International Journal of Biosciences | IJB |
ISSN: 2220-6655 (Print); 2222-5234 (Online)
Website: https://www.innspub.net
Email contact: info@innspub.net
Vol. 28, Issue: 2, p. 210-221, 2026

RESEARCH PAPER OPEN ACCESS

Impact of organic and mineral fertilizers on the growth and biomass production of amaranth (*Amaranthus cruentus* L.) in Burkina Faso

Sidnoma Marie Emeline Vanessa Sompougdou*[1], Hugues Roméo Bazié[1], Philippe Bayen[2], Caroline Bassono[3]

[1]*Plant Ecophysiology Research Team, Biosciences Laboratory, Life and Earth Sciences Training and Research Unit, Joseph Ki-Zerbo University (UJKZ), Ouagadougou, Burkina Faso*

[2]*Applied Sciences and Technologies Training and Research Unit, Daniel Ouezzin Coulibaly University (UDOC), Dédougou, Burkina Faso*

[3]*Nitidae, Ouagadougou Kossiam, Burkina Faso*

Key words: Amaranth, Organic fertilizer, Mineral fertilizer, Agromorphological parameters, Yield

Received: February 04, 2026 **Published:** February 18, 2026

DOI: https://dx.doi.org/10.12692/ijb/28.2.210-221

ABSTRACT

Amaranth (*Amaranthus cruentus* L.) is one of the most leafy vegetables widely consumed in Burkina Faso. However, inappropriate input and unsuitable doses constitute a constraint to the optimal productivity of amaranth. This study aims to evaluate the effect of four organic fertilizers and two mineral fertilizers on the agromorphological performance of amaranth. A split plot experimental design was used with fertilizer type as the main factor (seven levels) and application dose as the second factor. Poultry manure (PM) was applied at rates of 5, 10 and 15 t/ha, while liquid organic fertilizers derived from poultry manure (LOFPM), cow dung (LOFCD), and small ruminant droppings (LOFSR) were applied at respective doses of 0.1L, 0.085L, and 0.075L each diluted in 1,5L of water. NPK fertilizer was applied at 100, 200 and 300 kg/ha, while urea was used at doses of 50, 75 and 100 kg/ha. The Witness (Control) had no fertilizer input. The agromorphological parameters assessed included number of leaves, plant height, collar diameter, and yield. The results indicated that PM produced the highest number of leaves (73.00±29.93), followed by LOFPM (59.82±26.75). The highest yields were obtained with LOFPM (7971.11±427.20 kg/ha) and PM (7195.55±211.58 kg/ha) with no significant difference ($p>0.05$). All LOFPM doses allowed for a high yield without significant difference ($p>0.05$). In contrat, PM showed a dose dependent effect with 15 t/ha producing significantly higher yields that the lower doses.

***Corresponding author:** Sidnoma M. E. V. Sompougdou ✉ sompougdouvanessa@gmail.com
* https://orcid.org/0009-0006-9007-7619

Co-authors:
Hugues R. Bazié: https://orcid.org/0000-0002-6300-8953
Philippe Bayen: https://orcid.org/0000-0002-3620-4342

INTRODUCTION

The global population growth and the reduction of arable land lead to food insecurity and persistent malnutrition, particularly in developing countries (de Bruin *et al.,* 2021) and this is a major concern for developing countries. In Burkina Faso, more than 3.7 million people suffer from undernourishment (Fletcher and Kubik, 2016). In response, governments and development aid organization including the United Nations Children's Fund (UNICEF), the World Food Programme (WFP), and other partners have implemented strategies to combat malnutrition. These strategies are based on diversifying food sources relying on cereals by providing nutritional supplements from local vegetables, which are rich in minerals, vitamins, and nutritional factors (Soro *et al.,* 2012; Jamnadass *et al.,* 2020). Among the local vegetables is amaranth, whose leaves are rich in proteins, essential amino acids such as lysine, threonine, methionine, and tryptophan, as well as minerals including calcium, magnesium, iron, phosphorus, and potassium (Berger *et al.,* 2003; Achigan-Dako *et al.,* 2014). It adapts easily to all agroecological conditions and grows rapidly (Westphal, 1985). This makes it a valuable crop for sem-arid regions and vegetable of great economic importance. In Burkina Faso, amaranth cultivation is expending particularly in urban and peri-urban areas compared to rural areas and is one of the main leafy vegetables consumed (Hama-Ba *et al.,* 2017). The national production of amaranth in 2018 was estimated at 1357 tons over an area of 246 hectares in Burkina Faso (MAHRH, 2020). The findings of Ouédraogo *et al.* (2021) revealed three species of amaranth cultivated in Burkina Faso, namely *Amaranthus cruentus*, *Amaranthus hypochondriacus* and *Amaranthus dubius*. Amaranths are commonly called 'Bolombourou' in mooré and are grown as leafy vegetables. However, vegetable production faces multiple biotic and abiotic problems that negatively affect yield (Son *et al.*, 2017). Limited by low fertility levels and soil degradation, the low productivity of amaranth cultivation is exacerbated by the lack of adequate and rational input of fertilizers (Ognalaga *et al.,* 2015). Thus, it is beneficial to optimize the productivity of amaranth per unit of land used through the systematic use of appropriate fertilizer doses. To do this, the use of organic fertilizers could be an alternative for soil fertilization and one of the suitable solutions for producing healthy amaranth without compromising the balance of soil biodiversity. Studies on the effect of organic fertilization on amaranth have been conducted in Benin by Koussihouèdé *et al.* (2016) and Gbessemehlan *et al.* (2022). These authors successively worked with compost made from animal manure and found that doses ranging from 20 to 30t/ha of compost yielded the best amaranth productivity. Furthermore, Ognalaga *et al.* (2015) in Gabon used cow dung and pig manure and showed that a dose of 20t/ha had the best growth performance. Recently, liquid organic fertilizers containing bioavailable macro- and micro-nutrients have gained popularity in agroecological practices. However, their effects on amaranth cultivation remain untested. Moreover, no studies have yet been conducted in Burkina Faso to evaluate the impact of organic fertilizers on amaranth, nor have comparative analyses between organic and mineral fertilizers commonly used in market gardening been undertaken.

