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Agro-Morphological Diversity of some Improved and Local Rice (*Oryza sativa*) Varieties in Irrigated Lowland in Guinea Savannah of Côte D'ivoire

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Summary: Problem*:* In Côte d'Ivoire, rice is a staple food crop for the populations. However, only half of local increasing demand is covered by domestic rice production because of poor seed quality and quantity. **Objective*:*** The general objective of this study is to determine the most discriminating phenotypic traits of 20 irrigated rice accessions, including 10 improved varieties produced by AfricaRice and 10 local varieties of Côte d'Ivoire, and identify those with the best production potential. **Methodology and Results*:*** Nine qualitative and 20 quantitative traits were scored in field conditions on each of the 20 rice varieties. A multiple correspondence analysis performed with the 9 qualitative descriptors separated the 20 rice varieties into 3 groups that globally distinguished improved varieties from local ones. Descriptive statistics of quantitative traits showed significant phenotypic differences between all the varieties. A principal component analysis revealed 6 rice variety groups determined by 79.82% of the observed variability. A hierarchical ascending classification separated the rice varieties into 6 agro-morphological diversity groups which were then all confirmed by a discriminant factorial analysis (DFA). The DFA also showed that plant height, number of tillers per plant, number of panicles per plant, leaf width, shape of the seeds, seed yield and weight of 1000 grains are the descriptors which most determine the agro-morphological diversity of the 20 varieties. **Conclusions and Application of Results**: The 10 improved rice varieties are characterized by medium stem height, high tillering, long and round grains, and higher grain yield than local varieties. These improved varieties thus have a certain interest in the sense that high yield is a capital characteristic for rice growers, but also because the high tillering plays a very important role in the control of weeds.

Keywords: Agro-Morphological Characterization, Rice Varieties, Lowland Agro-Ecological Conditions, Guinea Savannah

I. Introduction

Rice is a major staple food for peoples in both urban and rural zones worldwide (Ojo *et al.*, 2009) as occurring in Côte d'Ivoire since the year 1980 (ONDR, 2016) thanks to its culinary qualities and relatively accessible prices. However, only half of local demand is covered by domestic rice production because of poor seed quality and the high consumption quantity. To mitigate this deficit, Côte d'Ivoire uses massive imports of milled rice estimated in 2016 at 1,498,102 tons for about 383 billion FCFA (ONDR, 2017) in coast.

Unfortunately, only 5% of world rice production, meaning 31 million tonnes out of 650 million tonnes of annual production is available for international trade. In addition, rice production in West Africa covers only 2/3 of local demand and requires the import of 3 million tonnes of milled rice (Bahan *et al.*, 2012). Thus, the population of Côte d'Ivoire, estimated to 22.67 million persons with an annual growth rate around 2.6% and a national poverty rate of 46.3%, is exposed to a risk of food insecurity (INS, 2016).

To address this threat of food insecurity, Côte d'Ivoire has undertaken various agricultural policies since 1960 with the establishment of institutional organisms such as the Rice Development Company (SODERIZ) and the National Office of Rice

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Development (ONDR) targeting the increase of national production. The creation of these organisms for Ivorian rice production is based on the exploitation of several assets of the country such as large areas of land suitable for rice cultivation (lowlands and plains); a very favourable climate with abundant rainfall; a high level of know-how of the producers and the existence of improved varieties with relatively high potential production and good organoleptic qualities (ONDR, 2016). However, the average yields are still very low (1 to 2 t / ha) because the available improved varieties are hybrids whose high production potential is due to heterosis that is gradually lost after several production cycles since rice mainly reproduce by self-pollination (Yoshida, 1981). It is therefore necessary to ensure the permanent production of good quality F1 hybrid seeds to maintain high yields across growing seasons.

The present study is based on the principle that any genetic improvement program or conservation of genetic resources of a given plant species first requires the knowledge of the available genetic diversity (Tendro, 2010). The overall objective is to analyse the phenotypic diversity of 20 rice accessions including 10 improved varieties produced by AFRICARICE and 10 local varieties of Côte d'Ivoire in order to determine the most discriminating traits to characterize the most yielding irrigated lowland rice varieties.

