Determination of the Performance, Proximate and Some Mineral Components of *Corchorus olitorius* L. Using Organic and Inorganic Materials as Nutrient Sources of Nitrogen Fertilizer

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Summary

Two field experiments were carried out during the 2020 and 2021 cropping seasons at the Landmark University Teaching and Research farms, Omu-Aran, Kwara State. The experiment comprised six levels each of poultry manure (PM) (0, 20, 40, 60, 80, and 100%) and urea fertilizer (0, 20, 40, 60, 80, and100%), applied at three different times (1, 2, and 3 weeks after sowing (WAS)). Results from this study showed that urea fertilizer and PM (sole or combined) increased the values for vegetative growth, yield, proximate and mineral contents (K, Ca, Mg and P) relative to the control. The two years results also showed that sole application of PM at 100% increased growth parameters, and mineral contents (Ca, K, Mg and P) relative to the sole application of 100% urea fertilizer at 1, 2 or 3 WAS. Inorganic fertilizer at all weeks of application increased the carbohydrate, ash and moisture content compared with PM. Applied 60% PM + 40% urea fertilizer at 1 WAS produced the best growth and yield parameters. In a similar vein, 40% poultry manure and 60% urea fertilizer applied at 2 WAS had the best values of proximate and mineral contents. Therefore, for those that desire to cultivate *C. olitorius* for its edible leaves, application of 60% PM + 40% urea fertilizer applied at 1 WAS is recommended. However, for those that want the quality of the *C. olitorius* leaves, 40% PM and 60% urea ferti-lizer applied at 2 WAS is recommended.

Key words

Corchorus olitorius L., performance, quality, organic and inorganic amendments

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Introduction

Jute (*Corchorus olitorius* L.), also known as Jute Mallow, Bush okro, Jew's Mallow, is a popular leafy vegetable that belongs to the family of Malvaceae. It is an erect annual herb that usually varies from 60 cm to almost 150 cm in height depending on the variety. The flowers are brightly yellow in small forms but come in clusters on the leaf's axils, forming a fruit inside. Jute is often cultivated in the tropics and warm temperate areas both for the leaves and the fiber in its stem. It is a plant that is widely distributed in subtropical and tropical regions of the world. It is a culinary and medicinal herb largely used as a vegetable in Asia and Africa. Egypt, Sudan, India, Bangladesh, the Philippines, Malaysia and Japan are among the nations that consume the leaves.

It is a leafy vegetable with high nutritional qualities and contains essential nutrients such as protein, calcium, phosphorus, iron, copper and other significant components such as vitamins A, B complex, C, fiber, carbohydrate, fat and has a high calorific value (Schippers, 2000). It has been reported (Grubben and Denton, 2004; Harborne et al., 1999) that the dry leaves of *C. olitorus* contain averagely about 4.8 g of protein, 4.5 mg of iron, 4.7 mg of vitamin A, 15% dry matter, 259 mg of Ca, 92 mg of folates; per 100 gg of the leaves it contains 105 mg of ascorbic acid and 1.5 mg of nicotinamide.

Chemical fertilizer has been shown to enhance crop performance positively, (Agbede et al., 2019) but its usage in Nigeria is restricted due to high costs and unavailability when it is needed. Also, organic manure such as poultry manure (PM), has been proven to be beneficial in improving crop yield. When compared to chemical fertilizers, PM is inexpensive, widely available at most times, environmentally friendly, with a long-lasting impact on a high potential of improving soil structure. The enormous amounts needed for large-scale crop production, however, restrict PM utilization (Adekiya et al., 2019). So, to prevent these problems there is a strong advocacy for combining inorganic with organic fertilizers (Uwah and Iwo 2011). Organic manure and urea as nitrogen sources have been shown to have a beneficial interaction. (McRoberts 2015). According to the study of Mani et al. (2016), employing locally accessible organic nutrient sources can improve efficiency and minimize the amount of chemical fertilizer needed.

For nutrient optimization using an integrated approach in *C. olitorius* production, PM is generally applied to the soil minimum two weeks before sowing (Uwah and Iwo 2011) in order to allow for its decomposition. Urea can be applied to *C. olitorius* at various phases of development. Delaying or applying urea to *C. olitorius* plants too early or at later stages of develpoment may have a negative impact on crop growth, yield, and quality. Therefore, to increase the effective and efficient utilization of nitrogen fertilizer by *C. olitorius*, it is essential to determine the best application period during the integrated nutrient management of *C. olitorius* using urea fertilizer and PM. This study was conducted to investigate the effects of sole and combined application of different rates of PM and urea fertilizer and time of applications of urea fertilizer on growth, yield and quality of *C. olitorius*.

Materials and Methods

Description of Experimental Site

Two field experiments were conducted in the year 2020 and 2021 cropping seasons at the Teaching and Research Farms of Landmark University Omu-Aran, Kwara state which has a latitude 8'8°N and longitude 5'6°E located in the derived savannah region of Nigeria. The experimental site has a bimodal annual rainfall pattern that extends between the months of April and November with an average of 1200 mm of rainfall, having its peak rain in June and October. The mean annual temperature is about 32 °C. The dry season commences in December and ends in March.

Treatment, Treatment Combinations and Experimental Design

The experiment comprised poultry manure (PM) and urea fertilizer each applied at six levels (0, 20, 40, 60, 80, and 100%) and three different times of urea fertilizer application (1, 2, and 3 weeks after sowing). The treatment combinations were as follows :- control (T_1), 100% of PM (T_2), 80% of PM + 20% urea fertilizer applied at 1 WAS (T_3), 80% of PM + 20 urea fertilizer applied at 2 WAS (T_4), 80% of PM + 20 urea fertilizer applied at 3 WAS (T_5), 60% of PM + 40% urea fertilizer applied at 1 WAS (T_6), 60% of PM + 40% urea fertilizer applied at 2 WAS (T_7), 60% of PM + 40% urea fertilizer applied at 3 WAS (T_8), 40% of PM +60% urea fertilizer applied at 1 WAS (T_9), 40% of PM +60% urea fertilizer applied at 2 WAS (T_{10}), 40% of PM + 60% urea fertilizer applied at 3 WAS (T_{11}), 20% of PM + 80% urea fertilizer applied at 1 WAS (T_{12}), 20% of PM + 80% urea fertilizer applied at 2 WAS (T_{13}), 20% of PM + 80% urea fertilizer applied at 3 WAS (T_{14}), 0 % of PM +100% urea fertilizer applied at 1 WAS (T_{15}), 0 % of PM +100% urea fertilizer applied 2 WAS (T_{16}), 0 % of PM +100% urea fertilizer applied at 3 WAS (T_{17}).

