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Research Article

Effect of Rice Precedent on Cassava Production in the Rice/Cassava Rotation 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 rice precedent effect on the cassava production . 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 crop is a good previous crop for cassava production, while cassava crop had no significant effect on rice production. The rice/cassava rotation harmed soil chemical parameters. Except for the improvement of nitrogen and phosphorus contents due to analysis error and the mobility of nutrients along the fertility gradient. Finally, M/R/M was found to be the best cropping sequence in a cassava-based cropping system.

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

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. More than 57% of rice production in Côte d'Ivoire is rainfed [2]. This form of rice cultivation is mostly traditional and characterised by crop associations and rotations. The characterisation 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 [3-6]. Cassava (Manihot esculenta, Crantz) is an important food security crop and it is an important source of food calories in sub-Saharan Africa, fulfilling a critical role as a food security crop [7] However, the extensive 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 [8,9] and enhancing crop residue and root system diversity, which affect soil biota activities, resulting in improved soil health and soil ecological interactions [10]. However, Numerous studies have reported that the influence of crop rotation on soil quality improvement depends on the type of crops cultivated in a particular rotation system [11,12].

It is in this context that this work was proposed to evaluate the rice precedent effect on cassava production in the department of

Man in western Côte d'Ivoire. Specifically, it aimed to evaluate the effect of rice cultivation on cassavagrowth and yield and determine the impact of the rice/cassava rotation on soil chemical parameters. Ultimately, this study should show that rice cropping is good or bad previous cultural for cassava production.

Materials and Methods

Study area

The study was carried out at the CNRA research station in Man, western Côte d'Ivoire (N 070 20' 58'', W 070 36' 05'' and 337 m in elevation) 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.

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}.

Experimental design

The experiment was conducted in a Randomized Complete Blocks Design (RCBD), of five (5) treatments and 4 replications (blocks). The factor studied was the effect of cultural precedent. Each micro plot has an area of 15 m^2 (5 m × 3 m). The randomised treatments within the block were separated by 1 m. Four replications spaced by 2 m were considered for a total of 20 micro-plots. The treatments were as follows

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

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

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 a 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.

Data collection

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 assimilable phosphorus content (Pass) was measured by the modified Olsen-Dabin method [16].

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}) = (dry weight of grains (g)/15 m^2) × (10000/1000000) × ((100-H)/86---------(1)

H= Moisture rate

SY (t ha^{-1}) = (dry weight straw (g)/15 (m^2)) × (10000/1000000) -------- (2)

MST (t ha^{-1}) = GY + SY -------- (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 tuberised roots, and stem circumference were measured with a decameter. Finally, the fresh weight of the tuberised roots was obtained per micro plot.

The yield of tuberised 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 Tuberised Roots (kg)

SASP: Surface Area of the Sub-Plot (m^2)

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.

Results

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 assimilable phosphorus (37ppm) content was observed.

The pH-water value decreased by 0.4 units after the experiment, while the nitrogen value increased (0.4g 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.

Variables	Pre-crop	After cropping
pH-H_2O	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
Pass (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

Table 2: Soil chemical status of the trial site before and after the experiment C: Organic Carbon, N: Total Nitrogen, Pass: Available Phosphorus, Ca: Calcium, Mg: Magnesium, K: Potassium, CEC: Cation Exchange Capacity, --: Not Determined.

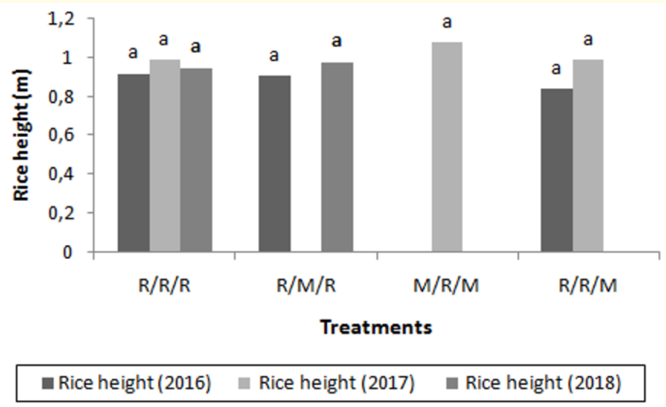

Figure 1: The average height of rice plants in rice/cassava rotations during 03 cropping cycles.