II. Material and Methods

II.1. Site of the study

The study was undertaken in the valley of M'be around the city of Bouaké in central Côte d'Ivoire. The locality belongs to the district of Bandama Valley and is situated about 8°06 North Latitude and 6°00 West Longitude. It is a guinea savannah zone characterized by an average temperature of 26.2°C and 1119 mm as annual rainfall. The studied lowland is classified in third order with alluvial deposits in the middle part against colluvial sand in the fringe.

II.2. Plant Material

The plant material is composed of 20 rice accessions including 10 improved hybrid irrigated varieties (AR034H, AR043H, AR051H, AR593H, AR597H, AR601H, AR624H, AR629H, AR630H, AR629H) provided by AfricaRice with a potential yield of 10 to 15 t/ha and 10 local varieties of Côte d'Ivoire (Palawan, *Djoukemé*, GT11, *Danané*, *Demamba*, *Kouiklonlé*, *Kpaté*, *Marigbe*, WITA9, *Soungrouba*). The variety WITTA 9 is a popular variety cultivated in Côte d'Ivoire and it was use as control in the experiment.

II.3. Methods

II.3.1 Experimental design

The experimentation was performed in three Fischer blocks separated by 3 m. Within each block, local and improved rice varieties were arranged separately in two sub-blocks 3 m apart. In each sub-block, seedlings of the different rice varieties were arranged separately in micro-plots of 3 m in wide and 5 m in long. The micro-plots were separated by 1 m and arranged randomly.

II.3.2. Transplantation of rice seedlings

After plowing with a tiller and successive flooding and drainage of the experimental plot, picketing was done according to the experimental design. The NPK fertilizer (15% - 15% - 15%) was applied as basal manure at the rate of 200 kg/ha or 200g / 15m^2. After 21 days in the nursery, one plantlet of each rice varieties was transplanted per hole spaced by 20 cm between plants and between lines.

II.3.3. Monitoring of Experimental Plots and Data Collection

Maloriz®, a post-emergence herbicide, was applied at the rate of 200 ml per 15l of water, 21 days after transplantation of rice seedlings. Two weeks after application of the post-emergence herbicide, the plots were irrigated to reach and maintain a maximum water height of 5 cm. The insecticide Decis® was applied at the rate of 2.5ml in 5l of water per 50m^2 in cases of insect attacks. Chemical weeding was performed with the herbicide Garize® at the rate of 200ml per 15l of water prior to maximum tillering and heading. This chemical weeding was supplemented by manual weeding to complete weed control. Urea was applied at the rate of 14 g per 15 m^2 at tillering stage and at the rate 19 g per 15 m^2 at heading stage.

Nine qualitative traits (Table I) and 20 quantitative traits (Table II) from the list of rice, *Oryza spp*, descriptors (IRRI 1980, Bioversity International, Africarice, 2007) were scored on each of the 20 rice varieties. At the maturity stage of the grains, plants of each rice variety were cut at the base of the tillers, then dried and beaten. The grains were then collected and the straw fragments and pebbles were removed. All the data were collected by leaving two border lines on each side of the micro-plots.

II.4. Statistical analyses:

Agro-morphological diversity of the 20 rice varieties related to qualitative traits was assessed by Multiple Correspondence Analysis (MCA). Descriptive statistics (mean values, standard deviations, and coefficients of variation) of each of the quantitative traits were calculated. One-way analysis of variance was performed to test the variety effect on values of quantitative traits. For each quantitative trait, the

Newman-Keuls test was used to compare average values of rice varieties to identify the ones with the best agro-morphological characteristics. Agro-morphological diversity of rice varieties related to quantitative traits was evaluated by a Hierarchical Ascending Classification (HAC) based on the Unweighted Pair-Group Method with Arithmetic Average. A Discriminant Factorial Analysis (DFA) was also performed using as categorical variables the groups provide by the HAC. All statistical analyses were performed with the software Statistica 7.1 (2005) and SPSS 24 (2017)

III. Results and Discussion

III.1 - Results

III.1.1 Diversity of the rice varieties due to qualitative traits

The projection of rice varieties in the space determined by the factorial axes 1 and 2 of the Multiple Correspondence Analysis distinguishes 3 agro-morphological groups. The Group I is represented on the negative side of the Axis 1. It includes the local varieties *Soungrouba* and WITA9 plus the new improved varieties AR624H, AR593H, AR034H, AR630H, AR043H, AR601H, AR051H, AR638H and AR629H. These varieties are characterized by straw-yellow grains, medium pubescent grain and easy ginning. The Group II consists of the local varieties *Danané* and GT11 plus the improved variety AR597H. This group is represented on the positive side of Axis 2 and is characterized by non-pubescent and tawny-red grains, medium apicoid and brown-red caryopsis. The Group III gathers the local varieties *Demamba, Marigbé, Kpaté, Palawan, Djoukeme and Kouikloné* represented on the negative side of axis 2. This group is characterized by very pubescent grains, falling flag leaves and semi-compact branches of panicles.

