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PERFORMANCE OF AMARANTH (*AMARANTHUS CRUENTUS*) AS INFLUENCED BY NPK FERTILIZER AND ORGANIC LIQUID FERTILIZER AT SAMARU, NORTHERN GUINEA SAVANNA OF NIGERIA

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ABSTRACT

Organic fertilizers have been proven to be more affordable, increase yields and safer for the ecosystem compared to chemical fertilizers. A study was carried out on the effect of NPK fertilizer and an organic liquid fertilizer (SuperGro) on *Amaranthus cruentus* in 2019 at the research field of the Institute for Agricultural Research and in 2022 at the *Teaching and Research Farm of Samaru College of Agriculture, Ahmadu Bello University, Zaria in the northern guinea Savannah of Nigeria*. SuperGro liquid fertilizer is 100% organic, made from poultry droppings and seabird guano. It contains (72 g L^{-1} N), (45 g L^{-1} P, 30 g L^{-1} K, 15 g L^{-1} S, 9 g L^{-1} Ca, 7 g L^{-1} Mg), micronutrients (5 mg L^{-1} Fe, 3 mg L^{-1} I, 1 mg L^{-1} Zn and 1 mg L^{-1} of marine salts. Treatments consisted of NPK 20:10:10 at 150, 300, 450 and 600 kg ha^{-1}, SuperGro at 0.5, 1.0 and 1.5 L $ha^{-1}$and a control plot (Zero fertilizer) laid out in a randomized complete block design with three replications. Data was collected on plant height, leaf area index, foliage yield and seed yield and were subjected to analysis of variance using the general linear model procedure of the statistical analysis system package. Results obtained showed that application of either of the fertilizers increased the parameters taken. However, foliage yield was highest with application of 1 L ha^{-1} of SuperGro where 75,556 kg ha^{-1} was obtained in 2019 and 86,632 kg ha^{-1} in 2022. Based on these results, 1 L ha^{-1} of SUPERGRO can be adopted for the production of *Amaranthus cruentus* rather than the use of chemical fertilizers.

Keywords: Amaranth, NPK Fertilizer, Organic Liquid Fertilizer, Samaru

INTRODUCTION

Amaranthus cruentus is a member of the Amaranthaceae family commonly cultivated in Nigeria. The foliage is majorly consumed as a vegetable in pot herbs as soups or sauces and is usually cooked with other vegetables as a main dish or by itself. The leaves are a rich source of vitamin A (flavonoid polyphenolic antioxidants like beta carotene, zeaxanthin and lutein), B, C, K and potassium which are very important for maintenance of cardiac health (Banerjee, 2020). *Amaranthus* is an annual dicotyledonous herbaceous plant with C4-photosynthetic pathway thus requiring a rich source of nitrogen. SuperGro is a 100% organic liquid fertilizer, made from poultry droppings and seabird guano thus a very rich source of macro (72 g L^{-1} N), (45 g L^{-1} P, 30 g L^{-1} K, 15 g L^{-1} S, 9 g L^{-1} Ca, 7 g L^{-1} Mg), micronutrients (5 mg L^{-1} Fe, 3 mg L^{-1} I, 1 mg L^{-1} Zn and 1 mg L^{-1} of marine salts (Na^{+}, Cl^{-}, Mg^{2+}, $SO^{2}{}_{4}^{-}$, Ca^{2+}, and K^{+}) (Anonymous, 2018). The use of chemical fertilizers has certain disadvantages; some of which are high cost of purchase, ground water pollution, imbalances in soil pH, loss of soil fertility and may be detrimental to health as it may contain toxic substances (Marlene, 2018). Organic fertilizers are however, cheaper in the study area, nontoxic, safer for the ecosystem, guarantees production of healthy food and serves as a medium for waste management thus reducing chances of environmental pollution (Salman, 2020). More so, the organic fertilizer used in this trial was as a liquid foliar spray which was applied directly on the leaves where the plants could easily absorb and use them up for its growth and development. The efficient nutrient delivery of liquid fertilizers not only reduces the need for large quantities of fertilizer but also mitigates issues related to solid waste and decreases groundwater pollution (Badran and Safwat, 2004, Ladan *et al*. 2021). Additionally, the profound impact on growth and yield components further underscores the benefits of using liquid organic fertilizers. The production and consumption of Amaranth is on the increase due to its nutritional and health benefits, it is therefore, important to increase its production sustainably. Farmers mostly use chemical fertilizers to get higher yields which have detrimental effects over time on the soil, environment and human health. These and previously highlighted disadvantages of chemical fertilizers necessitated this trial to study the performance of *Amaranthus cruentus* as influenced by application of organic liquid fertilizer or inorganic fertilizer at Samaru, Northern Guinea Savanna of Nigeria. This is with the intent to promote the use of organic nutrient sources especially foliar fertilizers in vegetable crop production as they possess abundant nitrogen (N) primarily in an inorganic form, allows for rapid nutrient delivery to plants similar to chemical fertilizers and foliar application not only simplifies the process but also lowers transportation expenses when compared to handling bulky solid manures (Gross *et al*., 2007, Ladan *et al*. 2021).

