International Journal of Science and Research (IJSR)
ISSN: 2319-7064
SJIF (2022): 7.942

Mineral Nutrition N, P, K, Ca, Mg and Zn Effects on Ratoon Rice (Oryza sp.) NERICA 5 Variety growth Parameters and Grains Yield under Upland Rainfield Conditions

Kouakou Olivier Konan[1], Mamadou Cherif[2], Brahima Kone[3], Théodore Kouadio ALLA[4]

[1, 2]Felix Houphouët Boigny University, Biosciences Unit, Plant physiology department, 22 BP 582 Abidjan 22, Côte d'Ivoire

[3] Felix Houphouët Boigny University, Earth Sciences Unit, Soil science department, 22 BP 582 Abidjan 22, Côte d'Ivoire

[4] Institut Pédagogique National de l'Enseignement Technique et Professionnel, Département de Formation des Formateurs aux Métiers de l'Agriculture, 08 BP 2098 Abidjan 08, Côte d'Ivoire

Abstract: ***Rice is a staple food in Sub-Saharan Africa characterized by limited production. While ratooning potential of rice is not practiced. Thus, trials have been carried out in savanna zone ofCote d'Ivoire humid forest to evaluate mineral N, P, K, Ca, Mg and Zn nutrition effects on ratoon rice (Oryza sp.) Nerica 5 variety growth parameters and grains yields under upland rainfield conditions. Theday after main crop harvest previously fertilized with NPK (10-18-18) at sowing and N (46 %) at tillering and panicle initiation stages, seven treatments have been applied in a complete randomized bloc with four replications.60 kg Nitrogen, 33 kg TSP, 90 kg KCl, 21 kg $CaCO_3$, 9 kg $MgSO_4$, 10 kg $ZnSO_4$per ha and 0 fertilizer as control were applied as basal dose. Fertilizers applied effects on ratoon were significant at 5 %. Tillers number were increased by Ca (207 Nbm^{-2}) and N (214 Nbm^{-2}) who increased panicles number (163-165 Nbm^{-2}).50 % flowering period were reduced by minerals tested while only Ca allowed highest grains yield (1, 4-1, 5 tha^{-1}) and agronomic efficiency (68, 77-74, 83 kg paddy / kg fertilizer) as Zn efficiency. Ca fertilizer application is recommended.***

Keywords: fertilization, rice, grains yield, ratoon, agronomic efficiency

1. Introduction

In field, success of ratoon rice rainfed cultivation depends on number of factors including cutting height, fertilization, protection of the plants against weeds, main crop age at maturity, light, temperature of growing medium and ratooning potential of the variety [**1**]. **S**tudies on the varietal potential for vegetative reproduction showed that NERICA ratoon have good reproductive potential without fertilization and cutting heights of 10 cm **[2]**. On the other hand, it has been proven that with cutting heights of 15 to 25 cm, yields of 1 to 2 tha^{-1} could be obtained in the absence of fertilizer with interspecific varieties [**3]**. Finally, it is noted that the height required for cutting the main crop depends on the cultivar **[4]**. Basal fertilization immediately after the main crop harvest significantly improves ratoon grains yield [**5-6-]**. Plant age corresponding to 80 or 100% of harvest maturity and characterized by greenish culms, favors ratoon rice high grain yield [**7]**. Ratooning capacity is certainly a characteristic of Poaceae such as rice [**2**] and sugar cane [**8**]. But it is also observed in many other families, including the Solanaceae, Caricaceae and Bromeliaceae [**9-10-11**]. According to [**12**], in rice, varieties with a long cycle (140 to 150 days) have a greater ratooning capacity than those with a shorter (100 to 110 days) or medium (120 to 135 days) cycle. However, [**13]** indicated that short cycle rice varieties, with long seeds, have a good ability to ensure vegetative restarts for better ratooning. In temperate regions, low temperatures of 20°C reduce the number of tillers and panicles while high temperatures of 30°C increase them [**14**].

Surly, in Côte d'Ivoire, no scientific study on upland rainfed rice ratooning has yet to be initiated. But, in rural areas, its exploitation is often left to the most disadvantaged social strata. Because low yields are very discouraging. As this opportunity to increase production by integrating the rice ratoon culture has not yet been the subject of scientific work, this study was carried out to: (i) determine mineral nutrition efficiency on growth potentialities, (ii) evaluate the effect of fertilizers on upland ratoon rice (Oryza sp) variety Nerica 5yields under rainfed conditions, (iii) determine minerals agronomic efficiencies.

2. Materiel and methods

2.1. Experimental site description and its floristic characteristic

Agronomic trials were carried out for two years, 2012 and 2013 on upland soil slightly inclined (0-2%) in Dabou (5°19'29.25" N 4°22'16.61" W) at an altitude of 54 m above sea level. Vegetation of five years fallow composed of six families (Amaranthaceae, Asteraceae, Convolvulaceae, Cyperaceae, Plantaginaceae and Poaceae) and fourteen species. The most abundant were *Gomphrena celosoides* (Amaranthaceae) and *Loudetia arundinacea* (Poaceae).

2.2. Rice variety

The rice variety used was NERICA 5. NERICA varieties are interspecific hybrid progenies between the two cultivated Oryza species, O. glaberrima and O. sativa **[15]**. The agronomic performance of this variety, characterized by an average flowering period of 63 days after germination, a cycle length and an average grain yield of 90 to 100 days and 4 tha^{-1}respectively **[16]**, have argued in favor of its use. Indeed, a bimodal rainfall regime, the rainy season has an average duration of 90 days. Thus, the cultivation of this variety ratoon can coincide with the short rainy season.

