



Restoration of Fertility of Gleyic Fluvisols to Increase Rice Yields using Shellfish Products in Toumbokro, Côte d'Ivoire

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Abstract

A study designed to characterize the effects of shellfish products on the chemical properties of fluvisols gleyic and yield of rice was carried out in Toumbokro, Yamoussoukro's region, Côte d'Ivoire. The work has been focused on soil amendment by three types of shells (*Achatina spp*, *Donax spp* and *Ostrea spp*). Three doses of shellfish products (500, 1000 and 1500 kg.ha⁻¹) and NPK fertilizer were tested in a split-plot design with three repetitions. At ground level, the study showed that the shellfish products have positive effects very marked on all the physical and chemical characteristics. The effects of these shellfish products on the richness of the soil occur gradually. The increase of pH, due to the products made, creates a condition favorable to microorganisms that become active and mineralize sufficient organic substances. The study indicates that shellfish products induce high levels of production of rice cultivation. The average of yield of the experiments carried out is set at 5.41 t.ha⁻¹ in Toumbokro. These performances, never recorded in subsistence agriculture, are explained by the effective correction of mineral deficiencies unsuspected soil by the flow of shellfish products. All the variables studied define the contribution of 1000 kg.ha⁻¹ shredded shells of *Achatina spp*, as the optimum for soil amendment.

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Introduction

In Côte d'Ivoire, soils are subjected to an increasingly intensive farm due to the growing needs generated by rapid population growth and lack of arable land (N'Goran *et al.*, 1997). The consequence of this pressure is the reduction in the fallow leading to the impoverishment of the soil and poor yield of the cultures (Yemefack *et al.*, 2000). The fall of the outputs constitutes a major concern for farmers. The use of chemical fertilizers, by their immediate beneficial effect on the productivity of food crops is one solution, but their high cost and availability make them almost inaccessible to small farmers (N'Goran, 1995). In addition to ecological and environmental problems caused by chemical fertilizers, mineral fertilizers alone cannot maintain soil fertility (Bado, 2002). Its exclusive use leads to an increase in acidity, a deterioration of physical

status and a decline in soil organic matter (Boli and Roose, 2000). In this context, the amendment basic mineral calcium should be an appropriate solution for improving soil fertility and crop yields. Many studies have shown that the amendments are important on various soil properties, thereby justifying their use (Lompo *et al.*, 1995). Ayanlaja and Sanwo (1991) showed that the decomposition of plant residues can significantly improve the level of nutrients and organic matter in soil. But the use of amendments such as shell products has not been particularly studied (Moyin-Jesu, 2007), yet they constitute an optimal source of calcium (Kouadio *et al.*, 2010). Given their availability in Côte d'Ivoire, the use of shells products in agriculture could be a solution to the problems of soil fertility and food insecurity. The study was performed on fluvisols gleyic to assess interest in the use of shell products with a view to improving the

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chemical properties of soil and yield of rice in Toumbokro.

Materials and methods

Materials

Site description

The various experiments were carried in Toumbokro, Yamoussoukro's region, on the road of Yamoussoukro-Bouaflé. The climate of the region of Yamoussoukro is the equatorial regime transition attenuated (baoulean climate of guinean mesophilic domain). It is characterized by four seasons (Brou, 2001, 2005): the first rainy season from March to June, a slowdown of precipitation in July and August, a second rainy season in September and October, more irregular than the first; a very marked dry season, November to February, however, with some isolated rainfall. The rainfall is about 1200 mm per year, relative humidity around 80% (Amani *et al.*, 2010).

The average temperature of the area is 27.7 °C. But during periods of December to January and July to September, the average temperature drops to 25.4 °C, reaching its highest value during the period from February to March, where there has been an average temperature of 28.7 °C.

The site is limited:

- in south by the village of Bozi 2, belonging to the prefecture of Yamoussoukro;

- in east, the village of Yobouékro, in the prefecture of Yamoussoukro;
- in north by the village of Bocabo, as part of the prefecture Kossou;
- in west, the village of Yowrè-Bozi, prefecture of Bouaflé.

Amendment material

Fertilizer material used consists of shredded shells of *Achatina spp.*, *Donax spp.* and *Ostrea spp.*, rich in calcium (Figure 2) and complex fertilizer NPK 10 18 18.

Plant material

Rice is one of the foodstuffs used in the basic food of Ivorian populations. That speculation constitutes, with maize, yam and cassava, the four main food crops cultivated everywhere in Côte d'Ivoire (Akanza, 2010).

Methods

Experimental design

Experiments were carried out with a "split-plot" design with three repetitions. The experimental rice field consists of 9 blocks. Each block consists of 9 plots with 7 treatments shredded shells, a witness NPK, and an absolute indicator. Each plot is a square of side 3 m and 9 m² as surface. The distance between two plots was 3 m. Shredded shells are applied at doses of 500, 1000 and 1500 kg.ha⁻¹. Doses of 200 kg.ha⁻¹ of NPK 10 18 18 and 100 kg.ha⁻¹ of urea were applied to rice (Figure 3).

