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Total Nitrogen Absorption in Soil and its Uptake by *Amaranthus cruentus* Plant in Kwadon, Yamaltu/Deba Local Government Area of Gombe State, Northeastern Nigeria

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ABSTRACT: The objective of this paper was to investigate the total nitrogen absorption in soil and its uptake by Amaranthus cruentus plant in Kwadon, Yamaltu/Deba Local Government Area of Gombe State, Northeastern Nigeria using appropriate standard procedures. Data obtained show that the total N content was 0.53-1.32% with manure at 0-15 and 0.28-0.87% with manure at 15-30, while total N was obtained to be 0.19-0.53% without manure (control) at 0-15 and 0.11-0.59% at 15-30 without manure (control). The *Amaranthus cruentus* total N content was 0.06-2.10% with manure at 0-15 and 0.06-0.15% with manure at 15-30, whereas total N was obtained to be 0.02-0.09% both at 0-15 and 15-30 without manure (control). The total N content in soil was relatively higher than that of *Amaranthus cruentus.* The crop growth rate (GGR) was highest (146.21) and lowest (92.73) and (128.39) and lowest (61.54) on manure at days 0-15 and 15-30 of application, respectively. A similar trend was observed for total dry matter production (TDMP), leaf area index (LAI), leaf area ratio (LAR), and net assimilation rate (NAR). The highest (53.72) and lowest (25.42), and (53.72) and lowest (25.42) TDMPs were recorded on 15-30 and 0-15, respectively. The LAR and NAR were also the highest (5.31 and 0.07, respectively) on manure at day 0-15 after application. The lowest (2.21) LAR and (0.04) NAR were observed on days 0-15 after the application of manure. The manure exhibited the smallest positive changes in LAI, CGR, LAR, NAR, and TDMP after 15-30 days of application.

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Soil is a vital resource for producing the food and fiber needed to support an increasing global population (Pappendick and Parr, 2017). Soils that are at or below field capacity will have higher concentrations of both organic and inorganic P due to microbial and other soil-organism activity. Soil activity declines as soils dry out. Phosphorus availability also decreases in poorly drained and flooded soils (Beard, 2019). Soils with higher organic matter and clay content have a high capacity to absorb phosphate. Sandy soils with low organic matter content cannot absorb as much inorganic P as finer-textured soils (Beard, 2019). Organic amendments are widely recognized for enhancing the

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solubility of P in these types (Morash *et al*., 2024). The main nutrients present in fertilizers are nitrogen (N), phosphorus (P), and potassium (K) (macro nutrients), and other nutrients (micronutrients) are added in smaller amounts. Nitrogen fertilizers promote vegetative growth and are mainly responsible for the deep green of plants, which is essential for photosynthesis (Israel and Melash, 2021). The use of soil amendments is mainly to improve crop yields, which result from improved nutrient status in soil and other soil properties, such as organic matter (Urra and Garbisu, 2019). Christopher and Mohd (2011) reported limited preliminary information on the fertility requirements of amaranths. Nitrogen (N) is one of the critical mineral elements for plant growth and development (Sun *et al*., 2023). Unlike other essential nutrient elements, nitrogen is available to plants in either the cationic (NH_4^+) or the anionic (NO_3^-) forms (Olfati *et al*., 2012), and plant responses to specific forms of nitrogen vary among species (Zhou *et al*., 2011). In addition to the N level supplied to plants, the form of available nitrogen has a significant effect on the growth (Ali *et al*., 2013), yield, and quality (Sun *et al*., 2013) of plants. *Amaranthuscruentus* [L.], commonly known as Amaranth, belongs to the Caryophyllalesorder, Amaranthaceae family, Amaranthoideae subfamily, and Amaranthus genus (Wolosik and Parkowska, 2019; Raiyemo *et al.,* 2023). *Amaranthus cruentus* is a vegetable with high dietary value that is produced and consumed in most parts of Nigeria (Chidozie, 2020). Amaranth seeds are high in protein (15-18%) and contain substantial amounts of lysine and methionine, two essential amino acids that are not frequently found in other grains. Lysine plays a vital role in the treatment and prevention of *osteoporosis,* which makes bones prone to fracture (Szaboova *et al.,* 2020). The high value of vegetable production encourages growers to apply high nitrogen (N) rates and frequent irrigation to ensure high yields (Thompson *et al.,* 2020). It is one of the most widespread elements, comprising about 80% of the soil atmosphere (Kodra *et al.,* 2017). Nitrate is absorbed most often from natural sources, but vegetables accumulate a significant portion of nitrate from nitrogen-based fertilizers, which are used to fertilize plants for faster and bigger growth (Junta *et al*., 2014). Leafy vegetables, such as amaranthus and spinach, contain high concentrations of nitrate (Luetic *et al*., 2023). Higher levels of nitrate tend to be found in leaves, whereas lower levels occur in seeds or tubers; thus, leaf crops such as amaranthus generally have higher nitrate concentrations (Junta *et al*., 2014). Approximately 80% of dietary nitrates are derived from vegetable consumption (Brkicet *et al*., 2017). Sources of nitrites include vegetables, fruit, and processed meats; thus, human exposure to nitrate is usually associated with intake through vegetables and, to a lesser extent, with other foods and water (Junta *et al*., 2014).

