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Impact of the African rice midge (*Orseolia oryzivora*) on the yield of rice varieties grown in Baguinéda (Mali)

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Abstract
Rice growing occupies a key place in agriculture and the search for food security in Mali. However, in rice production, damage caused by the African rice midge (*Orseolia oryzivora*) is a major constraint and therefore an economically important insect. The African rice midge is a major pest in the South Sudanian zone where development conditions are favorable for it. This study aims to document the effect of the insect on the yield of IER irrigated rice varieties in Mali. The study was carried out in the IER irrigated area of Baguinéda during the agricultural seasons of 2016, 2017 and 2018. It made it possible to harvest the rice yield from a square of (25 m^2) in the 50 study plots and the counting the number of tillers, panicles, full spikelets, empty spikelets, galls, and grains per tuft, at the time of heading at the level of a yield square (1 m^2) placed within 50 study plots. All varieties of rice were susceptible to attack by the insect. An analysis of variance carried out from the data revealed a significant difference in the yield of the different rice varieties ($p < 0.05$). Average yields of rice varieties were very low and varied between 2.8 t/ha for SÉBÉRANG to 0.27 t/ha for BW, with a considerable yield loss of 44% in 2016 compared to the other two 2017 and 2018 agricultural seasons in the area.

Keywords: *Orseolia oryzivora*, midge, rice, yield, Baguinéda

1. Introduction
Rice is the world's leading cereal grown for human consumption. Its global production in 2017 amounted to 756.7 million tonnes and represents 20% of global food energy needs (FAO, 2017) [4]. It is the second cereal after corn in terms of tonnage produced (FAO, 2017) [4]. In Mali, the agricultural sector employs nearly 90% of the active population. Potential land for rice cultivation is estimated at 606,000 ha for lowland and floodplain rice cultivation and over 1,000,000 ha for IER rigated rice cultivation (Hamadoun, 2015) [7]. Rice growing occupies a key place in agriculture and the search for food security in Mali. National annual rice production reached 2,211,920 tons of paddy in 2014. This production is expected to increase due to the growth in demand for food in Mali and the sub-region. This speculation plays an essential role in national poverty reduction strategies. Mali has been committed since 2008 to the implementation of the West Africa Agricultural Productivity Program (WAAPP) to address these constraints (Hamadoun, 2015) [7]. The notorious lack of rice production is partly explained by multiple abiotic (drought, decline in soil fertility) and biotic (arthropods, diseases, weeds) constraints. Among the biotic constraints, insect pests occupy an essential place. In rice production, damage caused by *Orseolia oryzivora* Harris and Gagné (1982) [8] (Diptera: Cecidomyiidae) constitutes a major constraint and therefore an economically important insect. The insect is rife in several African countries Nwilene *et al.*, (2011b) [13]. In Mali, it is very present in the region of Sikasso, Koulikoro and Ségou in the lowlands and IER irrigated areas. The damage is caused by the larvae that feed inside the rice heights, which subsequently thicken and take the shape of an onion leaf or onion tube. Infestation levels vary from 30% in the lowlands to 80% in the Irrigated perimeters, particularly at the Office des Perimètres Irrigués de Baguinéda. In Mali, the distribution of midge indicates very contrasting ecological areas whose characteristics are not sufficiently known to explain the large variations recorded Hamadoun *et al.*, (2008) [5]. The perimeters of San and Baguinéda experienced upsurges of the pest with production losses of around 55% and Baguinéda, considered a midge niche in Mali.

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2. Methodology

Study site: The studies were conducted at the level of the Office of Irrigated Perimeters of Baguinéda (OPIB).