MATERIALS AND METHODS

The trials were carried out in the rainy season of 2019 at the research field of the Institute for Agricultural Research. Subsequently, in 2022, the trial was repeated at the Teaching and Research Farm of Samaru College of Agriculture, Ahmadu Bello University, Samaru, Zaria. These locations are situated in the northern guinea Savannah ecological zone of Nigeria, latitude 11°11'N, longitude 07°38'E, and an elevation of 686 meters above sea level.

The treatments consisted of inorganic fertilizer (NPK 20:10:10) applied at the rate of 150, 300, 450 and 600 kg ha^{-1}, organic liquid fertilizer (SuperGro) used as foliar fertilizer at 0.5, 1 and 1.5 L ha^{-1}, and a control plot (No fertilizer applied). These were laid out in a randomized complete block design replicated three times. Prior to initiating the experiment, soil samples were randomly collected from the study area at a depth of 0-30 cm using a tubular auger. After collection, the samples were meticulously mixed in a container, and from the combined bulk, a representative sample was obtained for further analysis to ascertain the initial soil fertility levels. The pH analysis was conducted using a Cyber-scan 20 pH meter in both water (at a ratio of 1:2.5 soil: water) and in 0.01M CaCl2 solution. The soil organic carbon was determined through the wet oxidation method (Walkely and Black, 1965). The total nitrogen was determined by micro Kjeldahl digestion distillation method (Bremmer, 1965). While available phosphorous was determined by Bray 1 method (Bray and Kurtz, 1945). The standard procedures outlined by Agbenin (1995) were employed to determine the levels of exchangeable cations (Ca, Mg, K, and Na) and the cation exchange capacity (CEC). For the cultivation process, the land was harrowed until a fine tilt was achieved. Subsequently, beds with dimensions of 3 x 2 square meters ($6m^2$) were created. The seeds were sown by broadcasting them evenly over the beds and lightly covered with soil. To promote moisture retention and protect the seedbeds, straw grasses were used as mulch. After the seedlings emerged, the mulch was removed to aid in the establishment of the seedlings. Data were collected on plant height, leaf area index (LAI), foliage yield and seed yield. Plant height (cm) was taken using a ruler from the base of the plant to its apex at the vegetative growth stage while at maturity plant height was measured from the base of the plant to the tip of the panicle. Leaf area index was taken using a ceptometer (Acupar LP-80). Foliage yield (kg ha^{-1}) was taken by harvesting the leaves from plants within the net plot which were weighed on a scale (Mettler Toledo SB 16001) and converted to kilogram per hectare. To determine the seed yield (kg ha^{-1}), matured panicles from plants within the net plot were harvested and air dried in a ventilated room and weighed using a weighing scale (Mettler Toledo SB 16001). The weight was thereafter converted to kilogram per hectare.