Organic manure (PM) and urea fertilizer were applied at the rate of 120 kg N ha^{-1}. The equivalents of applied PM rates to 0, 20, 40, 60, 80, and 100% were 0, 0.34, 0.68, 1.02, 1.36, and 1.71 kg while that of urea to 0, 20, 40, 60, 80, and 100% were 0, 20, 40, 60, 80, and 100 g N. The experiment was laid out in a randomized complete block design and replicated three times.

Plot Size

There were 17 plots per replicate. The land was marked out to plots of 2 m × 2 m. An alleyway of 1 m was left between each replicate and 0.5 m between plots. The gross and net plot sizes were 280.5 m^2 and 204 m^2, respectively.

Seed Variety

The seed variety used for the experiment was one of the local varieties called "Oniyaya". The leaves are shining with deep green colouration, deeply serrated, have good draw properties and are suitable for uprooting and cutting.

Cultural Practices

Preparation of land: This was done mechanically; ploughing was done once while harrowing was done twice to give a fine tilt after which a field layout was carried out to mark the number of treatment plots.

Application of amendment: The PM was incorporated per plot based on treatment using hoe at a depth of about 5 cm and allowed to mineralize for two weeks before sowing while urea fertilizer was applied based on treatment at three different times (1, 2 and 3 WAS) using band method of application.

Sowing: The seeds were soaked in cold water for 24 hours and drained before sowing and were sown manually by drilling. Dry soil was mixed with the seeds before drilling to make sure that seeds were not compacted together; between the rows, the seeds were sown 10 cm apart. Seedling was thinned to one (1) plant/stand at a distance of 10 cm between the plants after 7 days of sowing.

Weed control: Pre-emergence herbicide (Metolachlor) suitable for all types of weed was applied using a knapsack sprayer at the rate of 1.5 kg a.i ha^{-1} immediately after sowing the seed while manual weeding was performed 4 weeks after seed emergence.

Observation and data collection: Data were collected on the following parameters: - plant height (cm), number of leaves, stem diameter (cm), number of branches, total biomass (g), marketable weight (g), edible yield, proximate analysis and mineral composition.

Laboratory Analysis

Initial Soil Sampling and Sample Test

Soil samples were collected randomly from the experimental area before land preparation using a soil auger at 0 – 15 cm depth and bulked together to form a composite sample. The composite soil sample was taken to the University Crop and Soil Science Laboratory for routine analysis. Similarly, poultry manure was collected from the Teaching and Research Farm of Landmark University, Omu-Aran and taken to the laboratory for analysis of their nutritional composition.

Proximate Analysis of *C. olitorius* Leaves

Proximate analysis of leaves of *C. olitorius* was carried out at Landmark University Soil and Crop Science Laboratory. The dried samples of leaves were grounded and analyses were carried out for ash content, crude fat, crude fibre, crude protein and moisture content with the use of standard chemical methods as suggested by the Association of Analytical Chemists (AOAC, 2006).

Determination of Mineral Elements in *C. olitorius* Leaves

Representative samples of fresh *C. olitorius* leaves were collected from each replicate plot for analysis of the concentrations of mineral elements in them; the analysis was undertaken at the Crop and Soil laboratory of Landmark University, Omu-Aran, Nigeria. Samples collected were oven-dried for 24h at 80 °C, and grounded in a Willey mill. Mineral elements were determined according to the methods recommended by the Association of Official Analytical Chemists (AOAC 2003). 1 g of each sample was digested using 12 cm^{-3} of the mix of HNO_3, H_2SO_4, and HClO4 (7:2:1 v/v/v). Concentrations of Ca, Mg, P and K were determined by an atomic absorption spectrophotometer. The Kjeldahl digestion and distillation method as described by Partey (2014) was used to determine the nitrogen content of the leaves.

Determination of the Yield Parameters (whole, marketable and edible yield) of *C. olitorius*

Representative samples of the harvested plants were taken immediately after harvest to determine the whole, marketable and edible yield of *C. olitorius*. The whole yield includes the aerial parts and the roots (total biomass). The marketable yield was determined after separating the aerial part of the plant from the root while the edible yield was determined by separating the leaves from the stem of the representative plant per plot. Each of these parameters was determined by weighing the representative samples using OHAUS Corporation, USA precision balance, having a capacity of 2100 g and readable at 0.01 g (Aboyeji et al., 2021) and the values were recorded.

Results

Soil Physical and Chemical Properties of the Experimental Sites prior to Planting and

Analysis of Poultry Manure Used for the Study

The results of the soil physical and chemical properties of experimental sites prior to planting and analysis of poultry manure that was used in the study are presented in Tables 1 and 2 respectively. The soil was mainly sandy loam, containing 16.5% of silt in both years, clay 15.4 % and 15.3% in 2020 and 2021 respectively, and slightly acidic with a pH of 5.72 in both years. The two years experimental soils were low in OC, N, P, K and Mg but moderate in calcium (Ca) according to the critical value of 3.0% OM, 0.20% N, 10.0 mg kg^{-1} available P, 0.16–0.20 cmol kg^{-1} exchangeable K, 2.0 cmol kg^{-1} exchangeable Ca and 0.40 cmol kg^{-1} exchangeable Mg recommended for crop production in ecological zones of Nigeria (Akinrinde and Obigbesan, 2000).

Table 1. Soil properties prior to experimentation

Property	2020	2021
Sand (%)	68.1	68.2
Silt (%)	16.5	16.5
Clay (%)	15.4	15.3
Total N (%)	0.14	0.14
Organic matter (%)	1.92	1.92
Exchangeable Ca (cmol kg^{-1})	2.41	2.39
Exchangeable Mg ($cmolkg^{-1}$)	0.36	0.33
Exchangeable K ($cmolkg^{-1}$)	0.15	0.33
Available P($mg{\cdot}kg^{-1}$)	9.15	9.12

Table 2. Analysis of poultry manure used for the study

Parameters	Mg (%)	O. C (%)	Mg (%)	K (%)	P (%)	N (%)	pH (H_2O)	C:N
Values	0.57	21.5	0.57	1.80	1.35	2.91	6.80	7.38

It has been found that poultry manure is high in major nutrients required for the growth of vegetables such as *C. olitorius*. The poultry manure's macro and micronutrient contents are expected to enhance the soil fertility, improve the soil structure and improve the performance of *C. olitorius*.

