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Effect of rice/cassava rotation on agronomic parameters of rice and cassava grown on Ferralsol in western Côte d'Ivoire

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Abstract

The rice/cassava rotation is one of the dominant rice-based cropping systems in western Côte d'Ivoire due to the inaccessibility of chemical fertilisers. The low productivity of this cropping system makes it necessary to think about improving agronomic performance. The objective of this study is to determine the effect of the rice/cassava rotation on the agronomic parameters of these crops. To achieve this objective, an agronomic trial was set up at the CNRA Research Station in Man on a Ferralsol. Five cropping sequences were compared in a Fischer block design with 5 treatments and 4 replications: 2 intensive monocultures of rice (0.20 m × 0.20 m) and cassava (1 m × 1 m) and 3 alternations of rice and cassava (R/M/R, M/R/M and R/R/M (farmer control)). The parameters measured were height, tillering, and yield of rice and cassava, as well as soil chemical parameters. The results showed that rice in rotation with cassava had a significant effect on cassava production, while cassava had no significant effect on rice grain yield. The rice-cassava rotation harmed soil chemical parameters. Except for the improvement of nitrogen and phosphorus contents due to biochemical reactions in the rhizosphere and the mobility of nutrients along the fertility gradient. Finally, R/M/R was found to be the best cropping sequence in a rice-based cropping system.

Keywords: Rotation; Previous crop; Performance; Ferralsol; Man; Côte d'Ivoire

1. Introduction

Rice is the most consumed and cultivated cereal in Côte d'Ivoire. However, Ivorian rice production, estimated at 918,000 tonnes of milled rice, only covers 51% of national consumption needs [1]. To meet all the needs of its population, the country, therefore, resorts to imports. This policy is not reassuring, however, given the narrowness and uncertainty of the world market. Since 2012, the Ivorian government has therefore initiated and implemented a national rice development strategy (SNDR), the short-term objective of which is rice self-sufficiency by 2020.

More than 57% of rice production in Côte d'Ivoire is rainfed [2]. This form of rice cultivation is mostly traditional and characterized by crop associations and rotations. The characterization of rice-based cropping systems revealed that rainfed rice is mainly associated with maize and vegetable crops in the south, center-west, and north of the country, while it is mainly associated or alternated with cassava in the west of the country [3, 4, 5, 6]. However, the extensive

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dynamics of these cropping systems place objective limits on the sustainability of the production systems. This is why some farmers, concerned about the restriction of arable land and soil fertility, opt for crop rotation (alternating crops) addition to crop rotation. Crop rotation plays a key role in managing and maintaining soil fertility, improving soil structure [7, 8] and organic matter content [9, 10], improving water use efficiency [11], increasing mycorrhizal associations [12]. However, very little work has been done on the characterization of the rice/cassava rotation. It is in this context that this work was proposed to evaluate the agronomic performance of the rice/cassava rotation in the department of Man in western Côte d'Ivoire. Specifically, it aimed to evaluate the effect of rice cultivation on cassava yield, to evaluate the effect of cassava on rice grain yield, and determine the impact of the rice/ cassava rotation on soil chemical parameters. Ultimately, this study should show the best sequence for the rice/cassava rotation.

2. Material and methods

2.1. Study area

The study was conducted at the CNRA research station in Man, western Côte d'Ivoire (N 070 20' 58'', W 070 36' 05'' and 337 m altitude) on the mid-slope of a 200 m toposequence. The single-mode rainfall regime starts in March and ends in October, followed by a dry season from November to February. The initial vegetation of the experimental site is a fallow of fewer than 5 years, with a predominance of *Panicum maximum*. The soil is not very humus-rich, with a sandy-clay texture on the surface (0-20 cm) and a sandy-clay texture at depth (20-60 cm). It has good internal drainage and is loose in the superficial horizons (0-5 cm). However, the rate of coarse elements is high (> 50%) between 20 cm and 60 cm in the depth. These coarse elements are essentially manganese nodules.

2.2. Plant material

The plant material consists of a rice variety and a cassava variety. The improved rice variety selected is IDSA 10. IDSA 10 has a short cycle (sowing-maturity cycle 105 days), a potential yield of 4 t ha^{-1}, and a height at maturity of 110-115 cm. The improved cassava variety selected is BOCOU 5. The BOCOU 5 variety has an erect habit, a planting-harvest cycle of 12 months, and an estimated potential yield of 40 t ha^{-1}.