The data collected were subjected to analysis of variance (ANOVA) following the procedures described by Snedecor and Cochran (1967), using the general linear model (GLM) procedure of the statistical analysis system (SAS) package, specifically version 9.1, as outlined in SAS (1990).

RESULTS AND DISCUSSION

Results of soil analysis on Table 1 showed that the soil of the experimental site was loam in 2019 and clay loam in 2022. The pH in water in 2019 was 5.47 which is strongly acidic while in 2022 it was 6.85 which was almost neutral. The pH in $CaCl_2$ in both years was strongly acidic. The organic carbon in 2019 (9.80 g kg^{-1}) was very high while in 2022 (1.81 g kg^{-1}) was low. The soil total nitrogen content was medium in both years (1.10 g kg^{-1} in 2019 and 1.50 g kg^{-1}in 2022). The available phosphorus in 2019 (10.2 mg kg^{-1}) and 2022 (7.0 mg kg^{-1}) were low. Furthermore, the soil calcium content were medium in both years, magnesium content was high, potassium content was medium in 2019 and high in 2022, sodium content was medium in both years while values for Al + H^+ and CEC were low.

Table 1: Physical and chemical properties of soil samples taken from the experimental site during the 2019 and 2022 rainy seasons

	2019	**2022**
Particle Size Distribution (g kg^{-1})		
Sand	420	156
Silt	460	333
Clay	120	511
Textural class	Loam	Clay loam
Chemical properties		
pH in H_2O	5.47	6.85
pH in 0.01M $CaCl_2$	4.81	4.32
Organic carbon (g kg^{-1})	9.80	1.81
Total N (g kg^{-1})	1.10	1.50
Available P (mg kg^{-1})	10.2	7.0
Exchangeable bases (cmol kg^{-1})		
Ca	2.86	3.2
Mg	0.41	0.86
K	0.11	0.63
Na	0.18	0.22
AL + H^+	0.29	0.39
CEC	3.85	4.52

Soil samples were analyzed at the analytical laboratory, Agronomy Department Ahmadu Bello University Samaru Zaria in 2019 and at analytical laboratory, Soil Science Department Ahmadu Bello University Samaru Zaria in 2022.

Table 2 shows the meteorological data during the year 2019 and 2022 rainy season. The year 2019 had higher amount of rainfall and better distribution during the season than 2022. Similarly, average temperature and relative humidity were higher in year 2019 than 2022.

Table 2: The meteorological data for Samaru during the rainy seasons of 2019 and 2022 showing average monthly rainfall, temperature, and relative humidity

	2019			2022		
Month	**Rainfall(mm)**	**Average temperature (°C)**	**Average relative humidity (%)**	**Rainfall (mm)**	**Average temperature (°C)**	**Average relative humidity (%)**
May	146.7	30.15	58.1	91.8	28.9	62.4
June	110.3	26.8	75.5	238.4	25.8	75.4
July	314.2	25.8	78.1	178.1	25.2	73.8
August	243.2	25.3	81.2	251.4	24.7	80.3
September	237.4	26.7	73.4	448.1	25.4	78.1
October	217.4	26.2	76.4	39.3	26	55.2
November	00	25.1	33.1	00	23.2	25.9
Total	1269.2			1247.1		

Source: IAR Meteorological Unit Ahmadu Bello University, Zaria

The results on Figure 1 showed increases in plant height with application of fertilizer and even at the control. The tallest plants were recorded with application of NPK at the rate of 300 kg ha^{-1}in 2022 which were similar to plants on the control plots in both years. Increases in amaranth height were also recorded with application of NPK at 150 kg ha^{-1}which were similar in height with application of 1.5 L ha^{-1} of SuperGro liquid fertilizer in 2019. Increases in height recorded with application of NPK fertilizer could because it was a compound fertilizer containing essential nutrients nitrogen (N), phosphorous (P) and potassium (K) which are macro nutrients often found to be limiting in the soil although needful for optimum plant growth and development (Steven *et al*., 2020). Furthermore results of soil analysis (Table 1) shows that the nitrogen and phosphorus content of the soil was low thus the increases with addition of nutrients. The shortest plants were recorded where 0.5 L ha^{-1} SuperGro liquid fertilizer was applied in the two years. This could be because the nutrient supplied was insufficient to result in significant increase in the height of the amaranth plants.