Effects of the Application of Organic and Inorganic Fertilizers on the Plant Height of *C. olitorius*

Table 3 shows the effects of organic and inorganic fertilizers on plant height in the 2020 and 2021 cropping seasons. It was observed that the plant height increased significantly (P = 0.05) with the application of amendments in both years. Poultry manure alone at 100% increased plant height when compared with the application of urea fertilizer alone (100%) either at 1, 2 or 3 WAS. The application of poultry manure at 60% and urea at 40% at 1 WAS increased the plant height relative to other applications either poultry manure alone, urea alone or combined. The application of urea fertilizer at 1 WAS increased the plant height relative to weeks 2 and 3 applications. The order of decrease in plant height was week 1 > week 2 > week 3.

Effects of the Application of Organic and Inorganic Fertilizers on the Stem Diameter (cm) of *C. olitorius*

The effects of organic and inorganic fertilizers application on the stem diameter of *C. olitorius* are as shown in Table 4. All amended treatments (except 0% PM and 100% urea fertilizer applied at 2nd and 3rd weeks after sowing (WAS) increased the stem diameter significantly (P < 0.05) relative to the control. Application of poultry manure at 60% and urea at 40% at week 1 seems to produce the widest stem diameter across the two sites. Application of urea fertilizer at 1 week after sowing *C. olitorius* seeds increased the stem diameter relative to week 2 and 3 applications. Also, the order of decrease in the stem diameter was week 1 > week 2 > week 3. Also, there was a progressive increase in the stem diameter across weeks 4, 5, and 6.

Table 3. Effects of the application of organic and inorganic fertilizers on the plant height (cm) of *C. olitorius* during the 2020 and 2021 cropping seasons

PM (%)	Urea fertilizer (%) per time application (week)	WEEK 4		WEEK 5		WEEK 6	
		2020	2021	2020	2021	2020	2021
Control		8.03^{h}	6.67^{h}	9.84^{g}	8.00^{g}	11.78^{j}	9.33^{hi}
100	0	32.00^{de}	33.19^{a}	33.67^{de}	34.77^{a}	35.22^{de}	36.22^{a}
80	20 @ 1	38.67^{bc}	30.78^{ab}	40.33^{bc}	32.33^{ab}	42.22^{bc}	34.11^{ab}
	20 @ 2	32.86^{de}	22.99^{d}	34.22^{de}	24.56^{c}	35.89^{de}	26.34^{d}
	20 @ 3	30.77^{bc}	16.22^{de}	32.56^{de}	17.78^{d}	34.22^{de}	19.33^{e}
60	40 @ 1	49.55^{a}	27.89^{bc}	51.00^{a}	29.22^{bc}	52.78^{a}	30.89^{bc}
	40 @ 2	44.55^{ab}	22.45^{d}	45.99^{ab}	24.00^{c}	47.56^{ab}	25.57^{d}
	40 @ 3	33.86^{cde}	10.11^{f}	35.89^{cd}	19.56^{d}	37.67^{d}	20.67^{e}
40	60 @ 1	35.55^{cd}	28.45^{bc}	37.11^{bc}	30.11^{bc}	38.78^{d}	31.56^{bc}
	60 @ 2	32.22^{de}	28.22^{bc}	32.34^{de}	29.89^{bc}	35.34^{de}	31.44^{bc}
	60 @ 3	30.55^{ef}	13.89^{e}	28.67^{ef}	15.11^{de}	33.78^{ef}	16.22^{f}
20	80 @ 1	30.11^{ef}	8.11^{g}	31.67^{de}	10.11^{ef}	33.33^{ef}	11.11^{gh}
	80 @ 2	24.44^{f}	$18.11d^{e}$	29.33^{efg}	19.78^{d}	28.22^{fg}	21.33^{e}
	80 @ 3	20.66^{fg}	12.22^{e}	21.78^{ef}	13.00^{de}	22.78^{h}	14.00^{fg}
0	100 @ 1	19.33^{fg}	8.33^{g}	21.33^{ef}	9.33^{ef}	23.11^{h}	10.22^{gh}
	100 @ 2	17.11^{fg}	5.67^{h}	18.78^{fg}	7.00^{fg}	18.55^{i}	7.89^{ij}
	100 @ 3	10.00^{g}	4.00^{h}	12.00^{g}	5.22^{h}	14.00^{ij}	4.89j

Note: Values followed by similar letters under the same column are not significantly different at P < 0.05 according to Duncan's multiple range test

Table 4. Effects of the application of organic and inorganic fertilizers on the stem diameter (cm) of *C. olitorius* during the 2020 and 2021 cropping seasons

PM (%)	Urea fertilizer (%) per time application (week)	WEEK 4		WEEK 5		WEEK 6	
		2020	2021	2020	2021	2020	2021
Control		3.95^{d}	2.00^{ef}	6.33^{ab}	2.70^{ef}	5.19^{ef}	2.86^{de}
100	0	5.30^{bc}	6.30^{a}	5.32^{bc}	6.68^{a}	9.48^{bc}	6.88^{a}
80	20 @ 1	6.38^{ab}	6.04^{ab}	6.15^{ab}	6.06^{ab}	13.88^{a}	6.26^{ab}
	20 @ 2	6.34^{ab}	6.01^{ab}	6.43^{ab}	6.12^{ab}	10.97^{ab}	6.25^{ab}
	20 @ 3	6.39^{ab}	4.43^{cd}	6.96^{ab}	4.82^{cd}	10.58^{ab}	5.63^{bc}
60	40 @ 1	7.14^{a}	6.00^{ab}	7.37^{a}	6.13^{ab}	11.20^{ab}	6.38^{ab}
	40 @ 2	6.35^{ab}	4.80^{cd}	6.29^{ab}	4.98^{cd}	13.90^{a}	5.04^{bc}
	40 @ 3	5.81^{bc}	2.20^{ab}	6.08^{ab}	2.37^{ef}	10.83^{ab}	4.39^{bc}
40	60 @ 1	6.40^{ab}	5.63^{bc}	6.69^{ab}	5.78^{bc}	10.17^{ab}	6.08^{ab}
	60 @ 2	5.33^{bc}	5.56^{bc}	5.44^{bc}	5.78^{bc}	10.68^{ab}	5.97^{bc}
	60 @ 3	6.38^{ab}	3.65^{d}	6.56^{ab}	3.70^{de}	10.94^{ab}	3.82^{cd}
20	80 @ 1	6.33^{ab}	3.46^{d}	5.48^{bc}	3.58^{de}	10.24^{ab}	3.90^{cd}
	80 @ 2	5.93^{ab}	2.87^{e}	6.33^{ab}	2.91^{ef}	7.44^{de}	3.80^{cd}
	80 @ 3	3.86^{d}	2.58^{e}	4.04^{cd}	2.63^{abc}	4.39^{a}	2.56^{de}
0	100 @ 1	5.59^{bc}	5.10^{bc}	6.10^{ab}	5.69^{bc}	8.01^{cd}	5.76^{bc}
	100 @ 2	4.06^{cd}	2.12^{e}	5.66^{bc}	2.46^{ef}	4.78^{f}	3.40^{cd}
	100 @ 3	3.42^{d}	1.54^{f}	4.56^{cd}	2.18^{f}	5.79^{ef}	2.31^{de}