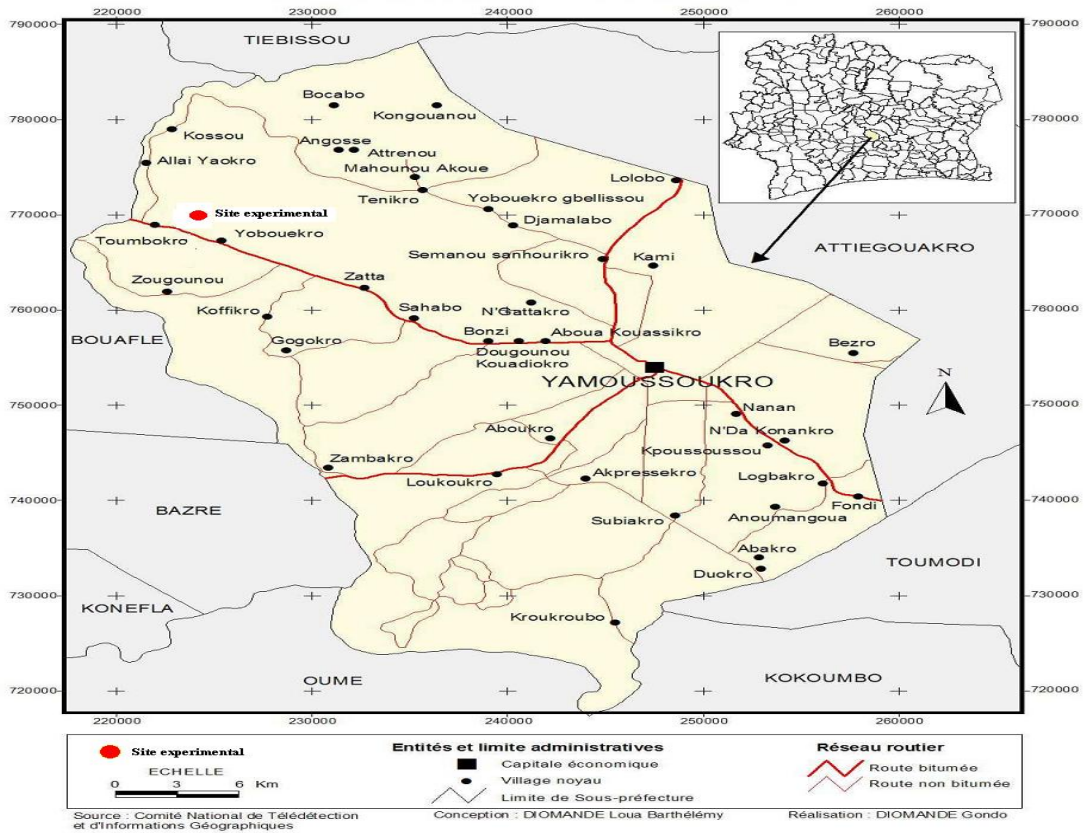


Figure 1: Location of the experimental site



Figure 2: Shells used for soil (Kouadio *et al.*, 2010)



Figure 3: Experimental design

Statistical analysis

A statistical study was conducted to compare the theoretical and practical knowledge accumulated during the processing of data and observations. With the ANOVA (Analysis of Variance), Fischer, based on the null hypothesis for significance levels $\alpha = 0.05$ and 0.01 , we verified the possible changes at each site the effect of different fertilizers on soil physical properties, the content of various chemical elements and different agronomic parameters.

Whenever the calculated probability is significant, the Tukey HSD test for a significance level $\alpha = 0.05$ and 0.01 , is performed to compare means and appreciate the significant differences between them. The data met the assumptions of the analysis of ANOVA, including normality and homogeneity.

Characteristics of farming systems and environment (year of cultivation, varieties of rice and soybean, previous crop, soil type ...) and biological variables measured are used to explain variations in yield and its components. It first checks the relationship between variables (rather than qualitative) of the system of culture and environment. For biological variables (quantitative), as the height and grain yields, the means and variances are calculated for all individuals (plots of measurement) of the sample. Data processing was done with the software STATISTICA 7.1 for Windows. Analyses of variance were conducted with the GLM (General Linear Model: Analysis of variance of the Tukey test at 5%). Figures and graphs were performed with Excel (Microsoft).

Results

The results concern the chemical composition of shells used for soil amendment, the induced effects of shellfish products on the physicochemical characteristics fluvisols gleyic and induced effects of shredded shells on agronomic parameters of rice.

Chemical composition of the shells used in soil amendments

The chemical composition of shredded shells was determined (Table 1). They are rich in calcium ($\text{Ca}^{2+} = 20.88 \text{ cmol.kg}^{-1}$ for the shredded shells *Achatina spp* $\text{Ca}^{2+} = 19.98 \text{ cmol.kg}^{-1}$ for homogenates shell *Donax spp* and $\text{Ca}^{2+} = 27.48 \text{ cmol.kg}^{-1}$ for the shredded shells *Ostrea spp*). The values of C / N ratios are above 10, and indicate that the shredded shells used are genuine products of amendments.

