Global Journal of Agricultural Research
Vol.10, No.2, pp.26-35, 2022
Print ISSN: 2053-5805(Print),
Online ISSN: 2053-5813(Online)

Straw yield optimization strategy for rice (*Oryza* sp L. var Nerica L14) regrowth under strictly rainfed conditions : impact on mineral content

Gogbeu Dan Gbongué Lucien[1*], Konan Yao Kouakou François[2], Amari Ler-N'ogn Dadé Georges Elisée[1], Coulibaly Ben Idriss[1], Camara brahima[1], Tuo Seydou[1], Kouakou Tanoh Hilaire[3] and Koné Daouda[1]

[1]Université Félix Houphouët-Boigny, UFR Biosciences, 22 BP 582 Abidjan 22, Côte d'Ivoire.
[2]Université Jean Lorougnon Guédé, UFR Agroforesterie, BP 150 Daloa, Côte d'Ivoire
[3]Université Nangui Abrogoua, UFR Sciences de la Nature, 02 BP 801 Abidjan 02, Côte d'Ivoire

Citation : Gogbeu Dan Gbongué Lucien, Konan Yao Kouakou François Amari Ler-N'ogn Dadé Georges Elisée, Coulibaly Ben Idriss, Camara brahim, Tuo Seydou1, Kouakou Tanoh Hilaire and Koné Daouda1Straw yield optimization strategy for rice (Oryza sp L. var Nerica L1) regrowth under strictly rainfed conditions : impact on mineral content, *Global Journal of Agricultural Research* , Vol.10, No.2, pp.26-35

ABSTRACT : *In order to increase the quantity and quality of rice straw, experiments were conducted with six types of fertilizers with elemental sources (N-P-K-Ca-Mg-Zn) in Dabou, a locality located in the south of Côte d'Ivoire in the Grand Pont region. Examination of the results showed that fertilisers significantly improve the yield and straw quality of Nerica L 14 rice. However, better yields were obtained with nitrogen (1048.275 kg.ha^{-1}) and phosphorus (810.55 kg.ha^{-1}) as major elements while calcium and zinc as trace elements boosted yields to 763.65 kg.ha^{-1} and 810.25 kg.ha^{-1} respectively. As for the mineral content of the straw, only calcium and magnesium had a high influence.*

KEY WORDS : Nerica L14, rice straw, fertilizers, yields.

INTRODUCTION

Rice is the third most important cereal produced in the world after wheat and maize. With an annual volume of 600 million tonnes of paddy (CIRAD, 2021). However, food self-sufficiency is still a major challenge for all countries south of the Sahara. This inability to satisfy the nutritional needs, even if only in quantitative terms, of a constantly growing population is the result of the strong interaction of two factors: one circumstantial and natural (scarcity and uneven distribution of rainfall), the other structural and human (population increase) (Paula, 1999). Therefore, increasing rice production through a good mastery of cultivation techniques would be a solution to this imbalance. Also, rice production is not only limited to human consumption as its residues are used in various ways. In sub-Saharan Africa, in countries such as Senegal, Mali and Burkina Faso, where fodder is scarce at certain times of the year, rice straw is used to feed livestock (Kouable and Tre, 2014).

In Côte d'Ivoire, not only is straw production low, but its use remains unknown to the majority of the population. Encouraging the valorisation of this rice by-product would be a new alternative for sustainable development but also for agro-pastoral development. Indeed, livestock farming contributes about 4.5% to agricultural GDP and 2% to total GDP, and is nevertheless an important activity that concerns a large number of livestock farmers in Côte d'Ivoire, estimated at more than 360,000 people (Kouassi et *al*., 2020). It contributes to strengthening food security, diversifying and increasing people's incomes, and preserving and improving the environment, in particular through the development of the agriculture-livestock association (Kouable and Tre, 2014). Based on this observation, it would be important to increase and enrich rice residues. The present work is conducted within the framework of identifying mineral fertilisers likely to induce a higher straw yield from NERICA L 14 rice regrowth and, secondly, to determine fertilisers that improve the mineral content of NERICA L 14 rice regrowth straw.

