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Comparison of the performances of six (6) introduced varieties of rainfed rice (*Oryza* sp) in two agroecological zones in south-west of Republic of Congo

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ABSTRACT

Description of subject. The National Institute of Agronomic Research (IRA), with the collaboration of Africa-Rice, introduced around one hundred varieties of rainfed rice in 2010 in the Republic of Congo. This action helps to correct the food deficit, reduce massive rice imports and address food insecurity in the country. It has led to the identification of six (6) varieties of rice with interesting adaptability skills.
Objective. This study aims to assess and compare the production potential of the six (6) varieties of rainfed rice in southwestern Congo.
Methods. The study was carried out during the 2015 - 2016 and 2016 - 2017 agricultural seasons, in the Loudima (savannah) and Sibiti (forest) Research Stations. It relied on agro-morphological parameters and yield. This is a Fisher block experimental set-up with six (6) treatments and three (3) replicates.
Results. The results show that the yields obtained during the 2015 - 2016 campaign are 1.98 ± 0.35 to 2.76 ± 0.55 t / ha for Loudima and 3.86 ± 0.96 to 4.81 ± 0.92 t/ha for Sibiti. The number of tillers per foot being from 13.67 ± 1.2 to 16.3 ± 3.8 for Sibiti and 4.33 ± 0.58 to 7 ± 1 for Loudima. Likewise, the yields at the two stations in 2016-2017 are respectively 6.53 ± 1.67 to 9.33 ± 0.45 and 4.1 ± 0.35 to 4.47 ± 0.21 t/ha. The number of tillers, being from 13.33 ± 1.5 to 15 ± 1 for Sibiti and 9.67 ± 3.1 to 18.33 ± 3.2 for Loudima.
Conclusion. These results confirm that the six (6) varieties of rainfed rice present very encouraging production potential in the two localities. They represent a solid basis for the revival of this agricultural sector which will contribute to food security and to fight against poverty in the country.

Keywords: Introduced varieties of rain-fed rice, production potential, food security and poverty reduction, agro-ecological zones, Republic of Congo.

RESUME

Comparaison des performances de six (6) variétés introduites de riz pluvial (Oryza sp) dans deux zones agroécologiques du sud-ouest de la République du Congo
Description du sujet. L'Institut National de Recherche Agronomique (IRA), avec la collaboration d'Africa-Rice, a introduit une centaine de variétés de riz pluvial en 2010 en République du Congo. Cette action contribue à corriger le déficit alimentaire, à réduire les importations massives de riz et à lutter contre l'insécurité alimentaire dans le pays. Elle a permis d'identifier six (6) variétés de riz présentant des capacités d'adaptabilité intéressantes.
Objectif. Cette étude vise à évaluer et comparer le potentiel de production des six (6) variétés de riz pluvial au sud-ouest du Congo.
Méthodes. L'étude a été réalisée au cours des campagnes agricoles 2015-2016 et 2016-2017, dans les stations de recherche de Loudima (savane) et de Sibiti (forêt). Elle s'est appuyée sur des paramètres agro-morphologiques et sur le rendement. Il s'agit d'une configuration expérimentale en bloc Fisher avec six (6) traitements et trois (3) répétitions.
Résultats. Les résultats montrent que les rendements obtenus lors de la campagne 2015 - 2016 sont de 1,98 ± 0,35 à 2,76 ± 0,55 t/ha pour Loudima et de 3,86 ± 0,96 à 4,81 ± 0,92 t/ha pour Sibiti. Le nombre de talles par pied étant de 13,67 ± 1,2 à 16,3 ± 3,8 pour Sibiti et de 4,33 ± 0,58 à 7 ± 1 pour Loudima. De même, les rendements aux deux stations en 2016-2017 sont respectivement de 6,53 ± 1,67 à 9,33 ± 0,45 et de 4,1 ± 0,35 à 4,47 ± 0,21 t/ha. Le nombre de talles, étant de 13,33 ± 1,5 à 15 ± 1 pour Sibiti et de 9,67 ± 3,1 à 18,33 ± 3,2 pour Loudima.

Conclusion. Ces résultats confirment que les six (6) variétés de riz pluvial présentent un potentiel de production très encourageant dans les deux localités. Ils représentent une base solide pour la relance de ce secteur agricole qui contribuera à la sécurité alimentaire et à lutter contre la pauvreté dans le pays.

Mots-clés : Variétés introduites de riz pluvial, potentialités de production, sécurité alimentaire et lutte contre la pauvreté, zones agro écologiques, République du Congo.

1. INTRODUCTION

Today, rice (*Oryza sp*) is the food source for about 50% of the world population (ADRAO, 2001; Zhang *et al.*, 2004;). It is the second important food crop in the world after wheat among cereals (Moukoumbi *et al*., 2011). Since 2003, rice cultivation covers 150 million hectares for a production of 395 million tons of Paddy. In 2009, world rice production was estimated at around 680 million tonnes with a projected record harvest of 710 million tonnes in 2010 (FAO, 2004). Countries such as Thailand, Vietnam, China, India and the United States are the main exporters while African countries and those in the Middle East are importers (FAO, 2004).

As a result of the population expansion that developing countries are currently experiencing, the demand for rice is growing. Agricultural development plans are proposed to reduce food insecurity and fight poverty in these countries (Seck *et al.*, 2013). The recently acquired performance using NERICA rice (New Rice for Africa) in Africa with very good tillering skills, reasonable size and high yields (Mande *et al*., 2005; Kambou, 2008; Nadie, 2008; Kouakou *et al*, 2016;), reflect the efforts made.

In the Republic of Congo, rice is the second most important food commodity after cassava with imports of around 550,000 tonnes from 2000 to 2008 (MAE, 2009). Currently, rice imports are in step with demographic expansion and are a national concern, included in the National Agricultural Development Plan - PNDA 2018-2022 (MAEP, 2018). This obviously helps correct the food deficit, reduce rice imports and address growing food insecurity. In this regard, environmental factors must be considered since they have a significant effect on the productivity of agricultural plants (Diamouangana, 2003; Moundzeo *et al*., 2013).