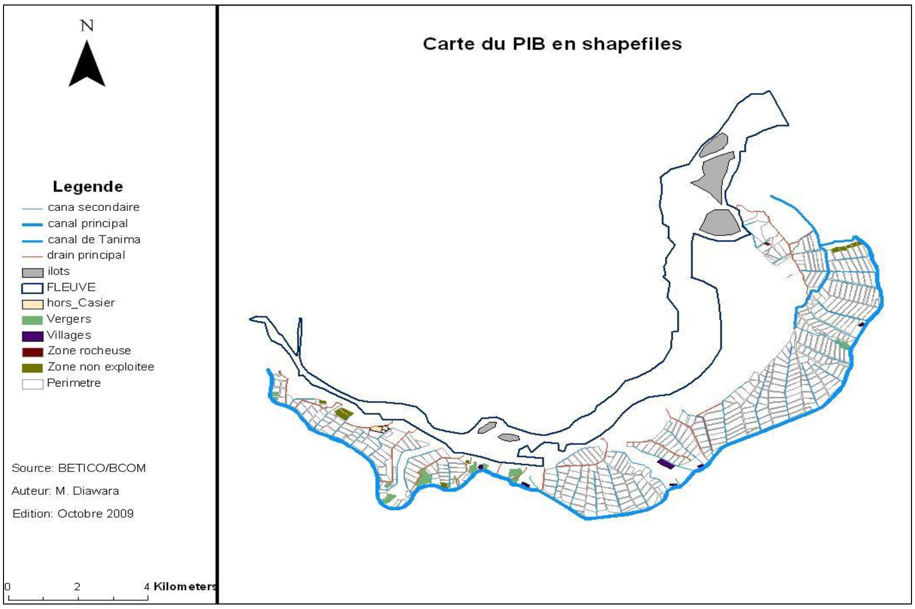

Fig 1: Presentation of the Baguinéda Irrigated Perimeter Office (Diawara, 2010)

Type and period of study

The study was longitudinal on 50 study plots, located from the start of sector 1 to the end of sector 4 of the Baguinéda IER irrigated Perimeter Office (OPIB) for the assessment of damage, identification of the 'insect. It spanned the period from January 2016 to December 2018.

Biological material

Biological materials are rice galls, lavas, nymphs and adults of *O. oryzivora*.

Sampling of study plots

The number of different operators was chosen randomly from an exhaustive list, made available to us by the OPIB management. It is from this list that the survey units were drawn. A sample of 50 farmers for the study was obtained from a previous study, which had the theme: “Development of a spatial repository for monitoring rice pests in the Irigated of Baguinéda (PIB)”.

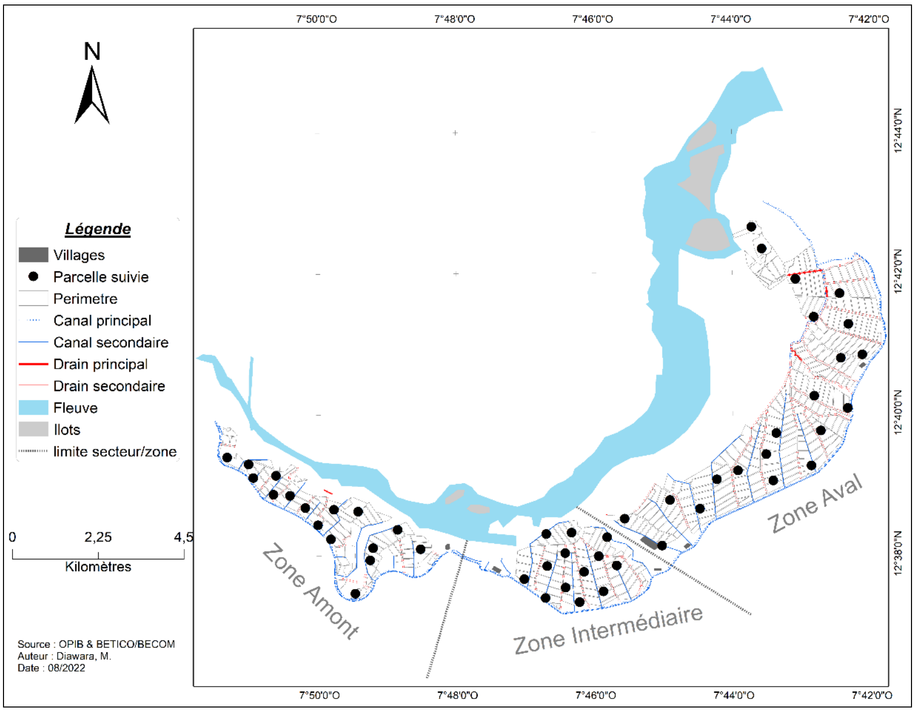

Fig 2: Sampling map of the 50 study plots, distributed between the three sectors of the Baguinéda Irrigated Perimeter

To determine yields, on the one hand it was done by harvesting rice plants at the level of a yield square (25 m^2). The harvested rice plants were threshed and weighed. On the other hand it was based on counting the number of tillers per tuft, panicle per tuft, full spikelet per tuft, empty spikelet per tuft, gall per tuft, and grain per tuft, at the time of heading, by harvesting at the level of a yield square (1 m^2) placed on each of the four sides as well as in the middle of the 50 study plots.