The fertilizing potential of these products is assessed using the potential of hydrogen above the neutral ($\text{pH} = 8$ for E homogenates, $\text{pH} = 8.3$ for D homogenates and $\text{pH} = 8.4$ for homogenates H) and values the sum of exchangeable bases ($21.84 \text{ cmol.kg}^{-1}$ for homogenates E; $20.58 \text{ cmol.kg}^{-1}$ for homogenates and $28.42 \text{ D cmol.kg}^{-1}$ for homogenates H).

Induced effects of shellfish products on the physicochemical characteristics fluvisols gleyic Effects on acidity and organic matter content of soil

✓ pH water, pH KCl et Al^{3+}

The addition of shredded shells influenced the soil pH. Water pH increases from 5.6 to 6, after the provision of fertilizers. Similarly, the KCl pH increased from 5.3 to 6.4. The levels of exchangeable aluminum (Al^{3+}) were also changed after the addition of fertilizers to the soil. These levels declined from 1.7 to $0.01 \text{ cmol.kg}^{-1}$ after soil amendment (Table 2).

✓ Nitrogen, organic matter and C/N

Examination of data analysis shows that the contribution of shredded shells on the soil influenced the levels of nitrogen and organic matter. The nitrogen contents increased, except for the soils that received fertilizers E and E * H, at doses of 500, 1000 and 1500 kg.ha^{-1} , which showed a decrease. This increase in content rose from 0.20 to 0.31 g.kg^{-1} .

The organic matter content was increased following the application of the shellfish products. This increase in levels of MO is more pronounced with the addition of fertilizers E, in doses of 500 kg ha^{-1} (5.01 g.kg^{-1}).

The C / N ratio has changed after the soil amendment. It reached 13.55 at the rate of 1000 kg.ha⁻¹, with fertilizers E*H (Table 2).

Effect on the adsorption complex and the cation exchange capacity (CEC)

Adsorption complex and CEC

Examination of the data analysis indicates that the adsorption complex and the CEC have been influenced by the addition of fertilizers to the soil.

Levels of Ca²⁺ have increased after the addition of shellfish fertilizers. This increased level of calcium in the soil increased from 5.66 to 8.45 cmol.kg⁻¹. Only fertilizers E, at a dose of 1000 kg.ha⁻¹, lowered the calcium content.

The levels of Mg²⁺ were increased after the input of shredded shells, with the exception of soils amended with fertilizers H, at a dose of 500 kg.ha⁻¹, where they decreased slightly. Increased

levels of Mg²⁺ varied from 2.99 to 3.89 cmol.kg⁻¹.

K⁺ contents also increased after the input of shellfish fertilizers. However, the products E, H and E*D*E*H, at doses of 500, 1000 and 1500 kg.ha⁻¹, lowered the levels of K⁺ in the soil.

The levels of Na⁺ declined after the addition of fertilizers. This decline has increased from 0.38 to 0.013 cmol.kg⁻¹.

The levels of CEC increased after the appendage of shredded shells in the soil. The CEC increased with the addition of shredded shells E, in doses of 500 kg.ha⁻¹ (88.25 cmol.kg⁻¹) (Table 3).

Effects of phosphorus and trace elements

Phosphorus

The results of data analysis point out that the contribution of the ground shells shredded increased the levels of phosphorus. This increase in levels of available P was done at all amended soils. It went from 33 to 126.66 mg.kg⁻¹. Total phosphorus levels also increased in amended soils.

Table 1: Chemical composition of shredded shells

Shells	Chemical elements Acidity	Nitrogen, organic matter (g.kg ⁻¹) et phosphorus (mg.kg ⁻¹)				Absorption Complex (cmol.kg ⁻¹)				Trace elements (g.kg ⁻¹)			
		pH	C	N	C/N	P	Ca ²⁺	Mg ²⁺	K ⁺	Na ⁺	Fe	Mn	Cu
<i>Donax spp</i> (D)	8.3	1.42	0.11	12.91	0.14	19.98	0.06	0.50	0.04	200	10	19	0
<i>Achatina spp</i> (E)	8.0	2.89	0.25	11.56	0.05	20.88	0.06	0.89	0.01	52	6	18	0
<i>Ostrea spp</i> (H)	8.4	1.52	0.16	9.50	0.06	27.48	0.14	0.71	0.09	42	7	21	0

Table 2: Changes in acidity and organic matter content in gleyic fluvisols

Treatments	Exchange acidity			Nitrogen and organic matter (g.kg ⁻¹)		
	pH water	pH KCl	Al ³⁺ (cmol.kg ⁻¹)	MO	N	C/N
Tap	5.6 ± 0.01 b	5.3 ± 0.01 b	1.2 ± 0.0008 a	2.64 ± 0.007 b	0.21 ± 0.015 b	6.35 ± 0.41 c
E1	6.6 ± 0.1 a	6.4 ± 0.05 a	0.02 ± 0.0001 b	5.01 ± 0.03 a	0.15 ± 0.01 b	8.32 ± 0.25 c
E2	6.3 ± 0.1 a	5.7 ± 0.04 a	0.01 ± 0.0004 b	2.81 ± 0.006 b	0.13 ± 0.01 b	12.59 ± 1.05 b
E3	6.1 ± 0.01 a	5.8 ± 0.04 a	0.01 ± 0.0004 b	2.61 ± 0.007 b	0.13 ± 0.01 b	11.97 ± 1 bc
H1	6.2 ± 0.01 a	5.7 ± 0.04 a	0.01 ±	4.00 ± 0.004 a	0.22 ± 0.01 a	10.6 ± 0.53

