Assessment of Nutritional Status of Rainfed Rice in Benin Using Diagnosis and Recommendation Integrated System (DRIS)

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Authors' contributions

This work was carried out in collaboration among all authors. Author FNA designed the study, wrote the protocol, collect the leaf samples and wrote the first draft of the manuscript. Author BTCO managed the analysis of leaf samples at laboratory. Authors GDD and ECA managed the analyses of the study and performed the statistical analysis. Authors AS and GLA managed the literature searches. All authors read and approved the final manuscript.

Original Research Article

ABSTRACT

The fertilizer used in Benin by rainfed rice farmers, doesn't meet the required expectation because of lack of many essential agronomic information to formulate the appropriate nutrient compositions. Despite all the advances in improvement of rice production, its yields in traditional cropping systems are very low and the only inputs of Nitrogen, Phosphorous and Potassium do not effectively increase rice yields. The purpose of this study was to assess nutritional status of rainfed

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rice crops in Benin. The study covered the rainfed rice production areas of Benin Center where 72 leaves samples were taken on 3600 plants from the farmer fields. The concentrations of nitrogen, phosphorus, potassium, calcium, magnesium, iron and zinc were determined in leaves samples. The preliminary DRIS (Diagnosis and Recommendation Integrated System) norms for the rainfed rice growing in the Benin center were selected for various nutrient ratios obtained from the high yield population of the rainfed rice crop. The yields of the two subpopulations were significantly different ($p < .0001$). The nutrient requirement for the rainfed rice production was ranked as N> Fe> Zn>K>Mg>P>Ca. The DRIS-derived sufficiency ranges for N, P, K, Ca and Mg from the nutrient indexing survey of the rainfed rice plants grown in Benin center were 1.91-3.66, 0.30-0.64, 2.00-3.89, 0.37-1.05 and 0.18-0.38g kg^{-1} respectively. The limits for Fe and Zn were 89.27-206.3 and 8.21-24.91 mg kg^{-1} respectively. On the basis of sufficiency ranges, 4.22, 57.75, 66.20, 56.34, 45.07, 46.50 and 29.57% of samples were low in N, P, K, Ca, Mg, Fe and Zn respectively. The DRIS norms put emphasis on nutrient balance and help to differentiate between healthy and unhealthy rice plants from the nutrition status. However, it needed further researches to determine the amount of the fertilizers to supply in order to maintain nutrient balance.

1. INTRODUCTION

Benin exhibits the low rate of fertilizer use with an average consumption estimated at less than 5 kg ha^{-1} [1]. The fertilizer that is used in Benin doesn't meet the required expectation because of the manufacturers and distributors who lack many essential agronomic information to formulate the appropriate nutrient compositions [2].This improper use of the fertilizers is likely one of the major factors contributing to declining rice yield in Benin, since no local nutrition guidelines are available. Likewise, soil nutrient mining remains an option for the farmers since they do not see any responses in crop yield when fertilizers are applied [3]. This fact induces nutrient imbalance into the plants, which tend to be worse because of the increased intensity in cropping, greater erosion, and the lack of inputs from the organic or inorganic sources of nutrients. In order to develop an adequate alternative and formulate sustainable recommendations about the fertilizer, it is necessary to evaluate the level of nutrient imbalance into the plants. Foliar analysis has been practiced widely for nutritional status evaluation in plant and fertilizer programs planning. It is considered like an important tool to monitor the nutrient status of plants [4]. Usually, plant nutritional status evaluation is done by sufficiency range approach. In this approach, leaf nutrient concentration is compared to the values of sufficiency range. Below it is considered as deficiency, and above it is considered as excessive. However, this critical value approach has limited applicability due to the variation caused by the time of sampling, stages of plant growth, specific position of leaf tissue sampled,

only the evaluation of the deficiency or the excess of a single nutrient at a time [4,5]. Then, the use of this approach for the evaluation of crops nutritional status is questionable since it fails to measure nutrient balance and do not consider various interactions between nutrients. In contrast, the DRIS method, proposed by Beaufils [6], is based on the comparison of dual relationships in samples with the standard or the norms of values rather than the individual concentration of nutrient to interpret leaf tissues analysis. Likewise, nutrient ratios in leaf tissues are not influenced by the time of sampling, stage of plant growth and with the position of the plant parts [4]. In Benin, DRIS has been found appropriate to diagnose nutrient status of pineapple [7], groundnut [8], Sorghum [9], yam [10], maize [11], cotton [12]. However, the information on the rainfed rice plant nutrition status based on DRIS approach lacks.

