

Influence of Poultry Droppings on the Production and Mineral Profile of Cowpea (*Vigna unguiculata* (L.) Walp) in Kombé (Brazzaville, Congo)

**J. Yoka^{1*}, B. O. D. Bassoukissa¹, Y. F. Assongba², J. J. Loumeto¹, J. G. Djego²
and L. S. Baba-Moussa³**

¹*Laboratoire de Biodiversité, de Gestion des Ecosystèmes et Environnement, Faculté des Sciences et Techniques, Université Marien NGOUABI, Brazzaville, BP: 69, Congo.*

²*Laboratoire d'Ecologie Appliquée, Faculté des Sciences Agronomiques, Université d'Abomey-Calavi, Cotonou, Bénin.*

³*Laboratoire de Biologie et de Typage Moléculaire en Microbiologie, Faculté des Sciences et Techniques, Université d'Abomey-Calavi, Benin.*

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Cowpea (*Vigna unguiculata* (L.) Walp.) is one of the most important seed legumes in the tropics and subtropics. It is an important staple in sub-Saharan Africa, particularly in the arid savannahs of West Africa. The present study conducted in the Kombé area (Brazzaville) aims to assess the impact of poultry droppings on the yield and mineral profile of cowpea. Seeds of three cowpea cultivars (C1, C2, C3) were sown in a completely randomised system in two plots. Prior to sowing, a treatment of one dose of poultry droppings was applied in one of the two plots, which was named fertilised plot containing treatments C1D1, C2D1 and C3D1. The plot without droppings was the control plot with treatments C1D0, C2D0 and C3D0. The biomass of leaves, pods and seeds was assessed by the harvesting method followed by drying and weighing. Chemical data of leaves and soils were obtained after laboratory analysis. The results show that leaf biomass, pod biomass and

seed biomass ranged from 1.8 t DM/ha to 3.4 t DM/ha, 960.2 kg/ha to 1706 kg DM/ha and 563.4 kg DM/ha to 1263.7 kg DM/ha respectively. Treatments C1D1 and C3D1 were respectively the most productive in leaf biomass and pod and seed biomass. The nitrogen and phosphorus contents in the leaves do not seem to be influenced by the addition of poultry droppings. However, these contents are improved in the soil after the application of poultry droppings. Poultry droppings have a beneficial effect on yield in terms of leaf, pod and seed biomass. Poultry droppings may be useful as an organic fertilizer for cowpea cultivation.

Keywords: Cowpea; cultivars; poultry droppings; production; Kombé.

1. INTRODUCTION

Cowpea (*Vigna unguiculata* (L.) Walp) is an important seed legume in tropical and subtropical regions, particularly in sub-Saharan Africa, which accounts for almost all of the world's production [1]. The green pods and fresh seeds of cowpea are consumed throughout the African continent, but also in Asia and Latin America. The seeds are a valuable source of vegetable protein, vitamins and income for humans, and fodder for animals. To address malnutrition and undernourishment in developing countries, where meat consumption remains a luxury, cowpea is a substantial palliative in terms of protein intake in human and animal nutrition [2]. It thus balances cereal- and tuber-based diets that are generally low in protein [3]. Cowpeas contribute to food security and poverty reduction [4]. The most important use of cowpeas is as seeds, which are either boiled, eaten with other seeds or incorporated into sauces, or processed into powder or paste and used in the preparation of many dishes. Cowpea is also important as fodder for livestock. In West Africa, after the pods have been harvested, cowpea tops are an important source of feed for livestock [5].

With regard to livestock feed, although studies have shown that the savannahs surveyed in the Congolese basin offer significant potential for cattle, sheep and goat rearing [6], the national report on the state of animal genetic resources in Congo Brazzaville of April 2003 attests to the fact that natural pastures, especially in densely populated areas, are subject to significant seasonal variations in productivity and nutritional value. Hence, supplementation with high nutritional value plant species is recommended.

Cowpea cultivation is characterized by yield instability [7]. In several countries, low yields are thought to be due to low soil fertility, particularly in terms of available nitrogen and phosphorus [8]. In order to optimize cowpea production, fertilization could also be a solution

to this constraint [4]. Cowpea is well adapted to drought, phosphorus and nitrogen deficiencies, soil acidity and diseases and pests [9]. This makes it a year-round crop. Cowpea can be used as a cover crop and green manure for soil protection against water erosion [10]. Because of its role in restoring soil fertility and its compatibility in several crop combinations, cowpea is an essential component of cropping systems in the savannah zones of tropical Africa [11]. Most of the cultivated area is in West Africa [12] and together with Central Africa it covers 80% of the cultivated area [13].