Study site

The experimental site is a floodplain located in the Dabou region (05°21'484"N and 04°22'518"W), 27 km from Abidjan, in southern Côte d'Ivoire. It is a savannah-inclusive forest zone (Caliman, 1990) with an average annual rainfall of 1200 mm and a bimodal rainfall regime (SODEXAM, 2019). The soil is ferralitic and highly leached on neogenous sand. The average annual temperature is 26°C. The sub-equatorial climate of this locality is characterised by two rainy seasons: one centred on the month of June, the other more reduced, occupying the months of October and November (Caliman, 1983).

Plant material

The plant material consists of the straw of NERICA L 14 rice regrowth. Nerica rice is an interspecific variety resulting from a cross between the species Oryza sativa (of Asian origin) and Oryza glabberrima (of African origin). NERICA L 14 has a short cycle of 90 days.

Fertilisers applied

For fertilisation of the main crop, NPK fertiliser (10-18-18) and urea at 46% nitrogen were applied. For the regrowth crop, super triple phosphate ($Ca(H2PO4)2-H2O$) with 43% phosphorus (P), potassium chloride (KCl) with 60% potassium (K), magnesium sulfate ($MgSO4. H2O$) with 16% magnesium (Mg), zinc sulphate ($ZnSO4H2O$) with 36% zinc (Zn), calcium carbonate ($CaCO3$) with 40% calcium (Ca) and urea with 46% nitrogen (N) were used.

METHODS

Setting up the experimental plots

Site preparation

An experimental plot of 1053 m2 (39 m × 27 m) was cleared mechanically with a machete. Once dried, these weeds were incinerated and piled outside the experimental area.

Installation of the main crop

For the establishment of the main crop, four rectangular blocks were staked out, each composed of seven microplots, which are themselves rectangular using the Pythagorean rule (3-4-5). The microplots are separated by 0.5 m wide bunds. A 0.5 m drainage channel separates two consecutive blocks (Koné et *al*.; 2000). Two weeks before transplanting, each microplot was marked by deep ploughing with a daba. In each microplot, 21-day-old seedlings were transplanted in rows at a spacing of 20cm×20cm after an application of 200 $Kg.ha^{-1}$ of NPK

(10-18-18) as a background fertiliser. At tillering (30-45 days) and at heading an application of 35 kg.ha^{-1} of urea (46%) was made in each experimental area (Koné et *al*., 2000).

Establishment of the regrowth crop

The establishment of the regrowth crop was done according to the set-up in Figure 1. Thus, after harvesting the main crop, cut to 15 cm above ground level, the seven microplots in each of the four blocks are considered as treatments in a completely randomised block design. Each of the seven) microplots in a block, with the exception of the control (which received no treatment), received only one treatment, i.e. 100 kg.ha^{-1} urea, 55 kg.ha^{-1} super triphosphate, 150 kg.ha^{-1} potassium chloride, 33 kg.ha-1 calcium carbonate, 15 kg.ha^{-1} magnesium sulphate and 10 kg.ha^{-1} zinc sulphate respectively.

Measured parameters

Agromorphological parameters of regrowth

Measuring the height of the plants

The height of 36 resprouts was measured on days 15 and 30 after cutting and at maturity (day 45 after cutting) with a tape measure from ground level to the tip of the longest leaf (Adigbo et *al*., 2006; Nguetta et *al*., 2006).

Determining the number of tillers/m^2

This parameter was assessed on 36 feet of the observation plot of each treatment at 15th, 30th and full maturity. The tillers from each of the 36 feet were manually counted and the values were summed (Gala et *al*., 2011).

Method for the determination of nitrogen

The organic nitrogen is mineralised as ammonium sulphate by the combined action of sulphuric acid and mineralisation catalysts. After this phase, the NH4+ ions resulting from this mineralisation, as well as those pre-existing in the water, are then transformed into ammonia by a soda lye and then carried by a steam stream to a trapping solution where it is measured by simple volumetry (acid/base titration) (Simone et *al*, 2017).