To support producers in selecting effective fertilization strategies that enhance amaranth productivity while minimizing environmental and health risks, it is crucial to document the effects of organic fertilizers. This study was therefore designed to assess the impact of different fertilizer types on amaranth production. The general objective was to propose an optimal fertilizer combination for improving amaranth yields. Specifically, the study aimed to (1) evaluate the effect of fertilizer type on amaranth growth and (2) assess its impact on yield.

MATERIALS AND METHODS

Experimental site

The experimentation was conducted from April to May 2023, in Bawiga village located in the municipality of Sapouy in the province of Ziro, located between latitude 11° 36' 22.47" N and longitude 1° 38' 44.40" W (Fig. 1). Most of the Ziro province is subject to the sudanese climate with an average of between 1000mm and 1200mm. The average temperatures ranges between 35°C and 40°C during the dry season and between 25°C and 29°C during the rainy season. The vegetation in Sapouy is predominantly composed of open woodlands and dense woodlands. Dominant woody species includ , *Annona senegalensis*, *Anogeissus leiocarpus*, *Piliostigma reticulatum*, *Lannea microcarpa*, *Faidherbia albida*, *Vitellaria paradoxa*, *Balanites aegyptiaca*, *Bombax costatum*, *Afzelia africana*, *Daniela oliverie*, *Grewia cissoides*, *Terminalia macrosptera*, *Detarium microcarpum*. Common herbaceous species include, *Andropogon gayanus*, *Andropogon pseudapricus*, *Pennisetum pedicelatum*, *Loudetia togoensis*, are the main species encountered (Yanda, 2022). Four types of soils are listed in the municipality of Sapouy. The large part of the territory of the municipality is dominated by hydromorphic soil type. There are also raw mineral soils, poorly developed soils as well as vertisols and para-vertisols (Yanda, 2022). A physical soil analysis based on the granulometry of the fraction "less than 2 mm" made before the experiment on the site revealed a sandy loam texture consisting of 8.48% clay, 21.48% silt and 70.04% sand.

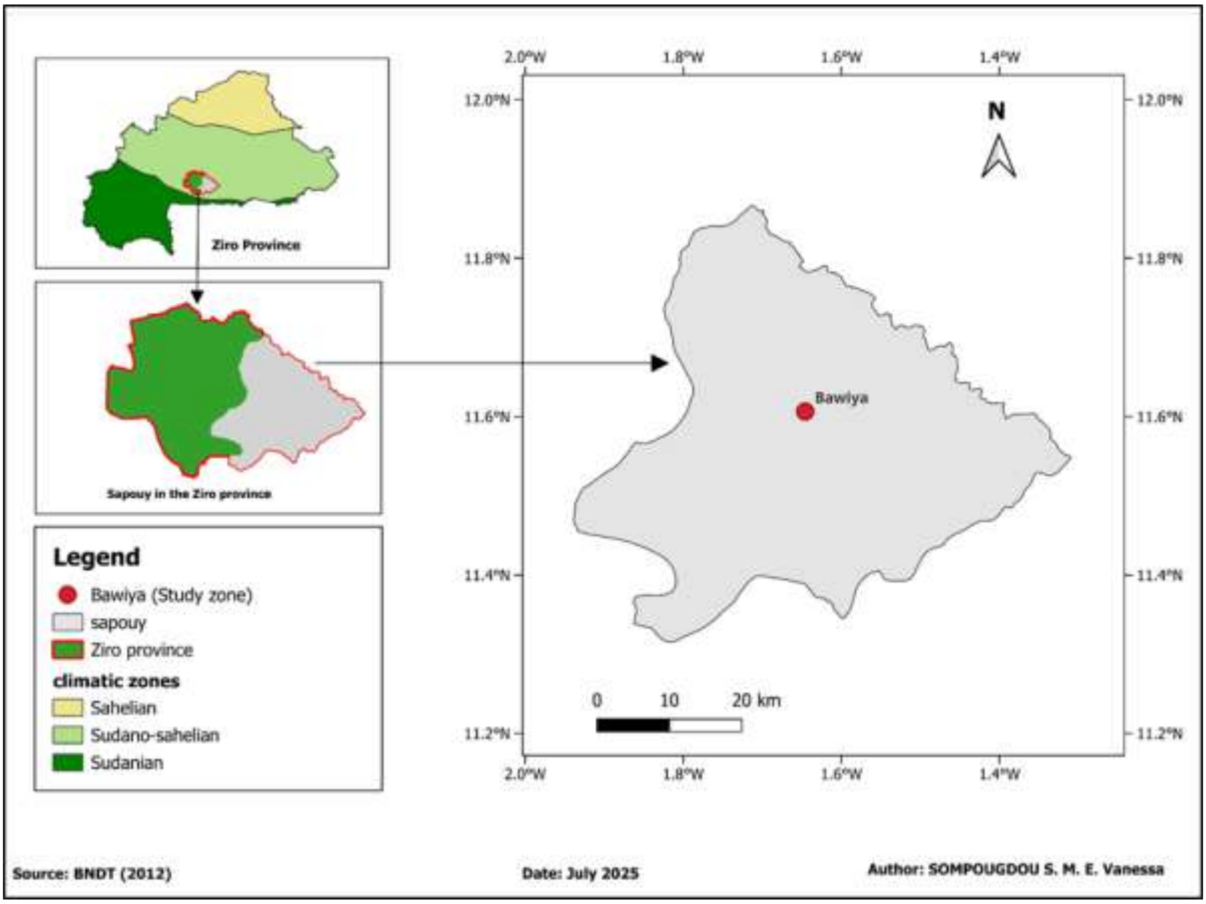

Fig. 1. Localization of the study area

Species description and fertilizer

Amaranth is an annual plant of the Amaranthaceae family and belonging to the genus Amaranthus. It can grow up to 2.5 meters tall, with a cylindrical, fibrous, and succulent stem, hollow with ridges and bracteoles at maturity. This specie belongs to plants that possess the C4 photosynthetic pathway and are characterized by their ability to adapt to different agro-climatic conditions and water stress. The study used the green morphotype with black seeds of *Amaranthus cruentus*, the most known and cultivated species of Amaranth in Burkina Faso