Despite its wide adaptation and importance, cowpea productivity is generally very low due to many biotic and abiotic constraints. The main constraints in cowpea production are: insect pests (aphids, thrips, sucking bites, pod borers and bruchids), diseases (bacterial, viral and fungal), parasitic plants (e.g. *Striga*), drought or heat, and agricultural practices (Ishikawa et al., 2013). The use of organic manures maintains or improves soil fertility with very good crop yields in a sustainable manner [14, 15, 16].

Recent studies on cowpea fertilization show that cowpea has constraints to achieve good yields. Nodule, flower and pod production capacity, seeds per pod and 100-seed weight are the key variables in predicting cowpea yield [17]. Also, the capacity to produce nodules, flowers and pods, seeds per pod and weight of 100 seeds are the determining variables for predicting yield in cowpea [17]. Bado [18] indicates that this crop, despite its ability to fix atmospheric nitrogen, additional fertilizer is needed as a growth stimulant at start-up. Some et al. [19] have shown that the use of compost on cowpea significantly improves its resistance to water stress and can increase its yield. The methods of fertilization should be also take into account the current context where there is a question of the acidifying effect of mineral fertilizers used alone by adding them to organic manure to organic fertilizer.

Poultry droppings are of great importance in agricultural production; they provide great advantages in improving the biological properties and qualitative characteristics of the soil, which contribute to the fusion of many elements of plant nutrition. As an experiment, cowpea cultivation trials with different fertilizers (NPK, Ca and chicken droppings) were carried out in the Niari valley, precisely in Loutété [4]. This work differs with previous studies [4] by application to a sandy soil. The results obtained during the different trials show that chicken droppings, which increase yields, seem to be the most suitable fertilizer for cowpea cultivation in this study area.

However, in the Kombé area of Brazzaville, no studies seem to be conducted in this regard. The general objective of this study was to assess the impact of poultry droppings on the yield and mineral content of three cowpea cultivars (*Vigna unguiculata* (L.) Walp) in Kombé, with a view to their use in pasture improvement programmes in Congo. The specific objectives were (i) to estimate production in terms of leaf biomass, pods and seeds; (ii) to assess the mineral content of leaves in relation to the soil.

2. MATERIALS AND METHODS

2.1 Study Area

The study was carried out in Congo in Kombé, 17 km south of Brazzaville (between 0° and 2° South latitude, and between 15° and 16° East longitude). The study took place from November 2020 to February 2021

The climate of the area is of the low Congolese humid tropical type. The average annual temperature is 25.5°C; the average minimum is 19.19°C in July and the average maximum is 31.9°C in March [20]. The average annual rainfall is in the order of 1200 to 1400 mm, unevenly distributed. Rainfall is almost permanent; April and December are the rainiest months of the year in Brazzaville. The maximum rainfall is recorded in April. Ecologically, the dry season begins in June and ends in mid-September. The annual average relative humidity is close to saturation (98%). The average annual wind speed is 2.17 m/s with a maximum of 2.56 m/s in August and a minimum of 1.93 m/s in December.

The soils in the study area are predominantly sandy-clay, highly desaturated, low in base, very

permeable, and support vegetation dominated by the herb *Hyparrhenia diplandra* (Hack) Stapf and the shrub *Hymenocardia acida* Tull [20].

2.2 Plant Material

The plant material consisted of cowpea seeds (*Vigna unguiculata* (L.) Walp). These are the unidentified 'all purpose' cultivars named C1, C2 and C3. The seeds of cultivar C1 are ovoid and white in colour; those of cultivar C2 are light brown and ovoid in shape. Cultivar C3, on the other hand, is egg-shaped and dark brown in colour.

2.3 Methods

The trial was conducted in a landscaped area 20 m long and 15 m wide. Two plots, one serving as a control (unfertilised) and the other fertilised, each 18 m long and 5 m wide, were delimited and separated by a distance of 2 m. These plots were subdivided into three square blocks of 5 m each, and allowed the sowing of the three cultivars. These plots were subdivided into three square blocks of 5 m each, and allowed the sowing of the three cowpea cultivars (C1, C2 and C3) [20].

2.3.1 Soil preparation, amendment and sowing

Soil preparation was preceded by clearing the brush. Ploughing was carried out using a hoe to loosen the soil. Soil aeration and removal of buried waste including weed rhizomes was achieved by turning the soil over to a depth of about 25 cm. After soil preparation, amendment followed by spreading 75 kg of poultry droppings on the three blocks of the experimental plot, at a rate of 25 kg per block.