2.3. Fertilizers

During the main crop, NPK (10% N, 18% P, 18% K) was applied as basal dressing, while urea 46% was used as cover dressing. N (Urea; 46% N), P (TSP, 18-22% P), K (KCl, 50% K), Ca (CaCO3; 40% Ca), Mg (MgSO4. H2O; 17% Mg) and Zn (ZnSO4H2O; 36% Zn) were applied to the culms of the main crop plants.

2.4. Experiment site description

On farm agronomic trial was conducted in 2012 and 2013 at Dabou (05˚21'48''N; 04˚22'51''W; 80 m asl) a locality in South Cote d'Ivoire about 27 Km from Abidjan. It is a humid forest zone including endemic savannabiotype **[17]** and characterized by bimodal rainfall pattern with about 1200 mm as annual average rainfall amount. Two rainy seasons are altering with two dry seasons as shorter and longer periods of seasons respectively. Sub-equatorial climate is prevailing with average annual temperature of about 26˚C [**17-18**]. Hyperdystric Ferralsol is the major pedological trait of the area including Arenosol in places [26] but Fluvisols are dominant in the lowland ecology.

2.5. Landscaping and weeding

Experiment was laid out in a plot of 40 m and 19 m in dimension. Chemical fertilizer was applied at 0, 5 l of glyphosate in acid equivalent form (360 g/l) by spraying at total weed control. Three weeks later, vegetation was cleared manually and vegetable debris burned off the trial site.

2.6. Sowing and fertilizing treatments

Four blocks spaced by 1 m was carried out using 38 m x 3 m respectively for seven microplots of 5 m x 3 m spaced by 0, 5 m. Each year, in the rainy season, rice seeds were sown in rows directly at a rate of 3 to 4 grains per equidistant pocket of 20 cm [**19**] and at 2 to 4 cm depth. Thus, in 2012, considering rains delay, sowing was carried out in July. But in 2013, they were fulfilled on May. In each microplot, 200 $kgha^{-1}$ of NPK (10-18-18) were applied as basal. At tillering and heading, an input of 35 $kgha^{-1}$ of N in the form of urea (46%) was also made each time.

After the harvest, a second growing was observed as ratoon. Additional fertilizers were applied as six fertilizer treatments including 60 $kgha^{-1}$ urea, 33 $kgha^{-1}$ TSP, 90 $kgha^{-1}$ KCl, 21 $kgha^{-1}$ $CaCO_3$, 9 $kgha^{-1}$ $MgSO_4$and 10 $kgha^{-1}$ $ZnSO_4$ according to the recommendations of [**20-19**]in the main crop to supply stubble respectively N, P, K, Ca, Mg and Zn.

2.7. Data collection

2.7.1. Data of soil analysis

Before the experiment, in 2012, the soil was sampled in 0-20 cm depth of each micro plot using an augur. The samples were sun-dried, broken and sieved (2mm) [**21**] before laboratory analyses. Soil pH (Water and KCl) were determined by the glass electrode method. Its contents in Carbon and organic matter [**22-23],** exchangeable bases (K, Ca and Mg) [**24],** total N and CEC [**25**] and P assimilable **[26]** were determined. Furthermore, Fe, Cu and Zn contents [**23**], particles of coarse sands, fine sands, silts and clays [**27**] and soil texture [**28**] were determined.

2.7.2. Agromorphological data

In 2012 and 2013, numbers of tillers and panicles, 50% flowering period and the length of the cycle production were evaluated in a square meter of observation comprising 36 plants. At maturity, grain yields [1], fertilizers applied to ratoon agronomic efficiencies [2] and total grain yields considering the production of the main crop [3] were determined on an area of 8 m^2 after excluding the two rows border.

GY (tha^{-1}) = [MDG/HA] * [10000/1000]* [RH/100-SHR] [1]

MDG: mass of dried full grains in kg, HA: harvest area (8 m^2), RH: relative humidity, SHR: standard relative humidity (14%).

AEx (kg paddy / kg fertilizer applied) = (GYx-GYTe) / Dose of fertilizer applied [2]

AEx: agronomic efficiency of nutrient x, GYx: grain yield linked to the application of nutrient x, GYTe: grain yield of the unfertilized control.

TGY (tha^{-1}) = GY_{MC} + GY_R [3]

GY_{MC}: main crop grain yield, GY_R: ratoon grain yield

2.9. Statistical analysis

Average data values for tillers and panicles numbers, 50% flowering period, grain yields, agronomic efficiencies, rice production cycle length and total grain yields were generated and separated into homogeneous groups based on an analysis of variance using FISHER's least significant difference test at the α threshold of 0, 05 by SAS for Windows version 9.1.

3. Results

3.1. Granulometric and chemical characteristics of the soil

Grain size and chemical characteristics of upland soil determined in 2012 as well as the optimum values have been recorded in **Table1**. The pH_{Water} (6, 35) at 0-20 cm depth was lower than the optimum values. For pH_{KCl}, its value was 6, 11. The difference between pH_{Water} and pH_{KCl} was 0, 24. The carbon (5, 78), total nitrogen (1, 04), organic matter (9, 96 g. kg^{-1}) contents were low. This soil used was also particularly poor in assimilable P, K, Mg, Ca, and very rich in trace elements such as Zn, Feand Cu compared to the threshold values. They were respectively 0, 3 to 0, 4 cmol. l^{-1}, 0.5 to 4 cmol. l^{-1}, 4 cmol. l^{-1}, 0, 3 to 0.4 g. kg^{-1}, 19 to 45 ppm, 0, 4 to 1, 8 ppm and 0, 5 to 2, 0 ppm. Relative to chemical balances, Ca/Mg (16, 28) and Mg/K (0, 87) ratios were respectively greater than 10 and less than 2. Ca/K ratio was included in the interval Standards. K/CEC and K/Ca +

Mg ratios were less than 2. Saturation coefficient of adsorbent complex of 20, 73% was low compared to the optimal values. The percentages of coarse (62, 2%) and fine (37, 3%) sands were very high compared to those of silts (0, 4%) and clays (0, 1%).