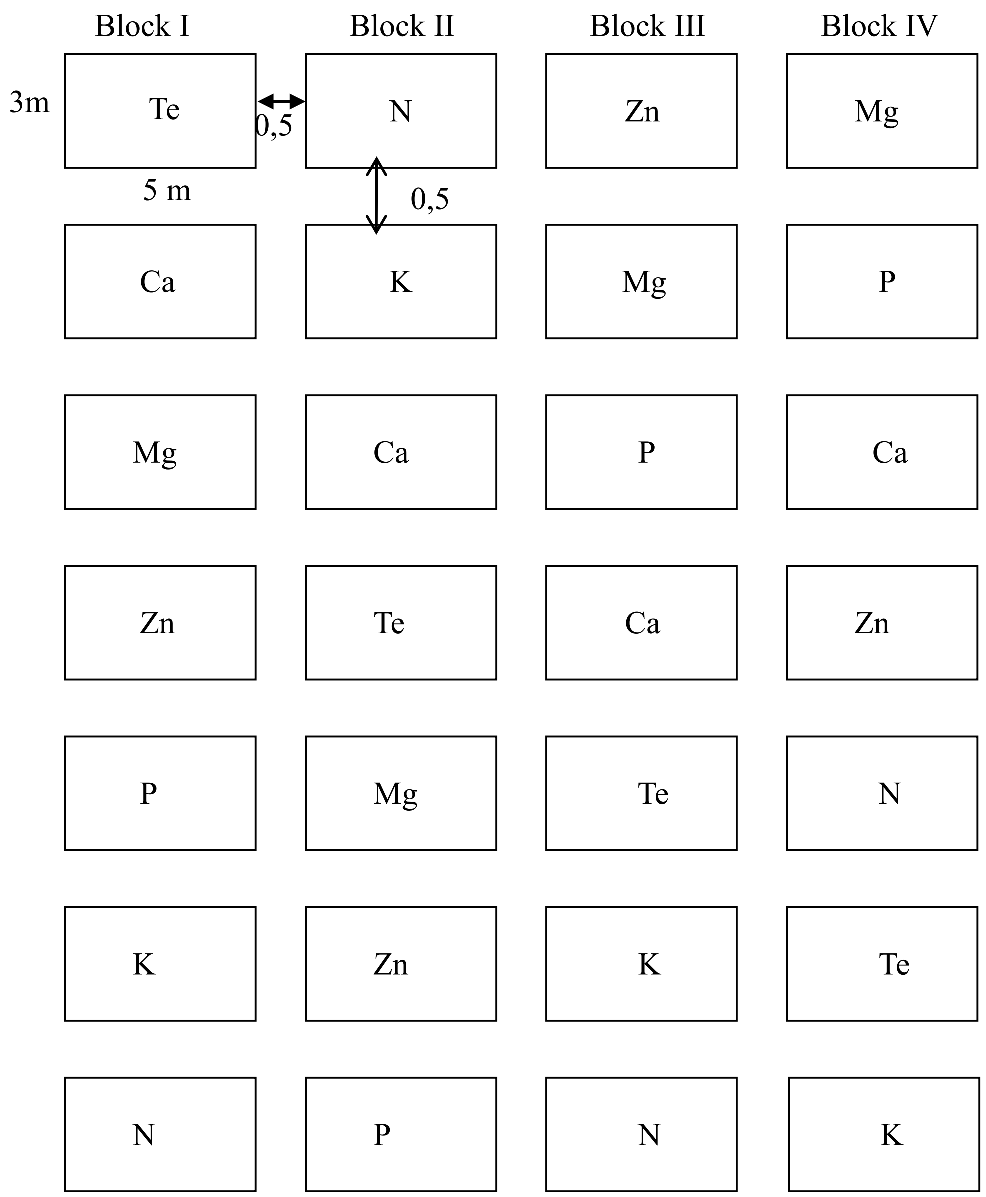

Figure 1: Schematic of the complete randomised scheme used in the establishment of the regrowth crop

Method for the determination of P, K, Zn, Mg and Ca

Extraction is done by digestion of the plant samples with perchloric acid. The determination of P is done by colorimetry, the principle of which is as follows: Under the effect of molybdate-vanadate, the phosphorus contained in the extract in the form of ortho-phosphate, gives a complex (phospho-vanado-molybdate) with a yellow colour whose intensity is measured with a spectrophotometer at a wavelength of 400 nm. The phosphorus content of the straw was determined relative to a standard curve of a phosphorus stock solution (25 ppm), obtained under the same conditions as the sample. The values are expressed as a percentage of dry matter (% DM). The determination of K, Zn, Ca and Mg was performed by atomic absorption

@ECRTD-UK: https://www.eajournals.org/
Publication of the European Centre for Research Training and Development -UK

spectrometry. After nebulisation of the sample from a mixture of air and acetylene, the determination of the element was carried out by measuring the absorption of emitted light. For each element there is a well-defined wavelength. The concentration of the studied element in the extract is evaluated by referring to a calibration curve previously made from a stock solution of each mineral.

