

Agro-Morphological Characterization of Rice Varieties in an Irrigated Lowland in the Guinean Savannah Zone of Côte d'Ivoire

ABSTRACT

Aim: To measure the agro-morphological characteristics of rice varieties and to evaluate grain yields.

Study design: split-plot design with three replicates.

Place and duration of the study: In the M'bé II valley (8°06 N, 6°00 W, 180 m), not far from the village of Tabako, on the Bouaké – Katiola axe; about 24 km from Bouaké.

Methodology: The area of 1,815 m² was cleared and subdivided into subplots 3 m apart, in which 15 m² sub-plots were spaced 1 m apart in a split-plot design. **10 hybrid and 10 local varieties were taken for the study.**

NPK(15-15-15) was applied as a bottom dressing at 200 g per 15 m² before transplanting. The varieties were transplanted at a spacing of 20 cm x 20 cm, after 21 days in the nursery. The trial was irrigated via the drainage canal using a run-of-river system. Urea was applied at rates of 14 g per 15 m² at tillering and 19 g per 15 m² at heading stages. Glyphosate, a broad-spectrum herbicide to kill all types of weeds or plant, and propanil, a post-emergence herbicide to kill weeds only. The insecticide DECIS (Lambda-cyhalothrine) was used to kill insect pests.

Results: The eight mean's value of local rice varieties was higher than that of improved varieties, whatever the plant growth stage. Conversely, the average number of tillers was always higher for the improved varieties. With a vigour index of (IV) 4.12, the improved varieties had a lower mean flowering time of 83 days than the one of local varieties which was 100 days. However, there was no effect of variety ($P > 0.05$) on the vigour index of hybrid varieties. However, for the semi-flowering cycle, a highly significant difference ($P = 0.0001$) was observed among hybrid varieties. The local variety Dememba showed a higher chlorophyll content of 52 µgmg⁻¹. Varieties AR043H, AR034H and AR051H had the highest grain yields, around 8 tha⁻¹, while local varieties Dememba and Kouiklonlé had the lowest. In contrast, the varieties Koité and GT11 yielded about 5 tha⁻¹. The variety Danané had one of the lowest yields of 1.5 tha⁻¹.

Conclusion: Identification of parental germplasm is important to quantitatively and qualitatively improve lowland rice production on the basis of agro-morphological traits.

Keywords: Lowland rice, hybrids, split-plot, Gbèkè, Côte d'Ivoire

1. INTRODUCTION

Rice (*Oryza* sp.) [29] is the most widely grown cereal in the world after wheat, accounting for 20% of cereal consumption [1]. Mainly produced in Asia [2], rice is consumed by more than half the world's population, with nearly 50 million consumers in Africa [3], [4].

Côte d'Ivoire, despite its natural potential, remains a rice-importing country due to its high urbanization, relatively high demography and annual per capita consumption of 58 kg [4], [5], [6]. However, it is possible to achieve rice self-sufficiency, since it can be grown in all the country's ecologies (plateau and lowland).

One of the weaknesses of the rice industry is the predominance of rainfed rice [30], which occupies around 80% of the land area, with a low yield of around 1 tha⁻¹, to the detriment of irrigated rice. Irrigated rice yields vary between 6 and 8 tha⁻¹ [7], with the possibility of two cropping cycles per year [5].

These observations show that lowlands used need to be enhanced in order to increase national production. Furthermore, Côte d'Ivoire has only 35,000 ha of lowlands [8], which cannot be fully exploited with the current yield potential of existing varieties. Therefore, if rice growing is to be limited to the lowlands, rice yields need to be raised to around 15 tha⁻¹ by improving the production technological packages; a practice that is strongly recommended to curb the adverse effects of climate change [9], [10].

It is well known that seed contributes 30% to agricultural production [11] against 50% for soil fertility [12]. For this reason, an effective varietal selection strategy should combine this pair of factors, which often control the remaining 20% of production factors constituted by biotic stresses [13], [14], [15], [16].

In this context, study should be initiated with a view of identifying low-input genotypes that could sustainably support rice cultivation on family farms in Africa. Therefore, the objective of this study was to evaluate the agro-morphological characteristics of 20 lowland rice varieties with a view to selecting the best varieties for use in a varietal creation and improvement program.

