Residual Effect of Organic Fertilisation on Some Agronomic and Physico - Chemical Properties of Three Varieties of Cassava (*Manihot esculenta* C.)

Serge Couhoulé Allou[1], Cathérine Bomoh Djedji Ebah[2], Bilo Régis Jean - François Loa[3], Françoise Akissi Kouamé[4]

[1, 3, 4]Laboratory of Food Biochemistry and Tropical Products Technology, Department of Food Science and Technology, University NanguiAbrogoua, Côte d'Ivoire,
[1]Email: *serge_allou[at]yahoo.fr*

[2]National Center for Agronomic Research, Laboratory of Chemistry - Technology of Technological Research Station, Côte d'Ivoire
Email: *bomohebah92[at]gmail.com*

Abstract: ***Cassava (Manihot esculenta C.) is the second food crop produced after yam in Côte d'Ivoire with many products derived widely consumed. Faced with the impoverishment of the soil, organic fertilization is increasingly used by farmers. The study proposes is to assess the residual impact of organic fertilization with cowpea plants (Vigna unguiculata L.) at planting densities of 62, 500; 125, 000 and 250, 000 plants / haand poultry manure at rates 5; 10 and 15 t/ha, on certain agronomic andphysico - chemical properties of varieties of cassavaYavo, BoCou 1 and Yacé. To do this, an experimental plot was installed. After 15 months of cassava cultivation in a first cycle where fertilizers were used, a second cycle of 15 months was conducted instead of the first without adding fertilizers. The parameters of cassava roots studied were determined for the second cycle. The resultsshow that the residual effect of these organics fertilizers increasedtuberized roots yield. These increases go up to 159.58% withpoultry manure. In addition, the residual effect of these fertilizers resulted in abeneficial increase, respectively, in dry matter and ash contents of up to 61.12% and 470.30%.***

Keywords: Fertilization, Agronomics, Physico - chemical, cassava

1. Introduction

Cassava (*Manihot esculenta* C.) is one of the main subsistence crops, widely cultivated in tropical and subtropical countries, mainly for its tuberous roots, high in carbohydrate, used for human consumption and animal feed [**1, 2**]. Cassava plays a key role in the fight against large - scale food insecurity as it is increasingly used as a raw material for food industries [**3**]. In the world, cassava is the fifth food crop after corn, rice, wheat and potatoes [**4**]. In Africa, it ranks third in food production after rice and maize [**5**]. In Côte d'Ivoire, cassava is ranked second among food crops produced after yams, with an annual production of 5, 608, 044 tonnes [**6**]. There are many products derived from cassava such asthe popular foods «attiéké» [**7, 8, 9**].

Cassava cultivation, as important as it is in the food security of populations in Côte d'Ivoire, is mainly practiced in an extensive system **[10]**. The result is the impoverishment of the soil in the face of which farmers increasingly use organic fertilization [**11**]. Organic fertilizers like cowpea legume (*Vigna unguiculata* L.) and poultry manure are biodegradable, durable and more environmentally friendly than they are their chemical counterparts [**12, 10**].

The agronomic interest of poultry manure lies in its relatively high organic matter content (206 to 472 Kg of organic matter per tonne of raw product) wichallow obtaining better production [**13**]. Poultry manure represents pure brown excrement produced by poultry raised without litter [**14**]. Under good breeding conditions, the average production of poultry waste varies between 130 to 150 Kg/m^2/year **[14]**. Likewise, fertilization with cowpea optimizes yields [**15**]. The main advantage of cowpea is its ability to meet its nitrogen needs from nitrogen in the air and to enrich the soils [**16**]. Cowpea is widely cultivated in association with other crops such as cassava [**17**]. The people eat its dry seeds as a pulse or its young leaves and immature pods as a fresh vegetable. The annual production of cowpea dry biomass would be about 50, 000 tons [**18**]. In addition to their actions on yield, these fertilizers are capable of modifying the physico - chemical and sensory qualities of crops depending on the fertilization route, eco - climatic conditions and the variety cultivated [**19, 20**].

Unfortunately, the effect of organic fertilization on the agronomic performance and physico - chemical quality of cassava remains elusive, as few studies have paid particular attention to it [**21, 22**].