According to N'guetta *et al.* (2006), the NERICA rice varieties, tested in the northern part of the country, presented interesting performances in rainfed and irrigated areas. Yields are around 7 t/ha, the average height around 120 cm and nearly 300 tillers are noted per square meter. In this context, the National Institute of Agronomic Research (IRA) received from Africa-Rice, a hundred NERICA varieties for adaptation studies in the different agro-ecological zones of the country. As a result of these scientific investigations, six (6) varieties of rainfed rice were identified and selected for their adaptability performance at the Loudima research station. It was then that IRA and Africa-Rice resolved to continue research in the south-west of the country, in the two main agro-ecological zones, once considered to be rice production basins. This makes it possible to meet the national demand for this foodstuff and to supplement the information linked to previous work carried out on it. The two agro-ecological zones are characterized by irregular rainfall, reduced insolation and a very pronounced water deficit during the growth phases of agricultural plants (Samba-Kimbata, 1991; Moundzeo *et al*., 2013).

The purpose of this study is to assess and compare the production potential of the six (6) varieties of rainfed rice introduced in the two agro-ecological zones in southwestern Congo. This should allow the dissemination of six (6) varieties of rainfed rice in the various production basins of the country.

2. MATERIAL AND METHODS

2.1. Location of the study area

The study was conducted in southwestern Congo, mainly in the two IRA Research Stations, located in Loudima (03 ° 43'52.9"S; 013 ° 24'21.9''E) for the Niari valley and Moulimba-Sibiti (04 ° 09'29,77"S; 013 ° 04'4,18"E) for the Chaillu Massif. The study area is between 3 and 4'5 ° south latitude and between 13 and 14 ° east longitude. It has an altitude varying from 150 to 200 m and remains subject to an equatorial climate of transition (Samba-Kimbata, 1978). The rainfall regime is bimodal with an average of around 1000 mm (Loudima) and 1200 mm (Sibiti). The dry and cool period lasts from June to September. The next hot and humid period extends from October to May with a drop in rainfall in December - January. The soils are of the ferralitic type, strongly desaturated and impoverished. They are characterized by complete alteration of secondary levels (iron oxides and hydroxides), elimination of bases along the profile and accumulation of manganese in the form of fine concretions (CPCS, 1969; FAO, 1998).

2.2. Vegetal material

The vegetal material was constituted of six (6) varieties of rice that come from the Africa-Rice collection (Table 1). Most of the different varieties come from an intra and interspecific cross between the Asian rice *Oryza sativa* L. for its good productivity and the African rice *Oryza glabberima*

Steud for its hardiness (WARDA, 2003). The *Oryza sativa* species has a very high production but remains susceptible to many diseases while the *O. glabberima* species has a low production but remains resistant to most diseases in rice.

Table 1. The six (6) varieties of rice used for agricultural experiments

N°	PEDIGREE	PARENTS	COMMON NAMES
1	ART3-3-L7P1-B-B-3	*Oryza sativa x Oryza glabberima Steud*	V1
2	ART3-9L6P5-B-B-2	*Oryza sativa x Oryza glabberima Steud*	V10
3	ART3-8L14P3-2-B-2	*Oryza sativa x Oryza glabberima Steud*	V11
4	ART3-8L3P1-B-B-3	*Oryza sativa x Oryza glabberima Steud*	V12
5	WAB95-B-B-40-HB	*Oryza sativa x Oryza glabberima Steud*	V19
6	FOFIFA 161	*IRAT 114 × FOFIFA 133 C546-F880-1-98-2-4-1*	V21

2.3. Methods

Rice cultivation was set up during the 2015-2016 and 2016-2017 agricultural seasons. It focused on a device in complete random blocks with three (3) repetitions, each comprising six (6) treatments, made up of the different varieties of rice. The elementary plots were 10 m long by 5 m wide. The distance between two blocks was one meter and 0.5 m between two elementary plots.

The soil was prepared by plowing 20 cm deep, followed by cross spraying with a tractor. The previous crop in Loudima was the common bean: Phaseolus vulgaris while in Sibiti on the other hand, the test was placed after a previous palm grove containing fern in the undergrowth. The sowing was direct at the rate of 4 to 5 seeds per pocket with a spacing of 20 cm x 20 cm. The basic manure was applied at the rate of 200 kg of NPK (15 N-15 P_2O_5-15 K_2O) per hectare.

During the test, the number of germinated pockets was recorded, five days (5) after sowing (JAS) while the thinning to two plants per pocket, was carried out after two (2) weeks of sowing. Two weedings were carried out at 14 and 60 JAS. Coverage was applied two (2) weeks after sowing and the first weeding. This, consisting of a dose of 50 kg of urea per hectare, repeated during panicle initiation (60 JAS).

The data were collected according to the morphological phases of the different varieties of rice. They concerned the size of the plants at 30 JAS, 60 JAS and at maturity, the vigor of the plants at 30 JAS, the sowing maturity cycle (CSM) of 50 and 85 % flowering of the rice variety. Also, the number of tillers per plant at 60 JAS and the yield per hectare are among the main data taken into account.

Statistical analysis of the data was done using the INSTAT V3-36 software (Stern *et al.*, 2002). The standard deviation being the main statistical parameter of dispersion taken into account and the different means were separated at the 5 % threshold following the student test.