2. MATERIALS AND METHODS

2.1 Description of experimental site

The field trial was conducted in the M'bé II valley (8°06 N, 6°00 W, 180 m), not far from the village of Tabako, on the Bouaké-Katiolaaxe; about 24 km from Bouaké. The experimental site was a semi-developed irrigated lowland in central Côte d'Ivoire, with a canal serving as the main drain. The surrounding vegetation was secondary, dominated by *Leersiahexandra* (poaceae) and *Rhynchospora.corymbosa* (Cyperaceae). The site's climate was subtropical, with a bimodal rainfall pattern. This climate was characterized by a mean annual temperature and rainfall of 28 °C and 1200 mm, respectively.

2.2 Experimental site soil

The experiment was carried out in a second-order plain (100 – 120 m wide) developed on a granite-gneiss subbasement with a Fluvisol characterized by a pH(water) of 5.5, an organic carbon concentration of 3.12 g kg⁻¹ and total nitrogen of 0.31 g kg⁻¹. The content of assimilable phosphorus with Olsen method was high, 150 g kg⁻¹, contrasting with the low content of potassium of 0.08 cmol kg⁻¹. High levels of calcium with 3.05 cmol kg⁻¹ and magnesium of 2.26 cmol kg⁻¹ were also determined for a Cation Exchange Capacity (CEC) of 2.02 cmol kg⁻¹. The ratios C:N and [(K:CEC) × 100] showed values of 10.06 and 3.9%. A five-year fallow dominated by *Leersiahexandra* (Poaceae) and *Frimbristulisspp* (Poaceae) preceded the experiment.

2.3 Plant material

Two categories of lowland rice varieties were tested: ten local varieties (VL) and ten improved varieties (VA). The local varieties of rice (VL), including the popular variety WITA9 (used as a control in this experiment), were collected across Côte d'Ivoire for their strong adoptions. The tested improved varieties of rice (VA) were selected at the AfricaRice research station in Saint-Louis (Senegal). These are low-lying hybrids with a potential yield of 10 to 15 t ha⁻¹ whose parents are ARSH X Sahel 180. Tables 1 and 2 list the characteristics of these varieties.

Table 1: Characteristics of local lowland rice varieties collected across Côte d'Ivoire

Locales varieties	Code	Type	Cycle (days)	Yield (t ha ⁻¹)
Palawan	VL1	Lowland	120	2 - 3
Djoukémé	VL2	Lowland	180
GT11	VL3	Lowland	180	1 - 2
Danané	VL4	Lowland	145
Demamba	VL5	Lowland	150	1 - 2
Kouiklonlé	VL6	Lowland	149	1 - 2
Soungrouba	VL7	Lowland	90
Marigbè	VL8	Lowland	75
WITA 9 (Témoin)	VL9	Lowland	105	6 - 10
Koité	VL10	Lowland	70	3

2.4 Soil fertilization

The mineral fertilizers used in the experiment were NPK (15-15-15) and Urea (CO(NH₂)₂, 46% N). NPK and urea were used as background and cover fertilizers, respectively. Two types of herbicides were also used: glyphosate, a broad-spectrum herbicide to kill all types of weeds or plant, and propanil, a post-emergence herbicide to kill weeds only. The insecticide DECIS (Lambda-cyhalothrine) was used to kill insect pests.

Table 2: Characteristics of hybrid varieties supplied by Africa Rice from Saint-Louis Research Centre, Senegal

Hybrid varieties	Code	Type	Cycle (days)	Yield (t ha ⁻¹)
AR624H	VA1	Lowland	90 - 120	10 - 15
AR593H	VA2	Lowland	90 - 120	10 - 15
AR034H	VA3	Lowland	90 - 120	10 - 15
AR051H	VA4	Lowland	90 - 120	10 - 15
AR630H	VA5	Lowland	90 - 120	10 - 15
AR043H	VA6	Lowland	90 - 120	10 - 15
AR601H	VA7	Lowland	90 - 120	10 - 15
AR638H	VA8	Lowland	90 - 120	10 - 15
AR629H	VA9	Lowland	90 - 120	10 - 15
AR597H	VA10	Lowland	90 - 120	10 - 15

2.5 Experiment set-up and management

After clearing an area of 1,815 m², the experimental plot was ploughed using a rototiller for slurring and drainage operations. It was then subdivided into subplots 3 m apart, in which 15 m² (3 m × 5 m) sub-plots were spaced 1 m apart in a split-plot design [17] (Figure 1). Variety groups (improved or local) were the main factor, while variety type (cultivar) was the secondary factor. Each treatment was replicated three times.