3.2. Agromorphological parameters of Nerica 5 rice cropping sequences

Tables 2 and 3 show the average numbers of tillers, panicles, duration of 50% flowering periods and rice production cycle. The differences between the means were significant ($p < 0.05$) to very highly significant ($p < 0, 0001$) excluding the panicle number values in 2013. Overall, ratoon rice produced fewer tillers, panicles than the plants in the main crop. They flower earlier (15 days) and develop their production cycle more briefly (52 days). Excluding all the other parameters evaluated, annual averages for 2012 indicate that the numbers of panicles of the main crop plants (180 panicles/m^2) were greater than those of ratoon (139 panicles/m^2). But in 2013, these values of 152 and 128 panicles/m^2 respectively were equally significant.

Table 1: Granulometric and Chemical characters in the composite sample of 0-20 cm depths of upland soil in 2012

Characteristics	Parameters	Values	va valOptimum values
Chemical	pH_{Water}	6, 35	6, 5 < VO < 7
	pH_{KCl}	6, 11	
	N (gkg^{-1})	1, 04	1, 26-2, 25
	C (g kg^{-1})	5, 78	10, 26-20, 5
	C / N	5, 55	11-15
	MO (gkg^{-1})	9, 96	20, 1-40, 2
	K (cmol kg^{-1})	0, 16	0, 1
	Mg (cmol kg^{-1})	0, 14	0, 5-4
	Ca (cmol kg^{-1})	2, 28	> 4
	CEC (cmol kg^{-1})	12, 44	12-15
	P ass (en ppm gkg^{-1})	0, 05	0, 3-0, 4
	Zn (mg kg^{-1})	9, 40	0, 5-2, 2
	Fe (ppm)	142, 16	1-300
	Cu (ppm)	12, 40	
	Ca / Mg	16, 28	2-10
	Ca / K	14, 25	4-17
	Mg /K	0, 87	2-4
	K / CEC (%)	1	> 2
	K / Ca + Mg	0, 07	> 2
Granulometric	SC (%): (K + Ca + Mg) / CEC	20, 73	60<TS<90
	Coarse sand (%)	62, 2	
	Fine sand (%)	37, 3	
	Silt (%)	0, 4	
	Clay (%)	0, 1	

Table 2 Averages of tillers and panicles number as well as the durations of 50% flowering period and rice production cycle

Crop sequence	Tiller number (Nbm^{-2})	Panicle number (Nbm^{-2})	50% flowering period (days)	Production cycle (days)
Main crop	276a	166a	60a	105a
Ratoon	170b	133b	15b	52b
MG	223	149	38	78, 88
$Lsd_{0.5}$	26, 78	19, 21	1, 21	3, 33
P > F	<0, 0001	0, 0012	<0, 0001	<0, 0001

MG: Grand mean; a and b in column are indicating mean values with significant difference respectively (Fischer test)

Table 3: Annual averages (2012 and 2013) of tillers and panicles number as well as 50% flowering duration and rice production cycle

Crop sequence	Tiller number Nbm^{-2}		Panicle number Nbm^{-2}		50% flowering period (days)		Production cycle (days)	
	2012	2013	2012	2013	2012	2013	2012	2013
Main crop	321a	230a	180a	152a	63a	58a	115a	95a
Ratoon	172b	168b	139b	128a	12b	17b	60b	45b
MG	246	199	159	140	38, 80	38, 30	87, 50	70, 26
$Lsd_{0.5}$	33, 19	35, 70	26, 62	27, 60	1, 14	1, 09	1	1, 07
P > F	<0, 0001	0, 0009	0, 0034	0, 0875	<0, 0001	<0, 0001	<0, 0001	<0, 0001

MG: Grand mean; a and b in column are indicating mean values with significant difference respectively (Fischer test)

3.3 Effects of fertilizer treatments on ratoon rice agromorphological parameters

For both years, the averages of fertilizer treatments effects on growth parameters (**Table 4)** were significant at 5% level, with the exception of production cycle length.

Regarding growth parameters, nitrogen effects on tillering (200 Nbm^{-2}) and panicles initiation (164 Nbm^{-2}), were the highest. This mineral, as well as P, K and Ca induced 50% lower flowering periods (13 to 14 days). However, cycles productions durations of fertilized and unfertilized ratoon fluctuated between 52 and 54 days.

By the annual averages (**Table 5),** fluctuations in the effects of minerals on all the parameters studied were observed, excluding ratoon production cycle length. In 2012, only Ca favored a higher number of tillers (207 Nbm^{-2}), panicles (176 Nbm^{-2}), associated with a lower flowering time (10 days). These values represented respectively 62, 53% (331 Nbm^{-2}), 102, 92% (171 Nbm^{-2}), and 16, 12% (62 days) of those observed in the main crop. N and K also induced a higher number of panicles (163 to 171 Nbm^{-2}) and a shortest flowering period (10 to 11 days). On the other hand, during the 2013 trials, only N effects on tillering (214 Nbm^{-2}) and panicles production (165 Nbm^{-2}) were the most important representing respectively 90, 67% (236Nbm^{-2}) and 120, 46% (137 Nbm^{-2}) of main crop production. Nitrogen also generated a low flowering period duration (17 days) like P, K, Ca, Mg and Zn. The cycle duration of ratoon production induced by these fertilizers (45 days) were not significantly different from that of the controls (48 days).