Statistical analysis of data

The collected data set was subjected to two types of analysis: an analysis of variance with ANOVA and, in case of differences, the means were classified into homogeneous groups using Turkey's HSD test at the 5% threshold. All these analyses were performed using Statistica 7.1 software.

Results

Plant height

The values for regrowth height under various mineral fertilisers are presented in Table 2. For the same time after cutting (15 or 30 days after harvest), the values recorded were not significantly different whatever the fertiliser applied. On the other hand, at maturity, the height of the regrowth varied significantly according to the treatments. The regrowth that received nitrogen and calcium fertilisers had the greatest height. The values recorded were 605.46 mm and 612.39 mm respectively. The values obtained from the other fertilizer treatments (P, K, Mg and Zn) were statistically similar to each other and to the control.

Total number of tillers /m²

Figure 2 shows the effect of fertiliser treatments on the total number of tillers per square metre at days (15, 30 and 45) after harvest of the main crop. At 15 after regrowth, the treatments applied had no significant effect on tillers. Values per square metre ranged from 341 for the Mg fertiliser to 494 for the control treatment (Te). Thirty days after fertiliser application, the total number of tillers per square metre of the nitrogen, potassium and calcium treated regrowths were 589, 460 and 457 respectively, and were significantly higher than the control (423). At maturity, the total number of tillers of the nitrogen-treated seedlings was significantly higher than that of the control (562 tillers.m^{-2}). Among the trace elements applied, calcium and zinc induced the highest number of tillers per square metre, 483 and 473 respectively.

Table 2: Variation in height (mm) of NERICA L14 rice regrowth as a function of time and fertilizer treatments

	Days after harvest of main crop		
Treatments	**15**	**30**	**45**
Te	342,97 a	520,12 a	523,24 a
N	357,31 a	595,12 a	605,46 b
P	381,56 a	587,08 a	572,53 a
K	367,99 a	584,78 a	574,44 a
Ca	363,86 a	577,32 a	612,39 b
Mg	375,49 a	575,27 a	560,38 a
Zn	344,33 a	517,89 a	522,08 a

In the same row and in the same column, figures followed by the same letter are not significantly different at the 5% level