NPK fertilizer (15-15-15) was applied as a bottom dressing at 200 g per 15 m² before transplanting. The varieties were transplanted at a spacing of 20 cm × 20 cm, after 21 days in the nursery, at a rate of one plant per hole in the subplots (Figure 2). The trial was irrigated via the drainage canal using a run-of-river system. Urea was applied at rates of 14 g per 15 m² at tillering [18] and 19 g 15 m² at heading [19] stages. These rates were calculated from the normal rate in t ha⁻¹.

A total herbicide glyphosate was applied after the first ploughing at a rate of 360 g L⁻¹. Another selective herbicide was applied two weeks after rice transplanting, at a dose of 72 g L⁻¹. Two weeks after herbicide treatment, all plots were irrigated to achieve and maintain a maximum water height of 5 cm. The insecticide DECIS, at a dose of 30 g L⁻¹, was applied when insect attacks became apparent. Two manual weeding operations were carried out during the trial.

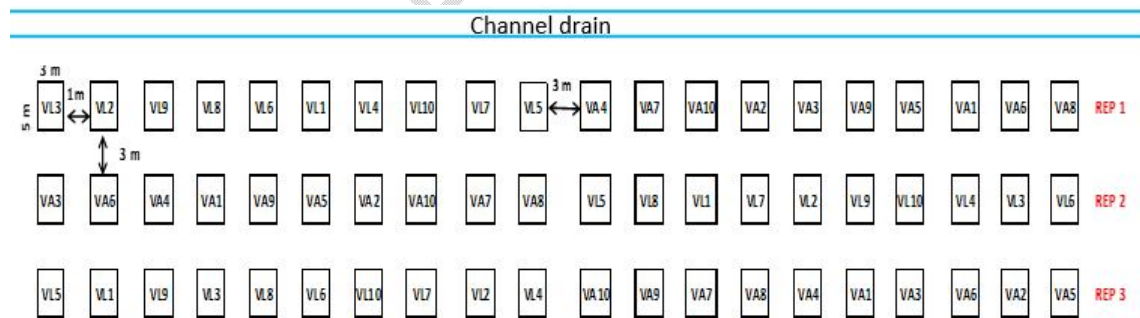


Figure 1: Split-plot experimental design

2.6 Data collection

2.6.1 Agro-morphological parameters of rice varieties

The morphological parameters determined were plant height, vigour index, number of tillers and number of panicles. These parameters were determined at each stage of rice variety development: tillering, heading and maturity [20], [21]. The height of the rice plants was measured monthly using a decametre. The number of tillers in thirty-six (36) tufts was counted randomly over 1 m² in each subplot at tillering and maturity to determine tillering density (number of tillers/m²). The number of panicles per metre squared was determined at maturity for each rice variety. The circumference of 3 tufts and their respective heights were measured to determine the vigour index (IV) of the plants at

heading and maturity. The vigour index was determined using the method of Berchoux and Lecoustre[22].

$$IV = \text{Log}[(C^2 \times H)/(4\pi)] \quad [1]$$

C: tillers conference; H: height mean of tillers



A :Experimental plot

B :Hybrid variety AR597H at tillering stage

Figure 2: General overview of the experimental plot

2.6.2 Physiological parameters of lowland rice varieties

The dates of placement in nurseries and that of 50% flowering were recorded to determine the duration of the physiological cycle. Chlorophyll content was measured using the SPAD-502 PLUS chlorophyllmeter at flowering.

2.6.3 Grain yields (RDG) of lowland rice varieties

At maturity, the rice varieties were harvested over an 8 m² area, leaving the 2 border rows to avoid border effects. After threshing and drying, the straw was weighed, while the rice grains were winnowed and weighed. The grains were oven-dried at 70 °C for 24 h ours and their moisture content was determined. Grain yields were calculated based on a standard moisture content of 14%. Grain yields (RDG) were calculated according to the following equation:

$$RDG (t ha^{-1}) = \frac{\text{grain dry weight (kg)}}{8 (m^2)} \times \frac{10000}{1000} \times \frac{100 - H}{86}$$

2.6.4 Statistical analysis of data

The collected data were subjected to analysis of variance (ANOVA) at a significance level of 0.05, using SAS software version 9.0 to test the effect of variety on the vegetative development of rice plants. Vegetative development mean values were separated using the Newman-Keuls stepwise multiple comparisons procedure. A Pearson correlation coefficient was calculated respectively between chlorophyll content, flowering time and other parameters such as water level in the plots, plant height, number of tillers, number of panicles and vigour index.