Statistical analysis

Data were entered using Excel 2013 software. Statistix.8.0 statistical analysis software, and R x 64 3.1.2., used for analyzes of variance in order to determine the significance of the averages recorded between parameters according to the different periods (day, month and year) per plot in the same study area. A statistical test (Tukey or Newman Keuls) was carried out to evaluate the correlations between the different results and with the cultural practices of each producer at the 5% significance level. The results were presented in the form of a table or a graph.

3. Results

Analysis of variance between varieties and agronomic yield parameters

The results of the variation in the number of galls and the yield of the different rice varieties for the 2016 rainy season represented in (Table 1), show a significant difference ($p<0.05$) recorded on the average number of spikelets full/tuft/m^2: the lowest average (8.662) is recorded on the BW variety and the highest (110.205) on the Sébérang variety. The average number of grains/tuft/m^2 is highly significant, the lowest (50, 480) BW and the highest (988, 122) with Sébérang. On the other hand, no significant difference for the other parameters was recorded.

Table 1: Analysis of variance (ANOVA) between the varieties and agronomic parameters observed in the 2016 rainy season

Varieties	Agronomic parameters						
	Average number of tiller/tufts/ m²	**Average number of panicles/tufts/m²**	**Average number of galls/clump/ m²**	**Average number of ears/tufts/ m²**	**Average number of spikes/tuft/ m²**	**Average number of grain/tuft/ m²**	**Weight (t)/ha**
Adny	18,682	3,273	10,081	2,562	20,421 b	216,960 b	1,188
Sébérang	23,529	6,995	12,782	5,724	110,205 a	988,122 a	2,800
IER wassa	17,257	3,035	6,855	2,901	10,303 b	95,848 b	1,159
BG	17,876	2,995	4,807	2,473	14,908 b	173,239 b	0,877
BW	14,241	3,025	7,604	2,500	8,662 b	50,480 b	0,268
CV	34,2	49,9	42,6	65,8	112,2	81,1	101,3
Probability	0.859	0.330	0.187	0.597	0.029	0.007	0.626
ES	6,25	1,677	3,659	1,832	24,14	175,4	1,184
Significance	NS	NS	NS	NS	S	HS	NS

CV = Coefficient of variation, ES = Standard Error NS = not significant S = significant, HS = highly significant a, b, etc.: mean values followed by the same letters in a column are not significantly different at the threshold ≤ 0.050.

In the 2017 off-season, the analysis of variance (ANOVA) did not reveal any significant difference between the varieties with the agronomic parameters observed. On the other hand, we noted arithmetic differences between the values (Table 2).

Table 2: Analysis of variance (ANOVA) between varieties and some parameters observed among producers in the 2017 off-season

Varieties	Agronomic parameters						
	Average number of tiller/tufts/ m²	**Average number of panicles/tufts/m²**	**Average number of galls/clump/ m²**	**Average number of ears/tufts/ m²**	**Average number of spikes/tuft/ m²**	**Average number of grain/tuft/ m²**	**Weight (t)/ha**
Adny	13,646	12,802	0,000	120,853	5,320	1495,972	5,000
IER wassa	11,942	11,137	0,017	95,582	3,357	1186,314	4,416
BG	9,496	8,273	0,000	79,063	6,197	880,394	4,640
BW	10,802	10,065	0,000	74,674	3,292	895,276	4,200
CV	18,1	17,6	54,9	56,5	54,9	53,5	20,4
Probabilité	0,415	0,292	0,757	0,839	0,436	0,767	0,822
ES	2,14	1,94	2,09	53,8	2,09	625,6	2,29
Signifiance	NS	NS	NS	NS	NS	NS	NS

CV = Coefficient of variation, ES = Standard Error NS = not significant S = significant, HS = highly significant a, b, etc.: mean values followed by the same letters in a column are not significantly different at the threshold ≤ 0.050.

In 2017 in the rainy season, as in the 2017 off-season, the varieties behaved in the same way for all the parameters observed; the analysis of variance did not reveal any significant difference. On the other hand, we noted arithmetic differences between the values (Table III).