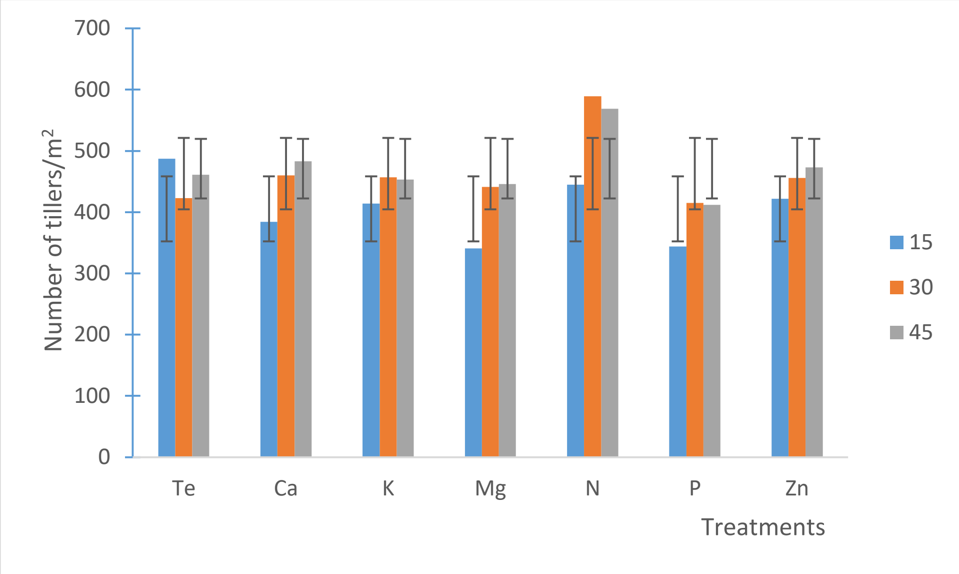

Figure 2: Effects of fertilizer treatments on the number of tillers/m^2

Straw yield

Figure 3 shows the effects of fertiliser treatments on straw yield of NERICA L 14 seedlings. The values of straw yields vary significantly according to the treatment applied. Thus, in the presence of nitrogen, the straw yield was significantly higher, with a value equal to 1048.27 kg.ha^{-1}. The lowest yields were noted in the regrowths that received potassium and magnesium fertiliser, as well as the untreated control. The values were equal to 608.425 kg.ha^{-1}, 594.325 kg.ha^{-1} and 648.625 kg.ha^{-1} respectively. Intermediate yields were observed following treatment of the regrowth with phosphorus (810.55 kg.ha^{-1}), calcium (763.65 kg.ha^{-1}) and zinc (810.25 kg.ha^{-1})

Mineral content of straw

The determination of the mineral content in the straw samples after the analysis reveals a variation according to the treatments (Table 2). Indeed, for the nitrogen (N) content, no significant difference is observed as all samples have a content approximately equal to that of the control (1.76%). The same situation is observed for the potassium content. On the other hand, the fertiliser treatments all had a significant influence on the magnesium content of the plant. For the calcium content, apart from the nitrogen and potassium treatments which did not induce a good content, i.e. 0.94% and 0.86% respectively, all the other treatments significantly influenced this quality. For the concentration of the element phosphorus (P), all the samples have a content highly superior to that of the control, i.e. 0.12%.

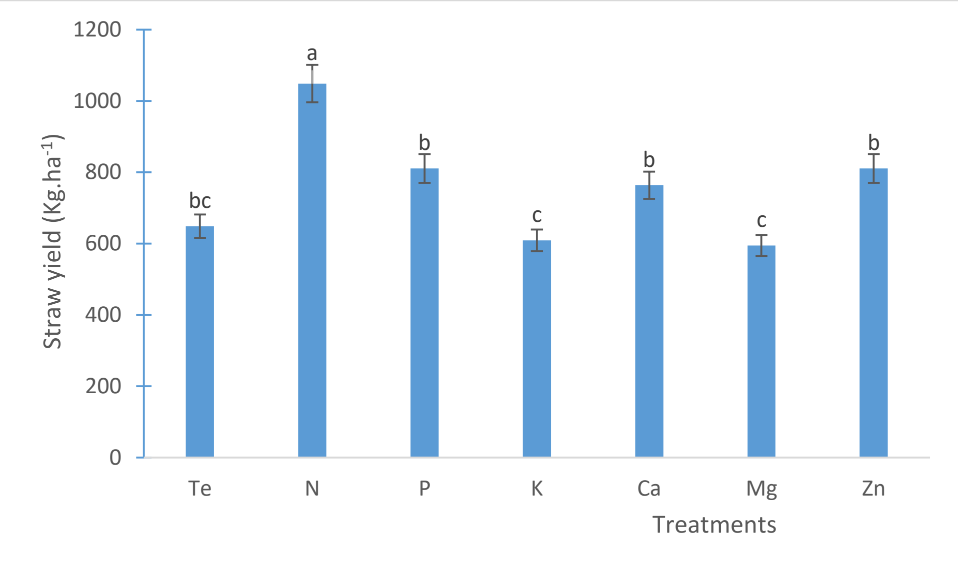

Figure 3: Straw yields of regrowth under different fertiliser applications
Bands marked with the same letter are not significantly different at the 5% level.

Table 2: Mineral contents of straw of NERICA L 14 rice regrowth under the effect of different fertilizers

	Mineral contents of straw expressed as a function of the percentage of dry matter				
Treatments	**N**	**P**	**K**	**Ca**	**Mg**
Te	1,76 a	0,12 b	1,77 a	0,76 b	0,15 b
N	1,56 a	0,15 b	1,89 a	0,94 b	0,26 a
P	1,63 a	0,28 a	1,62 a	1,19 a	0,25 a
K	1,47 a	0,23 a	1,60 a	0,86 b	0,26 a
Ca	1,64 a	0,14 b	1,47 a	1,04 a	0,30 a
Mg	1,63 a	0,19 b	1,55 a	1,10 a	0,27 a
Zn	1,76 a	0,22 a	1,49 a	1,18 a	0,27 a

In the same column, figures marked with the same letter are not significantly different at the 5% level.

