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Improvement of irrigate rice yield by using different cations rates in a lowland affected by the harmattan in savannah zone of Côte d'Ivoire

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Abstract: A good knowledge of rice mineral nutrition could help to improve rice growing, in harmattan period, permitting thus, a continuous rice culture during all year round. However, rice nutrition in exchangeable cations of lowland soil is still unknown. It is why, three agronomic trials have been driven in a secondary lowland, in Cote d'Ivoire Guinean savannah zone to 2014 to 2017. Into a randomized completed blocks, NPK was applied according to the rates of 30 kg N ha^{-1}, 60 kg P ha^{-1} and 50 kg K ha^{-1}.Then, the rates of 50, 100 and 150 kg.ha^{-1} were added respectively in the treatments of Ca and Mg combined with 10, 20 and 30 kg Zn ha^{-1}. Fertilizers were applied as basal and rice variety named NERICA L19 was transplanted per hill of three plants spacing by 20 cm × 20 cm. At tillering and the booting stages, 35 kg N ha^{-1} were applied respectively. NPK treatment was considered as the control of the experimentation. The calcium was revealed as the most important cation inducing synergistic effect on rice nitrogen nutrition. The optimal dose was identified at 90 kg Ca ha^{-1} for highest grain yield (3.58 tha^{-1}) in harmattan period. A fertilizer composes of 100 kgNha^{-1}, 60 kgPha^{-1}, 50 kgKha^{-1} and 90 kg Ca ha^{-1} was recommended for rice growing in Cote d'Ivoire Guinean savannah zone.

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INTRODUCTION

According to Africa rice center (Africa rice, 2011), Côte d'Ivoire has a high potential to develop and to increase its rice growing, thanks to the availability of favorable agro-ecology. Unfortunately, several constraints make obstacle to this assertion in the lowlands. Beyond the problematic of rice mineral nutrition, the rice growing is braked in our study area, by the occurrence of the harmattan, which reduces the yields unless at one ton by hectare (<1tha^{-1}) and constrained the producers to reduce the number of yearly cultural cycle in spite of water availability. Nothing that the temperature decrease wouldn't know how to justify this problem, seeing that rice is produced in colder ecological zones (Dupaigre, 2005). On the other side, we could suspect a soils insufficiency fertilization because, the available fertilizers on the market are essentially composed of N, P and K. The exchangeable cations absence: Ca, Mg and Zn, very implied in the synthesis of growth and reproduction hormones (FAO, 2005 and Roy *and al.*, 2006), into fertilization, would be an aggravating factor. Indeed, the weak content in ferromagnetic minerals in the rock-mother granito-gneissic can induce a weak content of soils in Mg, (Dobermann A. and Fairhurst, 2000). In the same way, the ionic balances (Na : Ca ; Fe : Ca and Mg : Ca) can affect Ca^{++} availability for rice plant, in irrigated condition, according to soil texture (Dobermann A. and Fairhurst, 2000). It is why, the present survey aims to recommend cation association, in the complex NPK fertilizer, to booster lowland rice growing, in the offing of economically viable rice growing, during the harmattan, to reinforce Cote d'Ivoire rice growing. To reach this objective, it would seem wise : (i) to determine the soil potential fertility of the studied site; (ii) to identify the most important exchangeable cation for rice nutrition in harmattan period and (iii) to determine the optimal dose of the indispensable cation, among Ca, Mg and Zn.

I) MATERIAL AND METHODS

The survey takes place in Bouaké into the valley of the M'bé I (8º06 N, 6º00 W, 180 m) in Côte d'Ivoire center which is a Guinean savannah zone (Diatta and Koné, 2003).

1-1) Trial setting up

The experimental device was a complete block randomized of four repetitions, containing, each, 10 micro-parcels for the 10 treatments. NPK treatment has been considered as the experimentation witness, while comparing it to the treatments containing an addition of Ca, Mg and Zn different doses. The NPK has been applied according to 30 N kg ha^{-1}, 60 kg P ha^{-1} and 50 kg K ha^{-1}. Then, the doses of 50 $kgha^{-1}$ of Ca (Ca1), 50 $kgha^{-1}$ of Mg (Mg1), 100 $kgha^{-1}$ of Ca (Ca2), 100 $kgha^{-1}$ of Mg (Mg2), 150 $kgha^{-1}$ of Ca (Ca3) and 150 $kgha^{-1}$ Mg (Mg3) have been added, respectively, in Ca and Mg treatments. For Zinc, we added the doses of 10 $kgha^{-1}$ of Zn (Zn1), 20 $kgha^{-1}$ of Zn (Zn2) and 30 Zn $kgha^{-1}$ (Zn3) in the NPK according to the treatments. The fertilizers have been applied in basis fertilizers, before the transplanting of NERICA L19 rice variety, after 21 days seed plot. The transplanting was made at the rate of three seedlings by seed hole, 20 cm interspaced, in the micro-parcels constituted to this effect. At the rice tillering and booting stages, 35 N kg ha^{-1} has been applied, every time, on all micro-parcels. The weeding was made manually, at 28 and 60 days after transplanting.