(Ouédraogo *et al.,* 2021). This morphotype has a short development cycle of 30 days and is characterized by oval, pointed, broad, elliptical, and alternate petiolate leaves with small, leaf-like bracts (Grubben, 1975).

The fertilizers used were poultry manure (PM), liquid organic fertilizer based on poultry manure (LOFPM), liquid organic fertilizer based on cow dung (LOFCD), liquid organic fertilizer based on small ruminant droppings (LOFSR), NPK (15-15-15), and Urea containing 46% nitrogen. The cow dung, poultry manure, and small ruminant droppings used as the basis for the liquid fertilizers all come from nearby domestic farms fed with household waste.

Experimental design

The experimental device was a split plot design with 2 factors and 3 replications. The first factor was the type of fertilizer with seven treatments: poultry manure (PM), liquid organic fertilizer based on poultry manure (LOFPM), liquid organic fertilizer based on cow dung (LOFCD), liquid organic fertilizer based on small droppings (LOFSR), NPK (15-15-15), Urea and the Control with no fertilizer applied. The second factor was the dose, with three levels specific to each type of fertilizer. The elementary plots were square boards of 1 meter on each side. The borders rows were excluded from data collection. Walkways of 0.5 m individual plot, while 1 m alleys between main plots were reinforced with mound to prevent cross-contamination. The Table 1 indicate the fertilizer application rate.

Each organic fertilizer was formulated using a combination of manure specific to its type, fresh biomass, ash, living soil, and water. These ingredients were added according to specific proportions and defined objectives. For each preparation, we added manure at a proportion of 1/3 of the content of the chosen container for the preparation, then 1/3 of fresh biomass (neem), followed by two shovelfuls of living soil (termite mound), ash, and finally water. Each product was stirred every day at the same time for two weeks and filtered for different applications.

Table 1. Quantity of fertilizers added by treatment

Dose applied per micro plot	NPK (g)	Urea (g)	Poultry manure (g)	Organic liquid fertilizers (l)
Dose 1	10	5	500	0.1
Dose2	20	7.5	1000	0.085
Dose3	30	10	1500	0.075

Analysis of fertilizers and soil

Prior to application; each fertilizer was sampled for laboratory characterization. Additionally, a soil sampling was carried out before setting up the trials using a soil auger at a depth of 0-20 cm at five (5) points along the two (2) diagonals to determine the nutrient composition of the soil. The acollected samples were analyzed for total nitrogen content using the Kjeldahl method, assimilable phosphorus using the Bray 1 method, the exchangeable potassium according to flame emission spectrometry, organic matter by calcination, organic carbon according to the Walkey and Black method, and pH (water) by the potentiometric method.

Installation and monitoring of the crop

The amaranth seedlings were produced in a nursery for 14 days before being transplanted into previously plowed and well-irrigated soil. The young plants were transplanted at a spacing of 20cm x 20cm corresponding to planting density of 250.000 plants/ha or 25 plants/m2. Irrigation was applied twice daily (30 L per plot), morning and evening. For monitoring, five plants per plot were randomly selected and labeled for repeated measurement.

Measurement of agromorphological parameters

Measurement of crop growth

Growth parameters measurement were taken weekly until the 28 days after transplanting (DAT), following the protocol of (Gbessemehlan *et al.*, 2022). These parameters included the stem collar diameter measured using a caliper, plant height measured from the collar to the tip of the last leaf using a graduated ruler, and number of leaves determined by manually counting all leaves per plant. These different measurements were recorded from five plants randomly selected plants per treatment.

Production parameters

Grubben (1975) reported that harvesting by pulling and successive cuttings can take place as early as 21 days or three (3) weeks after transplanting. The cuts were made 10 cm from the ground on the 28th day after transplanting and productivity was determined from the measurement of this fresh biomass per plot and the dry biomass obtained by oven drying of the materials produced at 70 °C until constant weight. The harvest was weighed on an ACCULAB Sartorius digital scale.

Data analysis

Data collected were digitized and then organized in an Excel 2013 spreadsheet. R software was used for statistical analysis of the data. The normality of the data was checked by the Shapiro-Wilk test before performing the analysis of variance (ANOVA) with fertilizer type and dose as factors. The comparison of means was made at a 5% threshold according to the Newman-Keuls test.

RESULTS

Chemical characteristics of organic fertilizers and soil

The results of the chemical analyses showed that PM contained the highest levels of nitrogen and potassium among the organic fertilizers assessed (Table 2). Within the liquid organic fertilizers, LOFPM exhibited higher concentration of nitrogen and assimilable phosphorus. As for the chemical composition of the initial soil, it had a lower content of nitrogen and organic matter than the different organic fertilizers (Table 2).

Table 2. Chemical characteristics of the organic fertilizers used and the soil.