Allou *et al*. [23] already carry out the evaluation of the immediate effect of cowpea and poultry manure on the agronomic and physico - chemical properties of the cassava varieties Yavo, BoCou1 and Yacé. The results showed that cowpea planting densities 62, 500; 125, 000 and 250, 000 plants per hectare, buried in the ground, led to the deterioration of the agronomic performance of the three varieties. On the other hand, the immediate effect of doses of 5; 10 and 15 tonnes of poultry manure per hectare resulted in improved performance. These fertilizers also caused an increase in the dry matter content of the cassava varieties, while the evolution of the other physico - chemical parameters studied (lipids, ash, starch, total sugars and reducing sugars) depended on the type of fertilization and the cassava variety.

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Therefore, this study suggests estimating the residual effect of different levels of the using, not combined, of Cowpea and poultry manure as organics fertilizers of the soil, on the agronomic and physico - chemical characteristics of the cassava roots.

2. Material and Methods

Cultivation soil

The study was carried out in the field of the National Agronomic Research Center (CNRA) in Anguédédou between May 2015 and August 2016. This site is located at 05 ° 19' 48.60" North latitude and 04°07'50.22" West longitude and at an average altitude of 39 m [**24**].

Experimental setup

Cassava cultivation was done according to the split - plot plan with two factors: the main factor "soil fertilization" and the secondary "cassava variety". For the "soil fertilization" factor, seven levels were considered: F1 (without fertilization), F2 (cowpea at the planting density of 62, 000 plants/ha), F3 (125, 000 plants/ha), F4 (250, 000 plants/ha)), F5 (poultry manure at 5 t/ha), F6 (10 t/ha); F7 (15 t/ha). The local cowpea cultivar touba was selected as an intercropping legume because of its agronomic performance and its considerable economic interest. Poultry manure has also been used as a manioc fertilizer due to its availability in the region. The nutrient content of the droppings was 14.9 g N. kg^{-1}, 5.6 g P. kg^{-1} and 4.3 g K. kg - 1 (dry matter). The "cassava variety" factor includes three levels: the improved cassava genotypes Yavo and BoCou 1 and the widespread local variety Yacé. The plots were fertilized once to perform two cycles. Fertilizers were only added during the first cycle and only the second cycle were considered. The number of trials (fertilization level X cassava variety) for this experiment is 21 with three repetitions. The elementary plots size were 12.8 m^2 per unit.

Analysis methods

All agronomic characteristics was observed on the experimental site during harvest. The harvested tuberous roots were weighed and counted. This made it possible to determine the yield, the tuberizedroots average weight per plant (TAWP) and the number of Tuberized Roots per elementary plot (NT). For the physico - chemical analysis, the undamaged roots were collected, taking care not to scratch them. Dry matter and ashes content were determined by the methods **AOAC [25]**and lipid by **AOAC [26]**. Reducing and total sugars rate were extracted according to the technical of **Martinez - Herrera and Siddhuraju [27]** and measured according to the methods of **Yao *et al.* [28]**. The starch content was determined according to the method described by **Jarvis and Walker [29]**. The samples were stored in the freezer at - 4°C or in a desiccator depending on the type of analysis concerned.

Statistical Analysis

A General Linear Model was used to analyse the data on the quality with the software STATISTICA 7.0 (Statsoft Inc, Tulsa - USA Headquarters). This software was used to know the level of meaning of observed differences. The homogeneity of the studied parameters was determined by the comparison of the averages according to the test of Duncan at the threshold of 5%.