DISCUSSION

For the variation of the height of the regrowth, all the fertilizers did not induce a significant difference on the heights of the plants aged 15 days and 30 days after harvest. However, from day 15 to day 30, the height of the regrowth increased regardless of the treatment. The growth of regrowth during the first 30 days depends mainly on the carbohydrate reserves in the stubble after harvest (Weinmann, 1940). The growth of NERICA L14 plants was not significantly affected by photosynthetic products in any of the treatments at the regrowth stage. From day 15 to day 30 the significant increase of the plant would be due to vegetative growth. This is not influenced by fertiliser application in a lowland ecosystem. The significant difference in height observed at maturity for the N-treated regrowth is consistent with the results of Muhammad et al (2008). In the regrowth stage nitrogen influences height growth (Zandstra and Samson, 1979). This growth-promoting effect is due to an activation of protein synthesis and plant metabolism related to growth (Yoshiba et *al*, 1972). Calcium induced significant growth at maturity. Certainly calcium promoted the uptake of other minerals such as nitrogen, phosphorus (Marschner et *al*., 1986) and potassium (Mirnia and Mohammadian, 2005). These various nutrients would have contributed to an increase in the height of the rice plants. For tillering, fertilisers did not induce a significant difference at day 15. On days 30 and 45, however, tillering was positively influenced by nitrogen. This stimulating effect of nitrogen on tillering at maturity is consistent with the work of Kouakou et *al*. The early stages of vegetative development, including the lifting of bud dormancy and the growth of regrowth, depend on the carbohydrates contained in the post-harvest stubble. Beyond day 30, the adequate content of absorbed nitrogen favours intense cell division in the meristems and influences the proliferation of secondary tillers around the main plant (Mohamed, 2009). On straw yield, major elements such as nitrogen and phosphorus positively influence straw production, while calcium and zinc are the most important trace elements. The high straw yield is perfectly related to the total number of tillers. Absorbed nitrogen, by stimulating physiological processes including cell division and cell elongation (Muhammad et *al*., 2008), increases the number of tillers. Nitrogen applied in the regrowth crop has influenced organogenesis at the regrowth stage, which then leads to abundant tillers production. Phosphorus is a major component of ATP, the energy source molecule for physiological processes such as photosynthesis, protein synthesis, nutrient translocation, mineral uptake and respiration (Yosef, 2012). Phosphorus positively influences tillering (Panhawar et *al*., 2011). In the lowland ecosystem, the increase in straw yield of NERICA L 14 regrowth is due to high tillering and accumulation of products from photosynthesis. The high straw yield in the regrowth crop is due to the application of calcium or zinc and is related to the facilitating role of these nutrients in the uptake of residual nitrogen, phosphorus and potassium (Doberman and Fairhurst., 2000) from the soil. Of all the fertiliser treatments, calcium carbonate and magnesium sulphate had a significant effect on straw quality. Calcium in its role as a facilitator contributed to the absorption of the other minerals (Doberman and Fairhurst., 2000). The content of all the minerals present was higher than the control (0.75%). These observed levels could be due to the fact that once the vegetative and reproductive functions of the rice are completed, the nutrients instead of going to the reserve organs to accumulate will go to other parts of the plant such as the straw. Magnesium would have played a similar role in straw quality.

CONCLUSION

At the end of our work we can retain the following: Mineral fertilization at the regrowth stage of NERICA L14 rice significantly influences the yield and mineral content of the straw of this plant through the action of certain fertilizers. Nitrogen, phosphorus, calcium and zinc provided a better yield. As for the mineral content of the straw, the action of calcium sulphate and magnesium sulphate had a significant influence on the quality of the straw. From this observation, straw can be a very important input for the improvement of animal production in Côte d'Ivoire because not only is it produced in large quantities thanks to the fertilisers provided, but it is also enriched with essential minerals (N, P, K, Ca and Mg) for livestock feed. Also, not all fertilisers have given convincing results. It would therefore be necessary to test the combined effect of (N-Ca), (N-Mg), (N-Zn), (P-Ca) and (P-Zn) fertilisers or to consider the combination of organic and mineral fertilisers.

REFERENCES

Le riz c’est la vie. Bulletin trimestriel de statistiques. Vingt troisième conférences régionales pour l’Afrique, année internationale du riz, Johannesburg. FAO, Rome Italie, 17p.