Effects of cropping precedent on rice growth and yield

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 cropping precedent on rice growth at the threshold of α = 0.05.

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 cropping precedent on the tillering of rice plants at the threshold of α = 0.05.

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 cropping precedent on rice grain yield.

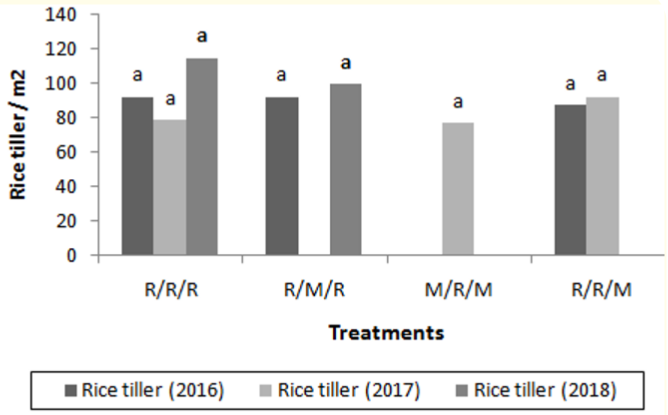

Figure 2: Average rice tillering in rice/cassava rotations for each cropping cycle.

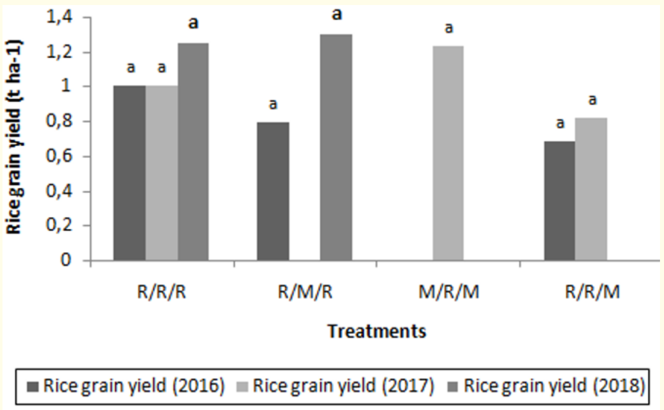

Figure 3: Average rice grain yield (P = 0.09) in rice/cassava rotation for three cropping cycles.

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.

Table 3 presents the effects of cropping precedent on rice yield according to cycle. To cycle 1 and cycle 2, there is no significant effect of cropping precedent on the rice yield.

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.

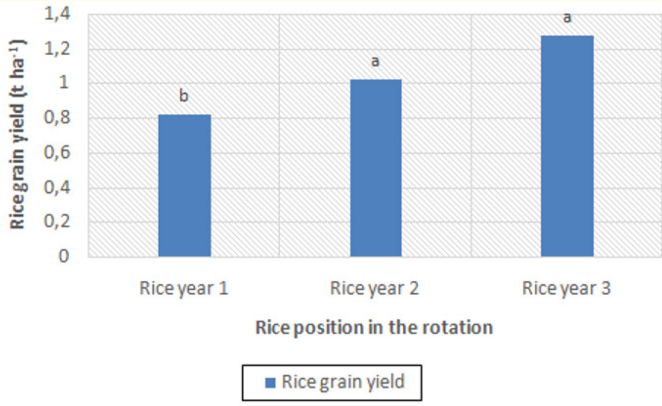

Figure 4: Rice grain yield o according to the rice position in the rotation (P= 0.02).
The letters a and b indicate mean values that differ significantly at the α = 0.05 threshold.

Effects of cropping precedent on agro-morphological parameters of cassava

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 cropping precedent 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.