3. Results

Residual effects of soil fertilizers on agronomic characteristics

Yavo variety case: Cowpea fertilization levels resulted in a significant increase at the 5% threshold in agronomic parameters (Table 1). The best yield (51.66±0.99 against 39.66 ± 0.84 t/ha without fertilizer) and tuberized roots average weight per plant (7.75 ± 1.09 against 15.16 ± 1.10 kg/plant without fertilizer) was obtained with residual effect of cowpea at 250, 000 plants/ha (F4). Moreover, the best number of tuberized roots per elementary plot (NT) was obtained with 62, 500 plants/ha (F2) which increased this number from 42 ± 5 without fertilizer to 57 ± 4 roots. Regarding poultry manure, fertilization levels resulted in an increase in agronomic parameters. The best residual effect of this organic fertilizer was obtained with 5 t/ha (F5) on the yield, 15t/ha (F7) on the TAWPand 10 t/ha (F6) on theNT. Indeed, the yield, the TWAPand NT were increased, respectively, from 39.66 ± 0.84 (F1) to 48.28 ± 1.63 t/ha (F5); 7.75±1.09 (F1) to 13.28±0.66 kg/plant (F7) and 42 ± 5 (F1) to 52 ± 3roots per elementary plot (F7).

BoCou 1 variety case: The table 2 shows that the best residual effect of Cowpea fertilization was obtained with 250, 000 plants/ha (F4) on yield with increasing from 45.24 ± 0.45 (F1) to 56.63±0.72 t/ha and TWAP with increasing from 8.81±1.18 (F1) to 14.68±0.31 kg/plant. On the other hand, the density 125, 000 plants/ha (F3) induced the best effects on NT with increasing from 45 ± 1 (F1) to 53±2. Poultry manure caused an increase in all agronomic parameters. The highest value observed (14.22±1.05 kg/plant) represents the best residual effect which was obtained with 10t/ha (F6) on the TWAP. In addition, the best residual effect was obtained with 15 t/ha (F7) on yield (57.44 ± 1.50 t/ha) and 5 t/ha (F5) on NT (62±3 roots per elementary plot).

Yacé variety case: The variation in agricultural yield, average root weight per plant and number of tuberous roots of the Yacé variety as a function of different levels of fertilization with cowpea and poultry manure is presented in the table 3.

The cowpea treatment F4 (250, 000 plants/ha) resulted in the highest value being obtained with the TWAP (from 3.52 ± 0.14 (F1) to 15.60±0.19 kg/plant). On the other hand, this legume significantly increased the yield from 16.03 ± 1.02 (F1) to 28.33 ± 1.33 t/ha and NT from 28 ± 3 to 43 ± 1 with 62, 500 plants/ha (F2). The best value of the yield (41.61 ± 0.40 t/ha) and NT (53 ± 3) in the case of poultry manure were obtained with 5 t/ha (F5). Regarding the TWAP, the best residual effect was obtained with 15 t/ha (F7). This treatment made it possible to go from 3.52 ± 0.14 (F1) to 15.35 ± 0.36 kg/plant.

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Table 1: Residual effect of organics soil fertilizers on the agronomics characteristics of Yavo

Treatments	*Yield (t/ha)*	*TWAP (Kg/plant)*	*NT*
F1	39.66 ±0.84a	7.75±1.09a	42±5a
F2	50.43±0.03c	15.10±1.66b	57±4c
F3	47.86±0.20bc	14.72±1.17b	52±1bc
F4	51.66±0.99c	15.16±1.10b	51±3bc
F5	48.28±1.63c	12.98±1.21b	48±2b
F6	47.66±0.45bc	12.99±0.86b	52±3bc
F7	44.10±0.38b	13.28±0.66b	43±1ab

Table 2: Effect of organics soil fertilizers on the agronomics characteristics of BoCou1

Treatments	*Yield (t/ha)*	*TWAP (Kg/plant)*	*NT*
F1	45.24±0.45a	8.81±1.18a	45±1a
F2	50.78±0.47b	12.22±0.43b	47±2ab
F3	49.33±0.65b	13, 70±1, 11b	53±2cd
F4	56.63±0.72c	14.68±0.31b	53±1cd
F5	50.35±2.51b	14.14±0.49b	62±3e
F6	49.30±1.01b	14.22±1.05b	49±2bc
F7	57.44±1.5c	13±1.09b	60±1de

Table 3: Effect of organics soil fertilizers on the agronomics characteristics of Yacé

Treatments	*Yield (t/ha)*	*TWAP (Kg/plant)*	*NT*
F1	16.03±1.02a	3.52±0.14a	28±3a
F2	28.33±1.33c	11.33±0.73b	43±1c
F3	21.20±2.33b	11.62±0.81b	43±1c
F4	25.26±2.07c	15.60±0.19c	42±1c
F5	41.61±0.40d	13.83±0.62bc	53±3d
F6	26.48±2.30c	14.45±0.27c	38±2bc
F7	24.66±1.22bc	15.35±0.36c	33±2ab