Parameters	LOFPM	LOFCD	LOFSR	PM	Soil
Total Organic Matter (%)	1.99	2.29	2.36	5.048	1.95 ±0.16
Total Carbon (%)	1.15	1.33	1.37	2.928	1.12 ±0.09
Total Nitrogen (%)	0.707	0.248	0.189	1.197	0.11 ±0.00
Assimilable Phosphorus (ppm)	4.245	3.098	3.901	23.91	11.37 ±3.36
Potassium Available (ppm)	16.717	17.933	17.933	682.61	118.99 ±19.95
Water pH P/V :1/2.5	5.7	7.3	7.5	7.26	6.40±0.07

Poultry Manure (PM), Liquid Organic Fertilizer based on Poultry Manure (LOFPM), Liquid Organic Fertilizer based on Cow Dung (LOFCD), Liquid Organic Fertilizer based on Small Ruminant droppings (LOFSR).

Effect of different types and doses of fertilizers on amaranth growth

Analysis of stem diameter revealed significant differences based on the type of fertilizers and dates of measurement. At 28 DAT, the fertilizers PM (17.61±0.89 mm) and LOFPM (15.73±0.75 mm) produced the higher diameter growths (Fig. 2). The lowers diameters were found for chemical fertilizers (NPK and Urea) and the control. Among the chemical fertilizers, NPK showed the best growth in diameter. Statistical analysis confirmed a significant interaction between fertilizer type and the date of measurement (df =18; F = 21.12; p <0.0001) indicating that both the nature of the fertilizer and the timing of assessment influenced stem diameter development.

Analyzing the effect of different doses within each type of fertilizer revealed no significant differences (p>0.05) across measurement date, except for LOFPM (7DAT), LOFSR (14DAT), PM (14 and 21 DAT) and Urea (21DAT) (Table 3).

Growth curves analysis for plant height revealed that poultry manure (PM) and liquid organic fertilizer based on poultry manure (LOFPM) produced the highest valued at 28 days after transplantation with heights of 29.20 ± 1.07 cm and 27.07 ± 1.16 cm, respectively (Fig.

3). These two treatments did not differ (p> 0.05) indicating comparable effectiveness in promoting height growth. The statistical analysis of height showed a significant interaction between the type of fertilizer and the date of measurement (df =18; F = 15.35; p <0.0001).

Analysis of height growth across different fertilizer doses revealed no significant difference (p>0.05) at any measurement except at 14 days after transplanting for the fertilization with LOFSR (p=0.044) and NPK (p=0.022) at 14 DAT (Table 4).

Table 3. Amaranth collar diameter plus or minus the standard error (mm) under the effect of fertilizer types and doses

Fertilizers	Doses	7DAT	14DAT	21DAT	28DAT
LOFPM	Dose1	1.48±0.09a	3.93±0.35a	8.68±0.77a	14.99±1.37a
	Dose2	1.32±0.10ab	3.93±0.24a	11.69±2.30a	16.73±1.50a
	Dose3	1.12±0.09b	3.27±0.27a	8.77±0.52a	15.48±1.07a
	p-Value	0.046	0.199	0.255	0.638
LOFCD	Dose1	1.06±0.15 a	3.39±0.31a	7.87± 0.74a	14.00±1.34a
	Dose2	1.4±0.17a	3.78±0.34a	8.02±0.84a	14.44±1.60a
	Dose3	2.28±0.71a	3.32±0.26a	6.00±0.58a	10.46±1.78a
	p-Value	0.132	0.53	0.106	0.164
LOFSR	Dose1	1.02±0.12a	2.75±0.17a	6.24±0.40a	11.69±0.84a
	Dose2	1.35±0.17a	4.32±0.43b	8.46±1.01a	15.97±2.37 a
	Dose3	1.67±0.30a	3.14±0.32a	6.89±0.68a	12.23±0.92a
	p-Value	0.111	0.005	0.108	0.118
PM	Dose1	1.24±0.12a	3.31±0.31a	7.77±0.66a	15.84±1.43a
	Dose2	1.49±0.20a	4.18±0.30a	9.85±0.79ab	18.81±1.88a
	Dose3	1.62±0.19a	5.69±0.54b	10.60±0.67b	18.18±1.27a
	p-Value	0.297	0.000	0.0217	0.371
NPK	Dose1	1.07±0.18a	3.16±0.39a	5.40±0.40a	8.89±0.37a
	Dose2	0.99±0.11a	2.87±0.35a	5.68±0.53a	8.38±0.65a
	Dose3	0.92±0.18a	2.14±0.13a	6.21±0.40a	10.16±0.57a
	p-Value	0.819	0.072	0.496	0.371
Urea	Dose1	0.99±0.19a	1.98±0.14a	2.67±0.15a	3.15±0.20a
	Dose2	1.52±0.19a	2.36±0.22a	3.88±0.40b	4.38±0.48a
	Dose3	1.30±0.18a	1.75±0.18a	2.70±0.31a	3.91±0.32a
	p-Value	0.17	0.081	0.010	0.060

For a given factor, the means followed by the same letters are not significantly different at the 5% significance level. Poultry Manure (PM), Liquid Organic Fertilizer based on Poultry Manure (LOFPM), Liquid Organic Fertilizer based on Cow Dung (LOFCD), Liquid Organic Fertilizer based on Small Ruminant droppings (LOFSR), NPK (15-15-15), Day after transplantation (DAT)

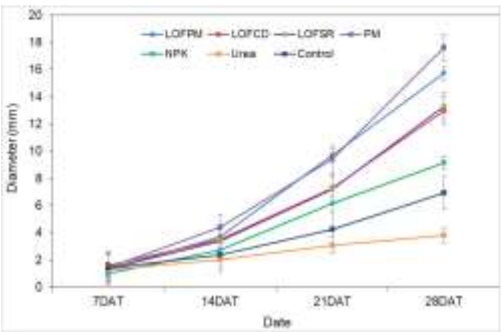

Fig. 2. Evolution of growth in diameter of amaranth according different fertilizers. Poultry Manure (PM), Liquid Organic Fertilizer based on Poultry Manure (LOFPM), Liquid Organic Fertilizer based on Cow Dung (LOFCD), Liquid Organic Fertilizer based on Small Ruminant droppings (LOFSR), NPK (15-15-15), Day after transplantation (DAT)