2.3. Experimental design

The trial was conducted in a Fisher block design, with 5 treatments and 4 replications. The factor studied was the effect of crop rotation. Each micro plot has an area of 15 m^2 (5 m × 3 m). The randomized treatments within the block were separated by 1 m. The four (04) replicates were spaced 2 m apart, in total 20 micro plots. The treatments were as follows:

Table 1 Treatments and crop rotation over the 3 years of experimentation (2016, 2017, and 2018)

Treatments	Crop succession over the 3 years
T1	Rice / Rice / Rice
T2	Cassava/ Cassava / Cassava
T3	Rice / Cassava / Rice
T4	Cassava / Rice / Cassava
T5 (On-farm control)	Rice/ Rice / Cassava

2.4. Setting up the agronomic test

Following the preparation of a 500 m^2 plot (land clearing and debris collection), a shallow ploughing (0-20 cm) of the soil was carried out with a rotary disc tractor (Foton tractor) after soil sampling using the diagonal method. This was followed by manual ploughing with a hoe to reduce clods and prepare the seedbeds. No fertiliser was applied before planting the crops. The rice was sown in rows of 5 grains per row at spacing of 0.20 m × 0.20 m. The cassava cuttings of 0.20 m were planted in the same row as the rice. The 20 cm cassava cuttings were planted horizontally at a depth of 5 cm synchronously with the rice sowing in micro plots. A total of three (3) cropping cycles were conducted (2016, 2017, and 2018) to assess the effect of the rotation on the agronomic parameters of rice and cassava, as well as on soil chemical parameters. At each harvest, the rice straw was left on the plot to be incorporated into the soil. Observations were made in the yield squares (1m^2) for rice and on the entire useful plot for cassava. The useful plot is obtained after eliminating the cassava border plants in each elementary plot.

2.5. Data collection

2.5.1. Soil sampling and analysis method

Before the experiment, five soil samples were taken from the 0-20 cm horizon using the diagonal method to form a composite sample. After the harvest of the crops, the soil was sampled in the 0-20 cm horizon of each micro plot using the same diagonal method. The soil analyses were carried out according to classical methods. The parameters determined were pH-water measured by the electronic pH meter in a soil/water ratio of 1/2.5. Organic carbon was obtained by the Walkley and Black method [13] and total nitrogen (N_total) by the Kjeldhal method [14]. Exchangeable cations (Ca^{2+}, Mg^{2+}, K^+) were determined after extraction with ammonium acetate (pH = 7) as described by the American Society of Soil Science (SASS)[15]. The available phosphorus content (Pav) was measured by the modified Olsen-Dabin method [16].

2.5.2. Growth and maturity parameters measured on rice

The parameters measured on the rice were carried out in the yield squares (1 m^2). Before the rice was harvested, the growth parameters measured were: sowing cycle - 50% heading, height at harvest, and tillering at harvest. After the rice harvest, the maturity parameters measured are the number of empty and full grains, grain yield, and straw yield.

Grain yield (GY) and straw yield (SY) were adjusted to 14% moisture after sun drying. The total biomass was also calculated by adding the grain yield and straw yield:

$$GY\ (t\ ha^{-1}) = (\text{dry weight of grains (g)} / 15\ m^2) \times (10000/1000000) \times (100-H) \quad \ldots\ldots\ldots\ldots(1)$$

H= Moisture rate

$$SY\ (t\ ha^{-1}) = (\text{dry weight straw (g)} / 15\ (m^2)) \times (10000 / 1000000) \ldots\ldots\ldots\ldots\ (2)$$

$$MST\ (t\ ha^{-1}) = GY + SY \ldots\ldots\ldots\ldots\ (3)$$

2.5.3. Growth and maturity parameters measured on cassava

Data were collected over the entire working plot. Plant height was measured at harvest from the soil surface to the apex. The length and circumference of the tuberized roots were measured with a decameter. Finally, the fresh weight of the tuberized roots was obtained per micro plot.