Table 3: Analysis of variance (ANOVA) between varieties and some parameters observed among producers in the 2017 rainy season

Varieties	Agronomic parameters						
	Average number of tiller/tufts/ m²	**Average number of panicles/tufts/m²**	**Average number of galls/clump/ m²**	**Average number of ears/tufts/ m²**	**Average number of spikes/tuft/ m²**	**Average number of grain/tuft/ m²**	**Weight (t)/ha**
Adny	18,228	14,753	0,626	3,533	108,201	1554,107	4,162
Sébérang	30,362	17,142	0,946	3,680	143,922	2166,364	3,400
IER wassa	15,367	10,779	1,745	0,972	11,830	248,115	4,800
BG	18,536	16,872	0,616	3,835	156,745	1909,816	3,400
BW	14,642	13,599	0,079	5,499	142,895	1858,163	4,000
Kogoni	20,322	15,441	0,867	2,135	149,958	1556,103	4,000

CV	34,9	19,4	94,7	58,6	52,6	53,1	14,7
Probabilité	0,267	0,504	0,531	0,532	0,599	0,575	0,257
ES	6,63	2,89	0,641	66,5	1,84	843,3	0,596
Signifiance	NS	NS	NS	NS	NS	NS	NS

CV = Coefficient of variation, ES = Standard Error NS = not significant S = significant, HS = highly significant a, b, etc.: mean values followed by the same letters in a column are not significantly different at the threshold ≤ 0.050.

In the 2018 off-season, the analysis of variance (ANOVA) reveals a significant difference (*p*> 0.05) between the varieties for yield per hectare. The Adny variety has the highest value (5.732T/ha). On the other hand, no significant difference was observed between the varieties for the other parameters (Table 4).

Table 4: Analysis of variance (ANOVA) between varieties and some parameters observed among producers in the 2018 off-season

Varieties	Average number of tiller/tufts/ m²	Average number of panicles/tufts/m²	Average number of galls/clump/ m²	Average number of ears/tufts/ m²	Average number of spikes/tuft/ m²	Average number of grain/tuft/ m²	Weight (t)/ha
Adny	16,66	13,67	0,00	167,67	2,33	1882	5,732 a
IER wassa	12,14	11	0,00	133,57	0,43	1597	4,688 b
BG	12	11	0,00	138	0,00	1660	4,800 b
Nènèkala	12	11	0,00	142	1,60	1682	5,200 ab
CV	17,26	13,09	-	10,91	180,17	22,42	5,61
Probabikité	0,0951	0,1556	-	0,0797	0,1927	0,8447	0,0048
ES	0,818	0,484	-	5,874	0,417	99,132	0,358
Significance	NS	NS	NS	NS	NS	NS	S

CV = Cœfficient de Variation, ES = Erreur Standard NS = non significative, S = significative.

In the 2018 rainy season, a statistical difference of p>0.05 was observed between the varieties for the average number of spikes/tuft/m². On the other hand, no significant difference was observed between the varieties for the other parameters (Table 5).

Table 5: Analysis of variance (ANOVA) between varieties and some parameters observed among producers in the 2018 rainy season

Varieties	Average number of tiller/tufts/ m²	Average number of panicles/tufts/m²	Average number of galls/clump/ m²	Average number of ears/tufts/m²	Average number of spikes/tuft/ m²	Average number of grain/tuft/ m²	Weight (t)/ha
Adny	19,96	16,6	0,28	143,54 a	1,60	1930,3	8,820
Sébérang	17,35	12,96	0,41	116,11 a	1,80	1568	8,812
IER wassa	16,25	13,01	0,37	75,08 b	1,10	1310,8	10,616
BG	19,56	13,51	0,062	80,70 b	1,00	117,5	9,468
CV	31,45	22,53	141,32	35,74	77,82	38,57	20,29
Probabilité	0,6056	0,1919	0,9630	0,0117	0,6893	0,1968	0,3348
ES	5,31	2,91	0,55	48,5	0,99	597,2	4,43
Signifiance	NS	NS	NS	S	NS	NS	NS

CV = Coefficient of variation, ES = Standard Error NS = not significant S = significant, HS = highly significant a, b, etc.: mean values followed by the same letters in a column are not significantly different at the threshold ≤ 0.050.

During the three rainy seasons of the study, no significant difference with *p*< 0.05 on the agronomic parameters was recorded (Table 6). The results showed that all varieties were susceptible to galling with a non-significant difference between them for the average number of galls/tuft/m².