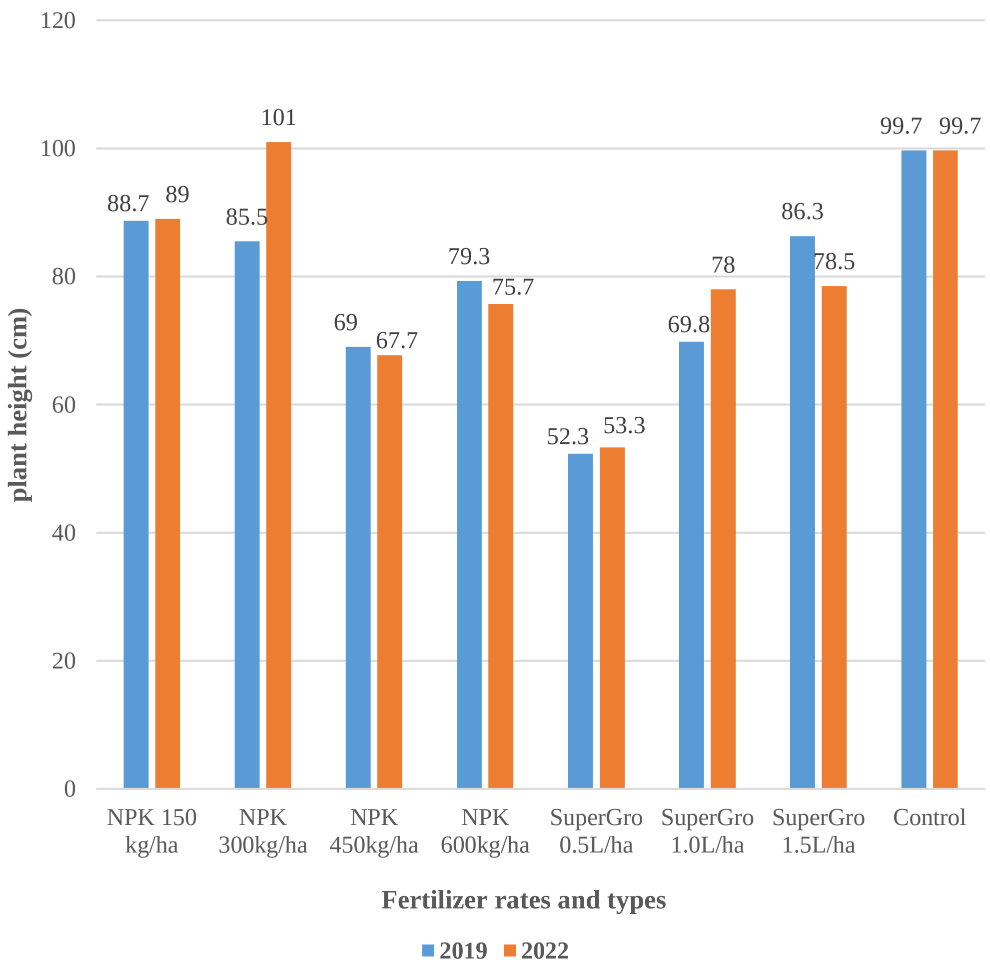

Figure1: Effect of NPK and organic liquid fertilizer (SuperGro) on plant height (cm) of *Amaranthus cruentus* at 7WAS during 2019 and 2022 rainy seasons at Samaru, Zaria.