1-2) Field data collection

For each treatment, 21 and 45 days after transplanting (DAT), rice tillers number has been counted by seed hole in $1m^2$ area. Then, to the maturity, the plant height and the rice panicles number have been determined in the same conditions. The harvest has been made on 8 m^2 of each micro-parcel, abandoned two border lines. After rice drying and manual beating, straw and rice grains have been separated. Straw has been weighed for the straw yield calculation (SY):

$$SY = ((\text{Straw Weight} / 10^6)) / (8/10^4).$$

After winnow, the grains have been weighed for each treatment before putting to the steamroom, during 24 hours, at 70°C, in order to determine the humidity rate (p.c.HUM). The grain yield (GY) has been calculated then, in relation to the humidity standard of 14 p.c.:

$$GY = (\text{Dry grain Weight} / 8) \times (10^4 /10^6) \times ((100 - \text{hum}) /86).$$

With the help of grain and straw yield, the total dry matter (TDM) output has been determined:
TDM = GY + SY

1-3) **Withdrawal, soil and plants analysis**,

The soil composite sample of every micro-parcel has been prepared withdrawing, on 0 - 20 cm thickness, with the auger, to every angle and to the center. After the harvest data statistical analyses, the soil samples of the witnesses parcels and the calcium treatments were the subject of soil and plant nitrogen content analysis, to verify our hypotheses on the calcium faculty to influence the N export and valorization.

1-4) Laboratory Analyses

Before the experimentation, soil has been sampled for the analyses:

-The Robinson pipette method for the determination of grain size fractions as described by (Gee *and al*., 1986);

- The methods of Walkley and Black (1934), the Kjeldhal method and colorimetry after digestion with perchloric acid (Olsen and Dean, 1965) to determine the carbon (C), phosphorus Total (P) and total nitrogen (N) ;
- Flame emission and atomic absorption spectrometry, after extraction with ammonium acetate for the identification of potassium (K), calcium (Ca), magnesium (Mg) and cation exchange capacity (CEC);
- The glass electrode method, in a soil: solution ratio of 1:2.5 to determine the pH;
- Ammonium acetate in the presence of EDTA (Norvell and Lindsay, 1969) to extract zinc (Zn).

1-5) Statistical analyses

Randomization analysis of the treatments was performed for each of the replicates using GenStat Discovery 3 software. The GY, SY, tillers (Till) and Panicles (Pan) number were subject to variance analysis (ANOVA) to identify the treatments that had a meaningful effect. The mean values were compared using least significant test (LSD) for $\alpha = 0.05$.The analyses of Pearson interrelationship have also been achieved for the determination of the relations between the soil parameters and the rice grain yield in each treatments. Moreover, surface curve response analysis of Ca rates was done to emphasize the yield trend according to the fertilizer rates in order to identify the optimum rate

II) RESULTS

2-1) Soil Characteristics of the site

There are in the lowland a flooding of variant height between 20 - 40 cm. Soil description reveals a gleysol with water stains in surface (0 - 20 cm). The results of soil analysis are presented in table 1 showing that the trial was set on a balanced texture soil (sand = 36 %; clay = 37 %; silt = 27%) characterized by 30.12 g/kg C content which is lower than the threshold level (40 g/kg) coupled with enough level (> 1 g/kg) of nitrogen which is 3.1 g/kg. However, the Ca^{2+}, and Mg^{2+} contents were respectively above threshold (> 2.00 $cmol \cdot kg^{-1}$) and (> 0.20 $cmol \cdot kg^{-1}$) indicating Ca and Mg satisfactory whereas the K estimated to 0.08 cmol/kg is lower threshold (0,10 cmol/kg) attesting a deficiency in K. From where the justification of the CEC (20.2 cmol/kg) exactly sufficient (20 cmol/kg critical threshold). The pH (5.5) weakly acidic is coupled to assimilated phosphor sufficient content (> 10 mg/kg) of 15 mg/kg.