Several studies have been carried out in Benin to improve rice production. AfricaRice over the last years, developed many varieties of rice [13]. Studies on improving soil fertility under rice cultivation have also been done by AfricaRice. Those studies led to the development of a RiceAdvice application which is a science-backed crop management decision-support tool [14]. This application only takes into account the major elements (NPK) in fertilization. In addition, this application is inaccessible to the majority of rice farmers who are illiterate. Despite all these advances, rice yields in traditional cropping systems are very low and the only inputs of NPK do not effectively increase rice yields. To develop sustainable mineral fertilization alternatives, it is essential to take into account the major nutrients,

secondary nutrients and micro nutrients. To achieve this, it is important to assess nutritional status of rice crops in traditional systems in order to determine the deficient elements. The aim of the present investigation was to develop DRIS norms of major, secondary and micro nutrient elements and to derive the standard of the DRIS index for the rainfed rice nutrient status diagnosis in Benin.

2. MATERIALS AND METHODS

2.1 Plant Sampling and Site

In order to constitute a data base to calculate the DRIS reference norms for the rainfed rice crop, 72 plant samples were collected on 3600 plants from the rainfed rice field in the municipalities of Dassa-Zoumè and Glazoué in Benin center (Fig. 1).The average annual rainfall in this municipalities is around 1,100 mm and Luvisol are the dominant sols. Rice is an important crop grown in that area. The samples were collected during the rainfed rice growing season 2018/2019. Localities from which rice samples were collected are shown in Fig. 1. Elementary leaf sampling occurred along two diagonals of fields [15] while respecting a 20m deviation with the field margins [16]. Youngest fully developed rice leaves sample were collected at the panicle initiation and consisted to take four leaves per plant. To constitute the composite sample, a total of 200 leaves (4 leaves out of 50 plants) were taken as recommended by Schvartz et al. [15] for cereals. In every field where leaf samples were taken, rainfed rice yields were estimated after harvest. The leaf samples were dried in a hot air oven at 70°C to a constant dry weight before being ground in a Willey mill to pass through 0.5 mm screen.

2.2 Analysis of Samples

The leaf samples were digested with H_2SO_4 and H_2O_2 and analyzed for N by Kjeldahl method. Another part of dry samples were ashed in porcelain crucibles at 550°C in a muffle furnace. The ash were dissolved in concentrated nitric
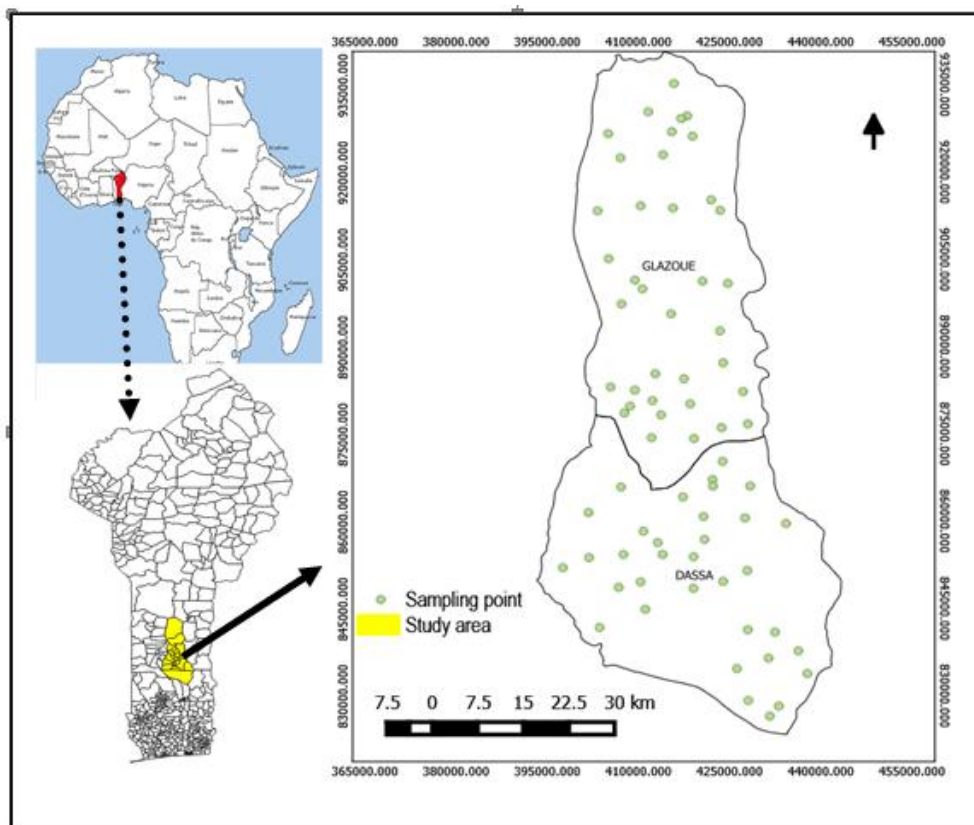