			0.0004 b			bc
H2	6.5 ± 0.01 a	5.9 ± 0.03 a	0.01 ± 0.0004 b	4.33 ± 0.004 a	0.21 ± 0.015 a	11.8 ± 0.86 bc
H3	6.2 ± 0.01 a	5.8 ± 0.03 a	0.01 ± 0.0004 b	2.79 ± 0.09 b	0.27 ± 0.01 a	9.59 ± 0.48 c
D1	6.5 ± 0.01 a	5.2 ± 0.01 a	0.01 ± 0.0004 b	3.97 ± 0.004 b	0.25 ± 0.01 a	9.25 ± 0.33 c
D2	6.4 ± 0.01 a	5.9 ± 0.02 a	0.01 ± 0.0004 b	3.57 ± 0.05 b	0.23 ± 0.01 a	9.05 ± 0.38 c
D3	6.2 ± 0.01 a	5.8 ± 0.02 a	0.01 ± 0.0004 b	2.23 ± 0.08 b	0.22 ± 0.01 a	10.8 ± 0.99 bc
E*H 1	6.2 ± 0.02 a	5.8 ± 0.02 a	0.02 ± 0.0001 b	3.91 ± 0.002 a	0.19 ± 0.015 b	11.8 ± 0.89 bc
E*H 2	6.1 ± 0.01 a	5.6 ± 0.02 a	0.02 ± 0.0001 b	3.88 ± 0.003 a	0.16 ± 0.06 b	13.55 ± 0.5 a
E*H 3	6.2 ± 0.01 a	5.8 ± 0.02 a	0.02 ± 0.0001 b	3.89 ± 0.009 a	0.18 ± 0.017 b	12.66 ± 1.33 b
D*E 1	6.4 ± 0.01 a	5.8 ± 0.02 a	0.01 ± 0.0004 b	4.08 ± 0.009 a	0.28 ± 0.01 a	8.48 ± 0.25 c
D*E 2	6.3 ± 0.01 a	5.8 ± 0.02 a	0.01 ± 0.0004 b	4.04 ± 0.009 a	0.27 ± 0.06 a	8.2 ± 0.2 c
D*E 3	6.4 ± 0.01 a	5.7 ± 0.04 a	0.01 ± 0.0004 b	4.05 ± 0.02 a	0.27 ± 0.003 a	8.02 ± 0.11 c
D*H 1	6.5 ± 0.01 a	6.1 ± 0.03 a	0.01 ± 0.0004 b	3.55 ± 0.007 b	0.24 ± 0.015 a	8.52 ± 0.59 c
D*H 2	6.6 ± 0.01 a	6.1 ± 0.03 a	0.01 ± 0.0004 b	3.56 ± 0.007 b	0.28 ± 0.011 a	7.4 ± 0.33 c
D*H 3	6.6 ± 0.01 a	6.2 ± 0.03 a	0.01 ± 0.0004 b	3.58 ± 0.003 b	0.31 ± 0.012 a	6.6 ± 0.25 c
D*E*H 1	6.6 ± 0.01 a	5.8 ± 0.02 a	0.01 ± 0.0004 b	4.58 ± 0.011 a	0.28 ± 0.01 a	9.77 ± 0.34 c
D*E*H 2	6.5 ± 0.01 a	6.2 ± 0.03 a	0.01 ± 0.0004 b	4.53 ± 0.01 a	0.27 ± 0.01 a	9.52 ± 0.43 c
*E*H 3	6.3 ± 0.01 a	5.9 ± 0.02 a	0.01 ± 0.0004 b	4.58 ± 0.006 a	0.27 ± 0.015 a	9.66 ± 0.54 c
F	147.61**	12.77**	457.54**	253.44**	80.47**	29.02**
P cal	0	0	0	0	0	0
P theor	≤ 0.01	≤ 0.01	≤ 0.01	≤ 0.01	≤ 0.01	≤ 0.01

Means with the same letter in the same column are not significantly different at the level $\alpha < 0,05$ and $\alpha = 0,01$ according to Tuckey's test. ns = non significant; * = significant; ** = high significant and *** = very high significant, Cal = calculate, theor = theoretical. 1 = dose 1 = 500 kg.ha⁻¹; 2 = dose 2 = 1000 kg.ha⁻¹; et 3 = dose 3 = 1500 kg.ha⁻¹

Table 3: Evolution of phosphorus and trace elements of fluvisols gleyic Treatments