Table 6: Analysis of variance (ANOVA) between varieties and some parameters observed in the rainy season during the three years (2016, 2017 and 2018)

Varieties	Agronomic parameters						
	Average number of tiller/tufts/ m²	Average number of panicles/tufts/m²	Average number of galls/clump/ m²	Average number of ears/tufts/ m²	Average number of spikes/tuft/ m²	Average number of grain/tuft/ m²	Weight (t)/ha
Sébérang	22,461	14,040	2,143	3,040	152,261	1970,428	5,971
Adny	18,739	12,773	2,508	2,559	90,891	1285,479	5,451
Kogoni	20,322	15,441	0,867	2,135	149,958	1556,103	4,000
BG	19,047	10,951	2,052	2,364	96,354	1214,088	4,409
IER (wassa)	16,911	9,719	2,716	1,854	66,916	1001,156	6,331
BW	14,442	8,312	3,841	4,000	75,779	954,321	2,134
CV	32,6	45,3	163,5	70,9	72,7	69,4	61,5
Probability	6,109	5,520	4,039	1,782	68,31	898,8	3,330
ES	0,451	0,445	0,990	0,601	0,206	0,405	0,664
Significance	NS	NS	NS	NS	NS	NS	NS

CV = Coefficient of variation, ES = Standard Error NS = not significant

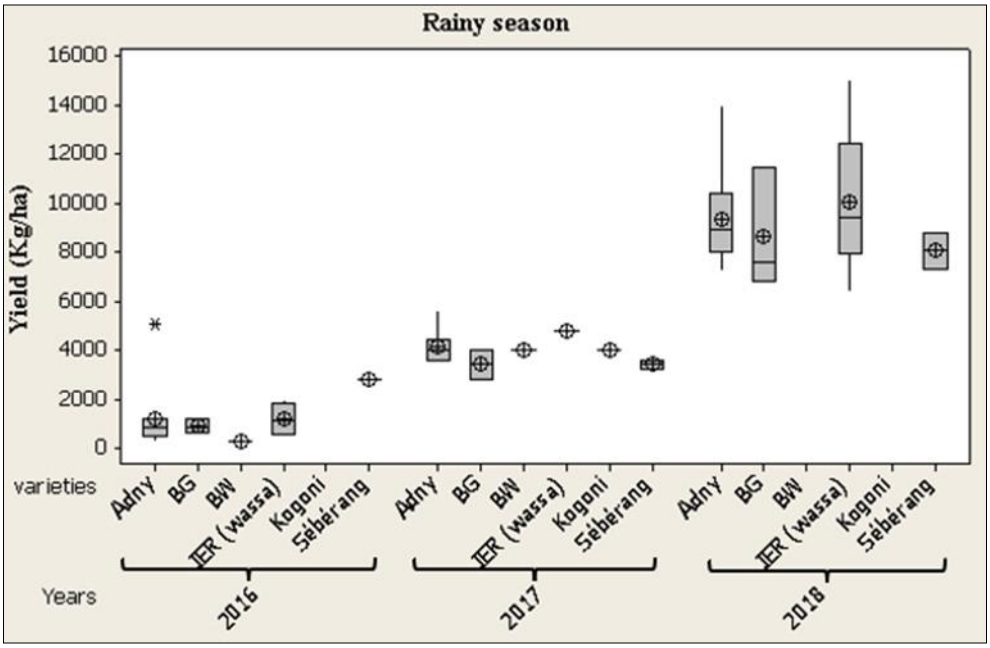

Fig 3: Evolution of the yield of varieties in the fields in the rainy season 2016, 2017 and 2018

This figure illustrates the evolution of rice yield in the irrigated plots of OPIB in the commune of Banguineda. Indeed, the figure indicates a considerable increase in yields of different varieties and a drop in the number of galls. On average, the lowest yields of the varieties were observed during the 2016 rainy season which recorded the highest number of galls, while the best were recorded in 2018. Interestingly, the IER Wassa variety had the best performance in all three environments. Its yield increases from 1159 Kg/ha (2016) to 10,033 Kg/ha in 2018. The low yields of rice varieties from the 2016 season can be explained by the strong midge attack during this year. We can therefore say that all the varieties studied are susceptible to midge.