The yield of tuberized roots was calculated according to the formula proposed by Bakayoko [17]

$$CY\ (t\ ha^{-1}) = TFWTR / SASP$$

With

CY: Cassava Yield
TFWTR: Total Fresh Weight of Tuberized Roots (kg)
SASP: Surface Area of the Sub-Plot (m^2)

2.6. Statistical analysis

The mean values of height, tillers, and yield were subjected to an analysis of variance to determine the effect of crop precedent on these agronomic parameters of rice and cassava. All this was done using SAS version 9 software at the 5% threshold.

3. Results

3.1. Impact of rice/cassava rotation on soil chemical properties

Table 2 shows the results of the soil chemical analysis. An increase in soil acidity was noted with the reduction in organic carbon, calcium, magnesium, and potassium content of the soil after cultivation. However, an improvement in nitrogen (1.8 g kg-1) and available phosphorus (37ppm) content was observed.

The pH-water value decreased by 0.4 units after the experiment, while the nitrogen value increased (0.4 g kg-1) and the available phosphorus (14 ppm). Compared to the soil condition, the cation exchange capacity (CEC) increased from 11.23cmol kg^{-1} to 9.73cmol kg^{-1} in the same order as the C/N ratio.

Table 2 Soil chemical status of the trial site before and after the experiment

Variables	**Pre-crop**	**After-cropping**
pH-H2O	4.9	4.5
C (g kg^{-1})	19.1	17.8
N (g kg^{-1})	1.4	1.8
C/N	13.64	9.8
Pav(ppm) Olsen method modified Dabin	23	36.4
Ca^{2}+ (cmol kg^{-1})	0.282	0.283
Mg^{2}+ (cmol kg^{-1})	0.146	0.071
K+ (cmol kg^{-1})	0.128	0.057
CEC (cmol kg^{-1})	11.25	9.73
Ca/Mg	2/1	4/1
K/Mg	1/1	1/1
(Ca + Mg)/K	3/1	6/1
K/CEC (%)	1.14	0.6

C: Organic carbon, N: Total nitrogen, Pav: Available phosphorus, Ca: Calcium, Mg: Magnesium, K: Potassium, CEC: Cation exchange capacity, --: Not determined.

3.2. Effects of rotation on rice growth and yield

3.2.1. Height of the rice plants

Figure 1 shows the average height of rice plants in rice/cassava rotations over the three cropping cycles. There is no significant effect of the rice/cassava rotation on rice growth at the threshold of α = 0.05.

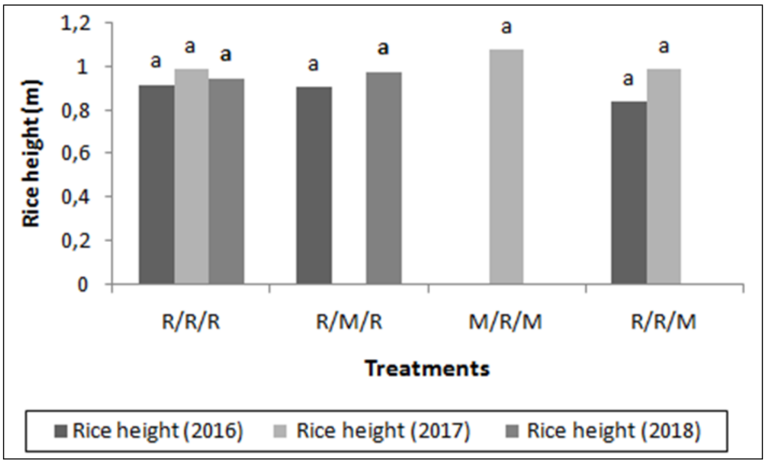


Figure 1 The average height of rice plants in rice/cassava rotations during 03 cropping cycles

3.2.2. Rice tillering

Figure 2 shows the tillering of rice plants in rice/cassava rotations over the 3 cropping cycles. The same trend, no significant effect of the rice/cassava rotation on the tillering of rice plants at the threshold of α = 0.05.