Table 4: Averages of tiller number, panicle number, 50 % flowering period and production cycle (2012, 2013) of rice ratoon treated relative to the main crop

Fertilizer treatments	Tiller number (Nbm^{-2})	Panicle number (Nbm^{-2})	50% flowering period (days)	Production cycle (days)
Te	146bc	109b	18a	54a
N	200a	164a	14b	52a
P	174b	137ab	14b	52a
K	184ab	153ab	14b	52a
Ca	183ab	148ab	13b	52a
Mg	165b	118ab	15ab	52a
Zn	138c	107b	15ab	52a
CV (%)	24, 54	36, 76	20, 45	15, 12
Lsd$_{0, 05}$	42, 01	49, 52	3, 10	8, 02
P>F	0, 0588	0, 1420	0, 1364	0, 8969

In the same column, values assigned different letters are significantly different (Fischer test).

Table 5: Annual averages (2012 and 2013) of ratoon rice growth parameters, grain yield rice and fertilizers agronomic efficiency relative to the main crop

Fertilizer treatments	Tiller number (Nbm^{-2})		Panicle number (Nbm^{-2})		50% flowering period (days)		Production cycle (days)	
	2012	2013	2012	2013	2012	2013	2012	2013
Te	169bc	123c	123b	90b	15a	20a	60a	48a
N	186ab	214a	163a	165a	11d	17b	60a	45a
P	176ab	171b	140ab	134ab	12c	17b	60a	45a
K	190ab	178ab	171a	134ab	10d	18b	60a	45a
Ca	207a	160bc	176a	120ab	10d	17b	60a	45a
Mg	153b	176ab	109bc	127ab	13b	17b	60a	45a
Zn	121c	163bc	90c	124ab	13b	17b	60a	45a
CV (%)	19, 20	23, 51	18, 50	34, 27	5, 77	4, 73	0	6, 22
Lsd$_{0, 05}$	48, 58	58, 23	37, 91	64, 52	1, 05	1, 24	0	4, 16
P > F	0, 03	0, 12	0, 0001	0, 43	<0, 0001	0, 0005	-	0, 45
MC parameters	**331**	**236**	**171**	**137**	**62**	**56**	**115**	**95**

In the same column, values assigned different letters are significantly different (Fischer test).

3.4 Fertilizer treatments effects ratoon rice grain yields and minerals agronomic efficiencies

Considering the two years 2012 and 2013 trials, grain yields average (1, 50 tha^{-1}) and agronomic efficiency (71, 8 kg of paddy / kg of fertilizer) related to Ca application (**Figure 1)** were significantly the largest, corresponding respectively to 35, 35 and 59, 71% of that of the main crop. According to the annual means recorded in **Table6**, the differences were highly significant ($p < 0, 0001$) at 5% level. Ca generated higher grain yields in 2012 (1, 57 tha^{-1}) and 2013 (1, 44tha^{-1}) associated with most important values of agronomic efficiencies 74, 83 and 68, 77 kg of paddy / kg of fertilizer respectively. However, Zn also generated such high agronomic efficiencies (70, 95 kg paddy/kg fertilizer) only in 2013.

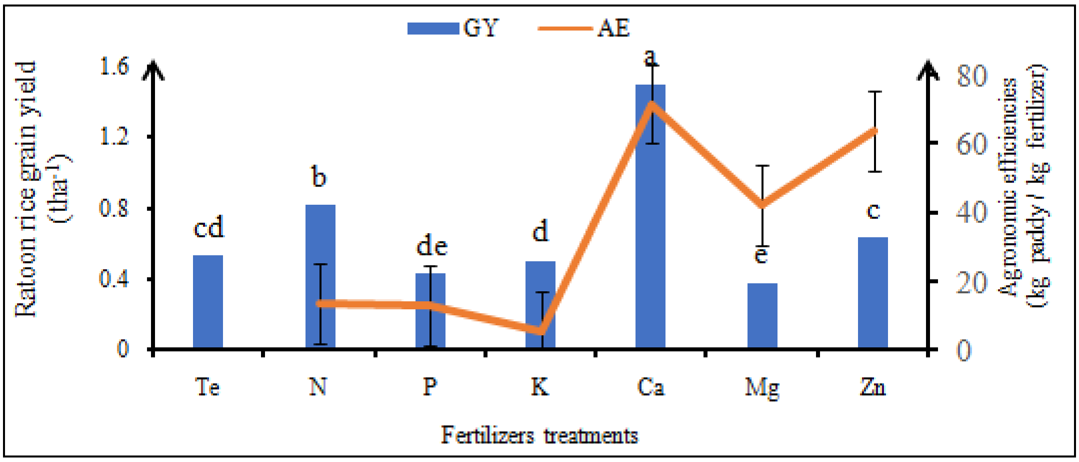

Figure 1: Ratoon rice grain yield (GY) and fertilizer agronomic efficiency (EA)

In histogram, bands with different letters are significantly different (Fischer test). On the curve, vertical lines represent error bars.

Table 6: Annual averages (2012 and 2013) of ratoon rice grain yields and agronomic efficiencies of fertilizers

Fertilizer treatments	GY (tha^{-1})		AE (kg paddy/ kg fertilizer)	
	2012	2013	2012	2013
Te	0, 56c	0, 51e	0f	0e
N	0, 72b	0, 92b	12, 03d	15, 33c
P	0, 28d	0, 59d	8, 44de	18, 00c
K	0, 29d	0, 72c	3, 18e	8, 08d
Ca	1, 57a	1, 44a	74, 83a	68, 77a
Mg	0, 28d	0, 47e	31, 56	53, 15b
Zn	0, 57c	0, 71cd	57, 05b	70, 95a
CV (%)	12, 31	11, 23	19, 29	14, 06
$Lsd_{0,05}$	110, 57	127, 08	7, 58	6, 92
P > F	<0, 0001	<0, 0001	<0, 0001	<0, 0001
MC parameters	**4, 443**	**2, 413**	-	-

In the same column, values assigned different letters are significantly different (Fischer test).

Total grain yields average values obtained and yield increase percentage the two years are shown in **Figure 2.** For each parameter, the differences between the values were significantly at 5% level. The total grain yields due to calcium (6, 10 t) was the highest. It corresponded to an increase of 57, 56% compared to the main crop values.