	Phosphorus (mg.kg ⁻¹)		Trace elements (g.kg ⁻¹)	
	P ₂ O ₅ t	P ₂ O ₅ ass	Mn	Fe
Tav	306.33 ± 1.53 b	30.67 ± 3.79 b	49.67 ± 1.53 a	27.33 ± 2.65 a
Tap	310 ± 1 b	33 ± 8.19 b	48.67 ± 0.58 a	28.5 ± 1 a
E1	785.33 ± 1.53 a	126.66 ± 1.53 b	15 ± 1 c	11 ± 1 c
E2	573.67 ± 1 ab	57 ± 2.08 b	44 ± 1 a	23 ± 1 ab
E3	607.33 ± 1.53 ab	54.33 ± 1.53 b	33 ± 1 ab	19 ± 1 b

H1	658 ± 1ab	56 ± 1 b	41 ± 1 a	20 ± 1 b
H2	668 ± 1.53 ab	55.67 ± 1 b	25 ± 1 b	14 ± 1 c
H3	715.33 ± 1 ab	66 ± 3.21 b	45.67 ± 2.08 a	16 ± 1 c
D1	303.33 ± 2.08 b	57.33 ± 4.93 b	18 ± 1 c	16 ± 1 c
D2	286.67 ± 1.53 b	82.33 ± 2.52 b	27 ± 1b	25.33 ± 1.53 a
D3	455.67 ± 1 b	56 ± 2.08 b	8 ± 1 c	27 ± 1 a
E*H 1	764.33 ± 1.53 ab	67.67 ± 1.53 b	45.69 ± 1.53 a	26.33 ± 1.15 a
E*H 2	761 ± 2.08 ab	64.67 ± 1 b	47 ± 2 a	24.66 ± 3.79 ab
E*H 3	758 ± 1ab	66 ± 1 b	46.33 ± 1.53 a	26.33 ± 1.53 ab
D*E 1	337.33 ± 1.53 b	63.33 ± 1.53 b	36 ± 1 ab	24.2 ± 1 ab
D*E 2	332.33 ± 1.53 b	62.67 ± 1.53 b	37.33 ± 1 ab	24.66 ± ab
D*E 3	333.67 ± 1.53 b	65.67 ± 2.08 b	37.67 ± 0.58ab	23.66 ± ab
D*H 1	573 ± 2.65 ab	64 ± 1 b	38 ± 1 ab	19 ± 1 b
D*H 2	576 ± 1 ab	65 ± 1 b	34 ± 2.08 ab	16 ± 2 c
D*H 3	579 ± 2.08 ab	65.33 ± 1 b	37.33 ± ab	16.66 ± 1.53 c
D*E*H 1	471 ± 1 b	34.67 ± 1 b	28 ± 1 b	21 ± 1 ab
D*E*H 2	472 ± 2.08 b	35 ± 1 b	26 ± 1.73 b	22 ± 1.73 ab
D*E*H 3	468 ± 3.79 b	33.67 ± 1 b	27.33 ± 1.53 b	24 ± 1.73 ab
F	400.10**	201.69**	831.41**	65.27**
P cal	0	0	0	0
P théor	≤ 0.01	≤ 0.01	≤ 0.01	≤ 0.01

Means with the same letter in the same column are not significantly different at the level $\alpha < 0,05$ and $\alpha = 0,01$ according to Tuckey's test. ns = non significant; * = significant; ** = high significant and *** = very high significant, Cal = calculate, theor = theoretical. 1 = dose 1 = 500 kg.ha⁻¹; 2 = dose 2 = 1000 kg.ha⁻¹; et 3 = dose 3 = 1500 kg.ha⁻¹

This change in total P content ranged between 306.33 and 785.33 mg.kg⁻¹ (Table 3).

Trace elements

Levels of trace elements were influenced by the addition of shellfish fertilizers. The levels of Mn²⁺ declined from 49.67 ± 1.53 to 8 g. kg⁻¹. As for the contents of Fe²⁺, they decreased in amended soils (Table 3).

Induced effects of shredded shells on agronomic parameters of rice

To better assess the effects of shredded shells on rice cultivation, the following agronomic parameters were measured in our investigations:

- ✓ rate followed;
- ✓ plant height;
- ✓ yield.

Effect on survival

Figure 4 reflects changes in average survival rate for the different treatments and doses. The results of ANOVA indicate no significant difference between treatments. The addition of shredded

shells did not influence survival rate of upland rice grown on fluvisols gleyic.

Effect on the average height of plants

Figure 5 shows the evolution of the average height of rice plants according to the different treatments and doses. Analysis of the results shows that the shredded shells have influenced the average height of plants, which ranged from 111.69 to 141.82 cm. The results of analysis of variance show that there are highly significant differences between the means of this variable, related to shellfish fertilizing ($F_{cal} = 2.93^{**}$; $P_{cal} = 0.000020$) (Table 4).

Effect on average seed yield

The addition of shredded shells to soil has increased the yield of rice grains from 2.06 to 5.41 t.ha⁻¹ according to the treatments. The best yields were obtained by the addition of fertilizer E, at a dose of 1000 kg.ha⁻¹ and H at 1000 and 1500 kg.ha⁻¹. Beyond 1000 kg.ha⁻¹ of E and H, a significant reduction in grain yield is observed. The addition of increasing doses of fertilizers D increased the grain yield of rice. This observation is similar to the combination of doses of products

Coquillère D * E, H and E * D * H. By cons, with the triple combination D * H * E, the rice yield decreases as as one increases the dose of fertilizers (Figure 6). Analysis of variance showed highly significant differences between means due to shredded shells (FCAL = 112.27 **; PC = 0.000000) (Table 4).