The LAI (Figure 2) of the amaranth were observed to be higher in 2019 at most of the fertilizer rates and the control. Higher LAI observed in 2019 could be because the amount of rainfall received in that year was higher and better distributed during the growth period of the crop than in 2022. Adequate moisture could have increased leafiness and leaf size which consequently increased the LAI. Researches carried out have also related water availability to LAI where a significant correlation existed between LAI and site water balance during the growing season. (Hoff and Rambal 2003, Waring 1983, Gholtz 1982, Grier and Running 1977). Additionally, the soil organic carbon content in 2019 was high (Table 1) which enhanced crop vigor and consequently the plant's ability to effectively utilize the SuperGro foliar fertilizer applied.

The highest LAI was recorded with application of 300 kg ha^{-1}NPK while the least was recorded at 450 kg ha^{-1}NPK in 2022. Decrease in LAI with increase in fertilizer up to 450 kg ha^{-1}NPKcould be associated with leaf burn or tissue damage due to high concentration of fertilizer as it was not properly diluted given the lower amount of rainfall received and poor distribution in year 2022 (Table 2).The application of SuperGro liquid fertilizer resulted in lower LAI than the fertilizer rates except at 450 kg ha^{-1}NPK. Lower LAI recorded when compared with the fertilizer rates could be because organic fertilizers generally release nutrients slowly which may not meet the immediate nutrient demands of the plant for leaf expansion as such resulting in a low leaf area index.

The application of SuperGro liquid fertilizer resulted in increases in LAI which were more evident in year 2022 except at 0.5 L ha^{-1}. Increases recorded could be because SuperGro liquid fertilizer is an organic liquid fertilizer made from poultry droppings and seabird guano which supplied both micro nutrients and macro nutrients required by the plant.