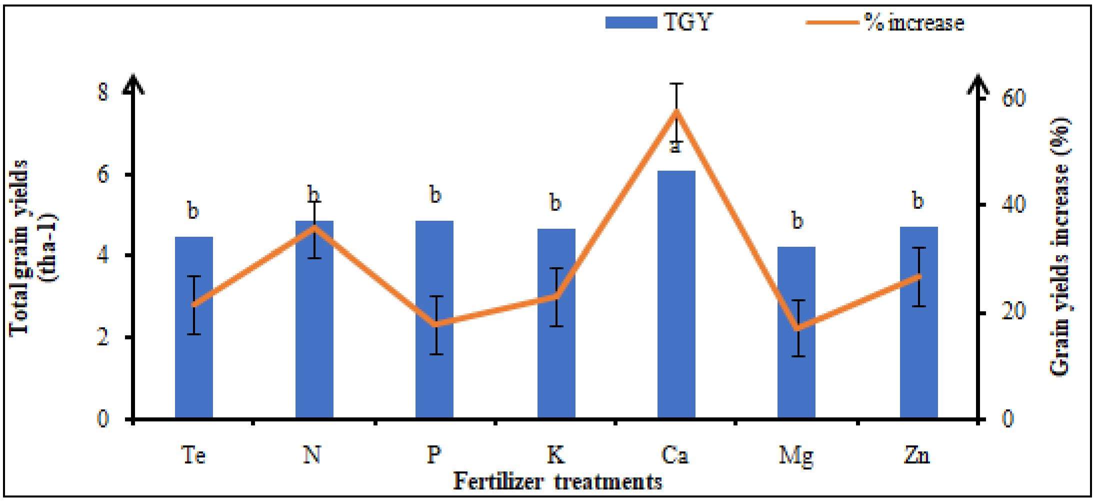

Figure 2: Total grain yield (TGY) and increase percentage according to the main culture production

In histogram, bands with different letters are significantly different (Fischer test). On the curve, vertical lines represent error bars.

4. Discussion

Analyzes of physical parameters indicated that soil horizon 0-20 cm had a sandy-loam texture as observed by **[29]** in another locality of Dabou. The importance of sandy fraction (99, 5%) could be linked to the detrital nature of the original soil material in the region occasioning high proportions of coarse sands (62, 2%) and more irrigation water filtration coupled to nutrient loss. The depth layers enriched in clay could constitute a source of subsequent water nutrition in the dry season. Moreover, the study of the chemical composition of the soil top horizon further indicated that the soil was weakly acidic with a low cation exchangeable capacity with reference to the difference in pH **[30]**.

There is an also low content of nitrogen and phosphorus according to the values indicated by many references [**31-32-33]**. These chemical characteristics were relevant to the sandy to sandy-loam textures as observed. In fact, soils with a sand to sandy-loam textures are generally light and poor in exchangeable cations. The acidity would justify the deficiency of these soils in exchangeable cations and phosphorus. Indeed, the H^+ protons, by occupying the binding sites of the exchangeable cations on the clay-humus complex, cause easiest leaching. These observations have already been reported by subsequent works, including those of [**34]**. The ratios of Ca / Mg ratios > 10; 4 < Ca/K < 17 and Mg/K < 2 are indicating that calcium has been in excess for magnesium and potassium contents while magnesium has deficiency relatively for potassium. In addition, the cation saturation coefficient (20, 73%), K / CEC < 2 and K / Ca + Mg < 2 ratios were very low, leading to the conclusion that potassium was deficient compared to the sum of calcium. and magnesium [**35]** on a desaturated soil adsorbent complex [**33]**. Potassium and magnesium could be factors limiting rice production. The soil was poor in organic matter with a low C/N ratio compared to the average value of 11 to 15 [**36].** The lack of organic matter in 0-20 cm depth could be due to poor root development in this layer with a sandy silty texture. The low values of C, N and low C / N are a sign of the more or less complete blockage of biological life and the mineralization process [**37]** partly due to the high aeration conditions of the soil. These chemical conditions would have led to its cation exchange capacity relative importance, the evolution of which is illustrated by the difference between pH_{Water} and pH_{KCl} **[38]**. Also, even a fallow period of 4 years would seem insufficient to restore the chemical properties of a soil with a sandy loam texture. However, given the saturation coefficient of cation exchangeable (20, 73%), mineral fertilization of this desaturated soil could improve its fertility and promote rainfed rice growing.

Compared to the growth parameters of the two sequences of rice cropping, the rice ratoon rice generated fewer numbers of tillers and panicles than the main crop. They flower earlier and develop their production cycle duration shortest. But ratoon rice can produce as many panicles in the main crop. The low tillering in ratoon rice could be the consequence of a reduced number of nodes on the culms of the main crop at a cutting height of 15 cm and a strong apical dominance suppressing the axillary buds. Thus, in reduced numbers in regrowth, these nodes, which would be zones with high meristematic activity for the formation of tillers, under the control of growth hormones [**39]**, would emit less than the plants in the culture. Main during the vegetative phase of the cycle [**40]**. These results contrast with those of [**41]**. In ratoon rice, the floral change would have been less important under the effect of less stimulating endogenous hormonal factors such as abscisic acid and ethylene than in the main crop (Huijser and Schmid, 2011). The earlier flowering of ratoon rice compared to the main crop has already been observed by [**42-43].** It is due to the short duration of the vegetative phase influenced by the reserve soluble sugars contained in the culms compared to that of the main crop [**43]**. This observation seems obvious so far as regrowth originates from the nodes bearing viable buds on the culms of the main crop whose roots were pre-existing. The fluctuations observed between 2012 and 2013 concerning the number of panicles according to the crop sequences showed the stimulation effect of endogenous factors specially onratoon rice vegetative buds floral turning could be linked to the physiological age of the culms [**44]**. For younger culms (95 days), these factors would be more favorable.