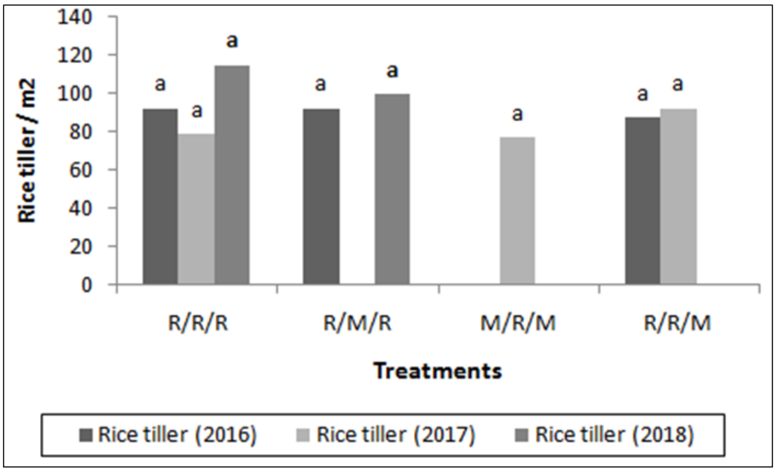


Figure 2 Average rice tillering in rice/cassava rotations for each cropping cycle

3.2.3. Rice grain yield

Figure 3 shows the average rice grain yield of the rice/cassava rotation for three cropping cycles. There is no significant effect of the rice/cassava rotation on rice grain yield.

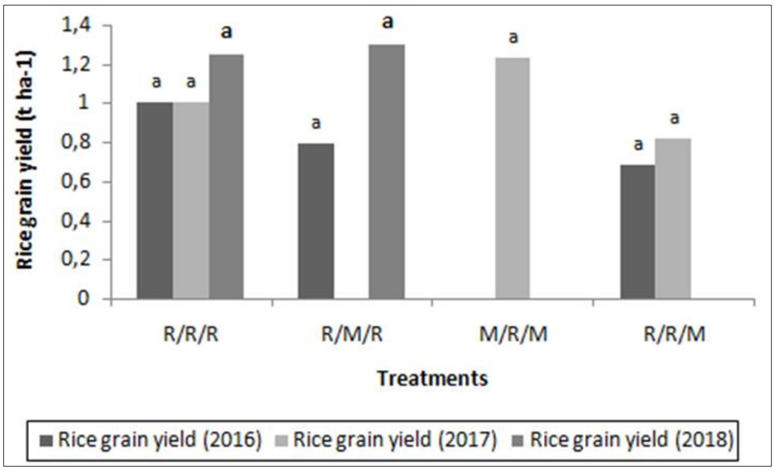
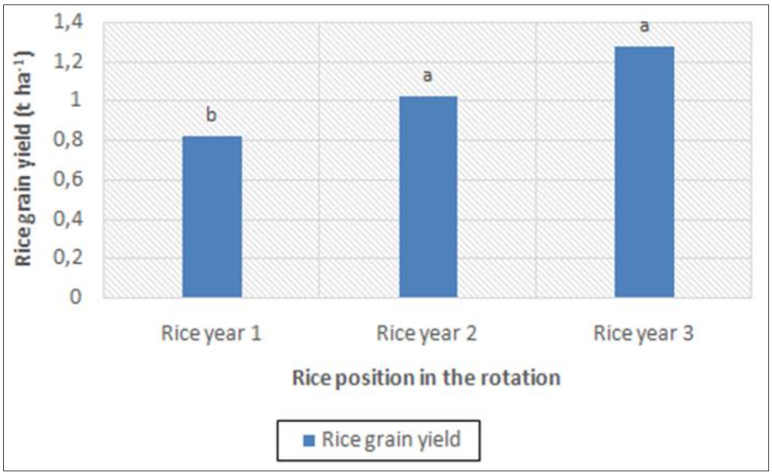


Figure 3 Average rice grain yield (P = 0.09) in rice/cassava rotation for three cropping cycles



The letters a and b indicate mean values that differ significantly at the α = 0.05 threshold.

Figure 4 Rice grain yield o according to the rice position in the rotation (P= 0.02)