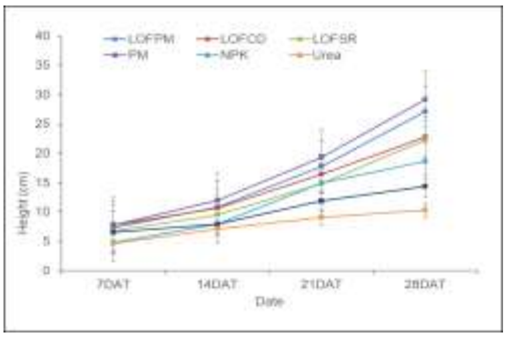

Fig. 3. Evolution of amaranth height growth according to transplanting dates under different fertilizers. Poultry Manure (PM), Liquid Organic Fertilizer based on Poultry Manure (LOFPM), Liquid Organic Fertilizer based on Cow Dung (LOFCD), Liquid Organic Fertilizer based on Small Ruminant droppings (LOFSR), NPK (15-15-15), Day after transplantation (DAT)

Table 4. Amaranth plant height plus or minus the standard error (cm) under the effect of fertilizer types and doses

Fertilizers	Doses	7DAT	14DAT	21DAT	28DAT
LOFPM	Dose1	7.19±0.47a	10.86±0.60a	16.03±1.09a	25.12±2.27a
	Dose2	7.24±0.42a	11.10±0.38a	18.63±0.73a	28.50±1.77a
	Dose3	7.46±0.40a	10.33±0.51a	18.51±0.82a	27.60±2.02a
	p-Value	0.9	0.553	0.081	0.482
LOFCD	Dose1	8.66±0.78a	11.53±0.82a	16.06±0.75a	21.33±1.70a
	Dose2	7.73±0.53a	10.46±0.85a	18.18±1.12a	26.53±2.03a
	Dose3	6.80±0.43a	9.80±0.51a	15.03±1.23a	20.46±2.63a
	p-Value	0.105	0.267	0.114	0.112
LOFSR	Dose1	6.66±0.43a	8.60±0.45a	13.70±0.67a	20.4±1.01a
	Dose2	6.88±0.33a	10.13±0.36b	16.76±1.57a	26.0±3.00a
	Dose3	6.61±0.54a	9.76±0.48ab	14.10±1.00a	20.2±1.17a
	p-Value	0.906	0.044	0.132	0.069
PM	Dose1	8.00±0.59a	11.80±0.60a	18.50±1.32a	26.26±2.26a
	Dose2	7.01±0.60a	11.20±0.52a	18.33±1.14a	29.73±1.53a
	Dose3	8.16±0.57a	12.73±0.55a	20.90±1.12a	31.60±1.56a
	p-Value	0.339	0.167	0.249	0.122
NPK	Dose1	4.90±0.32a	9.20±0.58a	14.33±0.88a	20.36±1.42a
	Dose2	5.00±0.38a	6.93±0.62b	13.80±0.97a	17.63±1.22a
	Dose3	4.39±0.26a	7.60±0.50ab	14.03±0.87a	17.93±1.33a
	p-Value	0.382	0.022	0.103	0.122
Urea	Dose1	4.63±0.30a	7.20±0.41a	8.93±0.44a	9.81±0.35a
	Dose2	4.93±0.37a	7.36±0.39a	9.85±0.90a	11.22±1.04a
	Dose3	4.36±0.30a	6.73±0.38a	8.33±0.43a	9.76±0.43a
	p-Value	0.483	0.516	0.247	0.243

For a given factor, the means followed by the same letters are not significantly different at the 5% significance level. Poultry Manure (PM), Liquid Organic Fertilizer based on Poultry Manure (LOFPM), Liquid Organic Fertilizer based on Cow Dung (LOFCD), Liquid Organic Fertilizer based on Small Ruminant droppings (LOFSR), NPK (15-15-15), Day after transplantation (DAT)

Table 5. Number of leaves per plant plus or minus the standard error under of fertilizer types and doses

Fertilizers	Doses	7DAT	14DAT	21DAT	28DAT
LOFPM	Dose1	6.93±0.37a	17.40±2.16a	36.60±5.39a	54.46±7.93a
	Dose2	6.80±0.27a	22.93±2.42a	47.46±5.41a	63.40±7.21a
	Dose3	6.86±0.30a	18.26±1.73a	45.80±4.44a	61.60±5.62a
	p-Value	0.958	0.154	0.28	0.637
LOFCD	Dose1	6.86±0.38a	18.66±2.04a	48.06±5.62a	63.53±6.55a
	Dose2	7.20±0.32a	19.60±1.97a	42.33±5.41ab	64.66±8.48a
	Dose3	7.06±0.40 a	15.73±2.10a	28.20±4.66b	35.73±5.61b
	P-Value	0.82	0.385	0.030	0.007
LOFSR	Dose1	6.73±0.28a	12.66±0.96a	33.06±3.71a	47.73±4.63a
	Dose2	7.13±0.35a	21.93±2.53b	53.33±7.57b	66.80±10.87a
	Dose3	6.60±0.34a	10.66±0.75a	35.60±2.66ab	49.06±3.29a
	P-Value	0.497	0.000	0.014	0.117
PM	Dose1	6.53±0.29a	16.73±2.81a	44.40±4.90a	60.33±6.32a
	Dose2	6.80±0.32a	21.46±2.87ab	57.66±6.13a	81.80±10.00a
	Dose3	7.20±0.32a	28.66±3.30b	61.13±4.24a	76.86±5.43a
	P-Value	0.331	0.025	0.064	0.12
NPK	Dose1	7.20±0.64a	17.33±1.90a	23.60±2.18a	39.06±2.35a
	Dose2	6.13±0.38a	12.86±1.35ab	31.20±3.20a	39.26±3.55a
	Dose3	5.66±0.27a	12.00±0.92b	33.93±2.47a	40.73±2.65a
	p-Value	0.065	0.028	0.766	0.12
Urea	Dose1	5.86±0.38a	10.13±1.03a	12.06±0.85a	13.66±0.65a
	Dose2	6.20±0.32a	8.86±0.42a	16.00±1.58a	18.33±2.15a
	Dose3	6.00±0.27a	8.20±0.40a	12.66±0.98a	17.53±1.17a
	p-Value	0.778	0.143	0.050	0.066