3. RESULTS

3.1. Growth parameters

The size of the plants of the six (6) varieties of rice during 2015-2016 and 2016-2017 in Sibiti and Loudima according to the main phenological stages (30 JAS, 60 JAS and Maturity), is presented in tables 2 and 3. We note that in 2015-2016 in Sibiti, the size of the plants at 30 days after sowing (JAS), is of the order of 39.4 ± 0.51 at 51.4 ± 2.2 cm against 32.03 ± 5 at 38.13 ± 1.6 cm at Loudima. The average size of the plants being respectively 47.4 ± 4.46 cm in Sibiti against 35.4 ± 2.31 cm in Loudima. The rice variety ART3-8L3P1 in Sibiti, presents a score of 51.4 ± 2.2 cm against 39.4 ± 0.51 cm of Fofifa. In Loudima, ART3-8L14P3 has a size at 30 JAS of 38.13 ± 1.6 cm against 32.03 ± 5 cm for ART3-8L3P1. Significant differences are noted between Fofifa and the other rice varieties in Sibiti and Loudima ($p < 0.05$). At 60 JAS, the size of the plants is of the order of 86 ± 2.6 to 100.3 ± 4.7 cm in Sibiti against 77.3 ± 4.2 to 95.3 ± 2.1 cm in Loudima. The average size of the plants, being respectively 93.3 ± 5 cm in Sibiti against 89.8 ± 6.47 cm in Loudima. Significant differences are noted between Fofifa and the other varieties of rice in Loudima ($p < 0.05$).

Table 2. Size of rice variety plants (cm) during 2015-2016 according to the phenological stages (30 JAS, 60 JAS and Maturity) in Sibiti and Loudima

Varieties of de rice	H30 JAS Sibiti (cm)	H30 JAS Loudima (cm)	H60 JAS Sibiti (cm)	H60 JAS Loudima (cm)	Maturity Sibiti (cm)	Maturity Loudima (cm)
ART3-9L6P5	49,5±5,2	34,8±1,3	91,67±3,1	89±4,3	108,1±5,7	97,33±4,5
ART3-3L7P1	46,4±5,5	36,5±3,8	90,33±3,6	91,3±13,1	97,67±4,2	93,3±2,1
ART3-8L3P1	51,4±2,2	32,03±5	95,67±6,8	93±4,36	109,3±9	100±5,3
WAB95-BB4	46,7±1,25	37,2±4,3	95,6±7,5	93±13,5	102,3±3,5	99,3±2,5
Fofifa	39,4±0,51	33,6±3,2	86±2,6	77,3±4,2	104,67±2,8	91±5
ART3-8L14P3	51,1±3,37	38,13±1,6	100,3±4,7	95,3±2,1	106,3±6,3	99±2
Mean (cm)	47,4±4,46	35,4±2,31	93,3±5	89,8±6,47	105,4±5,09	96,67±3,67

The size of the ART3-8L14P3 variety in Sibiti, is of the order of 100.3 ± 4.7 cm against 86 ± 2.6 cm for Fofifa whereas this variety of rice, in Loudima, presents scores of the order 95.3 ± 2.1 cm against 77.3 ± 4.2 cm for Fofifa. The averages are respectively of the order of 93.3 ± 5 cm in Sibiti against 89.8 ± 6.47 cm in Loudima. At maturity, the size of the rice varieties is of the order of 97.67 ± 4.2 to 108.1 ± 5.7 cm in Sibiti compared to 91 ± 5 to 100 ± 5.3 cm in Loudima. The averages are respectively of the order of 105.4 ± 5.09 cm in Sibiti against 96.67 ± 3.67 cm in Loudima. The ART3-9L6P5 variety has a size of around 108.1 ± 5.7 cm compared to 109.3 ± 9 cm for ART3-8L3P1. Significant differences are noted between H30 JAS, H60 JAS and Maturity in Sibiti and Loudima, whereas these are not during a phenological phase between the two localities ($p < 0.05$).

In 2016-2017, the rice varieties present at 30 JAS, a size of 36.3 ± 2.1 to 49.7 ± 2.8 cm in Sibiti against 43.8 ± 6.4 at 50.9 ± 5, 3 cm at Loudima (Table 3). The average being respectively 43.57 ± 4.58 cm in Sibiti and 48.1 ± 4.58 cm in Loudima. Significant differences are noted between on the one hand, Fofifa and ART3-9L6P5, ART3-8L3P1, WAB95-BB4 and ART3-8L14P3 in Sibiti and on the other hand, between Fofifa and the varieties ART3-9L6P5, WAB95-BB4 and ART3 -8L14P3 in Loudima. At 60 JAS, the size of the plants is of the order of 83.7 ± 4.5 to 93.9 ± 4.6 cm at Sibiti against 93.3 ± 8.5 to 108.7 ± 5.8 cm at Loudima. The average size, being respectively 85.77 ± 6.3 cm in Sibiti against 100.18 ± 6.90 cm in Loudima. Significant differences are noted between on the one hand Fofifa and the varieties of ART3-8L14P3 in Sibiti and on the other hand, between Fofifa and ART3-9L6P5, WAB95-BB4 and ART3-8L14P3 in Loudima ($p < 0.05$).

Table 3. Size of rice varieties in 2016-2017 according to phenological stages (30 JAS, 60 JAS and Maturity) in Sibiti and Loudima

Varieties of rice	H30 JAS Sibiti (cm)	H30 JAS Loudima (cm)	H60 JAS Sibiti (cm)	H60 JAS Loudima (cm)	Maturity Sibiti (cm)	Maturity Loudima (cm)
ART3-9L6P5	44,7±7,7	54,8±1,5	87±2,9	107±3	108,7±5,7	132,3±7
ART3-3L7P1	40,7±1,25	45,7±5,3	75±2,2	96±1,7	97,7±3,1	126,3±8,4
ART3-8L3P1	49,7±2,8	45,5±7,3	86±6,4	93,3±8,5	109,3±9	114,3±3,5
WAB95-BB4	44,3±1,2	49,7±5,4	89±7,5	108,7±5,8	102,3±3,5	137,3±8,4
Fofifa	36,3±2,1	43,8±6,4	83,7±4,5	93,3±4,9	104,7±2,9	117±6
ART3-8L14P3	45,7±3,3	50,9±5,3	93,9±4,6	102,8±7,7	106,3±6	146,7±5,7
Mean (cm)	43,57±4,58	48,1±4,58	85,77±6,3	100,18±6,90	104,83±4,34	128,98±12,33