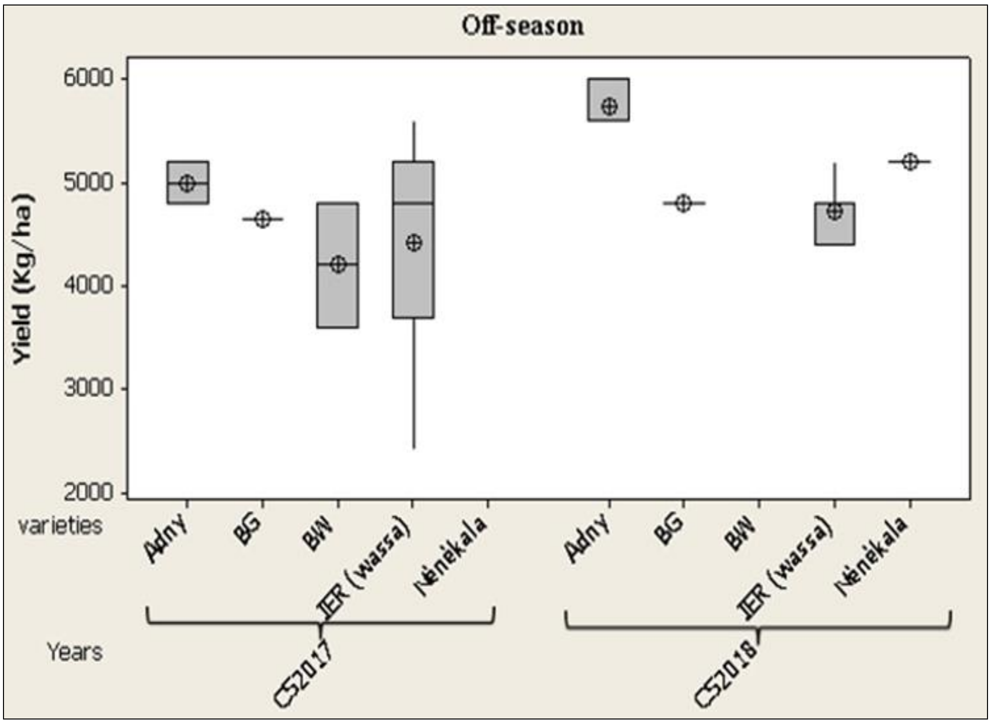

Fig 4: Evolution of the yield of varieties in the fields in the 2017 and 2018 off-season.

This figure shows an evolution in the yield of the varieties during the 2017 and 2018 off-seasons. The analysis of variance does not show a significant difference between the varieties during the off-season. On average all varieties had yields greater than 4t/ha. These results could be explained by strong sunshine with a virtual absence of African rice midge in the study plots.

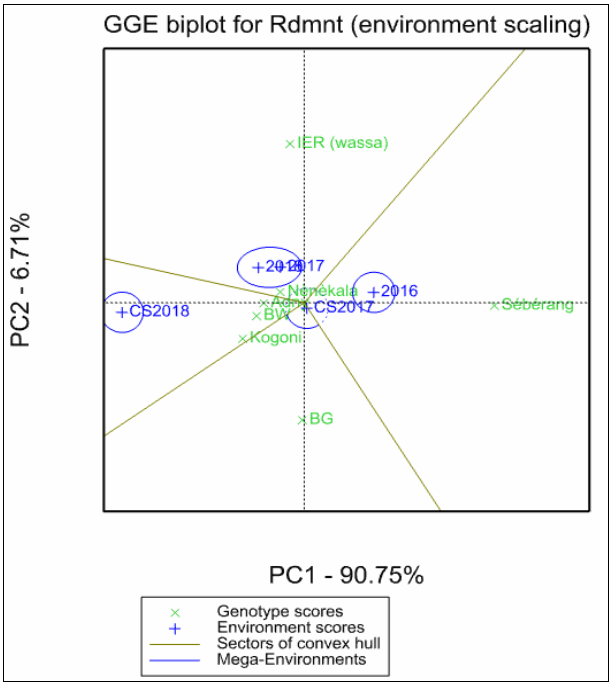

Fig 5: Genotype Main Effects and Genotype × Environment Interaction Effects (GGE) for Yield for Yield (in the five environments) in the rainy season 2016, 2017 and 2018 and in the off-season 2017 and 2018

The 2017 and 2018 rainy seasons form a mega-environment, indicating that these two conditions have similar environmental effects on the yield of varieties with a GxE interaction (Fig 5).