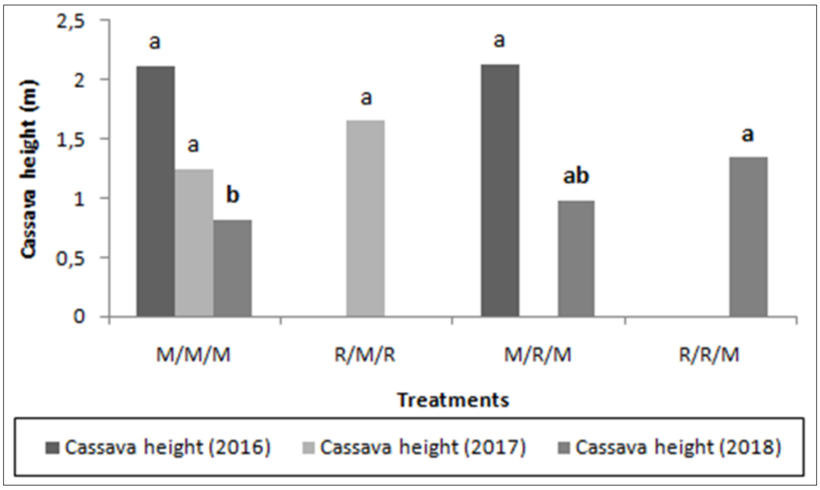
In continuous rice monoculture (R/R/R), no significant difference is noted despite an increasing trend in rice grain yield. For the previous cassava, it did not significantly (P = 0.303) affect rice yield in R/R/R and M/R/M.

Figure 4 shows the evolution of rice grain yield according to the position of rice in the succession. There is a significant effect of the position of rice in the succession on rice grain yield (P= 0.02). The grain yield of rice becomes better when rice appears in the third year of rotation.

3.3. Effects of rotation on agro-morphological parameters of cassava

3.3.1. Cassava height

Figure 5 shows the average height of cassava in the rice/cassava rotations over three years of cultivation. There is a significant effect of rotation on cassava growth (P = 0.05). There is a significant difference between the height of cassava in the R/R/M rotation and the other rice/cassava rotations according to the Lsd method.



Letters a and b indicate mean values that are significantly different at the α = 0.05 threshold.

Figure 5 The average height of cassava according to the rice/ cassava rotation during 03 years of cultivation

There is a decreasing trend in the height of cassava in continuous cassava monoculture (M/M/M) while the height is relatively improved after preceding rice as observed in R/M/R, M/R/M, and R/R/M.

3.3.2. Cassava yield

Table 3 The average cassava roots yield in rice/cassava rotation

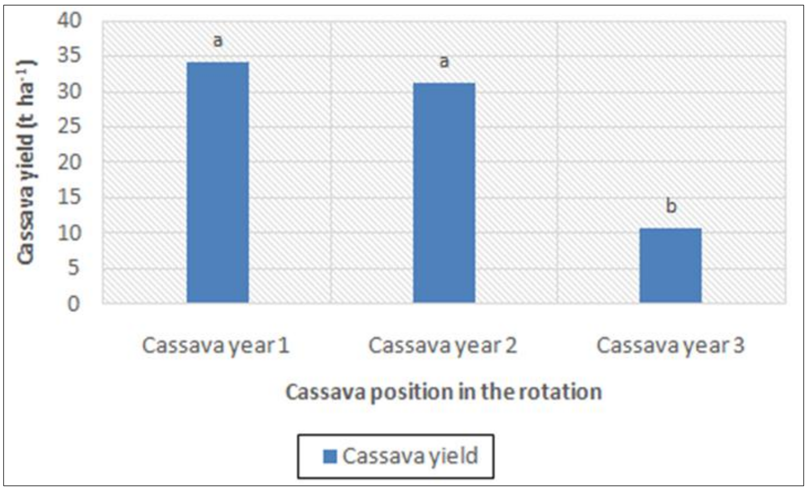
Treatments	Cassava root yield(t ha^{-1})		
	2016	2017	2018
R/R/R	--	--	--
M/M/M	30.50a	25.18b	7.40b
R/M/R	--	37.30a	--
M/R/M	37.93a	--	9.25b
R/R/M	--	--	15.51
GM	34.22	31.24	10.72
CV	22.49	38.21	28.59
P > F	0.221	<0.0001	0.011

The letters a and b in the same column indicate mean values that are significantly different at the α = 0.05 threshold.

Le Table 3 presents the average cassava root yield in the rice/cassava rotations. There is no significant difference between the average tuberized root yields in the rice/cassava rotations in 2016. However, in 2017 and 2018, there is a significant effect of this cropping alternation on cassava root yields for the rice/cassava rotations at the threshold of $\alpha = 0.05$.

The preceding rice (R/M/R, M/R/M and R/R/M) appears to have a better effect on cassava yield than cassava monoculture (M/M/M). One year of rice (R/M/R) at the head of the rotation appears to be much better than two years before cassava (R/R/M).