F1: without fertiliser, F2: Cowpea 62, 000 plants/ha, F3: Cowpea 125, 000 plants/ha, F4: Cowpea 250, 000 plants/ha. F5: poultry manure 5 t/ha, F6: poultry manure 10 t/ha. F7: poultry manure 15 t/ha, TWAP: tuberized roots average weight per plant, NT: number of tuberized roots per elementary plot. The data for seven (7) levels of fertilization on the same colonn with the different letters in small letter, for each category of effect, are significantly different ($p \leq 0.05$).

Residual effect of soil fertilizers on physico - chemical characteristics

Yavo variety case: The residuals effects of treatments on the dry matter, ash, Starch, reducing and total sugar content of Yavo was shown in Table 4. The legume Cowpea residual effect significantly increased the dry matter, ash and Starch content. The ash content is highly increased around 470.30% (from 1.1±0.19 (F1) to 6.27±0.03%) with 250 000 plants/ha (F4). In poultry manure, the levels of fertilization led to a significant increase in physico - chemical parameters. In fact, the residual effect of 15t/ha (F7) of poultry manure was better with the significant increasing in ash content of 433.33% (from 1.1±0.19 (F1) to 5.87±0.02%).

Table 4: Effect of organics soil fertilizers on the Physico - chemical characteristics of Yavo

Treatments	*Dry Matter (%)*	*Lipid (%)*	*Ash (%)*	*A (%)*	*Reducing sugar (%)*	*Total sugar (%)*
F1	25.82± 2.42a	1.66±0.31cd	1.10± 0.12a	85.02± 1.02a	1.16±0.14ab	23.63±0.55d
F2	41.60± 1.36d	0.79± 0.73a	2.95± 0.61bc	86.39± 0.04ab	1.11a	25.42±0.44f
F3	36.38± 1.03b	1.85± 0.04d	2.46±0.27b	89.24± 1.63de	1.12±0.84a	23.64±0.4d
F4	41.47±1.31d	1.50±0.07bc	6.27± 0.16d	86.15± 0.02ab	1.99±0.84c	22.50±0.46c
F5	37.59±0.48b	1.33±0.79b	3.37± 0.35c	87.09± 0.13bc	1.16±0.5ab	21.72±0.75b
F6	41.18±1.37cd	3.59±0.82e	3.59±0.13c	88.33±0.02cd	2.11±0.09c	19.13±0.40a
F7	40.06±1c	1.33±0.55b	5.87±0.24d	89.81±0.21e	1.46±0.02b	24.75±0.63e

F1: without fertiliser, F2: Cowpea 62, 000 plants/ha, F3: Cowpea 125, 000 plants/ha, F4: Cowpea 250, 000 plants/ha. F5: poultry manure 5 t/ha, F6: poultry manure 10 t/ha. F7: poultry manure 15 t/ha, A (%): Starch rate. The data for seven (7) levels of fertilization on the same colonn with the different letters in small letter, for each category of effect, are significantly different ($p \leq 0.05$).

BoCou1 variety case: The results of the residual effect of treatments with the Cowpea vegetable showed a significant increase in dry matter, lipids and total sugar content. In poultry manure, fertilization levels resulted in a significant increase in dry matter, ash and reducing and total sugar content (Table5). With the Cowpea vegetable, the density of 125, 000 plants/ha (F3) had the most beneficial residual impact which resulted in the increase of 95.50% (from 1.11±0.95 (F1) to 2.17±0.16%) lipid content. As for poultry manure residual effect, the level of 15t/ ha (F7) of this fertilizer resulted in the most beneficial increase of 108.46% (from 2.57±0.38 (F1) to 5.36±1.06%) on reducing sugars.