Sowing was done in rows on each plot. Three seeds were sown per plot [21], i.e. 300 seeds per block. The spacing used was 50 cm on the line and 50 cm between the lines (i.e. 50 cm x 50 cm).

The different treatments are (i) C1D0: cultivar 1 on control soil (unfertilised); (ii) C1D1: cultivar 1 on fertilised soil (poultry droppings); (iii) C2D0: cultivar 2 on control soil; (iv) C2D1: cultivar 2 on fertilised soil; (v) C3D0: cultivar 3 on control soil; (vi) C3D1: cultivar 3 on fertilised soil.

2.3.2 Dismantling, maintenance and phytosanitary treatment

Two weeks after sowing, weeding was carried out to retain vigorous plants and to fill in ungerminated pockets. Maintenance operations (weeding, hoeing) were carried out every fortnight after sowing, to avoid competition with weeds and harbouring insects [6].

In response to insect pests (locusts, caterpillars), two insecticide applications were made. The spraying was done with a 16 litre backpack sprayer and the insecticide used was Callidim 400EC. This insecticide is a liquid product from Arysta company, in France, and distributed in by Chimagro in Congo.

2.3.3 Data collection

2.3.3.1 Emergence and leaf biomass

After sowing, the period in which the cultivars reached 50% emergence was identified by counting the seedlings that emerged.

The two-month stage of vegetative growth corresponds to the favourable period for harvesting cowpea leaves as fodder [21]. Yoka et al [6, 22] state that it is during this period that the plant produces more leaves. Leaf biomass samples were collected by the clear-cut method, in 1 m² plots with four replicates, for each cultivar, using pruning shears. The samples obtained were packed in plastic bags and weighed before drying. The samples were dried in an oven at 70 °C to constant weight. After drying, an average biomass was calculated for each cultivar.

From these plant samples, leaf samples were made per cultivar for chemical analysis at the joint analysis laboratory of the Institut de Recherche en Sciences Exactes et Naturelles (IRSEN), Pointe-Noire centre (Congo). These analyses focused on ash, nitrogen, phosphorus and calcium.

2.3.3.2 Pod and seed production

Pod samples were taken for each cultivar from 1 m² plots with four replicates at two months after sowing. These samples were packed in plastic bags and weighed before open drying. The yield in terms of pods for each cultivar was calculated [6].

All pods produced were harvested to determine seed production and calculate the mass of 100 seeds.

2.3.3.3 Soil characterization

oil samples were augered from a depth of 0-20 cm in herbaceous above-ground biomass sample plots. The samples were wrapped in plastic bags and air-dried. They were subjected to chemical analyses at the joint analysis laboratory of the Institut de recherche en sciences exactes et naturelles (IRSEN), Pointe-Noire centre (Congo). These analyses concerned the pH of the water, organic matter, carbon, nitrogen, phosphorus and calcium.

The pH water was measured in a suspension with a soil/water ratio of 1/2.5. Total carbon was determined by the Walkley and Black method. The organic matter content was calculated by the method of destruction and weighing. Total nitrogen is determined by the Kjeldahl method. Phosphorus is determined by the cold colorimetric method [23].

2.3.4 Data processing

2.3.4.1 Calculation of the emergence

The emergence rate was determined from the following formula:

$$ER = NSE \times 100 / NSS$$

Legend:

ER: emergence rate; NSE: number of seedlings emerged;

NSS: number of seeds sown

This rate is used to determine the period that corresponds to 50% emergence.

2.3.4.2 Calculation of carrying capacity

Herbaceous above-ground biomass data were used to assess the optimal carrying capacity. The method recommended by Boudet and reported by Yoka [24] was adopted: the potential production consumed by cattle weighing an average of 250 kg live weight was estimated as 1/3 of the total biomass. The results obtained are expressed in LU/ha/year (LU: tropical cattle unit, cattle of 250 kg live weight) conducted under extensive conditions. It is determined by the following formula:

$$Cc = Ki \times \text{Quantity of biomass produced (t DM/ha)} \times 1000 / Cx D$$

Legend:

Cc: carrying capacity; C: intake capacity (in the tropics it corresponds to 6.25 kg); D: rearing time, 365 days; Ki: consumable fraction without complete denudation of pasture (it corresponds to 1/3); DM: dry matter.