Fig. 1. Study area and leaf sampling point

acid, evaporated to dryness on a sand bath and to precipitate silicate, taken up with concentrated nitric acid again, and transferred to volumetric flasks with several rinses of ultra-pure water. Atomic Absorption Spectrophotometer was used for determining calcium (Ca), magnesium (Mg), iron (Fe), zinc (Zn) and K in the emission mode. P was determined using vanado–molybdate method with a spectral photometer 1100.

2.3 Determination of Norms and Indices of DRIS

The leaf mineral composition data was divided into two subpopulations using the mean of yield + interval of confidence as criteria for cut-off [9, 7]. Then, there are the high yielding subpopulation in which the rainfed rice paddy yields were equal to or exceeded 2100.12 kg ha^{-1}, and the low yielding subpopulation in which grain yields were lower than 2100 kg ha^{-1}. Each parameter was expressed in as many forms as possible, e.g., N/P, P/N, K/N, N/K, etc. Mean values for various forms of expressions together with their associated CVs and variances were then calculated for the two subpopulation. The variance ratio between subpopulations for all forms of expressions was calculated [6]. Among different forms of expressions, the one showing higher variance ratio (variance of low yielding/variance of high yielding population) was selected as diagnostic norm which were used along with the standard deviation, to calculate the DRIS indices for diagnostic purposes. Founded on the values of all the DRIS functions, the DRIS index for each nutrient was calculated as follows:

X indice = [*f* (*X/A*) + *f* (*X/B*) +... -*f* (*M/X*) - *f* (*N/X*) -...]

where

f (*X/A*) =100[(*X/A*) (*x/ a*) - 1]/*CV* when (*X/A*) >(*x/a*) – *SD*

f (*X/A*) = 100[1 - (*X/A*) / (*x/a*)]/*CV* when (*X/A*) <(*x/a*) – *SD*

X/A is the ratio of concentrations of nutrients X and A in the sample while *x/a, CV* and *SD*, are the mean, coefficient of variation and standard deviation for the parameter *X/A* in the high-yielding population respectively. All indices were balanced around zero. The more negative an index, the more lacking in the nutrient it represented relative to other nutrients used in the diagnosis. Likewise, a large positive index indicated that the corresponding nutrients were present in relatively excessive quantity.

The sufficiency range for leaf tissues of the rainfed rice crop was determined by the DRIS technique. The DRIS norms as reference values of each nutrient element obtained from mineral composition of leaf tissues of high yielding subpopulation constituted the mean for sufficiency.

To interpret the DRIS indices, the concept of the fertilization response potential [17] was adopted (Table 1). This method compares nutrient index or its absolute value with the nutritional balance index (NBI). The nutritional balance index is the average of the distance to zero of all nutrients indices. For N indices,

NBI= (| Index A | + | IndexB | + ... + | Index N|)/N.

Table 1. Interpretation of the DRIS indices of the nutritional diagnosis in the rainfed rice crop

Indices	Absolute value of indices	Nutrient status
< 0	>NBI	Deficiency
> 0	>NBI	Excess
Independent	≤NBI	Adequate

NBI= nutritional balance index

The range of sufficiency are the values derived from the mean ± 4/3 SD and mean ± 8/3 SD, respectively [18,19,4]. The value of nutrients < (mean-8/3 SD) are considered deficient, whereas their low range included all values between (mean-8/3 SD) and (mean - 4/3 SD). Values between (mean - 4/3 SD) and (mean + 4/3 SD) are taken as sufficient, whereas the range between (mean + 4/3 SD and (mean + 8/3 SD) are expressed as high. The nutrient concentrations > (mean + 8/3 SD) are expressed as excessive or toxic.