At maturity, the rice varieties have a size of the order of 97.7 ± 3.1 to 109.3 ± 9 cm in Sibiti against 117 ± 6 to 146.7 ± 5.7 cm in Loudima. The averages are respectively of the order of 104.83 ± 4.34 cm in Sibiti against 128.98 ± 12.33 cm in Loudima. ART3-9L6P5 has a size of around 108.7 ± 5.7 cm compared to 109.3 ± 9 cm for ART3-8L3P1 in Sibiti. Similarly, ART3-8L14P3 has a size of 146.7 ± 5.7 cm compared to 114.3 ± 3.5 cm for ART3-8L3P1 in Loudima. Significant differences are noted on the one hand, between ART3-3L7P1 and the other rice varieties in Sibiti and on the other hand, between ART3-8L3P1 and the varieties ART3-9L6P5, WAB95-BB4 and ART3-8L14P3 in Loudima ($p < 0.05$).

Likewise, significant differences are noted between H30 JAS and H60 JAS in Sibiti and Loudima, while these are not between H60 JAS and the maturity stage in the two localities ($p < 0.05$).

Figures 1 and 2 represent respectively the size of the ART3-9L6P5 variety in 2015-2016 and 2016-2017 from 30 JAS at maturity stage in Sibiti and Loudima. We note that at 30 JAS (figure 1), the rice plants are 49.5 cm in 2015-2016 against 44.7 cm in 2016-2017 in Sibiti and 34.8 cm against 54.8 cm in Loudima. At 60 JAS, the rice variety plants were 91.67 cm in 2015 against 87 cm in 2017 in Sibiti and 89 cm in 2015-2016 against 107 cm in 2016-2017. Likewise, the plants of the rice varieties at the maturity stage are 112 cm in 2015-2016 against 108.7 cm in 2017 in Sibiti and 97.67 cm in 2015-2016 against 132.3 cm

in 2016-2017 in Loudima. . Significant differences ($p < 0.05$) are noted in Loudima at 30 JAS, 60 JAS and maturity between the heights recorded in 2015-2016 and 2016-2017. Likewise, non-significant differences ($p < 0.05$) are noted at Sibiti at 30 JAS, 60 JAS and at the maturity stage. The differences are significant ($p < 0.05$) between the phenological stages (30 JAS, 60 JAS and Maturity) at Sibiti and Loudima.

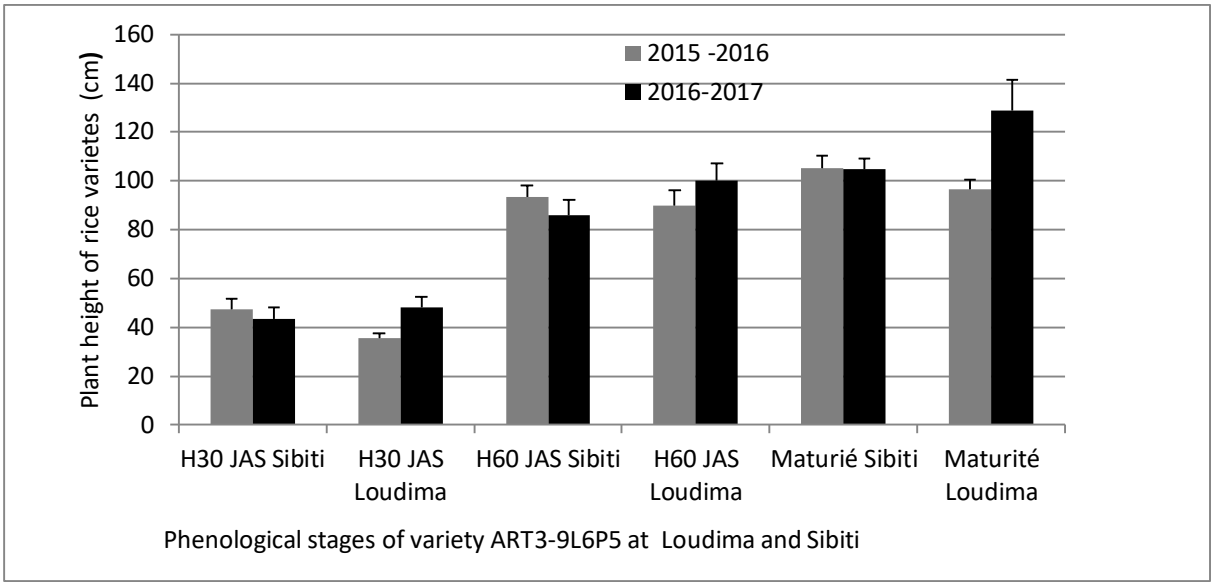

Figure 1. Size of the ART3-9L6P5 variety in 2015-2016 and 2016-2017 at 30 JAS, 60 JAS and during the maturity of rice plants in Sibiti and Loudima

In figure 2, the size of the rice varieties is presented according to the phenological stages (30 JAS, 60 JAS and Maturity) in Sibiti. It is noted that the size of rice varieties at 30 JAS is 39.43 to 51.43 cm, 86 to 100.23 cm at 60 JAS against 97.67 to 109.33 cm at the maturity stage.