Figure 6 presents the cassava yield according to the position of cassava in the succession. There is an effect of cassava position on cassava root yield (P<0.0001). This yield becomes very low when cassava is grown in the third year of the rotation.



The letters a and b indicate mean values that differ significantly at the α = 0.05 level.

Figure 6 Cassava root yield according to the cassava position in the rotation

4. Discussion

The soil in the experiment, which was initially low in acidity (pH= 4.9), showed an increase in this characteristic during cultivation (pH= 4.5). An improvement in the content of nitrogen and available phosphorus was observed, although the content of organic matter and exchangeable bases was reduced. It is difficult to understand the improvement in the content of available nitrogen and phosphorus when there was a reduction in the content of organic matter. However, this could be argued on the one hand by the mid-slope position of the plot which can benefit from the mobility of nutrients along the fertility gradient [18] and on the other hand by biochemical phenomena prevalent in the rihzosphere. Another approach would be the fact of rapid mineralization leading to the increase of the nitrogen content at the end of a crop cycle as observed while geochemical changes would occur at the level of clay minerals transforming for example kaolinite into illite or smectite. Indeed, on the top and upper slopes of the landscape, Ferralsols are characterized by kaolinitic clay depending on the nature of the bedrock and the intensity of hydrolysis [19]. It is assumed that the vegetation cover resulting from the rotation of the two crops probably reduced the hydrolysis effect causing an evolution from kaolinite to gibbsite by insertion of Al and Mg in particular in the network (isomorphic substitution). Hence the increase in the surface area and the specificity of the clay resulted in a higher exchange capacity as described by Brindley [20] and Bailey [21]. This analysis allows us to understand the degrading effect of deforestation on the quality of the soil, since the clearing of the land caused a retrogradation of the clay mineral to a less reactive type in a short period, contrary to the vegetation cover effect deduced during this study.

The rotation had no negative effect on height, tillering and grain yield of rice as reported by Suprihatin [22]. In other words, no significant difference between the grain yield of rice on the rice and cassava precedent was observed. This fact could be explained by the incorporation of rice straw into the soil [23]. According [24,25], the incorporation of rice straw allowed for nutrient recycling and improvement of soil quality. Also, rice has large root biomass that can maintain a good level of soil organic matter. Although cassava is known to be a soil-draining crop, its after-effect on rice yields was not detrimental to the previous crop. Indeed, soil loosening, phosphorus decomplexation through cassava endomycorrhizal, and the amount of organic matter left after cassava harvest would partly justify this result [26].

However, the effect of rotation on cassava height and root yield was significant. The rice crop precedent had a positive impact on cassava growth and yield. In other words, the after-effect of the rice crop was beneficial for cassava production. Indeed, rice crop residues allow nutrient recycling and improve soil fertility for the succeeding rice crop [23, 26]. These results are in agreement with those of zadi[27]; West and Post [28] who demonstrated the positive effect of burying rice straw on the production of the succeeding crop. In any case, the improvement of cassava yields on previous rice has been proven since the two crops (rice and cassava) do not have the same nutrient requirements. Cassava requires a large amount of potassium to complete its cycle, while rice requires a high amount of nitrogen. In terms of the horizons explored, the rice plant mainly captures its nutrients in the superficial horizon, whereas the cassava plant can explore deep layers in search of mineral resources. The grain yield of continuous monoculture rice (R/R/R) has an increasing trend due to the incorporation of rice crop residues (straw and root biomass). This is in contradiction with the work of Becker and Johnson [29], who found that continuous monoculture of rice without soil fertilization leads to a reduction in yield. Also, the ICDF survey [30], showed that rice cultivation disappeared from the cropping sequence in the third year, as production dropped tragically. This increasing trend of intensive monoculture rice production could be partly explained by climatic conditions.

Indeed, rainfall at the rice heading was higher in 2016 (374.9 mm) and 2017 (267.3 mm) than in 2018 (211.4 mm). High rainfall is detrimental to heading and harvesting [31]. On the other hand, the yield of the continuous cassava monoculture (M/M/M) has decreased over the years of cultivation. This was mainly due to soil depletion, as climatic conditions were favorable for a good harvest. Tongglum[32] showed that intensive monoculture of cassava without fertilizer application would reduce cassava yield. Compared to continuous monoculture, the rotation has a positive impact on rice and cassava production. In addition, the previous rice crop was a significant determinant in cassava production.