Table 1: Soil physic-chemical characteristics

	0 – 20 (cm)	20 – 40 (cm)	40 – 60 (cm)	60 – 80 (cm)
Clay (%)	37	36	39	37
Silt (%)	27	21	21	24
Sand (%)	36	43	40	29
pH (eau)	5.5	6.5	6.7	6.9
C-org (g/kg)	30.12	4	2.6	2.4
Nt (g/kg)	3.1	4.5	3.4	3.4
P-ava (mg/kg)	15	0.170	0.087	0.087
Ca^{2+} (cmol/kg)	3.05	3.50	4.30	4.40
Mg^{2+}(cmol/kg)	2.26	2.94	3.32	3.60
Ca^{2+}/ Mg^{2+}	1.34	1.19	1.29	1.22
K^{+}(cmol/kg)	0.08	0.08	0.08	0.1
CEC (cmol/kg)	20.2	9.6	11.2	11.4

2-2) Treatment effect on agronomic parameters

Table II shows the mean values of tillers and panicles number as well as their ratio. The treatment didn't have any effect on these parameters if the tillers number per square meter varied to 523 (NPKCa3) to 693 (NPKZn1), whereas the one of panicles was located between 439 (NPKCa2 and NPKCa3) and 539 (NPKZn1). The tillers and panicles ratio number oscillated between 78,05 and 83,43, respectively, for NPKMg1 and NPKMg3.

2-3) Mean rice grain yield

The figure 1 shows the mean values of rice grain yield (GY) gotten by applied treatments. There are a difference between the mean yield recorded due to the very highly meaningful effect (P = 0,007) of the treatment on this parameter. The biggest rice grain yield (3.58 $kgha^{-1}$) has been induced by the NPKCa2 treatment contrary to the NPKMg3 treatment that recorded the weak yield.

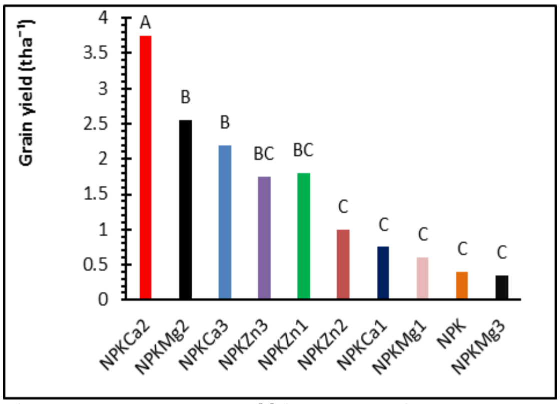

Figure 1: Mean rice grain yield (P > F = 0,007)
Values followed by a same letter are statically identical

2-4) Mean dry matter yield

The mean values of total dry matter growing (TDM) was reported in the table III after statistical analysis. We observe a difference between the mean values noted due to the treatment effect (P = 0,03). The NPKCa treatment has induced the biggest TDM yield (8.15 tha^{-1}). The TDM yield induced by the NPK treatments and NPKMg2 counted by the weakest recorded yields.

2-5) Rice nutrition in calcium

The table IV puts in evidence Pearson correlation analyzes between the applied treatments and the grain yield. We note a strong correlation between the rice GY and the NPKCa2 treatment (R = 0,95). The mean GY is influenced positively by the calcium treatment with the dose of 90 $kgha^{-1}$.

The figure 2 shows a more significant response in its quadratic form of the rice GY to the calcium different doses, with an optimal dose around 100 $kgCaha^{-1}$. The biggest mean GY (3.58 tha^{-1}) is reached with the dose of 90 kg Ca ha^{-1}, which constitutes the advisable optimal dose.

Table II : Mean values of tillers and panicles number as well as their ratio
Values followed by a same letter are statically identical in the column

Treatment	Tillers (m²)	Panicules (m²)	Panicule /Tiller
NPK	598 a	497 a	83,27 a
NPKZn1	693 a	539 a	80,37 a
NPKZn2	539 a	472 a	88,08 a
NPKZn3	593 a	529 a	89,58 a
NPKCa1	610 a	479 a	78,07 a
NPKCa2	519 a	430 a	83,46 a
NPKCa3	523 a	439 a	81,15 a
NPKMg1	610 a	475 a	78,29 a
NPKMg2	541 a	458 a	82,49 a
NPKMg3	583 a	488 a	83,43 a
P > F	0,80	0,98	0,85
C.V (p.c.)	23,81	27,35	12,63
G.M (p.c.)	580,83	481,15	82,82
Lsd (0,05)	199,70	190,06	15,11