Overall, the fertilizing treatments on regrowth revealed that nitrogen generated higher numbers of tillers and panicles. This mineral, along with P, K and Ca induced 50% lower flowering times. However, no significant effect of these minerals was observed on the length of ratoon production cycle. Mean grain yields and agronomic efficiency related to Ca application were the greatest. The results of the effects of fertilizer treatments on the growth parameters of ratoon rice highlighted the contribution of nitrogen to increased tillering and the production of panicles of Nerica 5 ratoon rice. These results were also observed in lowland Nerica L 14 **[45]**, in other interspecific upland rice varieties **[6]**. This demonstrates the importance of the effect of nitrogen fertilization in plant organogenesis. Indeed, nitrogen is involved in the synthesis of phytohormones such as auxins and cytokinins [**46]**, enzymatic proteins, synergistic absorption of other minerals. An increase in these cellular constituents would have enhanced cell divisions at bud meristems, their differentiation into tillers, and subsequent floral turning at panicle origin. Relative to the results for each of the two years, this effect is greater in younger culms, which would absorb more nitrogen through their more functional roots. These results were obtained in the main cycle of rainfed rice cultivation **[47]**. Annual fluctuations in the effects of minerals on all studied parameters were observed except for the length of the production cycle of ratoon rice. Probably, relationship between ratoon rice and chemical characteristics of the soil could be one of the causes. In 2012, only Ca favored a higher number of tillers, large panicles as with N and K, higher grain yield and agronomic efficiency associated with a shorter flowering time as with N and K. During the trials of the second year (2013), only N caused tillering, a production of larger panicles. These values represented respectively 90, 67% and 120, 46% of the main crop production. Nitrogen as well as P, K, Ca, Mg and Zn generated shorter flowering times. This generated high grain yields and agronomic efficiencies. Zn also generated similarly high agronomic efficiencies. Calcium-induced total grain yield was the highest and corresponded to an increase of 57, 56% over the main crop values. The soil is acidic, light with a sandy to sandy-loamy texture, poor in clay, in exchangeable bases, in nitrogen and in organic matter, and very rich in trace elements such as Zn, Fe and Cu compared to the threshold values. These characteristics give this soil a low ability to regulate physico-chemical phenomena with regard to clay poverty [**48]**. Its acidity and low organic matter content would have hindered the availability of P, K, Mg and Zn applied the first year unlike in 2013 for optimum growth. The first year, low saturation coefficient of exchangeable bases had to be improved thanks to the application of calcium by amendment of the clay-humus complex. This improvement would have increased cation exchange capacity, corrected chemical balances favorable to tillering, the production of panicles, the precocity of flowering and consequently grain yields and agronomic efficiency. According to the results for 2013 relating to tillering, panicle production and grain yields, the previous crop would have favored a correction of the balances between K, Ca and Mg for synergistic absorptions, as well as the organic matter content [**49**]. Thus, the effects of N on tillering and ratoon panicle production could be attributed to a synergistic uptake of Ca and Mg as well as P and Zn. The flowering earliness linked to the application of nitrogen diverges with the observations of [**50**]. The effect of nitrogen seems to be linked to its involvement in the increase of leaf chlorophyll content allowing photosynthesis activation in favorable light and water conditions **[51]**. The increase in foliar chlorophyll pigments would have led to a significant synthesis of carbohydrates compared to proteins and a high C / N ratio in favor of the floral shift. The results show that the nutrients (N, P, K, Ca, Mg and Zn) have an activating role on the metabolism of rice ratoon rice. They would have acted to elevate the C/N ratio inside the vegetative buds. These observations are consistent with those of [**52**]. Particularly Ca would have favored a better translocation of the photoassimilates contained in the vegetative organs towards the grains. Because Ca is involved not only in the formation of the middle lamellae of cell walls but also as a messenger positively influencing the opening and closing of stomata, photosynthesis, grain filling [**53**]. The egalitarian importance of the agronomic efficiency of Zn could be due to the presence of silt making this mineral more available for the plant [**54**] and also to its subsequent involvement in carbohydrate storage metabolism in rice grains [**55**].

5. Conclusion and Recommendations

In upland rice cultivation on soil with a sandy silty texture poor in exchangeable bases and organic matter, the regrowth of Nerica 5 is characterized by greater precocity, tillering and a lower grain yield (15, 59%) relatively to the main culture. In ratoon rice, nitrogen increases the number of tillers and panicles. Minerals P, K, N, Ca, Mg and Zn actively flowering plants. Ca increases grain yields to around 45, 36% of the potential of the main crop. Consequently, its agronomic efficiency is higher like that of Zn. An application of Ca at 21 kgha^{-1} is recommended in upland rice cultivation to increase the RDG of ratoon rice and obtain an RDGT of around 136, 58% of the potential of the main crop.

Acknowledgement

We address our sincere thanks to Dr. Sitapha Diatta for his precious help in the acquisition of Nerica 5 seeds. We also express our gratitude to Dr. Brahima Koné, initiator of this research work and for his help in carrying out the experimental protocol, statistical analysis and improvement of the article.

References

[1] **Ringera T. J., Jenesio K. I., Amugune O. & Kanya I. J.2014.** Ratooning ability and its effect on grain yield of upland Nerica rice varieties in Central Kenya. *International Journal of Agronomy and Agricultural Research*, **4** (4): 44-55.

[2] **Sanni L. O., Onadipe O. O., Ilona P., Mussasy M. D., Abass A. & Dixon A. G. O.2009.** Successes and Challenges of cassava enterprises in West Africa: A case study of Nigeria, Benin and Sierra Leone. IITA, Ibadan, Nigeria, 19 p.