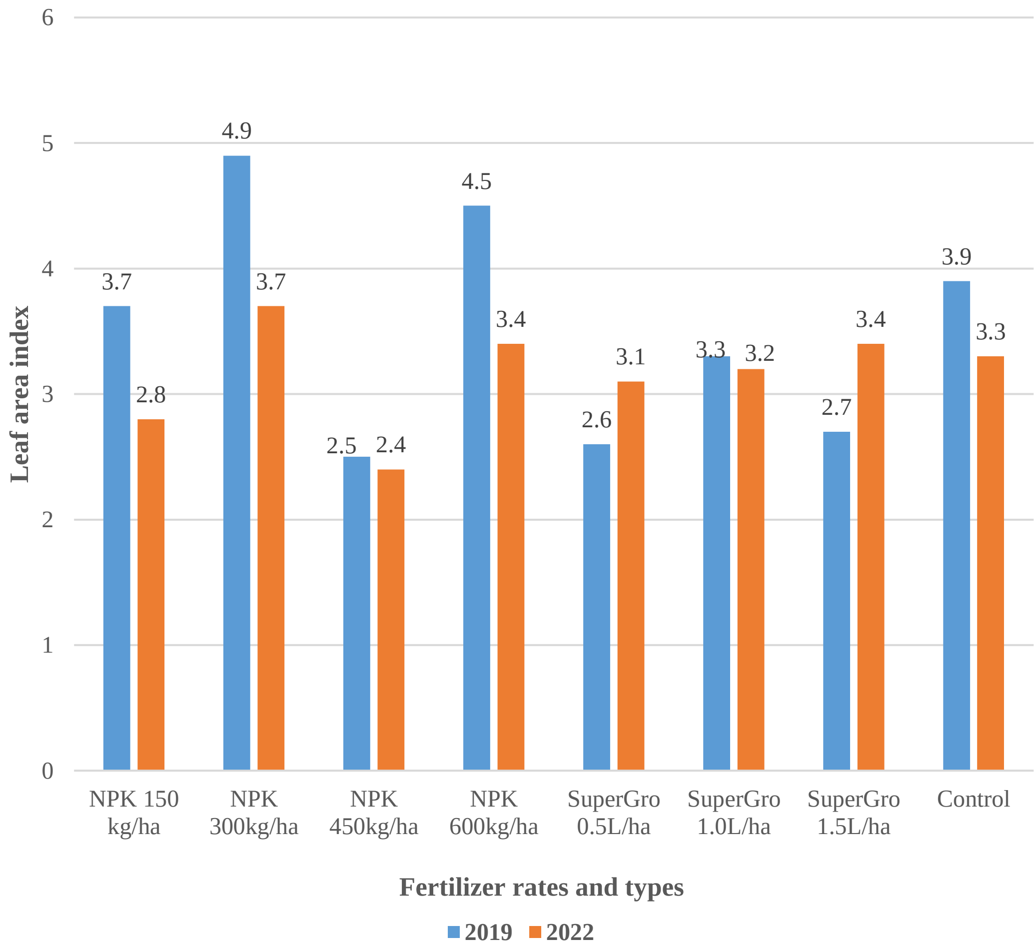

Figure 2: Effect of NPK and organic liquid fertilizer (SuperGro) on leaf area index of *Amaranthus cruentus* at 7WAS during 2019 and 2022 rainy seasons at Samaru, Zaria.

The foliage yield of the amaranth on figure 3 showed the highest yield with application of SuperGro liquid fertilizer at1 L ha^{-1} while the least was recorded at 450 kg ha^{-1}NPK.

Highest foliage yield at 1 L ha^{-1} of SuperGro liquid fertilizer applied could be due to the fact that liquid organic fertilizers contain a significant amount of soluble nutrients, making them more readily available to plants upon application compared to traditional solid-incorporated fertilizers (Badran and Safwat, 2004, Ladan *et al*. 2021). More so, SuperGro liquid fertilizer is made from poultry droppings and seabird guano, it thus contains both macro and micro nutrients which enhance plant growth. Xu *et al. (*2005) showed that vegetables grown with higher levels of organic manures grew better and resulted in higher total yield than those grown using synthetic fertilizer. Results on significant increases in plant height, number of leaves and fresh yield was reported by Ibrahim and Suleiman (2015) with application of poultry manure which they attributed to the fact that poultry manure contains N-P-K and other micronutrient that are essential for plant growth and development. Similarly, Ladan *et al*. (2021), reported that Roselle plants exhibited a positive response to liquid organic fertilizer due to its rich concentration of soluble nutrients, primarily nitrogen. These nutrients not only support the plant's growth and yield but also contribute to the overall soil health, facilitating continued plant development and prosperity. Furthermore, the utilization of liquid organic fertilizer has been found to enhance nutrient use efficiency and minimize the likelihood of nutrient loss (Criollo *et al*., 2011, Ladan *et al*., 2021).

The decrease in foliage yield with application of high NPK rates of 450 -600 kg ha^{-1} could be attributed to the fact that the application of high rates of mineral fertilizers can result in decrease pH level (soil acidification) which consequently may have reduced nutrient availability and increase toxicity to plants as reported by (Shi *et al.*, 2009, Guo *et al*., 2010, Han *et al.*, 2014 and Ngosong *et al.*, 2019).