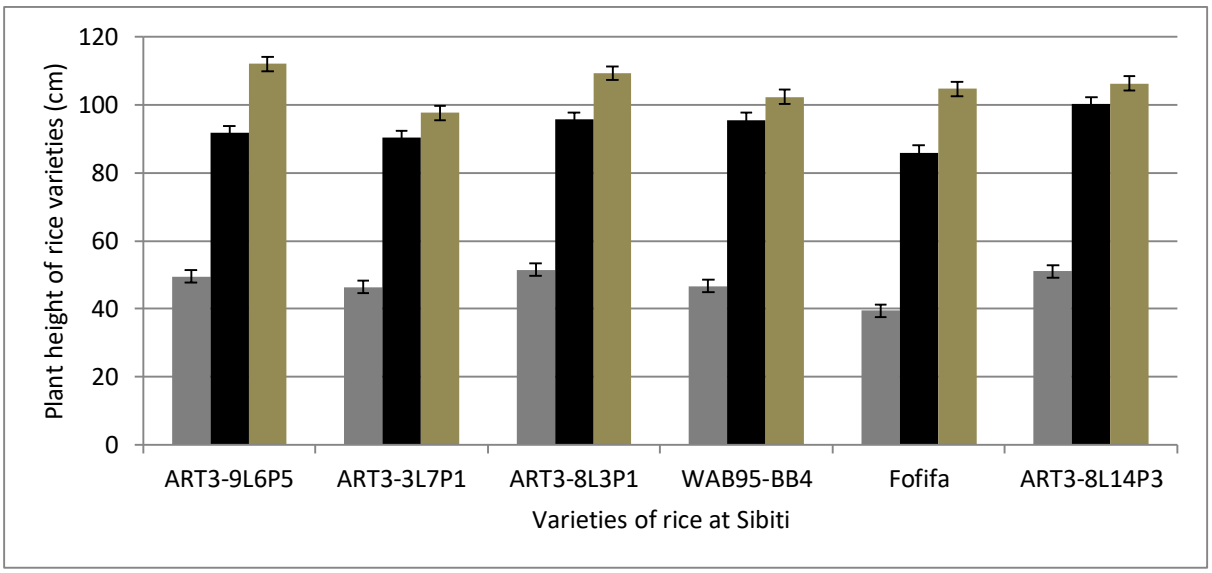

Figure 2. Size of rice varieties in 2015-2016 at 30 JAS, 60 JAS and at plant maturity in Sibiti

The ART3-9L6P5 variety has a size of 49.5 cm at 30 JAS, 91.67 cm at 60 JAS against 112 cm at maturity. Likewise, WAB95-BB4 shows plants of 46.7 cm at 30 JAS, 95.6 cm at 60 JAS versus 102.33 cm at maturity. Significant differences ($p < 0.05$) are noted between the three (3) phenological stages for the varieties ART3-9L6P5, ART3-8L3P1 and Fofifa. On the other hand, the non-significant differences ($p < 0.05$) between the last two stages (60 JAS and Maturity) for the varieties WAB95-BB4 and ART3-8L14P3.

3.2. Number of tillers per plant depending on the rice varieties and the vigor of the plants

The number of tillers per plant according to the rice varieties and the vigor of the plants in 2015-2016 and

2016-2017 in Sibiti and Loudima, are presented in table 4. In 2015-2016, we note that the number of tillers per plant is of the order of 13.67 ± 1.2 to 16.3 ± 3.8 for Sibiti against 4.33 ± 0.58 at 7 ± 1 for Loudima. ART3-9L6P5 and WAB95-BB4 were 14.33 ± 3.5 and 16.3 ± 3.8 respectively at Sibiti against 7.33 ± 1.2 and 5.67 ± 2.1 at Loudima. Non-significant differences ($p < 0.05$) are noted in Sibiti between varieties of rice, whereas these are noted in Loudima, between ART3-9L6P5 and ART3-8L3P1.

Likewise, the number of tillers in 2016-2017 is of the order of 13.33 ± 1.5 to 15 ± 1 for Sibiti against 9.67 ± 3.1 to 18.33 ± 3.2 for Loudima. ART3-9L6P5 and ART3-8L14P3 have respectively 14 ± 2 and 13.33 ± 1.5 at Sibiti against 18.33 ± 3.2 and 13.33 ± 1.5 at Loudima. Non-significant differences are noted at Sibiti whereas they are, between ART3-9L6P5 and ART3-8L3P1 at Loudima.

Table 4. Number of tillers per plant and plant vigor at 60 JAS in 2015-2016 and 2016-2017 in Sibiti and Loudima

Varieties of rice	Nomber of tillers Sibiti 2015-2016	Nomber de tillers Loudima 2015-2016	Nomber of tillers Sibiti 2016-2017	Nomber de tillers Loudima 2016-2017	Vigor Sibiti 2015-2016	Vigor Sibiti 2016-2017	Vigor Loudima 2015-2016	Vigor Loudima 2016-2017
ART3-9L6P5	14,33±3,5	7,33±1,2	14±2	18,33±3,2	1	1	2,33±1,2	2,33±1,2
ART3-3L7P1	13,67±3,2	4,33±0,58	14,33±2,5	12,67±3,1	1	1	2,33±1,2	1,67±1,2
ART3-8L3P1	13,67±2,5	5,33±0,58	14,67±0,58	9,67±3,1	1	1	2,33±1,2	3
WAB95-BB4	16,3±3,8	5,67±2,1	14,33±1,2	14,67±3,1	1	1	2,33±1,2	2,33±1,2
Fofifa	13,67±1,2	5,33±0,58	15±1	12,33±3,2	1	1	3	2,33±1,2
ART3-8L14P3	14,33±3,1	7±1	13,33±1,5	13,33±1,5	1	1	3	2,33±1,2
Mean	14,78±2,1	5,83±1,1	14,11±0,7	13,83±3,6	1	1	2,55±0,3	2,33±0,4

Regarding the plant vigor of rice varieties, it was noted that it was 1 in Sibiti during 2015-2016 and 2016-2017 against 1.67 ± 1.2 to 3 for Loudima. The averages in Loudima, being respectively 2.55 ± 0.3 in 2015-2016 and 2.33 ± 0.4 in 2016-2017. Non-significant differences ($p < 0.05$) were noted in 2015-2016 although they were, between ART3-3L7P1 and ART3-8L3P1 in 2016-2017.