Note: Values followed by similar letters under the same column are not significantly different at $P < 0.05$ according to Duncan's multiple range test

Effects of the Application of Organic and Inorganic Fertilizer on the Number of Leaves of *C. olitorius*

The results of the effects of organic and inorganic fertilizers on the number of leaves are presented in Table 5. Amended treatments increased *C. olitorius* number of leaves significantly when compared with the control (except for urea fertilizer alone applied at 2 and 3 WAS). Among all treatments, 60% PM and 40% urea fertilizer applied at 1 WAS increased the number of leaves in 2020, whereas it was 100% PM that increased the number of leaves in 2021. Also, the week of application of urea fertilizer increased the number of leaves with week 1 having significantly higher values compared with weeks 2 and 3.

Effects of the Application of Organic and Inorganic Fertilizers on the Number of Branches of *C. olitorius*

The results of the effects of organic and inorganic fertilizers on the number of branches in 2020 and 2021 are shown in Table 6. There was a significant difference between all treatments and the control except for urea fertilizer alone applied at 1, 2 and 3 WAS. Poultry manure at 60% and 40% urea applied at 1 WAS produced the highest number of branches. The early use of urea fertilizer (1 WAS) significantly increased the number of branches relative to 2 and 3 WAS. The number of branches increased progressively across the weeks.

Effects of the Application of Organic and Inorganic Fertilizers on the Yield Parameters of *C. olitorius*

Results of the effects of organic and inorganic fertilizer on the whole, marketable and edible yield of *C. olitorius* are respectively presented in Fig. 1, 2, and 3. This shows a significant difference between the treatments and the control in both years for edible yield (Fig. 3). Also, there were no significant differences in all yield parameters between PM alone and urea fertilizer alone applied at either 1, 2 or 3 WAS. However, applications of urea fertilizer at 1 WAS seem to increase yield parameters (whole, marketable, edible) higher than those of weeks 2 and 3, though the values are not significantly different (Fig. 4, 5 and 6). The application of 80% PM + 20% urea fertilizer at 1 WAS produced significantly higher values for the whole yield, marketable yield and edible yield, although these values were not significantly different from those produced by 80% PM + 20% urea applied at 2 WAS and 60%PM

Table 5. Effects of organic and inorganic fertilizers on the number of leaves of *C. olitorius* during the 2020 and 2021 cropping seasons

PM (%)	Urea fertilizer (%) per time application (week)	WEEK 4		WEEK 5		WEEK 6	
		2020	2021	2020	2021	2020	2021
Control		33.67^{de}	10.43^{ef}	35.89^{fg}	20.00^{g}	37.78^{e}	21.33^{i}
100	0	63.89^{cd}	45.06^{a}	54.22^{de}	84.22^{a}	63.89^{bc}	85.89^{a}
80	20 @ 1	63.55^{cd}	34.23^{b}	65.33^{cd}	67.66^{b}	66.78^{b}	69.33^{b}
	20 @ 2	58.78^{de}	28.87^{bc}	60.44^{cd}	53.86^{c}	61.89^{bc}	55.56^{cd}
	20 @ 3	55.89^{de}	13.87^{e}	58.78^{de}	39.56^{e}	60.67^{bc}	41.22^{e}
60	40 @ 1	89.11^{a}	31.49^{bc}	91.11^{a}	69.22^{b}	92.56^{a}	70.78^{b}
	40 @ 2	61.89^{cd}	30.26^{bc}	63.56^{cd}	48.45^{d}	67.11^{bc}	50.11^{d}
	40 @ 3	54.33^{ef}	25.44^{c}	56.11^{de}	48.67^{d}	57.56^{cd}	49.78^{d}
40	60 @ 1	60.56^{cd}	35.34^{b}	63.44^{cd}	67.66^{b}	65.00^{b}	69.00^{b}
	60 @ 2	51.11^{fg}	33.16^{b}	53.11^{de}	56.76^{c}	54.67^{cd}	58.33^{cd}
	60 @ 3	49.22^{fg}	16.91^{d}	51.11^{de}	34.00^{ef}	52.89^{cd}	35.22^{f}
20	80 @ 1	79.45^{ab}	27.00^{bc}	81.11^{ab}	33.44^{ef}	82.65^{ab}	35.11^{f}
	80 @ 2	68.89^{bc}	11.33^{ef}	71.00^{bc}	30.33^{f}	72.33^{ab}	31.45^{fg}
	80 @ 3	36.67^{h}	3.92^{h}	38.00^{f}	18.44^{h}	39.00^{e}	19.67^{i}
0	100 @ 1	52.22^{fg}	9.88^{fg}	54.11^{de}	13.67^{j}	55.89^{cd}	14.89^{j}
	100 @ 2	30.11^{de}	9.21^{fg}	32.00^{fg}	16.78^{h}	33.56^{e}	18.00^{i}
	100 @ 3	21.67^{e}	7.22^{g}	23.67^{g}	14.44^{ij}	25.56^{f}	15.67^{j}

Note: Values followed by similar letters under the same column are not significantly different at $P < 0.05$ according to Duncan's multiple range test

+ 40% urea applied at 1 WAS. In all yield parameters (whole yield, marketable yield and edible yield), the application of urea at 1 WAS had a non-significant higher value when compared with 2, and 3 WAS.