3. RESULTS AND DISCUSSION

Phosphorous, potassium, calcium, magnesium, iron and zinc leaf concentration of the two subpopulation were significantly different (p < .0001). Statistics for rice yield and leaf nutrient concentration data (Table 2) show that the high yielding subpopulation (>2100.12 kg ha^{-1}) recorded the highest means of phosphorous,

potassium, calcium, magnesium, iron and zinc leaf concentration. The means of nitrogen concentration are not so different between the two subpopulations (p = .86) while the highest nitrogen concentrations are observed in high yielding subpopulation. The yields of the two subpopulations were significantly different (p < .0001) that can be a good indicator of the precision of the DRIS norms established. From the statistical data of nutrient ratio expressions (Table 3), the DRIS norms were selected. Indeed, from reciprocal expressions such as N/K and K/N, the more appropriate nutrient ratio expression was selected (highest value of V_{low}/V_{high}). Therefore, 21 means value of nutrient ratio expressions in high yielding subpopulation involving N, P, K, Ca, Mg, Fe and Zn were chosen as the diagnostic norms for rice (Table 4). These expressions help to differentiate between healthy and unhealthy rice plants from nutrition status. Therefore, balance fertilization must take into account these norms because from the plant nutrient standpoint, the deficiency or excess of some nutrients depends on the application of other nutrients [5]. Indeed, there are two forms of interactions (synergism and antagonism) between nutrients. Sometime, adequate supply of nitrogen ensures optimum uptake of potassium as well as phosphorous, iron, manganese and zinc from the soils while optimal levels of calcium and zinc improve uptake of phosphorous and potassium [20]. Then, the recovery of one nutrient from the soil or a fertilizer application depends on the availability of some other nutrient [5]. However, excessive amounts of calcium reduces uptake of iron [20] and adequate supply of N, P and K, induce a deficiency of Ca and Mg; if not, there was an excess of Ca and Mg [21]. Hence, ratio of nutrient content in the rice leaf is more critical than the actual individual concentration for the rice nutrient status diagnosis.

From the mean values of nutrient ratio expressions taken as the reference values (Table 4), the DRIS indices were calculated for each nutrient. These indices range from negative to positive values depending on whether nutrients are relatively deficient or excessive. Nutrient requirement for the rainfed rice production was ranked as N>Fe>Zn>K>Mg>P>Ca (Fig. 2). It was indicated that nitrogen might be the most limiting nutrient, and Ca might be the last limiting nutrient for the production of rice. This most requirement of nitrogen for the rice crop was also found by Hundal et al. [19] in Ratipur village by the DRIS system. Wang et al. [22] reported that imbalanced nitrogen fertilizer rate applied into soils is the most important variable that limits the quality and yields of rice. Among the plant nutrients, nitrogen is one of the most yield limiting nutrients for the production of rice [23]. Iron, zinc, magnesium and potassium were also found as limiting nutrient for the rice production by the DRIS system [19]. In fact, many nutrients such as Zn, Fe and Mg rapidly react in soil components via oxidation and/or precipitation [24]. This makes them unavailable for the crop. Despite, Iron, zinc and magnesium are more limiting than phosphorus in the center of Benin for the rice crop, the recommendations made up until now in Benin do not incorporate these nutrients. It is therefore necessary to take these elements into account to improve the rice yield in Benin. However, according to Kelling and Shulte [25], a DRIS index from -15 to +15 indicates good nutrient balance in the plant; values from -25 to -15 indicate there is a possible deficiency and values lower than -25 show a likely nutrient-deficient plant. Therefore, P, K, Mg, Fe and Zn are adequate balance while there are possible deficiency in N. Likewise, the nutritional balance index (NBI) obtain is 13.22. Thus according to Wadt et al. [17] also (Table 1), P, K, Mg, Fe and Zn are in adequate range while N is deficiency and Ca is excess.
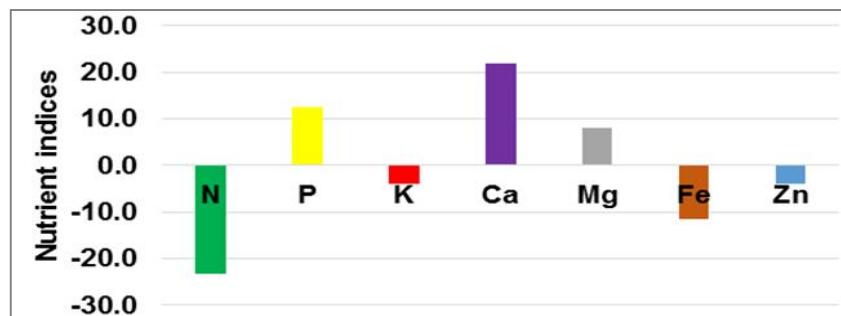