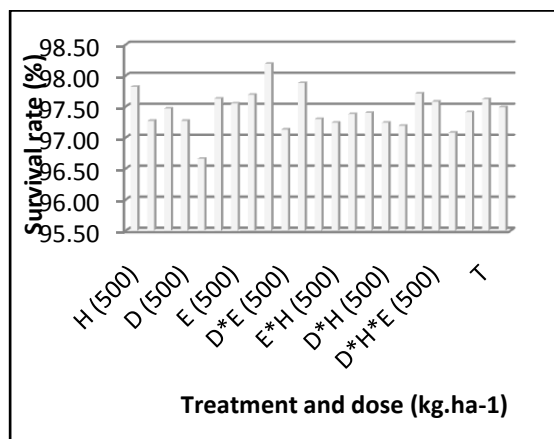


Figure 4: Evolution of the average survival rate

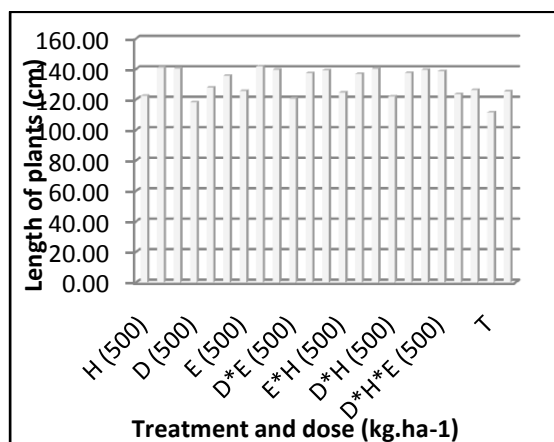


Figure 5: Evolution of the average plant height

Discussion

The various tests on shell products show that pH values obtained are in the range [8 to 8.4], indicating that the hydrogen potential is basic in nature (Kouadio *et al.*, 2010). Ca^{2+} is the dominant component of all the constituents of the

adsorbent complex, because the estimates are in the range of $19.98 \text{ cmol.kg}^{-1}$ (*Achatina spp*), $20.88 \text{ cmol.kg}^{-1}$ (*Donax spp*) and $27.48 \text{ cmol.kg}^{-1}$ (*Ostrea spp*) (Kouadio *et al.*, 2010). This is an amendment necessary to the recovery of soil pH. Shell products are limestone products. Then, they bring on the soil elements such as calcium (Ca) and magnesium (Mg). These two cations (Ca^{2+} and Mg^{2+}) contribute, on the level of the adsorbent complex, to reduce the acidity of the ground. The values of C / N ratio, estimated from the test results are above 10. The use of these shell products is justified because the pH, the calcium, the C / N ratio and CEC obtained show that these products could be a source of regulatory factors in the productivity of soil (Assa, 2005). Addition of shell products on soil has helped to raise the pH values, especially the products E and H rich in Ca^{2+} . To neutralize the acidity of a soil, the incorporation of Ca^{2+} is a current practice. Ca^{2+} and Mg^{2+} are fixed on colloids, and O^{2-} combine with the ions H^+ forming basic ions OH (Powell *et al.*, 1998).

The relatively high level of organic matter can be explained by the fact that the humidity and acidity prevents the degradation of organic matter resulting from the accumulation of detritus from the gallery forests or areas more upstream (Yemefack *et al.* 2004; Duguet, 2005). Continuous cultivation of the area, coupled with the non return of crop residues, contributed to the depletion of soil organic matter, very much like the finding of Naman *et al.* (2002). The results confirm absolutely the works of Mbonigaba *et al.* (2009) who showed that the quantity and especially the one of organic matter in tropical soils are insufficient, because of the acidification and aluminum toxicity. Improving the availability of organic matter for microorganisms by the Ca^{2+} in the soil, allows an increase in the amount of nitrogen mineralized (Peltier, 2001). The pH of moderately acidic soils studied would have favored the rapid mineralization of organic matter by stimulating biological activity (Elberling *et al.*, 2003; Duguet, 2005).