Proximate Composition of *C. olitorius* Leaves as Affected by the Application of Organic and Inorganic Fertilizers

Table 7 shows the results of the effects of organic and inorganic fertilizers on the proximate composition of *C. olitorius* leaves. The application of organic and inorganic fertilizers increased the moisture, ash and protein contents of the leaves relative to the control. The crude fiber and carbohydrate compositions were reduced relative to the control. There was no consistent pattern in the case of crude fat between all treatments and the control. Inorganic fertilizer (applied either at 1, 2 or 3 WAS) increased the carbohydrate, ash and moisture contents of the leaves when compared with PM. Also, urea fertilizer reduced the protein, fibre and fat contents of the leaves compared with organic manure (PM) alone. There is no significant difference between the times of application of urea fertilizer. Among all treatments, 40% poultry manure and 60% urea fertilizer applied at 2 WAS consistently produced the highest values of moisture content, crude protein and total ash content with reduced fat content in both years.

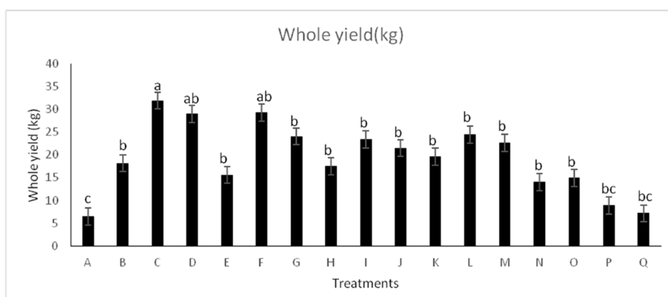

Figure 1. Effects of the application of organic and inorganic fertilizers on the whole yield of *C. olitorius* during the 2020 and 2021 cropping seasons

Note: A = control; B= 100% poultry manure (PM); C = 80% PM +20% urea applied @ 1 week after planting (WAP); D = 80% PM + 20% urea applied @ 2 WAP; E = 80% PM + 20% urea ap-plied @ 3 WAP; F = 60% PM + 40% urea applied @ 1 WAP; G = 60% PM + 40% urea applied @ 2 WAP; H = 60% PM + 40% urea applied @ 3 WAP; I = 40% PM +60% urea applied @ 1 WAP; J = 40% PM + 60% urea applied @ 2 WAP;K = 40% PM + 60% urea applied @ 3 WAP; L = 20% PM + 80% urea applied @ 1 WAP; M = 20% PM + 80% urea applied @ 2 WAP; N = 20% PM + 80% urea applied @ 3 WAP; O = 0%PM + 100% urea applied @ 1 WAP; P = 0%PM + 100% urea applied @ 1 WAP; Q = 0%PM + 100% urea applied @ 1 WAP. The vertical bars show the standard errors of paired comparisons; bars marked with different letters show means significantly different at 5% level according to Duncan's multiple range test (DMRT).

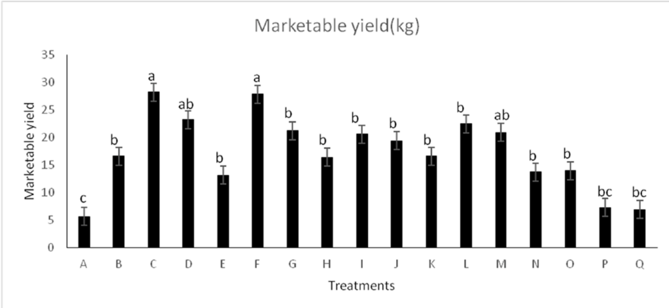

Figure 2. Effects of the application of organic and inorganic fertilizers on the marketable yield of *C. olitorius* during the 2020 and 2021 cropping seasons

Note: A = control; B= 100% poultry manure (PM); C= 80% PM +20% urea applied @ 1 week after planting (WAP); D = 80% PM + 20% urea applied @ 2 WAP; E = 80% PM + 20% urea applied @ 3 WAP; F = 60% PM + 40% urea applied @ 1 WAP; G = 60% PM + 40% urea applied @ 2 WAP; H = 60% PM + 40% urea applied @ 3 WAP; I = 40% PM +60% urea applied @ 1 WAP; J = 40% PM + 60% urea applied @ 2 WAP; K = 40% PM + 60% urea applied @ 3 WAP; L = 20% PM + 80% urea applied @ 1 WAP; M = 20% PM + 80% urea applied @ 2 WAP; N = 20% PM + 80% urea applied @ 3 WAP; O = 0%PM + 100% urea applied @ 1 WAP; P = 0%PM + 100% urea applied @ 1 WAP; Q = 0%PM + 100% urea applied @ 1 WAP.

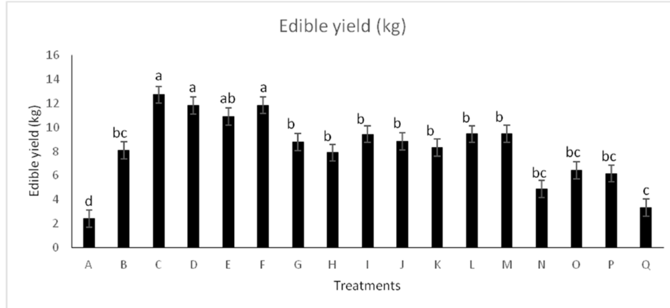

Figure 3. Effects of the application of organic and inorganic fertilizer on the edible yield of *C. olitorius* during the 2020 and 2021 cropping seasons

Note: A = control; B = 100% poultry manure (PM); C = 80% PM +20% urea applied @ 1 week after planting (WAP); D = 80% PM + 20% urea applied @ 2 WAP; E = 80% PM + 20% urea ap-plied @ 3 WAP; F = 60% PM + 40% urea applied @ 1 WAP; G = 60% PM + 40% urea applied @ 2 WAP; H = 60% PM + 40% urea applied @ 3 WAP; I = 40% PM +60% urea applied @ 1 WAP; J = 40% PM + 60% urea applied @ 2 WAP; K = 40% PM + 60% urea applied @ 3 WAP; L = 20% PM + 80% urea applied @ 1 WAP; M = 20% PM + 80% urea applied @ 2 WAP; N = 20% PM + 80% urea applied @ 3 WAP; O =0%PM + 100% urea applied @ 1 WAP; P = 0%PM + 100% urea applied @ 1 WAP; Q = 0%PM + 100% urea applied @ 1 WAP. The vertical bars here show standard errors of comparisons which was paired; bars using highlighted with differ-ent letters show that the means are significantly different at 5% level according to Duncan's mul-tiple range test (DMRT).