3.3. Number of days at 50 and 85 % flowering of rice varieties during 2015-2016 and 2016-2017 in Sibiti and Loudima

The number of days at 50 and 85 % flowering of rice varieties during 2015-2016 and 2016-2017, is presented in table 5. We note that at 50 % flowering, the number of days in Sibiti in 2015, is of the order of 72 to 84 days against 74 to 84 days for Loudima. The averages are respectively 76 days against 77 days. ART3-9L6P5 and ART3-8L14P3 respectively present 75 days and 84 days in 2015-2016 in Sibiti against 80 days and 84 days in Loudima. Significant differences ($p < 0.05$) are noted between ART3-8L14P3 and the other rice varieties in Sibiti. Likewise, non-significant differences ($p < 0.05$) are noted between ART3-8L14P3 and ART3-9L6P5 which differ from other varieties of rice in Loudima. In 2016-2017, the number of days at 50% flowering was 75 to 93.9 days in Sibiti against 70 to 79 days in Loudima. The averages are respectively 85.77 days against 73.4 days. ART3-9L6P5 and ART3-8L14P3 respectively present 87 days and 93.9 days in Sibiti against 77.3 days and 79 days in Loudima. Non-significant differences ($p < 0.05$) are noted between ART3-8L14P3 and WAB95-BB4 at Sibiti, on the other hand, they are between ART3-3L7P1 and the other varieties of rice. In 2016-2017 in Loudima, non-significant differences ($p < 0.05$) were noted between ART3-8L14P3 and ART3-9L6P5. On the other hand, ART3-3L7P1, ART3-8L3P1, WAB95-BB4 and Fofifa show significant differences ($p < 0.05$) with ART3-8L14P3 and ART3-9L6P5.

Table 5. Number of days at 50 and 85 % flowering of rice varieties in 2015-2016 and 2016-2017 in Sibiti and Loudima

Varieties of rice	50 % flower Sibiti 2015-2016	50 % flower Loudim 2015-2016	50 % flower Sibiti 2016-2017	50 % flower Loudima 2016-2017	85 % flower Sibiti 2015-2016	85 % flower Loudima 2015-2016	85 % flower Sibiti 2016-2017	85 % flower Loudima 2016-2017
ART3-9L6P5	75	80	87	77,3	90	97	96	104
ART3-3L7P1	75	75	75	71,6	97	90	92	93,3
ART3-8L3P1	75	75	86	70,6	97	90	90	92,33
WAB95-BB4	72	74	89	70	90	90	89	90,67
Fofifa	75	74	83,7	72	90	90	88	91,33
ART3-8L14P3	84	84	93,9	79	100	101,6	105	100,6
Mean (cm)	76±4,1	77±4,1	85,7±6,3	73,4±3,7	94±4,5	93,1±5	93,3±6,3	95,4±5,5

In 2015-2016, the number of days at 85% flowering was 90 to 100 days in Sibiti against 90 to 101.6 days in Loudima. The averages are respectively 94 days in Sibiti against 93.1 days in Loudima. ART3-9L6P5 and ART3-3L7P1 have respectively 90 days and 97 days in Sibiti against 97 days and 90 days in Loudima. Likewise, ART3-8L14P3 presents respectively 100 days in Sibiti against 101.6 days in Loudima. Non-significant differences ($p < 0.05$) are noted between ART3-3L7P1, ART3-8L3P1 and ART3-8L14P3 in Sibiti. On the other hand, ART3-8L14P3 shows significant differences with Fofifa, WAB95-BB4 and ART3-3L7P1 in Sibiti. It is the same for ART3-9L6P5 and ART3-8L14P3 in Loudima. In 2016-2017, the number of days at 85 % flowering was 88 to 105 days in Sibiti against 91.33 to 104 days in Loudima. The averages are respectively 93.33 days in Sibiti against 95.37 days in Loudima. In Sibiti, significant differences ($p < 0.05$) are noted between ART3-8L14P3 and the other varieties of rice, and between ART3-9L6P5 and Fofifa. On the other hand, between ART3-9L6P5 and ART3-5L7P1, non-significant differences ($p < 0.05$) are noted. Similarly at Loudima, non-significant differences ($p < 0.05$) are noted between ART3-9L6P5 and ART3-8L14P3. Non-significant differences ($p < 0.05$) are noted between 2015-2016 and 2016-2017 for 50 % flowering, as for 85 % flowering, but they are between the two groups (50 and 85 %).

3.4. Yield of rice varieties

The yields of the six (6) varieties of rice are presented in table 6. In 2015-2016, it was noted that the yields were of the order of 3.86 ± 0.96 to 4.81 ± 0.92 t / ha in Sibiti against 1.98 ± 0.35 to 2.76 ± 0.55 t / ha in Loudima. The averages are respectively 4.42 ± 0.38 t/ha in Sibiti against 2.49 ± 0.31 t/ha in Loudima. ART3-9L6P5 and ART3-8L14P3 show 3.86 ± 0.96 t/ha and 4.81 ± 0.92 t / ha respectively in Sibiti against 1.98 ± 0.35 t/ha and 2.76 ± 0.55 t / ha in Loudima. Likewise, ART3-3L7P1 and Fofifa show 4.76 ± 0.86 t/ha and 4.1 ± 0.16 t/ha respectively in Sibiti against 2.58 ± 0.43 t/ha and 2.58 ± 0, 41 t/ha respectively for the two varieties of rice in Loudima. Significant differences ($p < 0.05$) are noted at Sibiti, between ART3-9L6P5 and ART3-8L14P3 but, they are not, between ART3-3L7P1, ART3-8L3P1 and WAB95-BB4. In Loudima, significant differences ($p < 0.05$) are noted between ART3-9L6P5 and ART3-8L14P3. On the other hand, ART3-3L7P1 and ART3-8L3P1 did not present any significant differences ($p < 0.05$).