3. RESULTS AND DISCUSSION

3.1 Results

3.1.1 Plant height and number of tillers according to physiological stages

Mean values variation for plant height and number of tillers during the experiment at different stages of rice development are shown in table 3. Generally, the improved and local varieties had a normal development, which was reflected in the increase in their height and number of tillers. The average

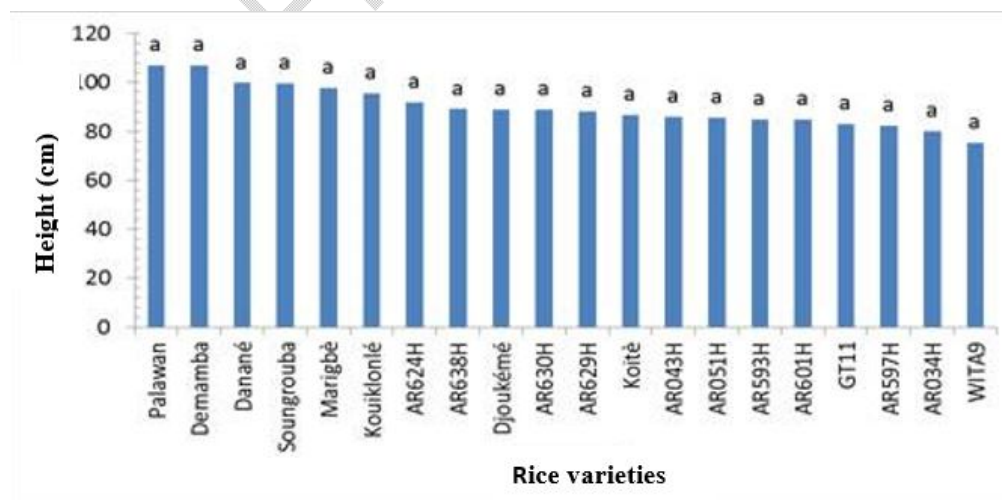
height of local rice varieties was greater than that of improved varieties, whatever the stage of development of the plants. Conversely, the average number of tillers was always higher for improved varieties, except, at maturity where local varieties had a maximum of 926 tillers, compared with only 643 for improved varieties.

Figure 3 shows the mean values of plant height and number of tillers per m² of each rice variety. No significant difference ($P > 0.05$) was observed among local and hybrid varieties plant height. Conversely to the rice plant height, significant difference ($P < 0.05$) was observed among the mean values of the number of tillers of the varieties (Figure 4). The local variety Koité had the highest mean of number of tillers with 520 tillers per m², followed by the improved varieties AR051H, AR597H, AR043H (500 tillers per m²) whose numbers of tillers were not statistically different from Koité's own. The local Djoukémé had the lowest number of tillers.

Table 3: Height and number of tillers according to physiological phases of rice varieties