Table 6. Effects of the application of organic and inorganic fertilizers on number of branches of *C. olitorius* during the 2020 and 2021 cropping seasons

PM (%)	Urea fertilizer (%) per time application (week)	WEEK 4		WEEK 5		WEEK 6	
		2020	2021	2020	2021	2020	2021
Control		6.22^{de}	4.11^{fg}	9.11^{cd}	5.44^{de}	9.67^{c}	6.78^{cd}
100	0	12.67^{cd}	9.89^{bc}	14.22^{bc}	15.33^{ab}	15.45^{ab}	16.89^{ab}
80	20 @ 1	14.56^{ab}	10.44^{ab}	16.44^{ab}	13.55^{cd}	16.67^{ab}	16.34^{bc}
	20 @ 2	11.67^{de}	8.45^{cd}	13.78^{bc}	14.89^{bc}	15.00^{abc}	15.00^{cd}
	20 @ 3	10.89^{de}	7.33^{de}	12.22^{cd}	11.89^{de}	13.67^{abc}	13.22^{bc}
60	40 @ 1	15.11^{a}	11.63^{a}	17.42^{a}	16.55^{a}	18.44^{a}	17.83^{a}
	40 @ 2	14.78^{ab}	6.44^{ef}	16.56^{ab}	10.22^{de}	18.22^{a}	12.00^{cd}
	40 @ 3	13.11^{bc}	3.44^{gh}	14.89^{bc}	8.00^{de}	16.56^{ab}	9.33^{cd}
40	60 @ 1	13.67^{bc}	9.89^{bc}	17.00^{a}	14.23^{cd}	16.78^{ab}	15.67^{bc}
	60 @ 2	12.66^{cd}	9.00^{bc}	15.22^{bc}	13.47^{cd}	16.67^{ab}	15.00^{bc}
	60 @ 3	11.33^{de}	7.67^{de}	13.00^{cd}	8.67^{de}	14.22^{bc}	5.33^{cd}
20	80 @ 1	13.11^{bc}	6.33^{ef}	15.00^{bc}	7.78^{de}	16.34^{ab}	8.89^{cd}
	80 @ 2	12.16^{cd}	4.89^{fg}	14.33^{bc}	7.34^{de}	16.00^{ab}	8.78^{cd}
	80 @ 3	7.78^{cde}	2.67^{hi}	9.11^{cd}	6.22^{de}	10.11^{bc}	7.33^{cd}
0	100 @ 1	9.78^{de}	5.11^{fg}	11.55^{cd}	6.22^{de}	13.11^{bc}	7.44^{cd}
	100 @ 2	8.22^{de}	4.00^{g}	10.11^{cd}	5.00^{de}	12.00^{bc}	6.00^{cd}
	100 @ 3	5.33^{e}	1.45^{i}	7.11^{d}	3.67e	8.45^{c}	4.78^{d}

Note: Values followed by similar letters under the same column are not significantly different at $P < 0.05$ according to Duncan's multiple range test

Table 7. Effects of organic and inorganic fertilizers on the proximate content of *C. olitorius* leaves in 2020 and 2021 cropping seasons

PM (%)	Urea fertilizer (%) per time application (week)	Moisture content (%)		Crude protein (%)		Total ash (%)		Crude fibre (%)		Crude fat (%)		Carbohydrate (%)	
		2020	2021	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021
Control		6.75	6.31	12.97	12.88	10.31	10.77	9.34	9.85	8.89	7.73	50.67	50.75
100	0	6.78	6.99	17.26	16.94	10.62	12.05	8.38	8.81	9.13	8.45	46.83	45.70
80	20 @ 1	6.75	7.03	17.05	16.75	10.75	11.93	8.95	9.33	9.09	8.78	47.41	46.14
	20 @ 2	6.81	7.13	16.97	16.67	11.03	10.98	7.27	7.33	9.12	9.03	48.80	48.86
	20 @ 3	7.02	7.08	16.89	16.72	11.25	11.45	8.08	8.07	8.95	8.44	47.84	48.24
60	40 @ 1	6.95	7.11	17.00	16.59	11.63	11.52	7.75	7.44	9.02	9.10	47.65	48.24
	40 @ 2	7.07	7.08	16.32	16.30	11.48	12.03	7.28	7.38	8.78	8.89	49.07	47.32
	40 @ 3	7.05	7.15	16.56	16.66	11.05	12.25	7.36	7.54	8.73	8.75	48.25	47.65
40	60 @ 1	7.12	7.18	16.74	16.05	11.60	12.12	7.25	7.37	8.70	8.76	48.59	47.52
	60 @ 2	7.39	7.52	17.33	17.45	11.85	12.26	7.24	7.39	8.65	8.34	48.84	48.64
	60 @ 3	6.84	7.95	17.03	15.89	11.06	11.55	7.17	7.47	9.06	8.48	48.84	49.68
20	80 @ 1	7.13	7.50	16.94	16.67	10.95	11.48	7.33	7.28	9.10	9.05	48.55	48.37
	80 @ 2	7.10	7.10	16.86	16.75	11.04	12.00	7.38	7.55	9.02	8.94	48.60	47.66
	80 @ 3	7.15	7.09	17.04	15.88	11.55	12.15	7.35	7.55	9.06	8.76	47.85	48.57
0	100 @ 1	7.17	7.12	16.65	15.97	11.48	11.67	7.38	7.49	8.89	8.65	48.43	49.15
	100 @ 2	7.20	6.95	16.70	16.79	11.65	11.68	7.36	7.55	8.17	8.07	48.92	49.00
	100 @ 3	7.18	7.03	16.75	16.86	11.67	12.18	7.27	7.63	8.78	8.33	48.35	47.97
	Median	**7.07**	**7.09**	**16.89**	**16.67**	**11.38**	**11.93**	**7.36**	**7.54**	**8.95**	**8.75**	**48.55**	**48.24**
	Mean	**7.19**	**7.09**	**16.66**	**16.34**	**11.30**	**11.87**	**8.42**	**8.62**	**8.89**	**8.62**	**48.44**	**48.20**
	SD±	**0.76**	**0.12**	**0.98**	**0.95**	**0.39**	**0.45**	**1.92**	**0.88**	**0.24**	**0.37**	**0.83**	**1.21**
	CV	**10.57**	**1.69**	**5.88**	**5.81**	**3.45**	**3.79**	**33.87**	**10.21**	**2.70**	**4.29**	**1.71**	**2.51**