Fig. 2. Nutrients indices for rainfed rice

Table 2. Summary statistics for rice yield and leaf nutrient concentration data for total (n=72) and high-yielding (n=28) sub-populations

Parameters	Low yielding subpopulation [N = 44]						High yielding subpopulation [N = 28]					
	Mean	SD	Var	CV	Min	Max	Mean	SD	Var	CV	Min	Max
Yield	1565.1	312.6	97723.6	20.0	1029.8	2077.3	2604.9	355.0	126020.6	13.6	2113.3	3454.9
Nutrients[g kg^{-1}]												
N	2.7	0.5	0.3	19.2	1.7	3.7	2.8	0.7	0.4	23.6	1.7	4.5
P	0.2	0.1	0.0	32.0	0.1	0.4	0.5	0.1	0.0	27.4	0.2	0.7
K	1.5	0.3	0.1	16.9	1.1	2.3	2.9	0.7	0.5	24.1	1.6	4.3
Ca	0.3	0.1	0.0	26.1	0.2	0.7	0.7	0.3	0.1	35.8	0.2	1.3
Mg	0.1	0.0	0.0	36.0	0.1	0.3	0.3	0.1	0.0	26.2	0.1	0.5
Nutrients[mg kg^{-1}]												
Fe	81.9	35.5	1258.9	43.3	27.3	203.8	147.7	43.8	1920.2	29.7	50.5	214.5
Zn	8.7	5.0	25.1	57.6	1.4	24.6	16.6	6.3	39.2	37.8	6.1	36.4

SD; Standard Deviation, Var.: Variance, CV: Coefficients of Variance, Min.: Minimum, Max.: Maximum

Table 3. Mean values of nutrient ratios for high and low-yielding sub-populations together with their respective coefficients of variance (CV's) and variances (low and high) and the variance ratios (Vlow/Vhigh)

Parameters	Low yielding subpopulation [N = 44]				High yielding subpopulation [N = 28]				Ratio Var
	Mean	SD	Var	CV	Mean	SD	Var	CV	
N/P	14.7	4.9	23.7	33.2	6.9	4.4	19.4	64.2	1.2
P/N	0.1	0.0	0.0	47.1	0.2	0.1	0.0	35.4	0.3
N/K	1.8	0.4	0.2	24.7	1.1	0.6	0.3	52.4	0.7
K/N	0.6	0.2	0.0	26.6	1.1	0.5	0.2	39.6	0.1
N/Ca	9.2	2.5	6.3	27.1	5.3	4.6	21.6	88.4	0.3
Ca/N	0.1	0.0	0.0	38.6	0.3	0.1	0.0	45.7	0.1
N/Mg	22.7	8.5	72.9	37.6	11.0	5.8	34.0	53.0	2.1
Mg/N	0.1	0.0	0.0	42.8	0.1	0.0	0.0	37.2	0.3
N/Fe	382.0	164.5	27051.6	43.1	240.9	204.6	41867.6	84.9	0.6
Fe/N	0.0	0.0	0.0	52.2	0.0	0.0	0.0	37.2	0.6
N/Zn	4652.0	4106.0	16861116	88.3	2026.0	1330	1768304	65.6	9.5
Zn/N	0.0	0.0	0.0	66.6	0.0	0.0	0.0	44.1	0.7
P/K	0.1	0.0	0.0	24.2	0.2	0.0	0.0	26.8	0.5
K/P	8.0	1.7	3.0	21.6	6.5	1.7	3.0	26.4	1.0