Table 6. Production of rice in Sibiti and Loudima during 2015-2016 and 2016-2017

Varieties of rice	Yield 2015-2016 Sibiti (t/ha)	Yield 2015-2016 Loudima (t/ha)	Yield 2016-2017 Sibiti (t/ha)	Yield 2016-2017 Loudima (t/ha)
ART3-9L6P5	3,86±0,96	1,98±0,35	4,4±0,2	6,53±1,67
ART3-3L7P1	4,76±0,86	2,58±0,43	4,23±0,42	7,13±0,98
ART3-8L3P1	4,44±0,32	2,27±0,34	4,47±0,21	7,33±0,4
WAB95-BB4	4,57±0,32	2,75±0,18	4,1±0,35	9,33±0,45
Fofifa	4,1±0,16	2,58±0,41	4,27±0,38	6,8±1,11
ART3-8L14P3	4,81±0,92	2,76±0,55	4,3±0,35	7,3±0,95
Mean (t/ha)	4,42±0,38	2,49±0,31	4,3±0,3	7,4±0,99

In 2016-2017, yields were around 4.1 ± 0.35 to 4.47 ± 0.21 t/ha in Sibiti compared to 6.53 ± 1.67 to 9.33 ± 0.45 t/ha in Loudima. The averages are respectively 4.3 ± 0.3 t/ha in Sibiti against 7.4 ± 0.99 t/ha in Loudima. ART3-9L6P5 and ART3-8L14P3 show 4.4 ± 0.2 t/ha and 4.3 ± 0.35 t / ha respectively in Sibiti against 6.53 ± 1.67 t/ha and 7.3 ± 0, 95 t/ha in Loudima. Likewise, ART3-3L7P1 and Fofifa present 4.23 ± 0.42 t/ha and 4.27 ± 0.38 t/ha respectively in Sibiti against 7.13 ± 0.98 t/ha and 6.8 ± 1, 11 t/ha in Loudima. Significant differences ($p < 0.05$) are noted at Sibiti, between ART3-8L3P1 and WAB95-BB4 but, they are not, between ART3-9L6P5 and Fofifa. In Loudima, significant differences ($p < 0.05$) are noted between WAB95-BB4 and other varieties of rice. On the other hand, ART3-3L7P1 and Fofifa do not present any significant differences ($p < 0.05$). Significant differences ($p < 0.05$) are noted on the one hand between the yields obtained during 2016-2017 in Loudima and the three others, and between the yields of Sibiti and Loudima in 2015-2016. On the other hand, the yields of 2015-2016 and 2016-2017 in Sibiti do not show any significant differences ($p < 0.05$).

4. DISCUSSION

In this study, height is the growth parameter taken into consideration. The rice varieties present a diversity of results, depending on the phenological stages (30 JAS, 60 JAS and Maturity), the agricultural seasons (2015-2016 and 2016-2017) and in the two localities (Sibiti and Loudima). In 2015-2016 for example, that the size at 30 JAS, is of the order of 39.4 ± 0.51 at 51.4 ± 2.2 cm in Sibiti against 32.03 ± 5 at 38.13 ± 1, 6 cm in Loudima. On the other hand in 2016-2017, the rice varieties present at 30 JAS, plants of 36.3 ± 2.1 to 49.7 ± 2.8 cm in Sibiti and 43.8 ± 6.4 to 50.9 ± 5.3 cm in Loudima. At 60 JAS, the height is of the order of 75 ± 2.2 to 93.9 ± 4.6 cm in Sibiti against 93.3 ± 4.9 to 102.8 ± 5.8 cm in Loudima. Likewise, mature plants are in the order of 97.7 ± 3.1 to 108.7 ± 9 cm in Sibiti compared to 117 ± 6 to 146 ± 5.7 cm in Loudima.

In this order, Nguetta *et al*. (2006) and Anonyme (2006) report that the size of the mature plant varies from 60 cm to more than 200 cm depending on the variety. The results obtained indicate that more than 90% of the varieties tested have an average size greater than 100 cm. Which is favorable for a manual harvest by the producers of Sibiti and Loudima. The differences observed between the phenological stages of the plant, the years of agricultural experimentation and the localities which have housed it, can be justified by the morphogenetic characteristics linked to each variety of rice (Mande *et al*., 2005; Guéi *et al*., 2003), environmental conditions (Moundzeo *et al*., 2013) and the variability of the parameters that depend on them. According to these results, the rice plants in Sibiti, whose size varies from 97.7-108.7 cm, belong to class 5, that is to say intermediate (90-120 cm), while in Loudima whose size varies from 117-146 cm, the varieties belong to the intermediate classes (90-120 cm) and 9 = high height (≥ 120). The latter is susceptible to lodging and can lead to losses.

The results report in 2015-2016, that the number of tillers per foot is 13.67 ± 2.5 to 19 ± 3.8 for Sibiti against 4.33 ± 0.58 to 7.33 ± 1.2 for Loudima. Likewise in 2016-2017, the number of tillers is 13.33 ± 1.5 to 15 ± 1 for Sibiti against 9.67 ± 3.1 to 18.33 ± 3.2 for Loudima. If we reduce the results obtained to the square meter, they are summarized on average in the two localities of 145 to 370 tillers and remain very close to those presented by N'guetta et al, (2006). This represents an indicator of good productivity. On the other hand, it is important to indicate that the yield is not directly correlated with the development of the plant (Guéi *et al.*, 2005) and that the number of tillers produced by a variety is linked to the stage of development of the plant. , which in turn, is strictly related to the variety (N'guetta *et al.*, 2006). From a tillering point of view, the results show that some varieties belong to the medium tillering class (10-19) while the others are in the low tillering class (5-9).