2.3.4.3 Interpretation of the content of different elements in soils

Some indications on the interpretation of the contents of different elements in soils have been taken into account to assess the chemical properties of soils [24]:

- OM (% of soil) < 1.5: low rate;
- OM varies between 1.5% and 3%: average rate; OM >3%: high rate
- If total nitrogen (% of soil): <1% low rate; 1 - 2% average rate; >2 high rate
- If total phosphorus (% of soil): <0.25% low rate; 0.25-0.75 average rate; >0.75 high rate.

3. RESULTS AND DISCUSSION

3.1 Emergence Rate

The data on the period at which the different treatments reached an emergence rate greater than or equal to 50% are :

- two days after sowing, treatments C1D1, C3D0 and C3D1 reached 89% emergence.
- four days after sowing, treatment C2D1 reached 82% emergence;
- five days after sowing, treatments C1D0 and C2D0 reached 83% and 75% respectively.

These data are similar to those found by Yoka et al. [6].

From these results, it appears that cultivar C1 on fertilised soil and cultivar C3 on control and fertilised soil emerged earlier. Cultivars C1 and C2 on control soil emerged late. Fertilization seems to have a beneficial effect on emergence rate in cowpea. This result is also similar to that found by Ampion et al. [4].

3.2 Leaf Biomass and Carrying Capacity

Data on leaf biomass and carrying capacity are presented in Table 1. At two months after sowing, leaf biomass varied between 1.43 t

DM/ha and 3.44 t DM/ha. Treatment C1D1 has the highest yield (3.44 t DM/ha). The lowest yield (1.43 t DM/ha) is noted in treatment C3D0. Treatments C2D1 and C3D1 show yields in terms of leaf biomass of 2.85 t DM/ha and 2.08 t DM/ha respectively. However, treatments C1D0 and C2D0 have yields of 1.54 t DM/ha and 1.83 t DM/ha respectively. It was found that the treatments with poultry droppings were more productive in terms of leaf biomass than the treatments without poultry droppings. From these results, it seems that fertilization with poultry droppings has a beneficial effect on leaf production in cowpea.

Cultivar 1 appears to be the most productive in terms of leaf biomass, followed by cultivar C3, on control soil and on soil fertilized with poultry droppings. Cultivar C2 is the least productive.

These results are much higher than those obtained by Yoka et al. [6]. This difference can be explained by the fact that the techniques used differ. Yoka et al. [6] used a row seeding technique with a spacing of 50 cm x 75 cm on mounds separated by at least one metre (1m), whereas in the present study the spacing used for row seeding in bunches is 50 cm x 50 cm. The closer spacing of the plants (50 cm x 50 cm instead of 50 cm x 75 cm) resulted in a higher biomass. The addition of poultry droppings could also explain this difference in leaf biomass compared to the work of Yoka et al [6].

The carrying capacity varies in the same direction as the leaf biomass. Overall it varies from 0.2 LU/ha/year to 0.5 LU/ha/year. The carrying capacity is higher for the poultry manure treatments. It is higher than that found by Amboua [25] who found a carrying capacity of 0.34 LU/ha/year, in a study of cowpea cultivation without poultry droppings.

The analysis of the results of the present study shows that poultry droppings play a crucial role in improving leaf biomass yields and consequently in terms of carrying capacity for cattle. In the tropics, the latter requires abundant leaf biomass in order to achieve a good carrying capacity to meet the needs of livestock farmers [6].

3.3 Biomass in Pods and Seeds

Table 2 presents the data in terms of dry pod and seed yield of cowpea at two months after

sowing. These data vary from treatment to treatment. Seed yields vary in the same direction as dry pod yields. Treatment C3D1 has the highest dry pod (1706.6 kg/ha) and seed (1263.7 kg/ha) yields. The lowest yields were found in treatment C2D0, with 960.2 kg DM/ha of dry pods and 565.4 kg/ha of seeds. Fertilisation with poultry droppings appears to improve pod and seed yields in cowpea at two months after sowing. These results are higher than those found by Moukala et al. [20] who worked at the same site. This difference could be explained by the contribution of poultry droppings.

Soil fertilisation with poultry droppings appears to improve yields in terms of leaf biomass, pod biomass and seed biomass of cowpea at two months after sowing. The improvement in leaf biomass and dry pod biomass yields by treating soils with poultry droppings was also demonstrated by Ampion et al. [4].

Treatments C1D0 and C1D1 did not produce pods, and therefore did not produce seeds at two months after sowing. Cultivar C1 could therefore be considered a forage cultivar, as it only produces leaves that can be used as fodder for livestock. From these results, it appears that cultivar C3 is more productive in dry pods and seeds than cultivar C2, both on control and fertilised soil.

The mass of 100 seeds does not seem to differ between the two treatments. It was between 14 and 16 g.