For a given factor, the means followed by the same letters are not significantly different at the 5% significance level. Poultry Manure (PM), Liquid Organic Fertilizer based on Poultry Manure (LOFPM), Liquid Organic Fertilizer based on Cow Dung (LOFCD), Liquid Organic Fertilizer based on Small Ruminant droppings (LOFSR), NPK (15-15-15), Day after transplantation (DAT)

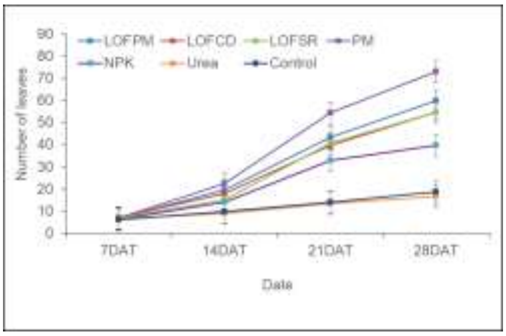

Fig. 4. Evolution of number of leave per plant according to transplanting dates under different fertilizers. Poultry Manure (PM), Liquid Organic Fertilizer based on Poultry Manure (LOFPM), Liquid Organic Fertilizer based on Cow Dung (LOFCD), Liquid Organic Fertilizer based on Small Ruminant droppings (LOFSR), NPK (15-15-15), Day after transplantation (DAT)

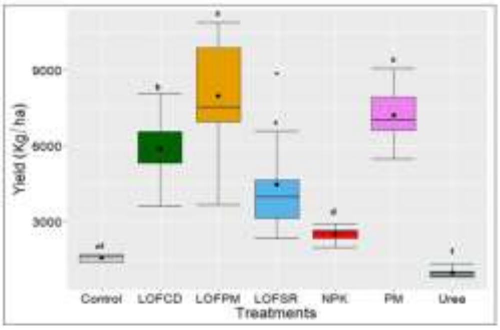

Fig. 5. Variation in fresh matter yields between different treatments. The median and the mean are represented by a horizontal line and a dot in the boxplot, respectively. Poultry Manure (PM), Liquid Organic Fertilizer based on Poultry Manure (LOFPM), Liquid Organic Fertilizer based on Cow Dung (LOFCD), Liquid Organic Fertilizer based on Small Ruminant droppings (LOFSR), NPK (15-15-15).

Analysis ofleaf count per plant revealed that PM produced a significantly higher number of leaves compared to LOFPM ($p<0.05$) compared to other types of fertilizers at 21 DAT (Fig. 4). However, at 28 DAT there was no significant difference between PM and LOFPM ($p=0.142$). The lowest number of leaves were found for chemical fertilizers (NPK and Urea) and the control with a significant difference between NPK and Urea ($p<0.05$). The statistical analysis of amaranth leaf shows a significant interaction between the type of fertilizer and the date of measurement (df =18; F = 14.65; p <0.0001).

Regarding effect of different doses within each type of fertilizer (Table 5), there was no significant difference between the different doses of fertilizer at 28 DAT, except for LOFCD, which showed a significant difference ($p=0.007$).

Effect of different types and doses of fertilizers on the yield of amaranth plants

The highest yield of amaranth was obtained with fertilization using LOFPM (7971.11±427.20 kg/ha) and PM (7195.55±211.58 kg/ha) with no significant difference, followed by LOFCD (5885.55±242.93kg/ha) and LOFSR (4464.44±380.88kg/ha). The lowest yield was obtained with mineral fertilizers (NPK and Urea) and control (Fig. 5).

As regards the different doses within the same type of fertilizer (Fig. 6), there was no significant difference between the three doses of LOFCD and LOFPM. For PM, dose 3 gave the best fresh biomass. For mineral fertilizers, dose 2 within the same type of fertilizer produced the highest fresh biomass. Moreover, all doses of organic fertilizers increased the yield of amaranth compared to chemical fertilizers.

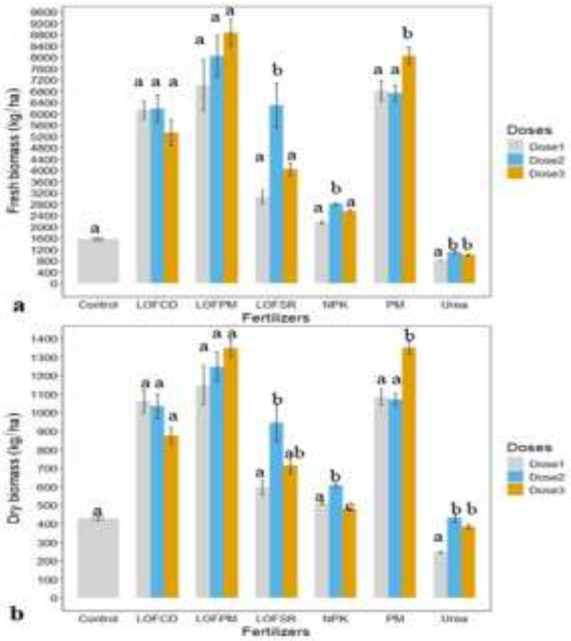

Fig. 6. Effect of fertilizer doses on plant fresh biomass (a) and Dry biomass (b). For a given factor, the means followed by the same letters are not

significantly different at the 5% significance level. Poultry Manure (PM), Liquid Organic Fertilizer based on Poultry Manure (LOFPM), Liquid Organic Fertilizer based on Cow Dung (LOFCD), Liquid Organic Fertilizer based on Small Ruminant droppings (LOFSR), NPK (15-15-15)