Adigbo.S.O., Wakatsuki.T., Fabusoro.E., Alarima C.I., Alao.O.A., Odedina J.N., Adeyemi .O.R. and Fabunmi. T.O., 2013. Evaluation of the performance of lowland rice-ratooned rice-vegetable as influenced by fertilizer rates in sawah rice systems. *Journal of Agricultural Science*; **5(1):**181 – 186.

Nguetta.A.S.P., Lidah 0.J. Y., Ebélébé.C.N.M et Guéi., 2006. Sélection de variétés performantes de riz pluvial (*oryza sp*) dans la région subéquatoriale du Congo Brazzaville. *Afrique Science* 2 (3): 352-364.

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), 219p.

Cirad (2021). Le marcheé mondial du riz ttp://hubrural.org/IMG/pdf/marche_mondial_riz.pdf Consulté le 12 mai 2022 à 8h.

Dobermann. A and Fairhurst.T, 2008. Rice: Nutrient disorders and Nutrient Management. Potash and phosphate institute.Institut of Canada and international Rice research institute (Editor), First edition. Oxford Graphic Printer Pte Ltd, 191 pp.

Gala B.T.J., Camara .M., Yao-Kouamé .A., Keli .Z. J., 2011. Rentabilité des engrais minéraux en riziculture pluviale de plateau: Cas de la zone de Gagnoa dans le centre ouest de la Côte d'Ivoire. *Journal of Biosciences*, 46: 3153-3162.

Koné. B, Diatta.S, Saïdou .A, Akintayo et Cissé. B, 2009. Réponse des variétés interspécifiques du riz de plateau aux applications de phosphore en zone de forêt au Nigeria. *Canadian journal of soil Scences*, 89(5): 553-564

Kouassi F.A., Majorein.V.; Ipou Ipou.J., Adou.C.Y., et Kamanzi.K., 2010. Alimentation des ovins des marchés de vente de bétail dans la ville d’Abidjan, Côte d’Ivoire, 1-2p.

Kouable Bi et Tré Bi., 2014. Rapport définitif de l'étude d'évolution des exportations du bétail malien suite aux récentes crises. 10p

Mirnia khand, M.Mohammadian., 2005. Rice, Nutritional elements disorders. Nutritional elements management. (Translation). Mazandaran university publications. 436p.

Mohamed Dicko, 2005: Analyse du fonctionnement d'une parcelle de riz irriguée sur le sol alcalin. Application à la gestion intégrée de la fertilisation azotée et du calendrier cultural dans le delta intérieur du fleuve Niger (Mali). Thèse de doctorat de l'école nationale supérieure agronomique de Montpellier, 257p.

Muhammad. S.I and Mirza .H, 2008. Ratoon rice response to different fertilizers doses in irrigated conditions. Md.Rokonuzzaman *Agriculturae Conspectus Scientificus*. 73(4):197-202

Panhawar Q.A, Othman.R, 2011.Effect of phosphatic fertilizer on root colonization of aerobic rice by phosphate-solubilizing bacteria. International conference on food engineering and biotechnology. IPCBEE. 9:145-149

Paula Fernandez., 1999. Effets des modes de gestion des terres en zone sahélienne sur les termes et l'évolution de leur bilan organique et biologique: conséquences pour une production céréalière soutenue - cas du Sénégal, octobre 1999, Lorraine, PP 101-125.

Simonne A.H., Simonne E.H., Eitenmiller R.R., Mills H.A and Cresman C.P., 2017. La méthode de Dumas pourrait-elle remplacer la minéralisation de Kjeldahl pour les déterminations de l'azote et des protéines brutes dans les aliments ?*Journal of the Science of Food and Agriculture*, Volume 73, Issue 1, pages 39–45.

SODEXAM., 2017. Données météorologiques de 2006-2017 d'Abidjan. Société d´exploitation et de développement Aéroportuaire, aéronautique et Météorologique : direction de la Météorologie Nationale, Port-Bouët-Abidjan (Côte d´Ivoire).

Weinmann .H, 1940. Storage of root reserves in rhodes grass. *Plant Physiology*, 15: 467-484.

Yosef.T.S; 2012. Effect of Nitrogen and Phosphorus Fertilizer on Growth and Yield Rice (*Oryza Sativa* L). *International journal of Agronomy and Plant Production*, 3 (12): 579-584

Zandstra H.G., Samson, B.T.S., 1979. Rice rtoon management.Discussion paper presented at the International Rice Research Conference, PP 16-21.