Parameters	Low yielding subpopulation [N = 44]				High yielding subpopulation [N = 28]				Ratio Var
	Mean	SD	Var	CV	Mean	SD	Var	CV	
P/Ca	0.7	0.2	0.0	32.4	0.7	0.2	0.0	30.8	1.0
Ca/P	1.6	0.5	0.3	31.5	1.5	0.5	0.3	34.6	0.9
P/Mg	1.6	0.4	0.2	25.1	1.7	0.4	0.2	25.9	0.8
Mg/P	0.7	0.2	0.0	23.7	0.6	0.2	0.0	27.8	0.8
P/Fe	27.1	10.9	119.0	40.2	33.7	9.3	86.6	27.7	1.4
Fe/P	0.0	0.0	0.0	42.7	0.0	0.0	0.0	26.6	4.7
Mg/Fe	18.4	9.1	83.2	49.7	20.6	6.5	41.6	31.4	2.0
Fe/Mg	0.1	0.0	0.0	48.2	0.1	0.0	0.0	28.4	4.8
P/Zn	304.2	192.7	37115.5	63.3	312.9	134.2	17999.4	42.9	2.1
Zn/P	0.0	0.0	0.0	50.7	0.0	0.0	0.0	31.5	3.9
K/Ca	5.2	1.4	1.9	26.8	4.6	1.6	2.5	34.6	0.8
Ca/K	0.2	0.1	0.0	26.4	0.2	0.1	0.0	33.6	0.4
K/Mg	12.5	3.5	12.6	28.3	10.6	2.0	4.2	19.2	3.0
Mg/K	0.1	0.0	0.0	28.6	0.1	0.0	0.0	20.3	1.6
K/Fe	214.9	93.7	8777.5	43.6	215.6	68.0	4620.7	31.5	1.9
Fe/K	0.0	0.0	0.0	45.7	0.0	0.0	0.0	31.4	2.5
K/Zn	2387	1515	2296012	63.5	1926.0	589.0	347204	30.6	6.6
Zn/K	0.0	0.0	0.0	57.7	0.0	0.0	0.0	30.6	3.7
Ca/Mg	2.5	0.8	0.7	32.9	2.5	0.8	0.6	30.6	1.2
Mg/Ca	0.4	0.2	0.0	36.1	0.4	0.1	0.0	33.1	1.2
Ca/Fe	43.3	21.4	455.8	49.3	48.5	10.6	112.6	21.9	4.0
Fe/Ca	0.0	0.0	0.0	45.8	0.0	0.0	0.0	22.6	6.9
Ca/Zn	494.7	331.1	109595.1	66.9	459.2	189.9	36070.3	41.4	3.0
Zn/Ca	0.0	0.0	0.0	68.4	0.0	0.0	0.0	41.1	4.0
Mg/Zn	201.6	135.1	18243.2	67.0	188.8	76.2	5807.5	40.4	3.1
Zn/Mg	0.0	0.0	0.0	53.1	0.0	0.0	0.0	33.4	3.4
Fe/Zn	13.2	12.1	147.5	91.9	9.5	3.4	11.9	36.2	12.4
Zn/Fe	0.1	0.1	0.0	59.0	0.1	0.0	0.0	35.0	2.8

SD; Standard Deviation, Var.: Variance, CV: Coefficients of Variance

Table 4. DRIS norms and CV's values for the high-yielding sub-population, and variance ratios (Vlow/Vhigh) of nutrient ratio expressions selected for inclusion in the DRIS model for rice