Superiority performance calculates the cultivar superiority measure of Lin & Binns (1988). For each genotype, it is the sum of the squares of the difference between its mean in each environment and the mean of the best genotype, divided by twice the number of environments. The varieties with the smallest superiority values tend to be more stable and closer to the best genotype in each environment Adny followed by IER (Wassa) (Table 7). Wricke ecovalence produces the Wricke (1962) ecovalence stability coefficient. This is the contribution of each genotype to the sum of squares genotypes per environment, in an unweighted analysis of genotypes per environment means. A low value indicates that the genotype responds consistently to changes in the environment. Thus the Nènèkala variety followed by BG is the most favourable to environmental change while Sébérang is little affected by the improvement of environmental conditions (T).

Table 7: Environmental genotype in rainy season (2016, 2017 and 2018) and off-season (2017 and 2018)

Genotype	Superiority performance	Ecovalence stability coefficient
Adny	366019	720338
IER (wassa)	500267	961100
Nènèkala	503333	248895
Kogoni	605392	2234817
BW	834264	1872386
BG	953820	453013
Sébérang	4020574	19643303

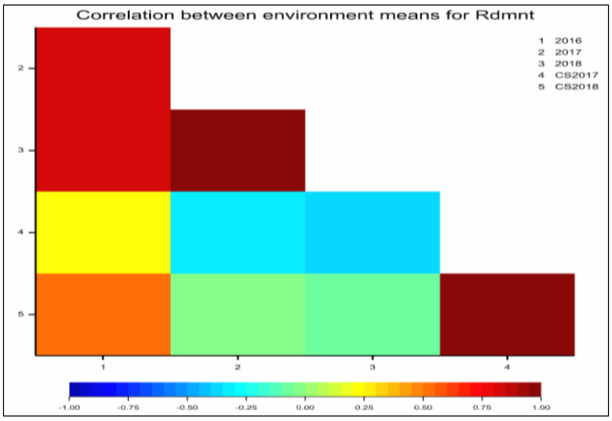

Fig 6: Correlation between the 5 environments for the grain yield of the varieties

This matrix visualizes the correlations with different colors; red colors indicate a positive correlation between environments and blue colors indicate a negative correlation between environments. There is a strong correlation between the three rainy seasons r>0.7, so the variety orders do not change much during the three rainy seasons. A weak negative correlation between the rainy seasons of 2017, 2018 and the off-seasons. So the performance of the varieties changes between the rainy seasons of 2017; 2018 and the off-seasons.

Discussion

The heavy onslaught of the 2016 rainy season greatly affected rice yield, with a significant difference recorded between varieties ($p< 0.05$). Average yields were very low and varied between 2.8 t/ha for Sébérang to 0.27 t/ha for BW. The loss of yield was considerable in the same year 2016, i.e. 44% compared to the two other agricultural campaigns 2017 and 2018 in the area. These results are similar to those of Williams (1997) [17] in Nigeria who demonstrated that the appearance of a gall at 5 heights 49-63 days after late transplanting causes 40% and 60% yield losses respectively. Similarly, Israel and Prakasa Rao (1968) [9] stated that a severe infestation of rice can prolong the pruning stage, delay flowering, followed by uneven maturity and result in a bushy appearance of the plant. Warda (2000) also reported yield losses in fields with 30% height infestation, suggesting that for every 1% additional infestation, a farmer can expect a 2-3% yield loss. As consequences, there would be a drop in photosynthetic activity, therefore a drop in the synthesis of carbohydrates and also the formation of empty grains. A significant difference was obtained between the seasonal action and the population damage of the rice midge. Similarly, a significant difference is observed between different stages of rice and crop development and rice midge population damage. Nacro researchers and collaborators claimed in 1996 that every 1% increase in gall corresponds to 2% loss in yield.

The environmental genotypes of the varieties (Adny, IER wassa, Nènèkala, Kogoni, BW, and BG) in the rainy season show the calculated superiority performance of the Adny and IER (wassa) varieties the measure of superiority of the cultivar of Lin & Binns (1988) as the most stable and closest to the best genotype in each environment. In the off-season, it is the Nènèkala variety which is the most stable and closest to the best genotype in each environment according to the ecovalence stability coefficient of Wricke (1962).

Conclusion

The study revealed that the majority of rice farmers in OPIB use the Adny variety. The results show higher rates of galls on this variety during the rainy seasons, which affects yield with an almost absence of galls on rice in the dry season in the irrigated area of Baguinéda. The infestation rate varied depending on the varieties and the growing season.

Conflict of interest statement

Authors declare that they have no conflict of interest.

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