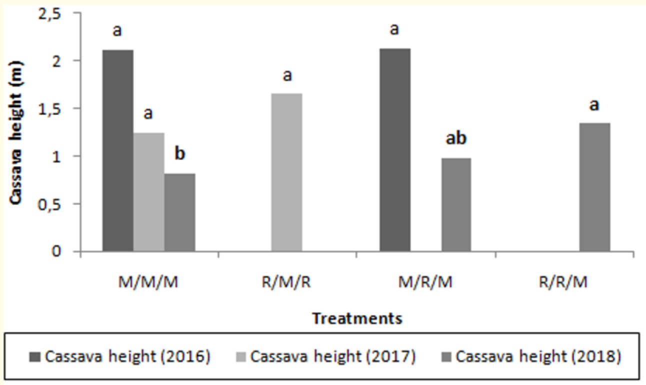

Figure 5: The average height of cassava according to the rice/cassava rotation during 03 years of cultivation.
Letters a and b indicate mean values that are significantly different at the α = 0.05 threshold.

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.

Table 4 presents the effect of cropping precedent on cassava stem circumference. There is no significant effect of cropping precedent on the cassava stem circumference in 2016 and 2017. Nevertheless, there is significant effect of cropping precedent on the cassava stem circumference in 2018. The rice preceding is improved cassava stem circumference.

Treatment	Cassava stem circumference (cm)		
	2016	2017	2018
M/R/M	14.50a	-	7.35ab
R/M/R	-	10.42a	-
R/R/M	-	-	8.92a
M/M/M	13.50a	8.95a	6.40b
GM	14.00	9.69	7.56
CV	12.37	12.19	14.53
P>F	0.445	0.128	0.02

Table 4: Effect of cropping precedent on cassava stem circumference.

Cassava yield

Table 5 presents the average cassava root yield in the rice/cassava rotations. There is no significant effect of fallow on the tuberized root yields in 2016. However, in 2017 and 2018, there is a significant effect of the rice precedent on cassava root yields at the threshold of $\alpha = 0.05$.

Treatment	Cassava roots 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	--	--	15.51a
GM	34.22	31.24	10.72
CV	22.49	38.21	28.59
P > F	0.221	<0.0001	0.011

Table 5: The average cassava roots yield according to cropping precedent.

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

Figure 6 presents effect of cropping precedent on cassava root yield.

Outside the fallow, the rice precedent had presented a positive effect on cassava root yield.

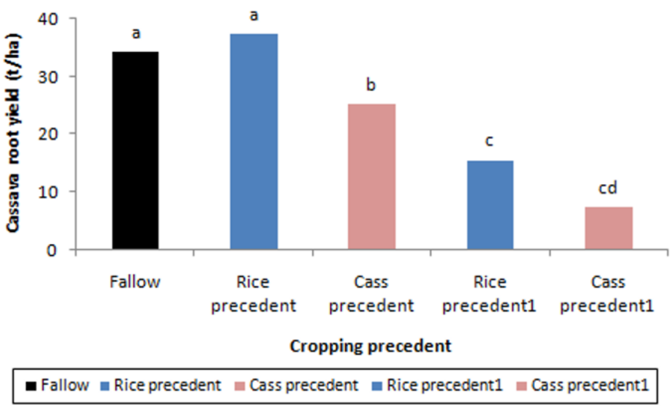

Figure 6: Average of cassava root yield under the cropping precedents

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 7 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.

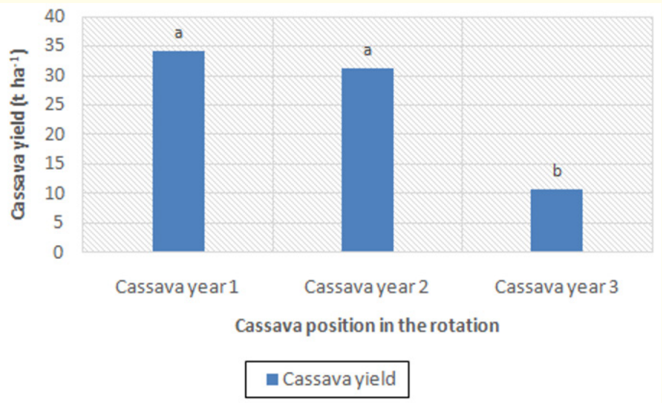

Figure 7: Cassava root yield according to the cassava position in the rotation.

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

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 assimilable 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 analysis error because rice straw bring an important of organic matter and removal on long-term soil fertility is much greater for K than for P. Another approach would be the fact of rapid mineralisation 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 characterised 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., *et al*. [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 previous crop had no negative effect on height, tillering and grain yield of rice as reported by Suprihatin et al. In other words, no significant difference between the grain yield of rice on the rice and cassava previous was observed. This fact could be explained by the incorporation of rice straw into the soil [22]. According [23,24], 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 [25].