Parameters	Mean	SD	Var	CV	Min	Max	Ratio Var
N/P	6.9	4.4	19.4	64.2	3.6	21	1.2
N/K	1.1	0.6	0.3	52.4	0.4	2.5	0.7
N/Ca	5.3	4.6	21.6	88.4	2	18.7	0.3
N/Mg	11	5.8	34	53	5	28.2	2.1
N/Fe	240.9	204.6	41867.6	84.9	115.9	802.3	0.6
N/Zn	2026	1330	1768304	65.6	789	6621	9.5
K/P	6.5	1.7	3	26.4	3.5	11.2	1
P/Ca	0.7	0.2	0	30.8	0.3	1.1	1
Mg/P	0.6	0.2	0	27.8	0.4	1.2	0.8
Fe/P	0	0	0	26.6	0	0	4.7
Fe/Mg	0.1	0	0	28.4	0	0.1	4.8
Zn/P	0	0	0	31.5	0	0	3.9
K/Ca	4.6	1.6	2.5	34.6	2.3	8.1	0.8
K/Mg	10.6	2	4.2	19.2	6	15.7	3
Fe/K	0	0	0	31.4	0	0	2.5
K/Zn	1926	589	347204	30.6	959	3402	6.6
Mg/Ca	0.4	0.1	0	33.1	0.2	0.8	1.2
Fe/Ca	0	0	0	22.6	0	0	6.9
Zn/Ca	0	0	0	41.1	0	0	4
Zn/Mg	0	0	0	33.4	0	0	3.4
Fe/Zn	9.5	3.4	11.9	36.2	4.5	16.7	12.4

SD; Standard Deviation, Var.: Variance, CV: Coefficients of Variance, Min.: Minimum, Max.: Maximum

Table 5. Sufficiency ranges of nutrient elements derived by DRIS technique from nutrient indexing survey of rice

Nutrient	Deficient	Low	Optimum	High	Excessive
Nutrients [g kg^{-1}]					
N	<1.03	1.03 - 1.91	1.91 - 3.66	3.66 - 4.53	>4.53
P	<0.13	0.13 - 0.30	0.30 - 0.64	0.64 - 0.82	>0.82
K	<1.05	1.05 - 2.00	2.00 - 3.89	3.89 - 4.84	>4.84
Ca	<0.03	0.03 - 0.37	0.37 - 1.05	1.05 - 1.39	>1.39
Mg	<0.09	0.09 - 0.18	0.18 - 0.38	0.38 - 0.48	>0.48
Nutrients [mg kg^{-1}]					
Fe	<30.85	30.85 - 89.27	89.27 - 206.13	206.13 - 264.55	>264.55
Zn	<-0.13	-0.13 - 8.21	8.21 - 24.91	24.91 - 33.25	>33.25

Table 6. Nutrient status of rainfed rice center Benin

Nutrient	% of total samples analyzed			
	Deficient	Low	Optimum	High
N	0	4.22	90.14	5.64
P	5.64	57.75	30.98	5.64
K	0	66.2	30.98	2.82
Ca	0	56.34	38.03	5.64
Mg	11.26	45.07	40.84	2.82
Fe	1.4	46.5	50.7	1.4
Zn	0	29.57	69.03	1.4

From the DRIS-derived sufficiency ranges obtained from the nutrient indexing survey of the rainfed rice crops cultivated in the center of Benin (Table 5), the percentages of samples analyzed which content optimal concentration of nutrient are presented in Table 6. Most part of samples had low concentration in potassium, phosphorous and calcium while nitrogen, zinc and iron concentration were in optimum ranges in more than 50% of samples. The DRIS-derived

sufficiency ranges for the panicle initiation stage in the present investigation were high for P and K than some already published sufficiency ranges [26,19]. However, for other five nutrient elements these were approximately similar. The DRIS might be considered as a good nutrient diagnosis tool for the rainfed rice fertilization guidance. To know the availability of nutrient from soil to the rainfed rice crop, it needs to consider the weather, climate, soil parameters, as well as genetic differences in the rainfed rice plants. Therefore, further researches are needed to determine the adequate amount of fertilizers to supply according to the rainfed rice nutrient requirement.

4. CONCLUSION

In this study, the mean values of nutrient ratio expressions involving N, P, K, Ca, Mg Fe and Zn were chosen as the diagnostic norms for the rainfed rice nutrient status on the base of the DRIS. These expressions put emphasis on nutrient balance and help to differentiate between healthy and unhealthy rice plants from the nutrition status. The DRIS indices were computed from these diagnostic norms. From these indices, the order of the nutrient requirement for the rainfed rice production is N>Fe>Zn>K>Mg>P>Ca. the negative indices were obtained with N, Fe, Zn and K while the positives indices were obtained with Mg, P and Ca. Therefore, application of N, Fe, Zn and K fertilizers might be able to enhance the yield of the rainfed rice. For this, it is needed further researches to determine the amount of fertilizers to supply, to improve the rainfed rice yield in center of Benin.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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