The productivity of these cropping sequences would depend on the base crop. Indeed, in a rice-based cropping system, the R/M/R cropping sequence would be the most efficient. This raises the question of how these rice/cassava rotations behave under fertilization.

Thus, for sustainable rice production through more rational land use, the rice/cassava rotation system would be an alternative for achieving food security.

5. Conclusion

The study of the effect of the rice/cassava rotation on the agronomic parameters of rice and cassava grown on Ferralsol has made it possible to highlight the performance of this cropping system. This work shows that rice cultivation has had a positive effect on cassava production. Rice cultivation was a good cultural precedent for cassava production, whereas cassava cultivation had no significant effect on rice production. These results showed a tragic reduction in the yield of the continuous cassava monoculture over the years of cultivation, while that of the continuous rice monoculture showed an increasing trend.

Except for the improvement of available nitrogen and phosphorus levels due to biochemical reactions in the rhizosphere and the mobility of nutrients along the fertility gradient, the rice/cassava rotation harmed soil chemical parameters. And the R/M/R sequence would be the best alternation of rice and cassava in a rice-based cropping system. However, further studies are needed to assess the carbon sequestration of this rotation system in the context of climate change.

Compliance with ethical standards

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Disclosure of conflict of interest

No conflict of interest

References

[1] FAO. 2016. Rice production/consumption in Côte d'Ivoire. FAOSTAT online. (show http://faostat.fao. org). Rome.

[2] ONDR. 2017. Statistics and production. Available at http://www.ondr.ci/sndr 20122020.php. consulted 02/01/2016.

[3] N'Da K. L. 2001. Study of traditional crop associations: the case of the rice-maize association in Dikodougou. D.U.T. thesis, URES of Korhogo, Université de Bouaké, Côte d'Ivoire, 26 p

[4] Camara M. and Koffi Y. A. 2004. Monograph of the semi-mountainous region of western Côte d'Ivoire, pp. 8-11.

[5] Bahan F. 2012. Characterization of rainfed rice-based crop associations: case of the sub-prefecture of Gagnoa. DEA thesis in pedology. Université Félix Houphouët-Boigny de Cocody. Abidjan (Côte d'Ivoire). 52 p

[6] Konan K.U., Koné B., Konan K. F., Keli Z. J., Bouet A., Yao-Kouamé A. 2021. Improvement of Intercropping Performance Assessment in a System with Difference of Crops' Cycle Durations: Calculation Methods for Rice-cassava Association. Journal of Food and Nutrition Research, Vol. 9, No. 5, pp : 251-257

[7] Raimbault, B.A., and T.J. Vyn. 1991. Crop rotation and tillage effects on corn growth and soil structural stability. Agron. J. 83:979–985

[8] Zhang S.; Li Q.; Zhang X.; Wei K.; Chen L.; Liang W. 2012. Effects of conservation tillage on soil aggregation and aggregate binding agents in black soil of Northeast China. Soil Tillage Res. 124, 196–202.

[9] Bremner E., Janzen H.H., Ellert B.H., and McKenzie R.H. 2008. Soil organic carbon after twelve years of various crop rotations in an Aridic Boroll. Soil Sci. Soc. Am. J. 72:970–974.

[10] Azuka C.V.; Obi M.E. 2014. Runoff-infiltration processes and some physical properties of Degraded Ultisol under different soil and crop management practices in Nsukka, South Eastern Nigeria. Acad. Res. J. Agric. Sci. Res. 2, 67–75.

[11] Tanaka, D.L., Anderson, R.L. and Rao, S.C. (2005) Crop sequencing to improve use of precipitation and synergize crop growth. Agronomy Journal, 97, 385-390.

[12] Johnson, N.C., P.J. Copeland, R.K. Crookston, and F.L. Pfleger. 1992. Mycorrhizae: Possible explanation for the yield decrease with continuous corn and soybean. Agron. J. 84:387–390.

[13] Walkley A. and Black I. A. 1934. An examination of Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Sci, 37: pp. 29 – 38.

[14] Bremner J.M. 1996. Nitrogen - Total. In: Sparks DL (ed) Methods of Soil Analysis, part 3 Chemical methods. American Society of Agronomy, Madison, WI, pp. 1085-1121.