The use of animal residues, such as poultry manure, for the growth and yield of vegetables and other crops has been advocated because of their low cost and availability (Malomo *et al*., 2018). Nitrate uptake occurs at the root level, and two nitrate transport systems have been shown to coexist in plants and to act coordinately to take up nitrate from the soil solution and distribute it within the whole plant (Céline *et al*., 2017). The use of ammonium (NH4+) as an exclusive N source has been implicated in poor plant growth compared with nitrate sources (Zhu *et al*., 2021). A continual dependence on chemical fertilizers may be accompanied by a decrease in organic matter content, increased soil acidity, degradation of soil physical properties, and an increased rate of erosion due to the instability of soil aggregates (Singh *et al*., 2015). One of the ways to maintain or improve soil fertility is by maintaining organic matter. The better the soil is fertile, the better will be the yield of amaranth (Jimoh *et al*., 2020). In light of this background, the objective of this paper is to investigate the total nitrogen absorption in soil and its uptake by Amaranthus cruentus plant in Kwadon, Yamaltu/Deba Local Government Areaof Gombe State, Northeastern Nigeria.

MATERIALS AND METHODS

Study Area: Kwadon is located about 9 km on Gombe-Biu road in the Yamaltu/Deba local government area of Gombe State, northeastern Nigeria. It is situated between latitudes 10°27 N and longitudes 11°28 E and 306 M above sea level in the northern Guinea Savannah ecological Zone of Nigeria. The study area is in the falls into the Guinea Savannah climate. The climate is tropical with two distinct seasons: a rainy season (May-October) and a dry/harmattan season (November-April) with 30.5°C and 850 mm mean annual temperature and precipitation, respectively, and with relative humidity ranging from 58% to 72% annually (Sulaiman *et al*., 2019). The study area is one of the major vegetable producers (Amaranthus, tomato, onion, pepper, chili pepper, lettuce, cabbage, etc.) in the region (Sulaiman *et al*., 2021). Agriculture is directly the largest employer in the study area. The dominant ethnic groups are Tera, Fulani, and Hausa (Nigerian Postal Service, 2009), and the occupation of Kwadon people is farming. The Y/DebaLocal Government Area was selected because it is the second largest area of dry season farming in Gombe State, Nigeria.

Sample and Sampling Techniques: Soil samples were collected randomly from four different farmlands. The soil was dug out at depths of 0-30 cm using a soil auger. In each of the four farms, one soil sample of 0-30 cm is weighed into a ratio of 4:1 with organic manure (that is, 80 grams of soil and 20 grams of organic manure), and another soil sample of 0-30 cm weighing 100 grams each served as the control. Four (4) of the collected soil samples with manure were placed in polythene bags labeled (soil with organic manure), and the remaining four (4) collected soil samples were placed in polythene bags labeled (soil without manure). Amaranthus cruentus seeds were planted in eight (8) polythene bags, where they were raised up to 21 days (3 weeks) by watering. All eight (8) samples of soil and the planted Amaranthus cruentus were analyzed in the department of biochemistry laboratory unit lab No. 1981, Gombe State University (GSU).