Table 4: Agronomic parameters measured on upland rice grown on gleyic fluvisols

Treatments	Agronomic parameters of upland rice			
	Survival rate (p.c.)	Tillering	Average height of plants (cm)	Yield (T/ha)
H1	97.82 ± 6.21 a	9 ± 1.13 b	122.48 ± 8.21 b	2.89 ± 0.40 c
H2	97.27 ± 6.25 a	12 ± 1.31 a	140.97 ± 9.66 a	5.41 ± 1.02 a
H3	97.47 ± 6.24 a	11 ± 1.29 b	140.38 ± 9.27 a	5.21 ± 0.98 a
D1	97.27 ± 6.20 a	9 ± 1.13 c	118.3 ± 7.37 c	2.85 ± 0.21 c
D2	96.66 ± 6.19 a	11 ± 1.29 b	127.88 ± 8.34 c	3.43 ± 0.41 c
D3	97.63 ± 6.11 a	11 ± 1.29 b	135.69 ± 8.66 a	4.23 ± 0.65 b
E1	97.55 ± 6.20 a	8 ± 1.09 c	125.74 ± 8.29 c	3.01 ± 0.31 c
E2	97.69 ± 6.30 a	12 ± 1.31 a	141.82 ± 9.28 a	5.4 ± 1.02 a
E3	98.19 ± 6.18 a	11 ± 1.29 b	139.66 ± 8.71 a	3.78 ± 0.41 c
D*E1	97.13 ± 6.27 a	7 ± 0.81 c	120.71 ± 8.02 c	2.8 ± 0.39 c
D*E2	97.88 ± 6.29 a	7 ± 0.81 c	137.35 ± 8.67 a	4.09 ± 0.54 b
D*E3	97.3 ± 6.25 a	10 ± 1.32 b	139.21 ± 8.72 a	4.13 ± 0.59 b
E*H1	97.24 ± 6.27 a	10 ± 1.32 b	124.66 ± 8.24 b	3 ± 0.31 c
E*H2	97.38 ± 6.28 a	9 ± 1.13 b	136.85 ± 8.55 a	4.18 ± 0.63 b
E*H3	97.4 ± 6.21 a	11 ± 0.57 b	140.24 ± 9.16 a	4.25 ± 0.67 b
D*H1	97.24 ± 6.22 a	12 ± 0.33 a	122.02 ± 8.07 b	2.94 ± 0.45 c
D*H2	97.19 ± 6.21 a	11 ± 1.29 b	137.57 ± 8.69 a	4.25 ± 0.66 b
D*H3	97.71 ± 6.27 a	11 ± 1.29 b	139.6 ± 8.70 a	4.01 ± 0.53 b
D*H*E3	97.58 ± 6.23 a	11 ± 1.29 b	138.69 ± 8.71 a	4.01 ± 0.53 b
D*H*E1	97.08 ± 6.28 a	11 ± 1.29 b	123.63 ± 8.21 b	2.58 ± 0.28 c
D*H*E2	97.41 ± 6.18 a	10 ± 1.32 b	126.3 ± 8.33 b	2.14 ± 0.59 c
T	97.62 ± 6.26 a	11 ± 1.29 b	111.69 ± 7.22 c	2.06 ± 0.21 c
NPK	97.49 ± 6.25 a	8 ± 1.09 c	125.44 ± 8.29 b	2.75 ± 0.44 c
F _{cal}	1.71 ns	11.14**	2.93**	112.27**
CV (%)	6.40	11.69	6.48	14.01
P _{cal}	0.02	0.000000	0.000020	0.000000
P _{theor}	≥ 0.05	≤ 0.01	≤ 0.01	≤ 0.01

Means with the same letter in the same column are not significantly different at the level $\alpha < 0,05$ and $\alpha = 0,01$ according to Tuckey's test. ns = non significant; * = significant; ** = high significant and *** = very high significant, Cal = calculate, theor = theoretical. 1 = dose1 = 500 kg.ha⁻¹; 2 = dose 2 = 1000 kg.ha⁻¹; et 3 = dose 3 = 1500 kg.ha⁻¹