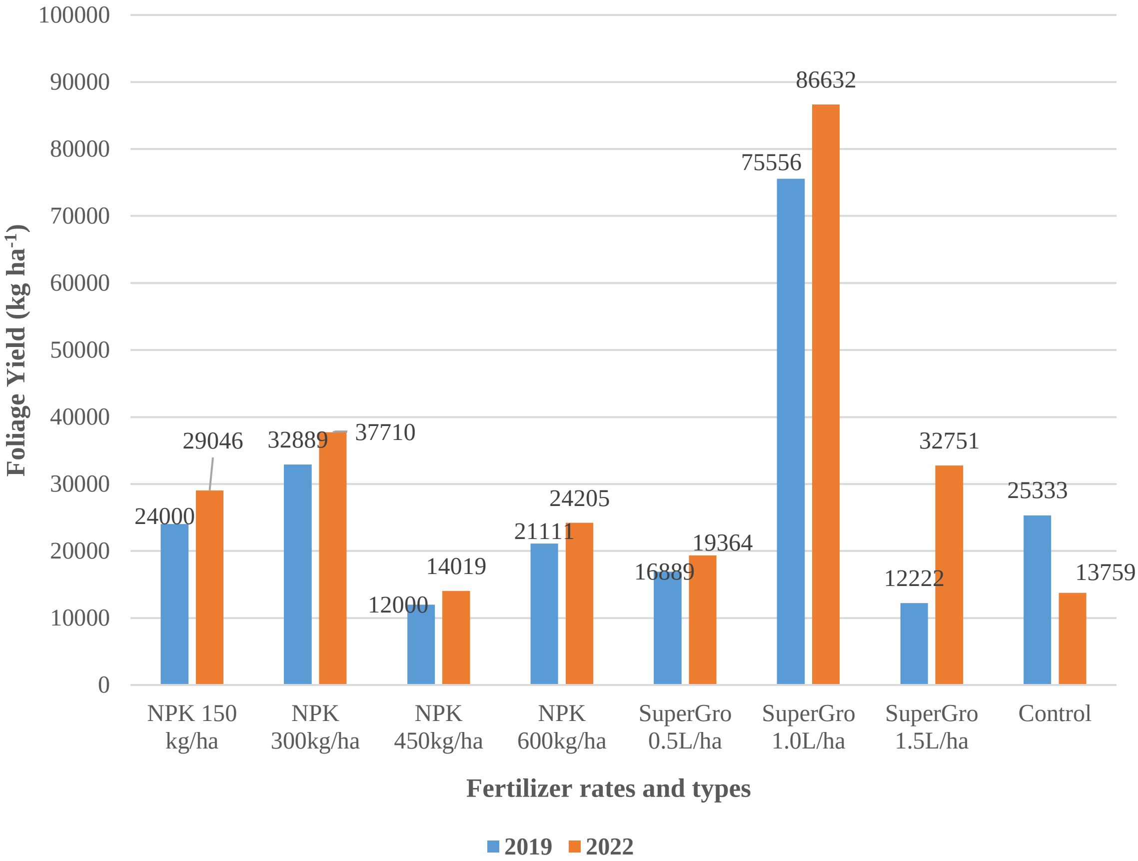

Figure 3: Effect of NPK and organic liquid fertilizer (SuperGro) on foliage yield (kg ha^{-1}) of *Amaranthus cruentus* at 7WAS during 2019 and 2022 rainy seasons at Samaru, Zaria.

Seed yield (Figure 4) was observed to be higher in 2022 at all the fertilizer rates and control. The highest seed yield was recorded with application of 600 kg ha^{-1} followed by the control. The least seed yield was recorded with application of 0.5L kg ha^{-1} SuperGro liquid fertilizer in 2019. Highest seed yield recorded with NPK fertilization could be attributed to adequate availability of phosphorus and other major elements with application of mineral fertilizers. Phosphorus has been specifically associated with improved flower formation and seed production which could result in the overall increase in seed yield. (Griffith, 2011).

High seed yield recorded on the control plots may have been affected by manure that was previously used for nutrition trials on the research field. Nitrogen in manures is stored in an organic form and it’s been released slowly as soils warm up and as crop N requirement increases (Anonymous, 2019). Therefore, the residual nutrients from the previous year may have been available and absorbed by the plants thus the seed yield increases recorded.