Determination of nitrogen and crude protein contents in plant samples: Proteins are the major compounds containing nitrogen, primarily in the form of amino acids, which are their building blocks. Nitrogen was used as an index, which was termed crude protein, as distinct from the true protein. The Kjedahl method of AOAC (1990) was used to determine the crude protein. Exactly 2.0 g of each sample is weighted into 100 ml of Kjedahl heater, and a few antibumping granules were added. One gram of the mixed catalyst ($CuSO_4$ and K_2SO_4 in ratio 8:1, respectively) and 15 mL of concentrated sulfuric acid were added. The flask is placed on a Kjedahl heater, which is heated until a clear solution is obtained. At the end of digestion, the flask is cooled, and the sample is quantitatively transferred to a 100-ml volumetric flask and made up to the gauge mark of the flask with distilled water. Approximately 10 mL of the digest was pipetted into a Markham semi-micronitrogen steel tube, and 10 mL of a 40% NaOH solution is added cautiously. The sample is steam distilled, liberating ammonia, and then into a 100-ml conical flask containing 10 ml of 4% boric acid and a drop of methyl blue indicator until the color changes from pink to green. Approximately 30 ml of sample volume is collected. The contents of the conical flask were then titrated with 0.1 M HCI. The endpoint was indicated by a color change from green to pink, and the volume (v) of the acid for each distillate was noted.

The nitrogen percentage per sample was calculated using the expression equation 1:

$$\%\ \text{nitrogen} = \frac{M \times v \times 14 \times 100 \times 100}{weightofsample \times 1000 \times 10} \quad (1)$$

Where; M = molarity of HCL; 14 = atomic weight of nitrogen; 100 = total volume of digest; 100 = percentage conversion factor; 10 = volume of digest taken; 1000 = conversion factor to litter; the crude protein was calculated as % Protein = 6.25 x% nitrogen.

Data Analysis: The data obtained was subjected to simple descriptive statistics (mean and standard deviation) using SPSS software version 25 for Windows (Sulaiman *et al.*, 2024).

RESULTS AND DISCUSSION

Nitrogen content in agricultural soils and Amaranthus cruentus in Kwadon: The total N content in each soil sample is presented in Table 1.

Table 1: Total nitrogen content in soil and *Amaranthus cruentus* from Kwodon, Y/Deba L.G.A

Locations	Description	Total-N in soil (%)	Total-N in *Amaranthus cruentus* (%)
Sample A	0-15 + Manure	0.71	0.13
	15-30+ Manure	0.28	0.08
	0-15 Control	0.19	0.02
	15-30 Control	0.11	0.02
Sample B	0-15 + Manure	0.53	0.06
	15-30+ Manure	0.59	0.06
	0-15 Control	0.37	0.02
	15-30 Control	0.41	0.03
Sample C	0-15 + Manure	1.32	0.21
	15-30+ Manure	0.86	0.15
	0-15 Control	0.44	0.07
	15-30 Control	0.49	0.08
Sample D	0-15 + Manure	0.81	0.17
	15-30+ Manure	0.87	0.13
	0-15 Control	0.53	0.09
	15-30 Control	0.59	0.09

The total-N content was 0.53% - 1.32% with manure at 0-15 and 0.28% - 0.87 with manure at 15-30, while total-N was obtained to be 0.19% - 0.53% without manure (control) at 0-15 and 0.11% -0.59% at 15-30 without manure (control). The *Amaranthus cruentus* total N content was 0.06%–2.10% with manure at 0–15 and 0.06%–0.15 with manure at 15–30, whereas total N was obtained to be 0.02%–0.09% both at 0–15 and 15–30 without manure (control). The total N content was relatively higher in the soil compared with the total N contents of Amaranthus *cruentus* (Fig. 1). A similar result was reported that soil contained higher total N than plant (Kodra *et al.*, 2017). The average total nitrogen content was higher than the reported value in Javanese paddy field soils (Kawaguchi and Kyuma, 1977), but lower than agricultural soils in Java, Indonesia (Junta et al., 2014) and on sawah soil properties (Darmawan et al., 2006). This may be due to the accelerated application of organic and/or inorganic nitrogen fertilizers (Junta *et al.*, 2014).