3.4 Mineral Content of Leaves

The mineral contents of the leaves are presented in Table 3. The ash contents vary from 7.26% (C1D1 treatment) to 10.01% (C2D1 treatment). Nitrogen contents varied from 3.77% (C1D0) to 4.44% (C2D1). Phosphorus levels

range from 0.29% (C2D0) to 1.34% (C1D0). Calcium levels range from 1.98% (C1D1) to 2.65% (C2D1). These contents are similar to those found by Yoka et al. [22].

These results show that overall, the poultry manure treatments seem to have high ash contents. As for nitrogen, phosphorus and calcium, the addition of poultry droppings does not seem to influence their content in cowpea leaves.

3.5 Soil Characteristics

The soil characteristics of the plots studied are presented in Table 4. They are variable with or without the addition of poultry droppings. The pH is acidic in all treatments; it varies from 3.82 (C1D0) to 4.82 (C3D1). The organic matter, nitrogen and phosphorus levels are average overall and vary from 1.53% (C3D0) to 2.09% (C1D1) for organic matter and from 0.11% (C3D0, C3D1) to 0.17 (C1D1) for nitrogen. Phosphorus levels are 0.03% for treatments C1D0, C2D0, C3D0 and 0.04% for treatments C1D1, C2D1 and C3D3. Calcium in the soils is present in very low amounts in all treatments. The C/N ratio is low; it varies from 7.11 to 8.09.

The analysis in Table 4 shows that overall, the poultry manure treatments appear to have slightly improved soils in organic matter, nitrogen and phosphorus. This could be explained by the fact that poultry droppings would provide more nutrients to the soil as shown by Ampion et al [4]. Poultry droppings would be an organic fertiliser to be encouraged in cowpea cultivation, with a view to improving agricultural yields. They could therefore be used in agricultural and pastoral development programmes.

Table 1. Leaf biomass and carrying capacity data for the six treatments at two months after sowing

Period	Treatment	Dry leaf biomass (g/m ²)	Dry leaf biomass (t DM/ha)	Carrying capacity (LU/ha/year)
2 months	C1D0	183.51	1.83	0.26
	C1D1	344.32	3.44	0.5
	C2D0	154.21	1.54	0.22
	C2D1	285.56	2.85	0.41
	C3D0	143.33	1.43	0.2
	C3D1	208.31	2.08	0.3

Legend: TBU: tropical cattle unit.

Table 2. Dry pod and seed yield of cowpea at two months after sowing

Drying method	Treatment	Dry pod yield (kg/ha)	Mass of 100 seeds (g)	Seed yield (kg/ha)
Open air	C2D0	960.2	15.8	565.4
	C2D1	1224.8	16.2	810.7
	C3D0	1421.6	14.7	951.3
	C3D1	1706.6	15.5	1263.7

Table 3. Mineral content of cowpea leaves

Content (%)	C1D0	C1D1	C2D0	C2D1	C3D0	C3D1
Ash	8.35	10.01	7.61	7.7	7.26	8.41
Nitrogen	3.77	3.81	3.81	4.44	4.43	3.84
Phosphorus	1.34	1.28	0.29	0.37	0.45	0.39
Calcium	2.03	1.98	2.38	2.65	2.27	2.63

Table 4. Chemical data of soils under cowpea cultivation

Type of analysis	C1D0	C2D0	C3D0	C1D1	C2D1	C3DD1
pH	3.82	3.95	3.85	4.54	4.52	4.82
OM (%)	1.75	1.96	1.53	2.09	2.07	1.59
N (%)	0.12	0.13	0.11	0.17	0.14	0.11
P (%)	0.03	0.03	0.03	0.04	0.04	0.04
Ca (%)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
C/N	8.41	8.76	8.36	7.11	8.57	8.09

4. CONCLUSION

The study showed that in the soil and climate conditions of Kombé, Congo, the experienced cowpea cultivars adapt well. The 2 and 5 day delays are necessary to have at least 50% emergence, in relation to the different treatments. With the addition of poultry droppings, cultivar C1, which produces more leaves than the other two cultivars and does not produce pods, could be used as a forage cultivar for the development of pastoral livestock programmes. The other two cultivars, with lower leaf biomass and producing pods and seeds, should be encouraged for human consumption.

Poultry droppings do not seem to influence the mineral content of cowpea leaves. However, they would improve these levels in the soil, which would result in improved cowpea yields in terms of leaf biomass and pod and seed biomass. Poultry droppings would therefore be an organic fertiliser to be encouraged in the development of food and feed crops.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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