Yacé variety case: The residual effects of treatments on the physico - chemical characteristics of Yacé was shown in Table 6. The legume Cowpea significantly increased the lipids content of 164.66% (from 0.94±0.21 (F1) to 2.50±0.19%) with residual effect of 125, 000 plants/ha (F3). That increase is the highest. In addition, cowpea significantly increased the dry matter, ash, Starch and total sugar content. In terms of the residual effect with poultry manure, the levels of fertilization led to a significant increase in physico - chemical parameters. This is the case for the dry matter, ash and lipids content. The residue influence of 5t/ha (F5) is the most beneficial. This resulted in an increase in the lipid content of 183.04% (from 0.94±0.21 (F1) to 2.67±0.62%).

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Table 5: Effect of organics soil fertilizers on the Physico - chemical characteristics of BoCou1

Treatments	*Dry Matter (%)*	*Lipid (%)*	*Ash (%)*	*A (%)*	*Reducing sugar (%)*	*Total sugar (%)*
F1	30.52±1.84b	1.11±0.95bc	2.76±0.30ab	86.31±0.02a	2.57±0.38c	22.79±0.18ab
F2	40.75±0.45e	0.70±0.59a	3.43±0.5b	86.96±1.61a	1.81±0.27b	24±0.63c
F3	36.81±0.13d	2.17±0.16d	3.22±0.21b	86.78±0.11a	1.23±0.24a	23.11±0.12b
F4	35.90±0.18d	1±0.16b	2.67±0.11ab	85.93±0.74a	1.36±0.38a	22.23±0.26a
F5	36.36±1.06d	1b	5.42±0.26c	86.21±1.74a	3.17±0.96d	24.36±0.04cd
F6	34.34±0.84c	1.33±0.15c	2.31±0.0a	86.24±2.05a	3.52±0.41e	22.31±0.36a
F7	28.62±0.13a	1.33± 0.19c	3.50±0.17b	87.13±0.47a	5.36±1.06f	24.63±0.36d

F1: without fertiliser, F2: Cowpea 62, 000 plants/ha, F3: Cowpea 125, 000 plants/ha, F4: Cowpea 250, 000 plants/ha. F5: poultry manure 5t/ha, F6: poultry manure 10 t/ha. F7: poultry manure 15 t/ha, TWAP: tuberized roots average weight per plant, NT: number of tuberized roots per elementary plot. The data for seven (7) levels of fertilization on the same colonn with the different letters in small letter, for each category of effect, are significantly different ($p \leq 0.05$).

Table 6: Effect of organics soil fertilizers on the Physico - chemical characteristics of Yacé

Treatments	*Dry Matter (%)*	*Lipid (%)*	*Ash (%)*	*A (%)*	*Reducing sugar (%)*	*Total sugar (%)*
F1	28.76±1.32a	0.94±0.21b	2.51±0.10a	85.64±0.49a	2.25±0.16de	24.10±0.63b
F2	37.83±0.75c	1.14±0.13b	2.90±0.07ab	87.66±0.33c	1.59±0.89c	25.42±0.42c
F3	45±1e	2.50±0.19d	3.33±0.08ab	88.33±0.63c	0.14±0.70a	27.37±0.24d
F4	39.94±0.66d	1.82±0.10c	4.44±0.26cd	86.98±1.11bc	1.17±0.59b	23.98±0.14b
F5	32.98±1.03b	2.67±0.62d	5.18±0.86d	85.91±1.45ab	1.96±0.97d	20.16±1.11a
F6	40.52±.90d	0.66±0.09a	2.53±1.20a	85.11±1.31a	2.31±0.08e	19.91±0.94a
F7	32.45±0.52b	1±.03b	3.77±0.30bc	85.32±2.03a	2.51±0.05e	23.60±1.31b

F1: without fertiliser, F2: Cowpea 62, 000 plants/ha, F3: Cowpea 125, 000 plants/ha, F4: Cowpea 250, 000 plants/ha. F5: poultry manure 5 t/ha, F6: poultry manure 10 t/ha. F7: poultry manure 15 t/ha, TWAP: tuberized roots average weight per plant, NT: number of tuberized roots per elementary plot. The data for seven (7) levels of fertilization on the same colonn with the different letters in small letter, for each category of effect, are significantly different ($p \leq 0.05$).