[3] **Anonyme 2010.** Growing NERICA in Zambia-Upland Rice. FoDiS (Food crop diversification support project) Information Series, pp.1-19.

[4] **Harrell D. L., Bond J. A. & Blanche A.2009.** Evaluation of the main-crop stubble height on ratoon rice growth and development. *Field Crops Research*, 114: 396-403. *Development*, **138**: 4117-4129.

[5] **Islam M. S., Hasanuzzaman M. & Rokonuzzaman Md.2008.** Ratoon rice response to different fertilizer doses in irrigated condition. *Agriculturae Conspectus Scientificus*, **73** (4): 197-202.

[6] **Negular R. B., Yadahalli G. S., Chittapur B. M., Guruprasad G. S. & Narappa G.2017.** Ratoon Rice: A Climate and Resource Smart Technology. *International Journal ofCurrent Microbiology and Applied Sciences*, **6** (5): 1638-1653.

[7] **Daliri M. S., Eftekhari A., Mobasser H. R., Tari D. B. & Porkalhor H.2009.** Effect of cutting time and cutting height on yield and yield components of ratoon rice (Tarom langrodi variety). *Asian Journal of plant sciences*, **8** (1): 89-91.

[8] **Prasanna S. M. & Pattar P. S.2014.** Successful ratoon management in sugarcane. *Journal of Agriculture and Applied Sciences*, **3** (4): 39-48.

[9] **Kahn B. A. & Leskovar D. I.2001.** A ratoon cropping system for fall bell pepper production. *HortScience*, **33** (5): 897-899.

[10] **Elder R. J., Reid D. J., Macleod W. N. B. & Gilespie R. L.2002.** Post-ratoon growth and yield of three hybrid papayas (Carica papaya L.) under mulched and bare-ground condition. *Australian Journal of Experimental Agriculture*, **42**: 71-81.

[11] **Junelyn S. & De la Rose, 2004.** Harvest more with ratooning. Bar Today.

[12] **Prashar C. K. R.1970.** Some factors governing rice-ratoon yields. *Plant and Soil*, 32: 540-541.

[13] **Evatt N. S. & Beachell H. M.1960.** Ratoon cropping of short season rice varieties in Texas. *International Rice Commission Newsletter*, **9** (3): 1-4.

[14] **Ichii M.1982.** The effect of light and temperature on rice plant rations. *Japanese Journal of Crop Science*, **51** (3): 281-285.

[15] **Somado E. A., Guei R. G. & Keya S. O.2008.** NERICA: The New Rice for Africa-a Compendium.210 p.

[16] **WARDA, 2008.** Africa Rice Trends 2007. Cotonou, Benin: Africa Rice Center (WARDA). Fifth edition, eds. Aliou Diagne, Ibrahima Bamba, Ali A Touré, Achille Medagbe, p.84.

[17] **Caliman J. P.1990.** Dégradation des propriétés physiques conditionnant la fertilité des sols sous culture du palmier à huile en Côte d’Ivoire: Essai de correction. Thèse de Doctorat ès Sciences, Sciences du sol, Université de Bourgogne, Dijon (France), 219 p.

[18] **Traore K. & Mangara A.2009**. Etude Phyto-Écologique des Adventices dans les Agro-Écosystèmes Élaeicoles de la Mé et de Dabou. *European Journal of Scientific Research* ISSN 1450-216X.31 (4): 519-533

[19] **Koné B., Saïdou A., Camara M., & Diatta S.2010.** Effet de différentes sources de phosphate sur le rendement du riz sur sols acides: Optimisation du phosphate sur un hyperdystric ferralsol. *Agronomie Africaine*, 22 (1) 55-63.

[20] **Koné B., Amadji G. L., Igue A. M. & Ogunbayo A.2009.** Rainfed upland rice production on derived savannah soil in West Africa. *Journal of Animal & Plant Sciences*, **3 (1):** 156-162.

[21] **Gee G. W. & Bauder J. W.1986.** Particle-size analysis. Methods of soil analysis. Part 1. Physical and mineralogical methods.2ème ed. Agron.9. ASA, SSSA, Madison, WI. Gobin, A., Campling, P., Deckers, 383-423 p.

[22] **Walkley A. & 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 Science, 37: 29-38.

[23] **CEAEQ (Centre d'Expertise en Analyse Environnementale du Québec) 2003.** Détermination des métaux, des oligoéléments, du phosphore et du soufre par les méthodes d'extraction Mehlich-III, extraction du bore à l'eau chaude et dosage par spectrométrie d'émission au plasma d'argon. Ministère de l'Environnement du Québec, 19 p.

[24] **Ciesielski H. & Sterckeman T.1997.** Determination of cation exchange capacity and exchangeable cations in soils by means of cobalt hexamine trichloride. Effects of experimental conditions. *Agronomy*, **25:** 9-16.

[25] **Kjeldahl J.1883.** A New method for the determination of Nitrogen in Organic Matter. Zeitschrift fur Anaytische Chemie, 22: 366-382.

[26] **Dabin B.1967**. Sur une méthode d'analyse du phosphore dans les sols tropicaux. Colloque sur la fertilité des sols tropicaux. Tananarive (Madagascar), 19-25 Novembre 1967, pp 99-115.

[27] **Delaune M., Reiffsteck M. & Feller C.1991.** L'analyse granulométrique de sols et sédiments à l'aide du microgranulomètre "Sedigraph 5000 ET"-Comparaison avec la méthode "pipette Robinson". Cahier Orstom, série Pédologie, 17 (2): 183-189.

[28] **Richer de Forges A., Feller C., Jamagne M. & Arrouays D.2008.** Perdus dans le triangle des textures. Etude et Gestion des Sols.15 (2): 97-111.