The Mineral Composition of *C. olitorius* Leaves as Affected by the Application of Organic and Inorganic Fertilizers

Table 8 shows the results of how inorganic and organic fertilizers affected the mineral compositions of *C. olitorius* leaves. Amended treatments increased the K, Ca, Mg and P contents relative to the control. K and P contents were not increased by urea fertilizer alone applied at 1, 2 and 3. The values of K for amended soils in 2020 was not significantly different relative to the control. All amended soil increased N content relative to the control. Organic manure (PM) increased K, Ca, Mg and P contents when compared to the application of urea fertilizer alone applied at 1, 2 or 3 WAS. Organic manure (PM) increased N contents relative to the urea fertilizer alone applied at 1, 2 or 3 WAS in 2020. There were no significant differences in the mineral composition between organic and inorganic fertilizer in 2021. In all, 40% poultry manure and 60% urea fertilizer applied at 2 WAS had the best values of K, Ca, Mg N and P contents.

Table 8. Effects of organic and inorganic fertilizers on mineral contents of *C. olitorius* leaves in 2020 and 2021 cropping seasons

PM (%)	Urea fertilizer (%) per time application (week)	K (ppm)		Ca (ppm)		Mg (ppm)		N (ppm)		P (ppm)	
		2020	2021	2020	2021	2020	2021	2020	2021	2020	2021
Control		1031.25	1030.25	1.3	1.29	0.65	0.20	1.14	1.04	680.71	143.16
100	0	1281.25	1312.50	1.70	1.60	1.30	0.20	1.68	1.74	962.54	1539.34
80	20 @ 1	1230.00	1218.75	1.55	1.65	2.10	0.60	1.63	1.77	863.49	1155.34
	20 @ 2	1233.33	1343.75	1.70	1.95	2.50	1.15	1.74	1.92	944.53	1140.82
	20 @ 3	1093.75	1125.00	1.55	1.45	1.40	1.15	1.89	2.03	938.23	1100.68
60	40 @ 1	1234.25	1281.25	1.40	1.90	0.25	0.70	1.42	2.20	1084.99	806.77
	40 @ 2	1088.00	1285.25	1.70	1.95	1.40	0.45	1.42	2.28	835.58	685.22
	40 @ 3	1031.25	1285.25	1.45	1.90	2.10	0.15	1.57	2.78	1030.07	902.22
40	60 @ 1	1156.25	1250.00	1.70	1.70	0.90	0.50	1.79	1.93	840.99	591.57
	60 @ 2	1156.00	1318.75	1.80	1.95	0.95	1.85	2.31	2.78	1796.56	1900.41
	60 @ 3	1126.25	1212.50	1.65	1.95	0.95	0.30	1.62	1.78	915.72	759.95
20	80 @ 1	1108.75	1156.25	2.05	1.80	0.95	1.20	2.20	1.73	1168.74	820.73
	80 @ 2	1031.25	1187.50	1.80	1.20	0.85	1.80	1.84	1.76	970.65	845.49
	80 @ 3	1062.5	1093.75	1.55	1.20	0.75	1.15	1.86	1.56	971.55	843.69
0	100 @ 1	1062.5	1031.25	1.41	1.70	0.50	1.50	1.59	1.73	517.74	162.43
	100 @ 2	1093.75	1093.25	1.50	1.90	0.75	1.55	1.56	1.78	776.16	928.33
	100 @ 3	1031.25	1030.25	1.30	1.90	0.50	1.50	1.57	1.73	733.78	598.76
	Median	**1062.50**	**1218.75**	**1.65**	**1.70**	**0.95**	**0.85**	**1.74**	**1.77**	**915.72**	**806.77**
	Mean	**1015.62**	**1191.50**	**1.629**	**1.62**	**1.15**	**0.93**	**1.76**	**1.87**	**890.12**	**707.30**
	SD±	**277.3**	**107.69**	**0.21**	**0.31**	**0.63**	**0.62**	**0.34**	**0.32**	**152.68**	**273.84**
	CV	**27.30**	**9.038**	**12.89**	**19.13**	**54.78**	**66.67**	**22.72**	**17.11**	**17.15**	**38.72**

Discussion

The stem girth, the number of branches, the plant height, the number of leaves, whole yield, marketable yield and edible yield increased significantly ($P = 0.05$) across all the treatments compared to the control in both years. This could be due to the applied soil amendments which contain nitrogen as one of the main nutrients needed by the plant for growth that was released into the soil for plant uptake (Aboyeji et al., 2021). According to Adekiya et al. (2019), N is the major nutrient element required for yield and growth components and a distinctive ingredient of functioning plasma. It is found in chlorophyll molecules, proteins, amino acids, nucleic acids (RNA and DNA), nucleotides, phosphatides, alkaloids, enzymes, coenzymes, hormones and vitamins.

An increase in the vegetative parameters and yield of *C. olitorius* as a result of nitrogen uptake revealed that the experimental soil was deficient in nutrients. It could also be ascribed to increased uptake of nitrogen from the soil-applied urea fertilizer which is an association of its role in chlorophyll synthesis and thus the process of photosynthesis and carbon dioxide assimilation (Jasso-chaverria et al., 2005) leading to improved growth. This proves that nitrogen stimulates the formation of new leaves and increases the plant height. Tovihoudji et al. (2015) also reported that urea fertilizer improved *C. olitorius* growth. Emuh (2013) and Adenawoola and Adejoro (2005) also found that the growth of *C. olitorius* improved with the application of poultry manure.