Table III: Mean TDM yield in function of the treatment

Treatment	Dry matter (tha^{-1})
NPKCa2	8,15 a
NPKZn3	6.60 a
NPKZn2	6,04 ba
NPKCa1	5,83 ba
NPKZn1	5,50 ba
NPKMg1	5,49 ba
NPKCa3	5,36 ba
NPK	5,25 ba
NPKMg3	5,41 ba
NPKMg2	4,55 b
P > F	0,03
C.V (p.c.)	39,36
MG (p.c.)	5,28
$Lsd_{0.05}$	1,93

Values followed by a same letter are statically identical in the column

Table IV: Correlation Coefficient (R) between GY and the treatment

Treatment	R	Probability
NPK	0,60	0,411
NPKCa1	---	---
NPKCa2	**0,95**	**0,052**
NPKCa3	-0,86	0,146
NPKMg1	0,67	0,330
NPKMg2	---	---
NPKMg3	-0,38	0,630
NPKZn1	-0,42	0,581
NPKZn2	-0,31	0,694
NPKZn3	-0,50	0,500

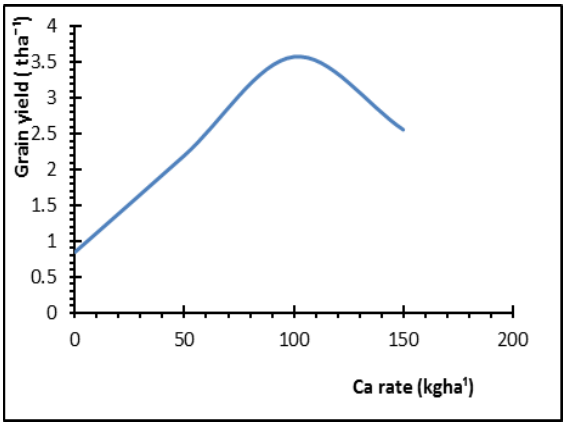

Figure 2 : Response curve to calcium difference doses

2-6) Calcium effect on the soil nitrogen optimization

According to the table V, the soil content in total nitrogen decrease in function to the increasing Ca doses (50, 100 and 150 $kgCaha^{-1}$), in parallel an increasing difference with the soil content in total nitrogen, before the experimentation. However, this tendency is not confirmed when we take in account the control (NPK) with the dose 0 kg $Caha^{-1}$.

III) DISCUSSION

3-1) Potential of rice production in the studied agroecology zone

The study site corresponds to a secondary lowland (Raunet, 1985 ; Ambouta *and al.*, 2005) more than 100 m wide, with variable texture soil, but balanced, permitting a good drainage (internal and external). If the ferrous toxicity, so much dreaded in rice growing, is not suspected in the studied zone, the strong thickness of the humus horizon observed in the hydrous zone reveals a slow mineralization of the organic matter that can cause soil mineral deficiencies. The hydromorphy being questioned (Lavigne *and al*., 1996), this situation should be accentuated in the actual lowland, with Nt and K weak contents observed before the trial setting up. Besides, the soil different textures observed let consider the possibility of Ca and Mg lixiviation, under the drainage effect after the reclamation, induced deficiency levels for rice growing (Dobermann and Fairhurst, 2000). This analysis is reinforced by the result of (Konan, 2013) works on the mineral deficiency survey of study site. Indeed, the author noted some deficiencies in nitrogen and potassium for rice growing. However, no meaningful effect of Ca has been signalled. The present survey and the one of (Konan, 2013) come to reinforce the knowledge on the small rise growing lowland of Bandama valley, which only benefitted from (Diatta and Koné, 2001) characterization studies. The present survey particularity is its occurrence during the harmattan, that is sane to reduce the rice yield unless 1 tha^{-1}. Indeed, during our experimentation, the mean yield was 2,66 tha^{-1}. However, the NPKCa2 treatment induced 3.58 tha^{-1} for, attesting an importance of calcium addition in the rice growing soils fertilization in harmattan period. All the same time, this yield of 3.58 tha^{-1} is even weak in comparison to 6 - 8 tha^{-1} (Touré and al., 2005) in lowland rice growing. However, our work performance overtakes the mean yield in rice growing in Cote d'Ivoire (Koné *and al.*, 2008).