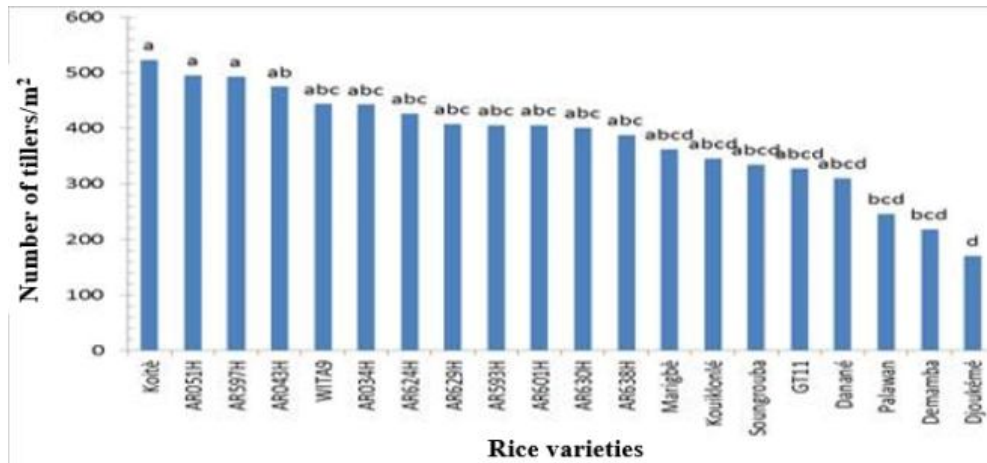
Tillering phase				
Varieties	Variable	Min	Moyenne	Max
Improved varieties	Plants height (cm)	47.36	56.69	67.16
	Number of tillers per m ²	215	359.2	485
Local varieties	Plantsheight (cm)	35.05	64.61	89.61
	Number of tillers per m ²	74	280.89	429
Headingphase				
Improved varieties	Plants height (cm)	88.16	98.97	109.66
	Number of tillers per m ²	-	-	-
Local varieties	Plants height (cm)	60.05	101.21	129.72
	Number of tillers per m ²	-	-	-
Maturity phase				
Improved varieties	Plants height (cm)	91.8	102.83	109.38
	Number of tillers per m ²	375	508.9	643
Local varieties	Plants height (cm)	94.91	114.77	129.02
	Number of tillers per m ²	119	386.34	926

- = missing data



Means followed by the same letters are not statistically different at the threshold of $\alpha = 0.05$.

Figure 3: Rice plant height mean values

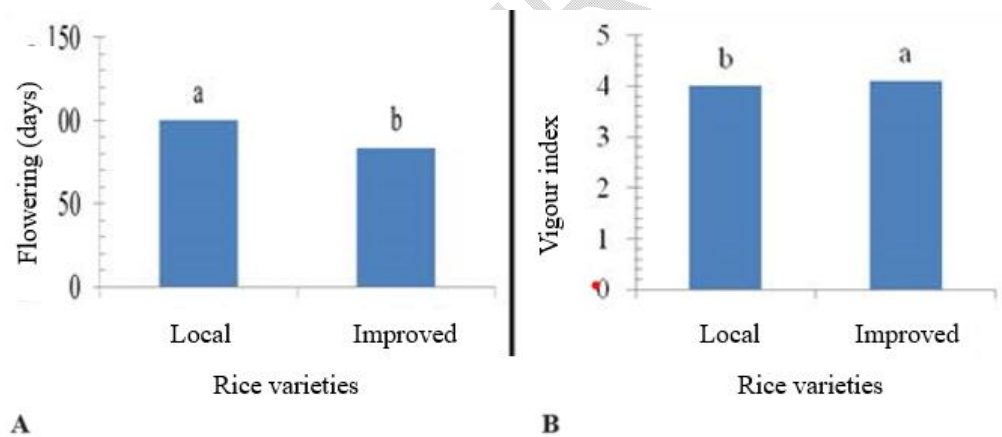


Means followed by the same letters are not statistically different at the threshold of $\alpha = 0.05$.

Figure 4: Mean value of rice plant number of tillers

3.1.2 Rice varieties flowering time and vigour index (IV)

The data of rice flowering time and vigour index showed a significant difference ($P < 0.05$) between local and improved rice varieties, respectively (Figure 5). Specifically, the improved varieties had a shorter average flowering time of 83 days than the local varieties with 100 days, on the one hand. On the other hand, the vigour index of the local variety significantly lower than the one's of the improved varieties.



The means followed by the same letters are not statistically different at the threshold of $\alpha = 0.05$.

Figure 5: Days to flowering (9A) and vigour index (9B) of rice varieties.

3.1.3 Improved rice varieties flowering time and vigour index (IV)

Variations in flowering time and vigour index for improved rice varieties are shown in Table 4. There was no effect of variety ($P > 0.05$) on the vigour index of improved varieties. On the other hand, a highly significant difference between improved varieties was observed for the mid-flowering cycle ($P = 0.0001$).

Table 4: Flowering time and vigour index of improved rice varieties.

Improved varieties	Flowering time (days)	Vigour index
AR043H	83b	4.19a
AR051H	83b	4.16a
AR593H	84a	4.15a
AR597H	83b	4.12a
AR630H	84a	4.14a

AR034H	83b	4.09a
AR624H	84a	4.13a
AR638H	83b	4.11a
AR601H	83b	4.08a
AR629H	84a	4.08a
WITA9 (Control)	108c	3.97a
Means	83.4	4.12
P	0.0001	0.83

Means followed by the same letters, in the same column, are not statistically different at the threshold of $\alpha = 0.05$.