4. Discussion

Agronomics characteristics

The residual effect results of cowpea and poultry manure show that yield, MMRT and NRT were significantly increased for all cultivated varieties. This performance is linked, on the one hand, to the characteristics of the genotype and, on the other hand, to the additional supply of nutrients in the soil by the addition of poultry manure [**30**]. Indeed, the addition of fertilizers increases the speed of plant growth and production. The good level of decomposition of cowpea debris and poultry manure makes available the major nutrients that promote the growth and good development of the plant as shown by **Feller [31]**. In fact, the process of decomposition of this debris would have resulted in good nitrogen mineralization by soil microorganisms. Subsequently, the availability and assimilation of nitrogen by the plant would explain the increase in yield, MMRT and NRT. **Onana [32]** and **Tendonkeng *et al*. [33]** confirmed these observations. Moreover, the same observations were made on the agro - morphological characteristics of strict upland rice [**34**]. **Lawlor *et al*. [35]** highlighted the positive impact of the use of poultry manure on the production potential of cassava. Other authors go in the same direction by highlighting the increase in the biomass of herbaceous and starchy plants with higher levels of nitrogenous fertilizers **[36, 37]**.

Physico - chemical characteristics

The contents of dry matter, lipids, ash, starch, total sugars and reducing sugars increased with the after - effect of cowpea or poultry manure. The increases in these parameters are due to a better development of the aerial parts of the plant, which led to obtaining a higher leaf area index by the availability, and assimilation of the nutrients brought to the soil with organic fertilization [**37**]. Indeed, organic fertilizers such as cowpea and poultry droppings enrich the soil with mineral elements such as nitrogen, phosphorus, calcium, potassium and magnesium, the absorption of which by the plant constitutes ash and is the origin of a good development **[32]**. This good vegetative development of the plant promotes the production of chlorophyll, an essential pigment for photosynthesis, which is a process at the base of all biosynthesis including those of the physico - chemical parameters studied [**33**]. The main reducing sugars of starches are also formed during photosynthesis and are stored in the form of starch, which contributes to the increase in dry matter **[39]**.

Organic fertilizers would have given up their mineral content because of a degradation process between the first and the second cycle [**40**]. This would probably have been done after spreading cowpea debris and poultry droppings during the first cycle. Moreover, the principle of decomposition of organic fertilizers over time as well as their impact on plants would be the basis of the arguments that imply the increase of these physico - chemical properties under the residual effect of poultry manure [**41**]. In fact, although no fertilizer was added for the second crop cycle, the availability of nutrients in the soil would be due to a process of mineralization of poultry manure, initiated from the first crop cycle. **Gnahoua [42]** made similar observations during his analysis on integrated soil fertility management. This author confirmed the availability and assimilation by cassava of nutrients resulting from the decomposition of organic fertilizers. In the specific case of

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starch content, the authors **Doue *et al*. [3]** corroborated the increase observed in certain varieties of cassava. According to them, the Yavo variety associated with legumes like groundnut and the addition of manure can be recommended as an appropriate agronomic technology for starch production.

5. Conclusion

This study is a contribution to improving the agronomic and physico - chemical parameters of cassava by the residual impact of the non - combined use of organic fertilizers. This improvement depends on the variety in play and the type of fertilization.
In this work, it appears that the after - effects of cowpea sowing densities and poultry manure doses increased in the three varieties, yield, average mass and number of tuberous roots.

The residuals effects of cowpea were reflected in the increase in dry matter and total sugar content for all varieties, ash and starch content in the Yavo and Yacé varieties, lipid content in BoCou 1 and Yacé and reducing sugar content at Yavo. Poultry droppings led to an increase in dry matter and ash content for all varieties, reducing sugar content in Yavo and BoCou 1 and specifically, the starch and total sugar content in Yavo as well as the in lipids at Yacé.

This study opens the way to strengthening food security by intensifying the production of quality cassava using organic fertilizers. It is essential to put natural fertilizers back at the heart of agricultural systems. It would therefore be necessary to extend the study of the influence of these fertilizers to other biochemical and rheological parameters so that the hypotheses put forward in an attempt to explain the causes of modification of the physico - chemical parameters of cassava tuberous roots are based on data that are more accurate.

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