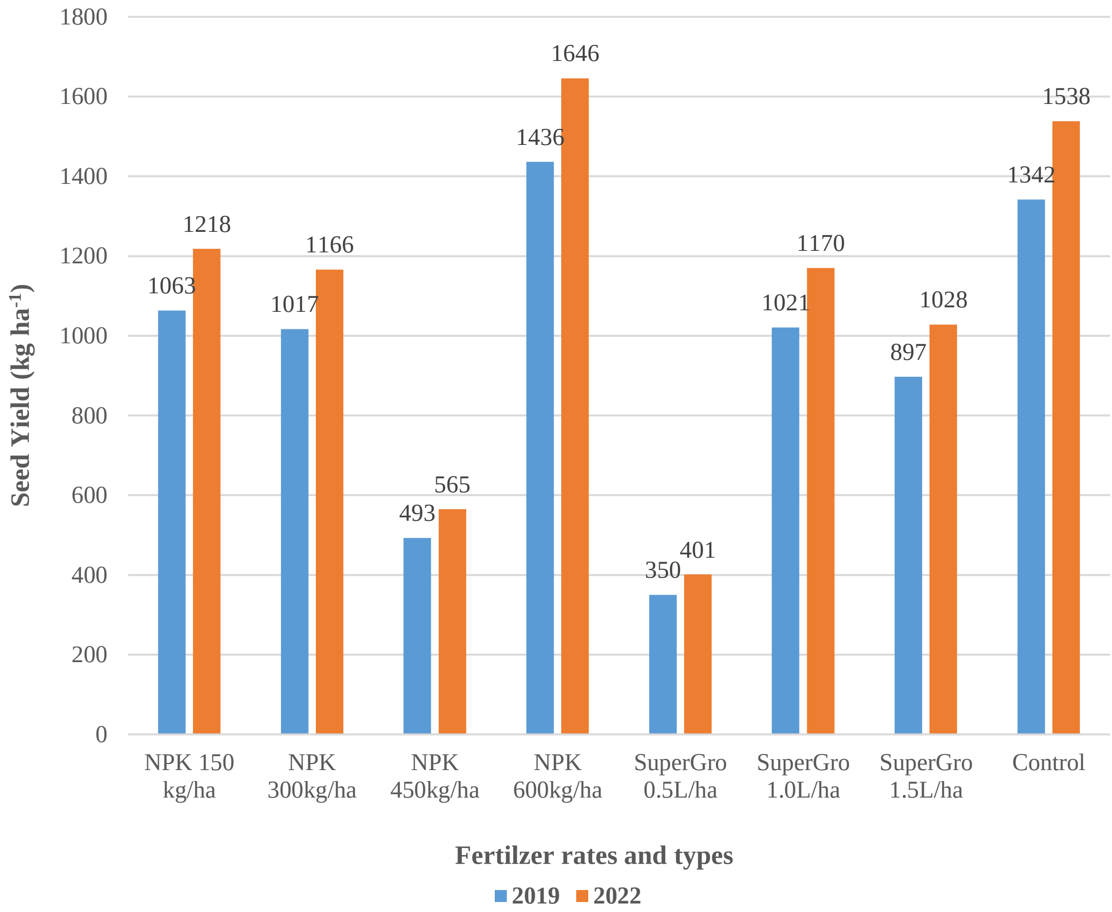

Figure 4: Effect of NPK and organic liquid fertilizer (SuperGro) on seed yield (kg ha^{-1}) of *Amaranthus cruentus* at 7WAS during 2019 and 2022 rainy seasons at Samaru, Zaria.

CONCLUSION

Based on the findings from this study, it was observed that applying 1 litre per hectare (ha^{-1}) of SuperGro liquid fertilizer resulted in the highest foliage yield for the cultivation of *Amaranthus cruentus* in the study area. Therefore, it is recommended that farmers in the region adopt the use of 1 litre ha^{-1} of SuperGro liquid fertilizer for their *Amaranthus cruentus* production. By implementing this recommendation, farmers can reduce or eliminate the reliance on chemical fertilizers for cultivating *Amaranthus cruentus* in Samaru, Zaria, located in the Northern Guinea Savanna of Nigeria. This approach not only promotes sustainable agricultural practices but also has the potential to contribute to environmental preservation by minimizing the use of chemical inputs.

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