The results show that the number of days at 50% flowering of rice varieties in 2015-2016 and 2016-2017, is 72 to 94 days in Sibiti against 74 to 84 days in Loudima. On the other hand, the number of days at 85% flowering of the rice varieties tested in 2015-2016 and 2016-2017, is 90 to 100 days in Sibiti against 90 to 104 days in Loudima.
Authors (Anonyme, 2006; N'guetta *et al.*, 2006) report that in Africa, the vegetative cycle of upland rice is 80 to 200 days and varies depending on the variety. They also specify that typical varieties of rice mature from 150 to 170 days against 120 to 140 days for improved varieties. Based on what has just been listed, it can be agreed that the six (6) varieties of rice tested are early (≤ 100 days) and short-cycle (100-119 days). They present in Sibiti and Loudima, a vegetative cycle of 75 to 85 days against 90 to 100 days, respectively to 50 and 85% of flowering of the varieties of rice. Which is very interesting for adaptation to climate change in the country.

Regarding yields, the results indicate that in 2015-2016, the six (6) varieties of rice have from 3.86 ± 0.96 to 4.76 ± 0.92 t/ha in Sibiti against 1.98 ± 0.35 to 2.75 ± 0.55 t/ha in Loudima. The varieties ART3-9L6P5 and ART3-8L14P3 having respectively 3.86 ± 0.96 t/ha and 4.81 ± 0.92 t/ha in Sibiti against 1.98 ± 0.35 t / ha and 2.76 ± 0.55 t/ha in Loudima. On the other hand in 2016-2017, the yields were 4.1 ± 0.35 to 4.47 ± 0.21 t/ha in Sibiti against 6.53 ± 1.67 to 9.33 ± 0.41 t/ha in Loudima.

The work of Nguetta *et al*. (2006) on the selection of efficient varieties of rainfed rice (Oryza sp.) In the subequatorial region of Congo-Brazzaville, give yields of the order of 1.42 to 6.64 t/ha after recalling that traditional varieties of rainfed rice produce up to 2 t/ha. Likewise, some works on rice (Anonyme, 2006; Bouet *et al*, 2005) specify that the yields concerning this agricultural speculation can reach 4 to 5 t/ha and under optimal cultivation conditions, are of the order of 8 to 10 t/ha. Also, Coulibaly and Ouologuem (2014) report that rice yields in the Office Niger (ON) area are 5.72 to 6.1 t/ha. The results of our study are very close to the aforementioned work. The differences between them, and the significant yields obtained, can be justified by the type of ecosystems used, which are the savannah (Loudima) and the forest (Sibiti). Indeed, the Sibiti area has a higher rainfall than that of Loudima and the agricultural experimentation carried out in 2016-2017 in the savannah area was conducted in a lowland site. However, this one is more supplied with water by surface runoff and sometimes, by the rise of the surface water tables (WARDA, 2001; Sie, 2003; Anonyme, 2006; Nadie, 2008). This corresponds to a hydromorphic environment, capable not only of meeting the water needs of plants but also of providing more of the organic matter necessary for their development. These authors point out that lowland sites, particularly those in West Africa, allow producers to meet their basic needs. They are increasingly designed to remove water constraints and improve the productivity of rainfed rice cultivation.

5. CONCLUSION

In this study, the results of which have just been discussed, the production potential of the six (6) varieties of rainfed rice were evaluated and compared in the agro-ecological zones of Sibiti and Loudima during the 2015-2016 and 2016-2017 agricultural seasons. The main parameters considered concern the size of the plants according to the phenological stages (30JAS, 60JAS and maturity), the number of tillers per plant and the vigor of the plants, the number of days at 50 and 85%

flowering of the rice varieties and the yields obtained in the two agro-ecological zones.

It emerges that in 2015-2016 and at maturity, the size of the rice varieties is of the order of 97.67 ± 4.2 to 108.1 ± 1 cm in Sibiti against 91 ± 5 to 99 ± 2 cm to Loudima. On the other hand in 2016-2017, the size of mature plants is 97.7 ± 3.1 to 108.7 ± 5.7 cm at Sibiti against 114.3 ± 3.5 to 146 ± 5.7 cm at Loudima. As the six (6) varieties of rice are 100 cm tall or greater at maturity, manual harvesting can be undertaken without difficulty by the producers of Sibiti and Loudima.

In 2015-2016, the number of tillers was 13.67 ± 1.2 to 16.3 ± 3.8 for Sibiti against 4.33 ± 0.58 to 7.33 ± 1.2 for Loudima. Likewise, the number of tillers in 2016-2017 is 13.33 ± 1.5 to 15 ± 1 for Sibiti against 9.67 ± 3.1 to 18.33 ± 3.2 for Loudima. The six (6) varieties of rice portend a large number of fertile tillers and suggest very encouraging production potential.

The number of days at 85% flowering in 2015-2016 is 90 to 100 days in Sibiti against 90 to 101.6 days in Loudima. Similarly, the number of days at 85% flowering in 2016-2017, is 88 to 105 days in Sibiti against 91.33 to 104 days in Loudima. The six (6) varieties of rice which show less than 100 days at 85% flowering suggest aptitudes of precocity.

Yields of rice varieties in 2015-2016 are around 3.86 ± 0.96 to 4.81 ± 0.92 t/ha in Sibiti against 1.98 ± 0.35 to 2.76 ± 0.55 t/ha in Loudima. In 2016-2017, the yields are 4.1 ± 0.35 to 4.47 ± 0.21 t / ha in Sibiti against 6.53 ± 1.67 to 9.33 ± 0.45 t/ha in Loudima. The differences in yields noted can be explained by the potential of the six (6) varieties of rainfed rice introduced, the type of ecology used during the experiment and the agricultural techniques put into practice. Thus, the rice production sites available to the country, such as the lowlands, must be developed and this cultivation should be revived to reduce as much as possible the imports linked to this foodstuff. This obviously makes it possible to respond to national concerns in terms of food security and the fight against poverty.

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