The poultry manure alone at 100% improves the stem girth, number of leaves, number of branches and plant height in relation to urea fertilizer alone (100%) either at 1, 2 or 3 WAS. This could be ascribed to the high content of nutrients (both macro nutrients and micro nutrients) in the poultry manure and also due to its low C: N ratio (7.38), leading to faster decomposition and subsequent release of nutrient, most especially nitrogen which leafy vegetable like *C. olitorius* need most. N has been known to increase leaf sizes, promote rapid growth as well as above ground vegetative growth. Apart from increasing soil nutrients, PM may also improve soil structure (Adekiya et al., 2020). The lower growth of *C. olitorius* due to urea fertilizer alone relative to PM is due to the fact that urea fertilizer is prone to losses by run-off, volatilization, leaching and/or denitrification. Mobile nutrient like N is highly soluble and is not adsorbed on clay complex especially in coarse-textured soils high in the sand (68%) as in the case of the study sites. In such soils, the loss of N by leaching will be very high coupled with the high rainfall of the area. These results are in agreement with that of Mogapi et al. (2013) on the effect of poultry manure and commercial fertilizer on growth of *C. olitorius*.

The integration of organic (PM) and inorganic (Urea) fertilizers increased the growth and yield of *C. olitorius* compared to their sole forms. This could be attributed to reduced nutrient loss through leaching by the combination which led to increased nutrient use efficiency following the inclusion of the inorganic N fertilizer with poultry manure (Abbasi et al., 2010; Souri et al., 2018). This study also revealed that urea fertilizer added to PM assisted in the mineralization of both micro and macro nutrients in poultry manure due to an improved supply of nutrients leading to better growth and yield. Okokoh and Bisong (2011) reported that PM combined with Urea-N had a better effect on *Amaranthus cruentus* growth than either Urea-N or poultry manure applied alone.

The treatment with 60% PM + 40% urea fertilizer applied at 1 WAS produced significantly higher values of growth and yield parameters of *C. olitorius*. This could be attributed to reduced nutrient loss through leaching by urea fertilizer as a result of the combination and maximal nutritional availability by PM at 80 % which was ascribed to the increased organic matter composition of the poultry manure.

Urea fertilizer application at 1 WAS has the best growth and yield in this study. This could be ascribed to the synchrony in the time of availability of an adequate amount of N (nutrient) from urea fertilizer present in the soil to the need by the *C. olitorius* plant for absorption and utilisation. Consequently, the application of urea (N) fertilizer to *C. olitorius* especially 3 WAS is possibly a waste as the *C. olitorius* plant, at that stage of growth, being a short-duration crop. does not have the capacity to use the nutrients in any significant amount.

The fact that the application of organic and inorganic fertilizers increased moisture and protein contents of *C. olitorius* relative to the control might be a result of an increase in the supply of nutrients. N encouraged better vegetative growth, development and growth of roots thereby boosting greater absorption of water. It also improved the composition of amino acids, which are the building blocks of protein, and enzymes (Brady and Weil, 2008). The ash content was a bit high probably due to a more balanced nutrient in the amended soils relative to the control that had lower nutrient contents. Higher values of carbohydrate are observed in control plot relative to amended soils, which corroborates with that of Adekayode (2004). PM increased protein, fibre and fat contents of *C. olitorius* relative to urea fertilizer alone; this can be seen as differences in the chemical composition of urea fertilizers as compared to PM.

The application of inorganic fertilizer (applied either at 1, 2 or 3 WAS) increased carbohydrate, ash and moisture content of *C. olitiorius* irrespective of the time of application compared with PM, which could be due to the additional nitrogen nutrient present in the urea fertilizer that promotes the quality of the plant and rapid release of the nutrients for plant consumption. PM releases nutrients only when the soil is warm and moist, which correlates with *C. olitorius* times of need, and they rely on soil organisms to break down organic matter, so nutrients are released more slowly than inorganic fertilizers. Urea fertilizers, on the other hand, give these nutrients in a more readily available form the possibility for immediate use in the soil. Mishra and Ganesh (2005) previously documented these tendencies in their study of how various fertilizers could impact nutritional status.

The combined application of amendments improved the potassium, calcium, magnesium and phosphorus contents of *C. olitorius* relative to the control. This can be ascribed to the availability of more nutrients in the soil from the integrated use of organic manure (PM) and inorganic fertilizer (urea) that brought about the increase in uptake by the *C. olitorius* plant. Organic manure (PM) contains both micro and macronutrients thereby increasing K, Ca, Mg and P contents of *C. olitorius* relative to the urea fertilizer alone applied at 1, 2 or 3 WAS. This could be related to the chemical components of NPK versus PM fertilizer, as well as its beneficial effect on soil ecology and plant metabolism according to Hassan (2012). The amount and quality of nutrients taken by the plant is influenced by the mineral nutrients present in the applied amendment and subsequently in the soil. The improved mineral contents of *C. olitorius* under integrated PM and urea fertilizer were a result of increased soil nutrients due to the combined application of PM and urea fertilizer leading to increased metabolic activities in the integrated plots relative to their single forms plots.

Conclusion

The results from this experiment revealed that urea fertilizer and PM (sole or combined) increased growth (number of leaves, plant height, number of branches and stem diameter), yield (whole yield, marketable yield and edible yield) parameters, proximate and mineral contents relative to the control. PM increased these parameters relative to urea fertilizer applied either at 1, 2, or 3 WAS. There were no significant differences in applying urea fertilizer at 1, 2 and 3 WAS. The incorporation of 60% PM and application of 40% urea fertilizer at 1 WAS produced the best growth and yield parameters. Similarly, 40% poultry manure and 60% urea fertilizer applied at 2 WAS had the best values of proximate and mineral contents of *C. olitorius*.

Therefore, for those that desire to cultivate *C. olitorius* for its edible leaves, the application of 60% PM + 40% urea fertilizer applied at 1 WAS is recommended. However, for those that want the quality of the *C. olitorius* leaves, the combination of 40% poultry manure and 60% urea fertilizer applied at 2 WAS is recommended.

CRediT authorship contribution statement

Chirstopher Muyiwa Aboyeji, Aruna Olasekan Adekiya: Conceptualization, Field experiment design, Manuscript preparation. **Khadijat Omowumi Suleiman:** Data collection and analysis. **Eyitayo Taylor Oshagbemi:** Figures preaparation and manuscript revision.

Declaration of Competing Interest

The authors have declared that they have no known potential conflits of interest, competing financial interests or personal relationships before, during and after this study that could have appeared to influence the work reported in this paper.

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