3.1.4 Local rice varieties flowering time and vigour index (IV)

Average variations in flowering time and vigour index for local rice varieties are shown in Table 5. The local Palawan variety had the longest flowering time (109 days), while the local Maribgè variety had the shortest flowering time (71 days), shorter than the improved varieties. The overall average flowering time for these varieties was 100 days. However, no significant effect ($P > 0.05$) of variety was observed between the mean vigour index values for local varieties contrasting with flowering time ($P = 0.0001$). However, the local varieties Koitè, GT11 and Soungrouba recorded relatively higher values.

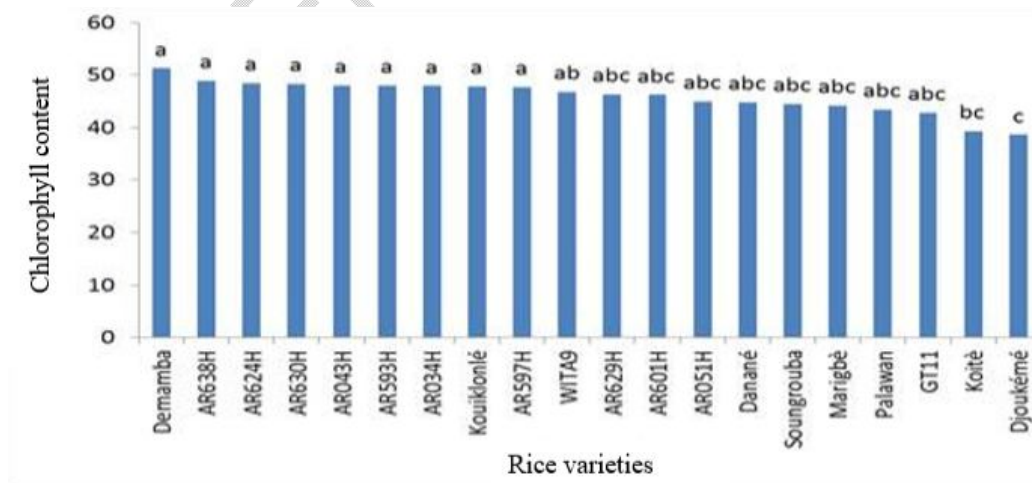
Table 5: Flowering time and vigour index of local rice varieties.

Local varieties	Flowering time (days)	Vigour index
Koitè	108b	4.23a
GT11	104c	4.04a
Soungrouba	89d	4.12a
WITA 9 (Control)	108b	3.97a
Danané	108b	4.02a
Kouiklonlé	108b	3.98a
Demamba	108b	4.02a
Palawan	109a	4.00a
Djoukémé	86d	3.89a
Maribgè	71e	3.89a
Means	100	4.02
P	0.0001	0.1

Means followed by the same letters, in the same column, are not statistically different at the threshold of $\alpha = 0.05$.

3.1.5 Chlorophyll content

A significant difference ($P < 0.05$) was observed in chlorophyll content among rice varieties (Figure 6). The local variety Demembahad the highest content of chlorophyll and was statistically identic to AR638H, AR624H, AR043H, AR593H, AR034H, AR597H, Kouiklonlé and Wita 9.



Means followed by the same letters are not statistically different at the $\alpha = 0.05$ threshold.

Figure 6: Rice varieties chlorophyll content

3.1.6 Relationship between chlorophyll content and plot water level, plant growth parameters

Chlorophyll content was significantly and positively correlated with water level only for the improved variety AR593H (Table 6). Also, positive and significant correlation was observed between Chlorophyll content and plant height of AR624H, AR034H and AR638H varieties. Contrarily, no significant correlation was observed between plant chlorophyll content and the other assessed variables.

Table 6: Pearson's correlation coefficient (R) and probability (P) of correlation between chlorophyll content, water level, average height and vigour index.

