERARI is an international public-private partnership that builds science-based approaches to site-specific fertilization for widespread adoption by farmers in Ghana for improved food and nutrition security. This calls for a transformation of the fertilizer and food systems that must be driven by evidence-based agro-technical perspectives embedded in multi-stakeholder processes.

To support this transformation, the following institutions have partnered to implement the Fertilizer Research and Responsible Implementation (FERARI) program:

- International Fertilizer Development Centre (IFDC)
- Mohammed VI Polytechnic University (UM6P)
- OCP Group
- Wageningen University and Research (WUR)
- University of Liège (ULiège)
- University of Ghana (UG)
- University for Development Studies (UDS)
- Kwame Nkrumah University of Science and Technology in Kumasi (KNUST)
- University of Cape Coast (UCC)
- University of Energy and Natural Resources (UENR)
- Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development (AAMUSTED) College of Agriculture Education
- Council for Scientific and Industrial Research in Kumasi (CSIR-SRI) and in Tamale (CSIR-SARI) and its subsidiary (CSIR-SARI-Wa)

FERARI operates in conjunction with the Planting for Food and Jobs program of the Government of Ghana (GoG) to embed development efforts into national policy priorities to reach impact at scale. It trains five Ph.D. and two post-doctoral candidates and dozens of master's-level students in building the evidence base for its interventions.

FERARI conducts hundreds of fertilizer response trials on maize, rice, and soybean, on-station and also with farmers, and demonstrates them to farmer groups in the northern and middle belt of Ghana. It conducts surveys among farmers and actors in the value chain to understand the drivers for use of fertilizers and other inputs and the marketing of the produce to enhance farm productivity and income. It helps the GoG to establish a Ghana National Fertilizer Platform, developing its soil mapping expertise toward an information platform.

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