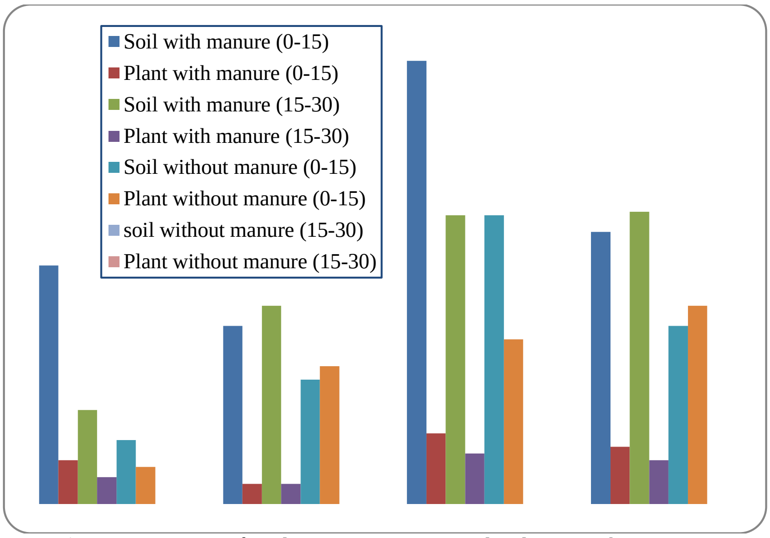

Fig. 1: Comparison of total nitrogen content in soil and *Amaranthus cruentus*

Physical growth parameters: Table 2 shows that the crop growth rate (GGR) was highest (146.21) and lowest (92.73) and (128.39) and lowest (61.54) on manure at days 0-15 and 15-30 of application, respectively. A similar trend was observed for total dry matter production (TDMP), leaf area index (LAI), leaf area ratio (LAR), and net assimilation rate (NAR). The highest (53.72) and lowest (25.42), and (53.72) and lowest (25.42) TDMPs were recorded on 15-30 and 0-15, respectively.

Table 2: Mean growth parameters and yield of *Amaranthus cruentus* in Kwadon, Y/deba L.G.A

Locations	Description	GGR	TDMP	LAR	LAI	NAR
Sample A	0-15 + Manure	118.34	34.76	4.47	6.53	0.06
	15-30+ Manure	105.26	31.68	3.81	6.32	0.06
	0-15 Control	87.61	24.39	1.71	3.46	0.04
	15-30 Control	65.25	19.52	1.64	3.32	0.04
Sample B	0-15 + Manure	92.73	25.24	2.62	4.79	0.05
	15-30+ Manure	61.54	21.13	2.21	4.16	0.04
	0-15 Control	48.26	15.54	1.87	3.73	0.03
	15-30 Control	52.35	18.67	2.11	4.45	0.04
Sample C	0-15 + Manure	146.21	53.72		8.37	0.07
	15-30+ Manure	128.39	46.45	4.59	6.95	0.06
	0-15 Control	117.42	38.31	4.23	6.31	0.06
	15-30 Control	102.63	36.50	4.15	5.82	0.06
Sample D	0-15 + Manure	132.36	46.92	4.72	7.56	0.06
	15-30+ Manure	123.58	41.32	4.36	6.25	0.06
	0-15 Control	115.26	32.37	3.75	6.13	0.06
	15-30 Control	106.73	25.525.31	2.21	4.37	0.06

Crop growth rate = GGR, total dry matter production = TDMP, leaf area index = LAI, leaf area ratio = LAR, and net assimilation rate = NAR

The LAR and NAR were also the highest (5.31 and 0.07, respectively) on manure at days 0–15 after application. The lowest (2.21) LAR and (0.04) NAR were observed on days 0–15 after the application of manure. The manure exhibited the smallest positive changes in LAI, CGR, LAR, NAR, and TDMP after 15-30 days of application.

Conclusion: The result of total N content in the soil was relatively higher than that of Amaranthus cruentus. Manure had the highest influence on Amaranthus cruentus growth in the early developmental stages days after application). Relatively high (C/N) organic manure, the rate of mineralization of different types of organic manure in the soils was reflected by the crop growth rate and net assimilation rate, which were in fact the gain in dry biomass of the plants. Results also showed a steadily increasing rate of mineralization, which enhanced the LAI, CGR, LAR, NAR, TDMP, and HI of baby Amaranthus cruentus, leading to higher productivity. The result of total N content in the soil was relatively higher than that of Amaranthus cruentus. Manure had the highest influence on Amaranthus cruentus growth in the early developmental stages (days after application). Relatively high (C/N) organic manure, the rate of mineralization of different types of organic manure in the soils was reflected by the crop growth rate and net assimilation rate, which were in fact the gain in dry biomass of the plants. Results also showed a steadily increasing rate of mineralization, which enhanced the LAI, CGR, LAR, NAR, TDMP, and HI of baby Amaranthus cruentus, leading to higher productivity.

Declaration of Conflict of Interest: The authors declare no conflict of interest.

Data Availability Statement: Data are available upon request from the first author or corresponding author

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