Rice varieties	Chlorophyll content					
	Water level (cm)		Plant height (cm)		Vigour index	
	r	P	r	P	r	P
AR624H	0.99	0.07	0.99	0.01	0.54	0.63
AR593H	0.99	0.004	0.36	0.76	0.15	0.90
AR034H	0.87	0.33	0.99	0.04	0.07	0.96
AR051H	0.59	0.60	-0.75	0.46	-0.81	0.40
AR638H	-0.47	0.68	-1	< 0.0001	-0.91	0.26
AR043H	0.04	0.97	0.98	0.11	-0.50	0.67
AR601H	0.96	0.17	-0.99	0.06	-0.95	0.19
AR638H	0.60	0.59	-0.12	0.92	-0.46	0.69
AR629H	0.79	0.41	-0.96	0.18	-0.64	0.56
AR624H	0.86	0.34	-0.63	0.56	0.61	0.58
Palawan	-0.53	0.64	0.68	0.53	0.99	0.06
Djoukémé	-	-	-	-	-	-
Gt11	0.19	0.88	-0.30	0.80	-0.02	0.99
Danané	0.81	0.40	0.94	0.23	0.99	0.07
Demamba	0.55	0.63	0.29	0.81	0.17	0.89
Kouiklonlé	0.69	0.51	-0.58	0.60	-0.88	0.31
Demamba	-0.66	0.54	0.63	0.56	0.66	0.54
Marigbè	-0.70	0.50	-0.44	0.71	0.98	0.14
WITA9	-0.96	0.17	0.22	0.86	-0.93	0.24
Palawan	0.46	0.69	0.89	0.30	-0.87	0.33

3.1.7 Relationship between flowering time and plant agronomic parameters

Relatively to the improved variety, the flowering time was only significantly correlated with vigour index. However, this correlation was weak and negative. Concerning the local varieties, significant, weak and positive correlations were observed between flowering time and number of panicles on the one hand, and between flowering time and vigour index (Table 7).

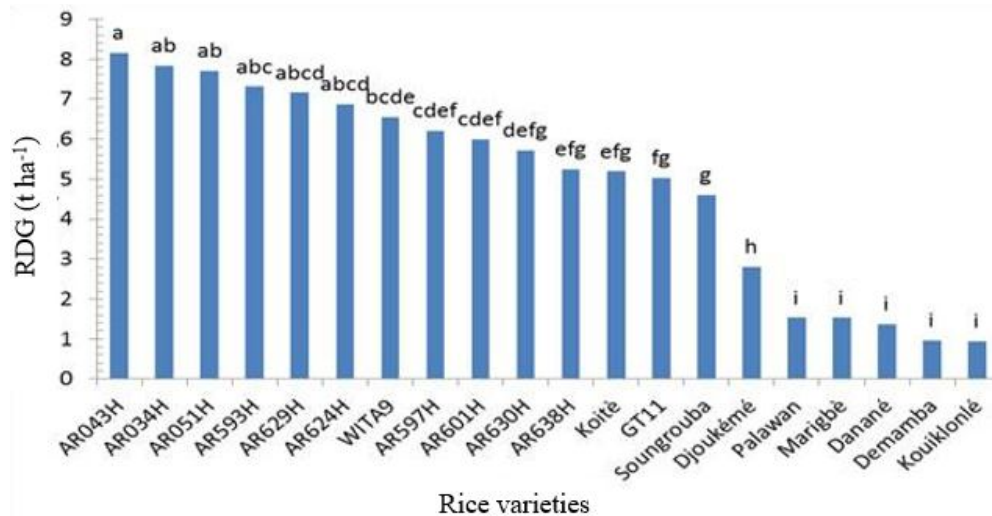
Table 7: Relationship between flowering time and water level, plant height, vigour index, number of tillers and panicles by varieties' group.

Rice varieties	Flowering time		
Improved varieties	Plant height	r	0.07
		P	0.69
	Number of tillers	r	-0.33
		P	0.07
	Number of panicles	r	-0.11
		P	0.54
	Vigour index	r	-0.13
		P	0.03
Local varieties	Plant height	R	0.00
		P	0.98
	Number of tillers	r	0.02
		P	0.07
	Number of panicles	r	-0.30

	P	0.10
Vigour index	r	0.34
	P	0.06

3.1.8 Grain yields of rice

Significant differences were observed among rice grain yield (Figure 7). The highest grain yields were recorded with of AR043H, AR034H, AR051H, AR593H, AR629H and AR624H. they were followed by the control variety WITA 9. All local varieties had lower grain yields than the improved varieties. The grain yield of AR043H, AR034H and AR051H were estimated at around 8 tha^{-1} . Koitè and GT11 varieties reported grain yields of around 5 tha^{-1} . The Danané variety had one of the lowest yields of 1.5 tha^{-1} .