DISCUSSION

Effect of different types and doses of fertilizers on amaranth growth

The growth parameters measured on amaranth on different dates showed significant effects with the application of different types and doses of fertilizers. All organic fertilizers induced the growth of amaranth compared to mineral fertilizers. The better performance of poultry manure and liquid organic fertilizer based on poultry manure from 21 DAT in terms of plant height, plant diameter, and number of leaves can be explained not only by their high nitrogen content, which according to Koussihouèdé *et al.* (2016) in Benin, is the most crucial element in the growth of amaranth, but also by the rapid mineralization of poultry manure. Kalombo *et al.* (2023) in the Congo found the best results for amaranth growth parameters with chicken manure. Gbessemehlan *et al.* (2022) in Benin found also similar results with composted poultry manure, which was already evident from 14 DAT compared to composted cow dung. However, despite the nitrogen content of LOFPM being lower than that of PM as revealed by the chemical analysis of the fertilizers, the growth trend of amaranth remains without significant difference in these two environments. This could be explained by the liquid form of LOFPM which would facilitate the bioavailability of mineral elements and their accessibility, thus promoting good growth of amaranth. The poor growth of plants following the application of isolated mineral fertilizers (NPK and Urea) is due to the fact that the mineral elements released by these fertilizers due to microbial activity are not sufficient to meet the amaranth needs. These results corroborate those of Ognalaga *et al.* (2017), who found low growth of cassava following the isolated application of these soluble mineral fertilizers in Gabon.

Effect of different types and doses of fertilizers on amaranth productivity

The application of mineral fertilizers such as NPK and urea resulted in relatively low fresh biomass yields of amaranth. This suggests that appling mineral elements may be insufficient to achieve optimal productivity of amaranth. However, the different types and doses of organic fertilizers significantly influenced biomass production compared to mineral fertilizers. Among the organic fertilizers, LOFPM and PM produced significantly higher yields compared to LOFCD and LOFSR. These results could be explained by the improvement of soil conditions thanks to their high nitrogen content, thus promoting optimal yield. The supply of organic amendments contributes to a favorable evolution of soil conditions for the benefit of good root development and good assimilation of released nutrients (Kaho *et al.,* 2011; Kasongo *et al.,* 2013). Ognalaga *et al.* (2015) in Gabon showed during their work on the restoration of soil fertility under amaranth cultivation that the use of organic fertilizers improves crop yields by improving the structure and chemical composition of the soil. Dose 3 (15 t/ha), which yielded the best productivity compared to doses of 10 t/ha and 5 t/ha, may be due to the fact that the nitrogen decomposition in the latter two doses was insufficient for optimal production, particularly during the amaranth production period of 28 days. This could influence nitrogen mineralization. We can also note the increased attack of amaranth leaves by butterfly caterpillars in the plots treated with the 10 t/ha dose, which could have an impact on biomass. Although the different doses of LOFPM did not show significant differences for amaranth yield, it was noted that the lowest dose of 0.075 L yielded a higher value compared to the higher dose of 0.1 L. This could be due to the fact that, being less diluted, the high nitrogen content was toxic to the plant. Similar findings were reported by Gbessemehlan *et al.* (2022) who observed a decline in amaranth yield in Bnenin when composted poultry manure was applied at 40t/ha compared to

30t/ha. Ognalaga and Itsoma (2014) also found a reduction in the growth of Hibiscus sabdariffa plants treated with *Leucaena leucocephala* L. rich in nitrogen compared to plants treated with *Chromolaena odorata* L. less rich in nitrogen. Atta *et al.* (2010) found that applying of 100 kg/ha of nitrogen resulted in a decrease in seed yield and the harvest index of calices in Roselle cultivation. Similarly, Hoque *et al.* (2004) and Ikeh *et al.* (2012) reported that while nitrogen and phosphorus are essential for plant growth,excessive doses can lead to yield decline across various crops.

CONCLUSION

The objective of this study was to compare the fertilizing potential of poultry manure, liquid organic fertilizers LOFPM, LOFCD, and LOFSR, mineral NPK fertilizers, and urea on agromorphological performance. The results show that poultry manure and LOFPM are more effective in increasing the diameter, height, and number of leaves, as well as the fresh and dry biomass production of amaranth, particularly with application rates of 15 t/ha and 0.075 liters diluted in 1.5 liters of water, respectively. This study provides information on the sustainable management of amaranth cultivation, specifically on the types of fertilizers best suited for optimal production. It contributes to optimizing inputs to maximize yield potential and quality. It can guide breeding programs to make amaranth production more profitable by targeting nutritional needs and responses to fertilization. However, it is necessary to replicate the study over time and at different sites in order to obtain the essential information to adapt the crop to various conditions and thus optimize its production and profitability.

ACKNOWLEDGMENTS

We thank all the actors who contributed to the realization of this manuscript, especially the NGO Nitidae which financially and materially enabled the completion of the study.

REFERENCES

Achigan-Dako EG, Sogbohossou OED, Maundu P. 2014. Current knowledge on *Amaranthus* spp.: research avenues for improved nutritional value and yield in leafy amaranths in sub-Saharan Africa. Euphytica **197**, 303–317. https://doi.org/10.1007/s10681-014-1081-9

Atta S, Sarr B, Bakasso Y, Diallo AB, Lona I, Saadou M, Glew RH. 2010. Roselle (*Hibiscus sabdariffa* L.) yield and yield components in response to nitrogen fertilization in Niger. Indian Journal of Agricultural Research **44**, 96–103.