However, the effect of previous crop on cassava height and root yield was significant. The rice previous crop 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]. The rice straw had the capacity of recycling valuable components, such as organic matter, nitrozen, phosphorus and potassium like for the micronutrients such as zinc (Zn) and the silicium (Si). Besides according [27] the chemical composition of rice straw is thought be affected by genetic factors (variety) and soil fertility. 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. This is verify by the rice grain yield after the cassava cropping. 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 [28], who found that continuous monoculture of rice without soil fertilisation leads to a reduction in yield. When the yield of the continuous cassava monoculture (M/M/M) has decreased over the years of cultivation. This was mainly due to soil depletion, because comparaison in rice straw the cassava bring in soil a few organic matter. Tongglum [29] showed that intensive monoculture of cassava without fertiliser application would reduce cassava yield. Compared to continuous monoculture, the rice previous has a positive impact on rice and cassava production. Therefore, rice crop is a good previous crop for cassava production. This study concurs with Chen., *et al*. [30] statement that said that increasing the diversity of crop rotations is the predominant approach to overcoming the negative aspects of short cropping sequences and monocultures in intensive cropping systems [31]. Also, cropping rotation, which consists of paddy rice (Oryza sativa L.) and upland crops, has been practiced for years as a primary form of land management to maintain rice production in southeastern China [32,33].

The productivity of these cropping sequences would depend the based cropping system. Indeed, in a cassava-based cropping system, the M/R/M/ cropping sequence would be the most efficient. Rice is known as silicon accumulator and plant benefits much from silicon nutrition [34], it would be interesting to explore in future study the silica in cassava yield elaboration.

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

Conclusion

The study of the effect of rice previous on cassava production in the rice/cassava rotation on ferralsol in western Côte d'Ivoire has made it possible to highlight the performance of this cropping system. This work shows that rice cultivation has a positive effect on cassava production. Rice cultivation was a good crop previous 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 M/R/M sequence would be the best alternation of rice and cassava in a cassava-based cropping system. However, further studies are needed to assess the silica in cassava yield elaboration.

Bibliography

1. FAO. "Production/consommation du riz en Côte d'Ivoire". FAOSTAT en ligne (2016).
2. ONDR. "Statistiques et production (2017).
3. N'Da KL. "Étude des associations culturalestraditionnelles: cas de l'association riz-maïs à Dikodougou". Mémoire de D.U.T., URES de Korhogo, Université de Bouaké, Côte d'Ivoire (2001): 26.
4. Camara M et Koffi YA. "Monographie de la région semi-montagneuse de l'ouest de la Côte d'Ivoire" (2004): 8-11.
5. Bahan F. "Caractérisation des associations culturales à base de riz pluvial : cas de la sous-préfecture de Gagnoa. Mémoire de DEA en pédologie. Université Félix Houphouët-Boigny de Cocody". *Abidjan (Côte d'Ivoire)* (2012): 52.
6. Konan KU., *et al*. "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* 9.5 (2021): 251-257.
7. Haggblade S., *et al*. "Cassava commercialization in southeastern Africa". *Journal of Agribusiness in Developing and Emerging Economies. Journal of Agribusiness in Developing and Emerging Economies* (2012).
8. Zhang S., *et al*. "Effects of conservation tillage on soil aggregation and aggregate binding agents in black soil of Northeast China". *Soil and Tillage Research* 124 (2012): 196-202.
9. Shah KK., *et al*. "Diversified crop rotation: an approach for sustainable agriculture production Advances in Agriculture" (2012): 8924087.
10. Witt C., *et al*. "Crop rotation and residue management effects on carbon sequestration, nitrogen cycling, and productivity or irrigated rice systems". *Plant Soil* 225 (2000): 265-278.
11. Wang L., *et al*. "Effects of seven diversified crop rotations on selected soil health indicators and wheat productivity". *Agronomy* 10.2 (2020): 235.
12. Feng H., *et al*. "Soil quality indicators as influenced by 5-year diversified and monoculture cropping systems". *The Journal of Agricultural Science* (2020): 1-12.
13. Walkley A and Black IA. "An examination of Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method". *Soil Science* 37 (1934): 29-38.
14. Bremner JM. "Nitrogen - Total. In: Sparks DL (ed) Methods of Soil Analysis, part 3 Chemical methods". American Society of Agronomy, Madison, WI (1996): 1085-1121.
15. Page AL., *et al*. "Methods of soil analysis, chemical and microbiological properties". Part 2. ASA Monograph No. 9. 2nd edition. American Society of Agronomy, Madison (WI) (1996): 154.
16. Bonn*eau* M. "Pédologie 2. Constituant et propriétés du sol". Deuxième Edition. Masson, Paris, France (1994): 665.
17. Bakayoko S., *et al*. "Rendements en tubercules frais et teneurs en matière sèche de soixante-dix nouvelles variétés de manioc (*Manihot esculenta Crantz*) cultivées dans le centre de la Côte d'Ivoire". *Journal of Animal and Plant Sciences* 14.2 (2012): 1961-1977.
18. Koné B., *et al*. "Estimation de la fertilité potentielle des ferralsols par la couleur: usage de la couleur en morphopédologie". *Canadian Journal of Soil Science* 89.3 (2009): 331-342.
19. Vendrame PRS., *et al*. "Acidity control in Latosols under long-term pastures in the Cerrado region, Brazil". *Soil Research* 51 (2013): 253-261.
20. West TO and Post WM. "Soil organic carbon sequestration rates by tillage and crop rotation". *Soil Science Society of America Journal* 66 (2002): 1930-1946.