[15] Page A.L., Miller R.H and Keeney D.R. 1996. Methods of soil analysis, chemical and microbiological properties. Part 2. ASA Monograph No. 9. 2nd ed. American Society of Agronomy, Madison (WI). P. 154

[16] Bonneau M., Souchier B. 1994. Pédologie 2. Constituant et propriétés du sol. Deuxième Edition. Masson, Paris, France, p. 665

[17] Bakayoko S., Kouadio K.K.H., Soro D., Tschannen A., Nindjin C., Dao D., Girardin O. 2012. Fresh tuber yields and dry matter contents of seventy new cassava (*Manihot esculenta Crantz*) varieties grown in central Côte d'Ivoire. Journal of Animal & Plant Sciences, ISSN 2071 – 7024, Vol. 14, Issue 2: 1961-1977

[18] Koné B., Diatta S., Oikeh S., Gbalou Y., Camara M., Dohm D.D and ASSA A. 2009. Estimation of the potential fertility of ferralsols by color: use of color in morphopedology. Canadian Journal of Soil Science, 89 (3), pp. 331-342.

[19] Vendrame, P.R.S., Brito, O.R., Martins, E.S. 2013. Acidity control in Latosols under long-term pastures in the Cerrado region, Brazil. Soil Research, 51, pp. 253–261

[20] Brindley G. W. 1966. Discussion and recommandations concerning the nomenclature of clay minerals and related phyllosilicates. Clay and clay minerals, (14) pp. 27-34

[21] Bailey S. W., Brindley G. W., Johns W.D., Martin R.T., and Ross M. 1971. Summary of national and international recommendations on clay mineral nomenclature. Clay and clay minerals. (19), pp. 129-132

[22] Suprihatin A., Purwanto B H., Hanudin E. and Nurudin M. 2021. Effect of cropping rotation patterns on rice productivity in irrigated rice fields. IOP Conf. Series: Earth and Environmental Science 752 (2021) 012002 doi:10.1088/1755-1315/752/1/012002

[23] Chen S. ; Liu S. ; Zhang X. ; Yin M.; Chu G. ; Xu C. ; Yan J. ; Chen L. ; Wang D. ; Zhang X. 2018. Effect of various crop rotations on rice yield and nitrogen use efficiency in paddy-upland systems in southeastern China. The crop Journal 6, 576-588

[24] Uddin and Fatema. 2016. Rice crop residue management and its impact on farmers livelihood. Progressive Agriculture 27 (2) pp: 189-199

[25] Zuber S.M., Behnke G.D., Nafziger E.D., Villamil M.B. 2015. Crop rotation and tillage effects on soil physical and chemical properties in Illinois. Agron. J. 107, 971–978.

[26] Howeler R.H. 1991. Long-term effect of cassava cultivation on soil productivity. Field Crops Researc h, 26: pp. 1-18.

[27] Zadi F. 2016. Effects of mineral manure and organic amendment on rice yield in a second-order lowland of m'bé foro (central Côte d'Ivoire). Dissertation for the PhD in Pedology at the University of Félix Houphouët-Boigny (Abidjan) Côte d'Ivoire. 171 p

[28] West T.O. and Post W.M. 2002. Soil organic carbon sequestration rates by tillage and crop rotation: A global data analysis. Soil Sci. Soc. Am. J. 66:1930-1946.

[29] Becker M., et Johnson D.E. 2001. Cropping intensity effects on upland rice yield and sustainability in West Africa. NutrcyclAgroecosys 59:107–117.

[30] ICDF-Ivorian Company for the Development of Food. 1993. Baseline Survey for Rice Production in Côte d'Ivoire. Abidjan: ICDF. 99 p

[31] WARDA. 1995. Training in rice production: a trainer's manual. Edition sayce, 33 pp.

[32] Tongglum A., Suriyapan P. and Howeler R.H. 2001. Cassava agronomy research and adoption of improved practices in Thailand – Major achievements during the past 35 years. In Howeler, R.H. and S.L. Tan (Eds.), Cassava's potential in Asia in the 21st century: present situation and future research and development needs. Proc. 6th Regional Workshop, held in Ho Chi Minh city, Vietnam. Feb 21–25, 2000. (in press), pp. 228-258