Berger A, Monnard I, Dionisi F, Gumy D, Hayes KC, Lambelet P. 2003. Cholesterol-lowering properties of amaranth flakes, crude and refined oils in hamsters. Food Chemistry **81**, 119–124. https://doi.org/10.1016/S0308-8146(02)00387-4

de Bruin S, Dengerink J, van Vliet J. 2021. Urbanisation as driver of food system transformation and opportunities for rural livelihoods. Food Security **13**, 781–798. https://doi.org/10.1007/s12571-021-01182-8

Fletcher A, Kubik W. 2016. Women in agriculture worldwide: key issues and practical approaches. Routledge.

Gbessemehlan AMR, Zoundji MCC, Babatounde N, Gangnon SAO, Akplo MT, Kouelo FA, Houngnandan P. 2022. Etude comparative de l'efficacité de deux types de composts organiques sur la performance agroéconomique de l'amarante (*Amaranthus cruentus* L) dans les jardins familiaux au Bénin. International Journal of Biological and Chemical Sciences **16**, 1122–1136. https://doi.org/10.4314/ijbcs.v16i3.18

Grubben GJH. 1975. La culture de l'amarante, légume-feuilles tropical: avec référence spéciale au sud-Dahomey. Wageningen University and Research.

Hama-Ba F, Parkoud C, Tenkouano A, Diawara B. 2017. Disponibilité, modes et fréquence de consommation des légumes traditionnels africains dans quatre localités du Burkina Faso. African Journal of Food, Agriculture, Nutrition and Development **17**, 11552–11570. https://doi.org/10.18697/ajfand.77.15960

Hoque R, Hossain MK, Mohiuddin M, Hoque MM. 2004. Effect of inorganic fertilizers on the initial growth performance of *Anthocephalus chinensis* seedlings in the nursery. Journal of Applied Sciences **4**, 477–485. https://doi.org/10.3923/jas.2004.477.485

Ikeh AO, Ndaeyo NU, Uduak IG, Iwo GA, Ugbe LA, Udoh EI, Effiong GS. 2012. Growth and yield responses of pepper (*Capsicum frutescens* L.) to varied poultry manure rates in Nigeria. ARPN Journal of Agricultural and Biological Science **7**, 735–742.

Jamnadass R, Mumm RH, Hale I, Hendre P, Muchugi A, Dawson IK, Powell W, Graudal L, Yana-Shapiro H, Simons AJ. 2020. Enhancing African orphan crops with genomics. Nature Genetics **52**, 356–360. https://doi.org/10.1038/s41588-020-0601-x

Kaho F, Yemefack M, Feujio-Teguefouet P, Tchantchaouang JC. 2011. Effet combiné des feuilles de *Tithonia diversifolia* et des engrais inorganiques sur les rendements du maïs et les propriétés d'un sol ferralitique au centre Cameroun.

Kalombo DK, Mwenya IK, Tchowa JK. 2023. Étude comparative de l'efficacité et de la durabilité des fumures organiques versus engrais chimiques dans le maraîchage de la commune de Kasenga (Haut Katanga, RD Congo). Journal of Applied Biosciences **189**, 19973. https://doi.org/10.35759/JABs.189.7

Kasongo LME, Mwamba MT, Tshipoya MP, Mukalay MJ, Useni SY, Mazinga KM, Nyembo KL. 2013. Réponse de la culture de soja (*Glycine max* L.) à l'apport des biomasses vertes de Tithonia diversifolia comme fumure organique sur un Ferralsol à Lubumbashi. Journal of Applied Biosciences **63**, 4727–4735. https://doi.org/10.4314/jab.v63i1.87247

Koussihouèdé HKI, Assogba-Komlan F, Aholoukpè NSH, Amandji GL. 2016. Influence comparée de la litière de volaille et des déjections compostées sur la productivité de l'amarante au Sud-Bénin. Bulletin de la Recherche Agronomique du Bénin **80**, 14–23.

MAHRH. 2020. Aménagements hydro-agricoles et irrigations: enquête permanente agricole 2009–2018. Annuaire des statistiques agricoles.

Ognalaga M, Itsoma E. 2014. Effet de Chromolaena odorata et de Leucaena leucocephala sur la croissance et la production de l'oseille de Guinée. Agronomie Africaine **26**, 45–55.

Ognalaga M, M'Akoué DM, Mve SDM, Ondo P. 2017. Effet de la bouse de vaches, du NPK 15-15-15 et de l'urée sur la croissance et la production du manioc au Gabon. Journal of Animal & Plant Sciences **31**, 5063–5073.

Ognalaga M, Odjogui PIO, Azi AO. 2015. Restoration of soil fertility using organic and mineral amendments in Gabon. International Journal of Agronomy and Agricultural Research **7**, 163–172.

Ouédraogo J, Kiebre M, Kabore B, Sawadogo B, Kiebre Z, Bationo KP. 2021. Identification and agronomic performance of Amaranthus species grown in Burkina Faso. International Journal of Agricultural and Applied Sciences **7**, 102. https://doi.org/10.11648/j.ijaas.20210702.15

Son D, Somda I, Legreve A, Schiffers B. 2017. Pratiques phytosanitaires des producteurs de tomates du Burkina Faso et risques pour la santé et l'environnement. Cahiers Agricultures **26**, 25005. https://doi.org/10.1051/cagri/2017010

Soro LC, Atchibri ALOA, Kouassi KK, Christophe K. 2012. Evaluation de la composition nutritionnelle des légumes feuilles. Journal of Applied Biosciences **50**, 3567–3573.

Westphal E. 1985. Cultures vivrières tropicales avec référence spéciale au Cameroun.

Yanda SWL. 2022. Projet de réalisation de systèmes d'adduction d'eau potable simplifiés dans la province de Ziro.