21. Brindley GW. "Discussion and recommandations concerning the nomenclature of clay minerals and related phyllosilicates". *Clay and Clay Minerals* 14 (1996): 27-34.

22. Bailey SW., *et al*. "Summary of national and international recommendations on clay mineral nomenclature". *Clay and Clay Minerals* 19 (1971): 129-132.

23. Chen S., *et al*. "Effect of various crop rotations on rice yield and nitrogen use efficiency in paddy-upland systems in southeastern China". *The Crop Journal* 6 (2018): 576-588.

24. Uddin and Fatema. "Rice crop residue management and its impact on farmers livelihood". *Progressive Agriculture* 27.2 (2016): 189-199.

25. Zuber SM., *et al*. "Crop rotation and tillage effects on soil physical and chemical properties in Illinois". *Agronomy Journal* 107 (2015): 971-978.

26. Howeler RH. "Long-term effect of cassava cultivation on soil productivity". *Field Crops Research* 26 (1991): 1-18.

27. Sun Q., *et al*. "Optimization of yield and wateruse of different cropping systems for sustainable groundwater use in North China Plain". *Agricultural Water Management* 98 (2011): 808-814.

28. ROXAS DB., *et al*. "The effects of variety of rice, level of nitrogen fertilization and season on the chemical composition and in vitro digestibility of straw". In "The Utilization of Fibrous Agricultural Residues as Animal Feeds" (1985): 47-52.

29. Becker M and et Johnson DE. "Cropping intensity effects on upland rice yield andsustainability in West Africa". *Nutrient Cycling in Agroecosystems* 59 (2001): 107-117.

30. Tongglum A., *et al*. "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 (2001): 228-258.

31. Song Chen., *et al*. "Effect of various crop rotations on rice yield and nitrogen use efficiency in paddy-upland systems in southeastern China". *The Crop Journal* 6 (2018): 576-588.

32. W Grzebisz., *et al*. "Virtual nitrogen as a tool for assessment of nitrogen management at the field scale: a crop rotation approach". *Field Crop Research* 218 (2018): 182-194.

33. S Chen., *et al*. "The influence of the type of crop residue on soil organic carbon fractions: an 11-year field study of rice-based cropping systems in Southeast China". *Agriculture, Ecosystems and Environment* 223 (2016): 261-269.

34. DY Liu., *et al*. "Effect of paddy-upland rotation on methanogenic archaeal community structure in paddy field soil". *Microbial Ecology* 69 (2015): 160-168.

35. Takahashi E. "Uptake, mode and physiological functions of silica". *Science Rice Plant* 2 (1995): 58-71.