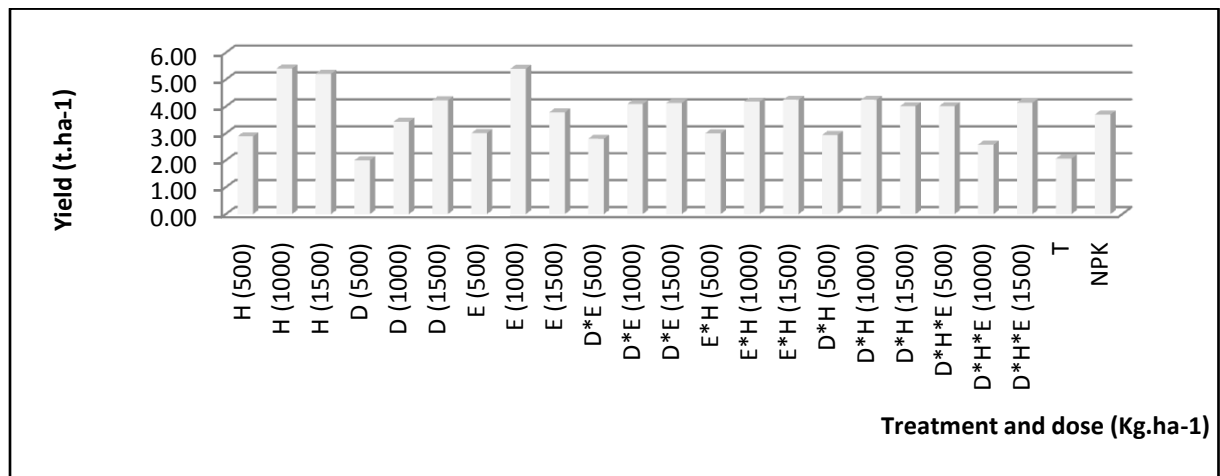


Figure 6: Average yield grain

According to Bado (2002), nitrogen and carbon are moving towards a steady state, regardless of cultural practices and thus, C / N ratio would be characteristic of a given ecosystem. Indeed, higher levels of organic matter and a higher CEC, prevent leaching of cations, reduce or eliminate the exchangeable aluminum through complexation, and increase soil pH (Bado, 2002). The quality of the amendments and their ability to provide nitrogen are usually evaluated by C / N ratio (Stevenson, 1994). Ca^{2+} content was increased after addition of shredded shells. This increase is more pronounced with the shredded shells of *Achatina spp.* Calcium plays a major role on soil physical properties. It changes the physical properties of soils. These results confirm those of Peltier (2001) and show that aeration and water retention in the soil are significantly improved following the calcium intake of a culture in acidic soil. Calcium is also under strong attraction by the charged sites on the scale of the clay particles (Tessier, 2002). Desaturation of the adsorbent complex major cations Ca^{2+} and Mg^{2+} is one of the causes of the decline in soil fertility (Akanza, 2010). Increases in pH and stimulation of the mineralization observed after the addition of shredded shells to the soil promote a possible increase in CEC (André, 1976).

The results of studies show that the levels of phosphorus increased in fluvisols gleyic. This increase in the bioavailability of phosphorus is due to the increase of pH (Kockmann and Fabre, 2006). The availability of phosphorus is thus partly dependent on pH. The observed high pH promotes the precipitation of P by iron, aluminum, calcium and clays.

According to Truong (1989), pH is a very important factor for the availability of phosphorus in the soil solution, and also for the solubilization and effectiveness of rock phosphates. Characterization of the adsorption complex (CEC) of unamended soils showed a low CEC, dominated mainly by iron and aluminum, and deficient in other cations. This deficiency can lead cations nutritional imbalance in the rice plant as reported in some works of Akanza (2010), who believe that multiple nutritional deficiencies may be a cause of iron toxicity observed in plants rice.

The similarity of development observed in rice can be easily explained by the fact that the experimental

sites are almost in the same climate zone and are on sandy clay soil, moderately acidic. Yet it is established that rice needs for growth, an optimum temperature of 26-28°C and a pH of about 6 to 6.8 (Hassan *et al.*, 2003). The stimulation of growth could be interpreted as a nutritional response to the calcium amendment, which allows the availability of other nutrients.

In the qualitative plan, the differences due to the amounts of shredded shells are very clear. They demonstrate that the variability of the mineral status of soil under cultivation is linked to calcium. In comparison with our results, the best yields of crops grown on fluvisols gleyic were obtained at a dose of 1000 kg.ha⁻¹ shredded shells of *Ostrea spp.* This is conform to the works of Biielders *et al.* (2002), who found yield increases of various crops such as sorghum and rice, by increasing organic matter. In addition, Ca^{2+} acts well on nitrogen mineralization and its availability for plants. This effect on improving nitrogen nutrition is due to Ca^{2+} than pH (Peltier, 2001). These effects of Ca^{2+} on crops have already been described by Fabre and Kockmann (2006), in particular the increased presence of good grasses and legumes. The results obtained with absolute control confirm the works of Bado (2002), who observed that on West Africa soils, the cultivation resulted in a steady decrease in soil organic matter and lower yields. During all the study, shredded shells affected rice yields. They also significantly increased maize yields. Soil original poverty in nutrients explains the effectiveness of the amendments on crop yields (Bado, 2002). The effectiveness of the basic inorganic soil amendment is related to the double role of the organic matter. The shredded shells improve physical and chemical properties and the availability of elements such as phosphorus (Bado, 2002), while providing nutrients through mineralization. Neutralizing soil acidity and providing nutrients to plants, shredded shells improve mineral nutrition, resulting in increased crop yields of rice and maize. The effectiveness of calcium on yield and nitrogen fixation suggest that the soil was very poor in Ca and Mg. Bationo and Ntare (2000), made the same observations and concluded that P, Ca, and Mg are the major nutrients limiting crop productivity in the tropical semi-arid West Africa area. The effectiveness of Ca can be explained by its dual role on of the nutrient,

the increase in the availability of P and the neutralization of soil acidity (Gerke, 1993).

Conclusion

This study, carried out on the gleyic fluvisols of the zone of Toumbokro, showed that the use of the shell products as calcic amendment, accessible to Ivorian farmers, is a way in the resolution of the problems of soil fertility and the improvement of the cultures. In terms of fertility, the chemical properties of the soil were improved after

amendment by shell products. The pH of the soil was adjusted in the interval of 6.1 to 7.5, very favourable with the availability of the nutritive elements to cultures. CEC, exchangeable bases, rates of saturation in bases and pH of the amended soils were increased compared to the not amended soils. Rice yields increased thanks to amendment by the shell products. Indeed, for the agronomic tests set up on the gleyic fluvisols, the best yields obtained are of 5.41 t.ha⁻¹ of rice.

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