Table V: Analysis results of the total nitrogen for the calcium different rates applied

Rates Ca (kg/ha)	Mean N_t (g/kg)	Dev Stat	Difference ($N_f - N_t$)		
			Inf limit	Sup limit	Prob
0	01,6	0,020	-01,9	-01,2	0,0007
50	02,1	0,045	-01,8	-00,4	0,017
100	01,8	0,029	-01,8	-00,9	0,0027
150	01,7	0,007	-02,1	-00,8	0,0219
N (g/kg) before trial					3,1

N_f = Nitrogen before the experimentation; N_t = residual nitrogen

3-2) Cations effect on rice growing

Cations application (Ca^{++}, Mg^{++} and Zn^{++}) didn't have any significant effect on the yield parameters studied (Tillers and panicles) in spite of these nutriments contents (Ca and Mg), sufficiently elevated in the studied soil. This observation lets believe in the inappropriate of their application in the studied zone fertilization. However, our works revealed that for Ca rates (100 $kgCaha^{-1}$) superior to the recommendations (50$kgCaha^{-1}$) known in rice growing elsewhere (Dobermann and Fairhurst, 2000), there are a rice response such as attest the outputs, whereas the Mg^{++} contribution entailed a depreciation of these parameters. One deducts an importance of Ca fertilization, contrary to Mg, while the works of (Konan, 2013) proved the latter interest. It is likely that the fertilizer composition would be at the origin of this contradiction in our survey zone. Indeed, we added Ca or Zn, or Mg in NPK, whereas this author drove a survey subtractive from NPKCaMgZn. In any case, our survey permits to indicate that the calcium is the most important cation in the rice nutrition in harmattan, period, on top of NPK, in a secondary lowland of Cote d'Ivoire.

3-4) Rice mineral nutrition and calcium effect

Soil initial content in Ca on the parcel of experimentation is superior to the critical threshold (2 $cmolkg^{-1}$) recognized for plants nutrition (Berryman *and al*., 984). However, the application of 100 $kgCaha^{-1}$ induced meaningfully the most elevated rice grain yield during our experimentation. We deduce that it is not about this nutriment direct effect on rice but, probably, an indirect effect by interaction with other nutriments, notably with the nitrogen, which would be the most important nutriment in this zone (Diatta and Koné, 2001 ; Becker M. and Bognonkpé, 2009 ; Konan, 2013]. Indeed, soil contents in total nitrogen after the trial as determined in Ca and control treatments, indicate, total nitrogen reduction from 50 $kgCaha^{-1}$ to 150 kg $Caha^{-1}$ dose. It would have a growth of Nt export by the rice according to Ca increasing doses, with the high grain yield. It is what explains the more significant character of rice answer linear expression to Ca increasing doses application although it displays a certain significant level for the quadratic pace. However, the optimal dose notion (Boyer, 1982) inherent to fertilizer effects, limited this Nt valorization by the Ca, to the dose 100 kg $Caha^{-1}$, whereas the optimum has been calculated at 90 kg $Caha^{-1}$, in spite of a high Nt export at the dose 150 kg $Caha^{-1}$. This analysis reveals a synergy between calcium and nitrogen in rice mineral nutrition, in harmattan period has like that could be observed by (Saijo and al., 2001). Assuredly the calcium plays a extreme importance plastic role, by favored acidic peptidics solubility to form the walls cellular pectocellulosic. Calcium necessity is also recognized for the smooth functioning of enzymes increasing number, such as some ATPase necessary to NO_3^- active transport. It is probably to this title that it intervenes on the intensity, but the respiratory capacity also, while being necessary to the mitochondrions correct formation (Lamrani, 2010). This faculty maintains plant cells functional efficiency and optimize mitochondrion activity, source of plant energy. Its activator action on some ATPase catalyzes many cellular metabolisms that confer to rice, a high capacity of adaptation to climatic, pedological and rough hydrous conditions.

CONCLUSION

In short, the study led watch, that our survey zone don't endure any Zinc and Mg deficiency, and that the ionic balances (Na: Ca ; Fe : Ca and Mg: Ca), don't affect Ca^{++} availability, for rice plant, in irrigated condition, according to the soil texture. Otherwise, it reveals synergy relation between calcium and nitrogen in harmattan period, for high rice grain yield obtaining, making this nutriment an important cation in rice growing. Although the mean yield of 3.58 tha^{-1} gotten with NPK treatment added of Ca (100 $kgha^{-1}$) is even weak, it remains superior to the mean yield lower to 1 tha^{-1} gotten in Cote d'Ivoire, in rainy season, into some agro-ecological zones and, afar, superior to harmattan period one. Because of that, this survey would recommend to practice rice growing in harmattan period in Guinean savannah zone of Cote d'Ivore, with rice variety NERICA L19 and 100 kg $Nha\text{-}^{1}$, 60 kg P ha 1,50 kg Kha^{-1} and 90 kg $Caha^{-1}$ application.

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