Bars with the same letters are not statistically different at $P=0.05$.

Figure 7: Grain yields of rice varieties

3.2 Discussion

The improved and local rice varieties showed normal development, with an increase in height and number of tillers during the different physiological stages. However, this growth slowed down from heading onwards.

Analyses showed that local rice varieties had a higher average height than the one of improved varieties. According to IRRI classification [23], local varieties with an estimated height of 115 cm are intermediate, while hybrid (improved) varieties with an average height of 103 cm are semi-dwarf. The two types of variety could then be distinguished by their size. Indeed, it was mentioned that improved rice varieties were semi-dwarf and local varieties were large or medium [24]. Hybrid rice varieties with a medium sowing-flowering cycle and a flowering time of 83 days were intermediate, while local varieties with a 100-day cycle were late.

According to the flowering scale [25], varieties with a sowing-flowering cycle of less than 70 days were early, those with cycles between 71 and 90 days were intermediate, while genotypes with cycles greater than 90 days were late. The early or intermediate cycle of varieties is a characteristic appreciated by growers. In fact, short-cycle varieties enabled growers to carry out at least two crop cycles on their plots. Furthermore, correlation analyses showed that the shorter the duration of the sowing-flowering cycle, the higher the number of tillers of hybrid varieties and their vigour index; the opposite was true of local varieties.

Improved rice varieties had an average chlorophyll content of around $47 \mu\text{mg}^{-1}$, which was high compared to the mean of local varieties. The rice varieties with the best tillering were the hybrid varieties, also characterized by an early sowing-flowering cycle. This result confirms the work of [26] on improved and local varieties. According to this author, improved rice varieties were better than local varieties because of their short cycle, good tillering and high yield.

Among these improved varieties, AR051H, AR597H and AR043H had the best agro-morphological characteristics. However, three local varieties, Koitè, WITA9 (control) and Marigbè, showed valuable characteristics since Koitè and WITA9 had good tillering and Marigbè had the shortest cycle of 71 days. These morphological traits are the comparative advantages of the varieties collected throughout Côte d'Ivoire.

Tillering potential and vegetative vigour, as induced by height at maturity, could constitute phenotypic assets for yield improvement [27]. To this end, molecular biology could explore the possibility of improving Ghd7 (Grain number, Heading 7th Days) gene transcription, already successfully tested for rice yield regulation (Osugi et al., 2011). Local varieties named Palawan, Demamba and Koitè, with high performance in plant height, leaf chlorophyll content and tillering, respectively, could constitute promising plant material for more studies.

The results of this work could have a significant impact on lowland rice cultivation, dominated by the flooded type (35,000 ha) [4]. The significant height of the varieties mentioned would then be a means of managing the risk of flooding, which is often responsible for losses in yield and grain quality [1]. The local rice varieties, Koitè and GT11, had yields of around 5 tha^{-1} , i.e. around 2/3 of those of the hybrids. However, the most valuable variety in the national genetic collection, Danané, had one of the lowest yields of 1.5 tha^{-1} . The local variety Danané, because of its fine, long grains with a good fragrance, this local variety (Danané) could be a good genetic base for future crosses with certain hybrids (AR043H, AR034H or AR051H) [28].

CONCLUSION

Rice is a staple food for more than half the world's population. Knowledge of the diversity of its traits within a crop population is fundamental to varietal improvement. The aim of this study was to evaluate the agro-morphological characteristics of 20 lowland rice varieties. The results show that there was agro-morphological variability in the collection of varieties studied. The study will have identified parental germplasm to quantitatively and qualitatively improve lowland rice production on the basis of agro-morphological traits. This study gave the lines of interest for possible varietal improvement. Danané's low tillering (fine, long grains, good fragrance), long cycle and low yield could be improved by hybrids such as AR043H, AR034H or AR051H. This type of cross should result in a variety with a shorter cycle and a high yield in the order of that of the hybrids, while keeping Danané's qualities. In addition, the involvement of growers in varietal selection programs could facilitate the adoption of new varieties selected by them according to their preferences. Multi-location trials are also essential to consolidate results and validate preliminary data. Molecular characterization is important to confirm or refute the variations observed, and to gain a better insight into the genetic potential of the material tested.

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