[29] **Ouattara G., Bomisso E. L., Cherif M., Camara B., Sorho F., Dick A. E. & Kone D.2015.** Effets du lit et de la densité de plantation sur la croissance végétative de l'ananas (*Ananas comosus* L., var. Md2) dans la localité de Dabou en Côte d'Ivoire. *European Scientific Journal*, **11** (18): 411-424.

[30] **Lacharme M.2001a.** La fertilisation minérale du riz. Mémento Technique de Riziculture, Fascicule n° 6, 19 p.

[31] **LANO, 2008.** Analyses des terres http: //www.lano. asso. fr/web/analysEssai Html. Consulté le 20 Juin 2017.

[32] **Ballot C. S. A., Mawussi G., Atakpama W., Moita-Nassy M., Yangakola T. M., Zinga I., Silla S., Kpérkouma W., Dercon G., Komlan B. & Koffi A.2016.** Characterization physicochemical soils to improve productivity of cassava (Manihot esculenta Crantz) in the region of Damara in south-central of Central African Republic. *Agronomie Africaine*, **28** (1): 9-23.

[33] **Koné B., Fatogoma S. & Chérif M.2013.** Diagnostic of mineral deficiencies and interactions in upland rice yield declining on foot slope in a humid forest zone. *International Network for Natural Sciences*, 11-19.

[34] **Akassimandou F. E., Hien M. P., Bouadou Oi B. F., Bolou Bi B. E., Bongoua A. J., Ettien D. J. B. & Yao-Kouamé A.2017.** Efficiences des nutriments P et K en riziculture irriguée dans un bas-fond secondaire en zone de savane guinéenne de la Côte d'Ivoire. *European Scientific Journal*, **13 (36):** 432-453.

[35] **Lacharme M.2001b.** La fertilisation minérale du riz. Mémento Technique de Riziculture, Fascicule n° 6, 19 p.

[36] **Lavigne D., Boucher L. & Vidal L.1996.** Les bas-fonds en Afrique tropicale humide: stratégies paysannes, contraintes agronomiques et aménagements in Pichot et al eds. Fertilité du milieu et stratégies paysannes sous les tropiques humides, Actes du séminaire international, CIRAD, pp 148-161.

[37] **Philippe D. V. & Virginie L.2002.** Le pHEau et le pHKCl du sol. Réussir sa forêt. Ecologie. Fiche technique **5**: 9-10.

[38] **Kahn M., Rozhon W. & Poppenberger B.2013.** The Role of Hormones in the Aging of Plants. *Gerontology*, **60**: 49-55.

[39] **Wopereis M. C. S., Diagne A., Rodenburg J., Sié M. & Somado A. E.2008.** Connaissance de la plante de riz. Curriculum APRA-GIR: Manuel technique.9 p.

[40] **Oad F. C., Ponpe S. C., Memon N., Oad, N. L. & Hazzan Z.2002.** Rice ratooning management. *Pakistan Journal of Applied Science*, **2**: 20-35.

[41] **Santos A. B., Fageria N. K. & Prabhu A. S.2003.** Rice Ratooning Management Practices for Higher Yields. *Communications in Soil Science and Plant Analysis*, **34**: 881-918.

[42] **Golam F., Taha R. M. & Prodhan Z. H.2014.** Rice Ratoon Crop: A Sustainable Rice Production System for Tropical Hill Agriculture. *Sustainability*, **6**: 5785-5800.

[43] **Santos A. P., Serra T., Figueiredo D. D., Barros P., Lourenco T., Chander S., Oliveira M. M. & Saibo N. J.2011.** Transcription regulation of abiotic stress response in rice: a combined action of transcription factors and epigenic mechanisms. OMICS 15, 839-857.

[44] **Kouakou O., Mamadou C., Brahima K., Dick E. & Konan K. F.2014.** Growth, yields and ratooning performance of lowland rice Nerica l14 as affected by different fertilizers. *Indian Journal of Science and Technology*, **2** (2): 18-24.

[45] **Kiba *et al.*, 2011.** Hormonal control of nitrogen acquisition: roles of auxin, abscisic acid, and cytokinin. *Journal of Experimental Botany*, **62** (4): 1399-1409

[46] **Endris Y. & Alemayehu B.2014.** Effect of Nitrogen Application on Grain Yield and Nitrogen Efficiency of

Rice (Oryza sativa L.). *Asian Journal of Crop Science*, **6**: 273-280.

[47] **Saidi D., Le Bissonnais Y., Duval O., Daoud Y. & Tessier D.2008**. Estimation et signification de la capacité d'échange cationique des sols salés du Cheliff (Algérie). Etude et Gestion des Sols, **15** (4): 241-253

[48] **Koné B., Fatogoma S. & Chérif M.2013.** Diagnostic of mineral deficiencies and interactions in upland rice yield declining on foot slope soil in a humid forest zone. *International Journal of Agronomy and Agricultural Research*, **3** (7) 11-20.

[49] **Ye T., Li Y., Zhang J., Hou W., Zhou W., Lu J., Xing Y. & Li X.2019.** Nitrogen, phosphorus, and potassium fertilization affects the flowering time of rice (*Oryza sativa* L.). *Global Ecology and Conservation*, **20**: 1-9.

[50] **Castro R. & Sarker A. B. S.2000.** Rice growth response to different proportions of applied nitrogen fertilizer. *Cultivos Tropicales*, **21 (4):** 57-62.

[51] **Cho L., Yoon J. & An G.2017.** The control of flowering time by environmental factors. *The plant journal*, **90:** 708-719.

[52] **Medvedev S. S.2005.** Calcium Signaling System in Plants. *Russian Journal of Plant Physiology*, **52** (2), 249-270.

[53] **Hafeez B., Khanif Y. M. & Saleem M.2013. Role of Zinc in Plant Nutrition.** *American Journal of Experimental Agriculture*, **3 (**2): 374-391.

[54] **Marschner H.1995.** Mineral nutrition of higher plants (2nd ed.). London: Academic Press.