III.1.2. Structuration of the diversity of rice varieties based on quantitative traits

III.1.2.1. Analysis of variances

Analysis of variance (ANOVA) showed highly significant effect of studied varieties ($p < 0.0001$) with significant differences of quantitative traits (Tables III and IV). The significance levels of the differences between rice varieties is high for seed thickness ($p = 0.0043 < 0.01$) and flag leaf length ($P = 0.0159 < 0.05$).

III.1.2.2. Analysis of the Diversity by Hierarchical Ascending Classification (HAC)

The dendrogram obtained by the Hierarchical Ascending classification (FIG. 2) shows, at the point of truncation 20, a clear separation of rice varieties into six (6) groups. The Group I consists of 8 new improved varieties AR624H, AR593H, AR601H, AR034H, AR051H, AR629H, AR630H and AR638H. The Group II includes local varieties WITA9 (control) and *Djoukeme*. The improved varieties AR597H and AR043H are in the group IV. The local varieties *Kpaté* and GT11 form the group V. The local varieties *Marigbè* and *Danané* constitute the group VI.

III.1.2.3. Discriminant Factorial Analysis

The classification matrix of groups of rice varieties provided by the discriminant factorial analysis confirms all the groups determined the hierarchical ascending classification (Table V). The λ Wilk test reveals that 9 of the 20 variables used for this analysis (Table VI) allow a significant discrimination of the groups ($p < 0.05$). These are weight of 1000 grains, grain shape, grain yield, grain length, leaf width, number of tillers per plant, number of panicles per plant, number of grains per panicle and plant height. According to the centered-reduced coefficients of the canonical discriminant function, components 1 and 2 account for 99.04% of the total variance (Table VII). The first canonical component explains 95.3% of the total variance and makes it possible to distinguish groups II, III, IV, V and VI. The Group I is located on the second canonical component (Table VII).

The projection of rice varieties in the space determined by components 1 and 2 of the discriminant canonical analysis (Figure 3) shows that the group I is negatively correlated to the component 2 and groups II, III, IV and VI are represented on the negative side of the axis 2. The Group V is positively correlated with the component 2. The Group I consists of eight (8) improved varieties (AR624H, AR593H, AR034H, AR051H, AR630H, AR601H, AR638H and AR629H) already grouped by the HAC. They are high-yielding varieties with high tillering and long and round grains. Among these varieties, 5 (AR624H, AR593H, AR034H, AR051H and AR629H) have higher average yields than the variety WITA9 (control). These varieties are also characterized by medium plant heights and very few empty spikelets per panicle. The Group II contains the same varieties as those of the group II determined by the HAC. This group is characterized by high rates of fertile spikelets per panicle and high weights of 1000 grains, medium grain lengths, low grain yields and narrow leaves. These are semi-round grain varieties. The variety WITA9 belongs to this group but has a grain yield close to those of the varieties in the group I. The Group III consists of local varieties, *Palawan, Demamba, Kouiklonlé and Soungrouba* which have tall plants. These varieties have low tillering and small numbers of panicles per plant so that the yield is also low except to the variety *Soungrouba* which has an average yield of 4.6 t / ha. On the other hand, the Group III is characterized by high weights of 1000 grains. Improved rice varieties AR043H and AR597H form the group IV. They have the same characteristics as the varieties in the Group I but they have highest grain yields. The Group V consists of local rice varieties GT11 and Kpaté. They are characterized by large stems, semi-round and medium-sized seeds and excellent tillering. These local varieties, on the other hand, have very small numbers of panicles per plant and low grain yields. The Group VI consists of the local varieties *Marigbé* and Danané as provided by the HAC. These varieties have medium plant heights, long and semi-round grains. This group is also characterized by low grain yields, very low tillering and very low numbers of panicles per plant.

III.2. Discussion

Agro-morphological characterization is a very important preliminary study in breeding programs, plant conservation and even agricultural policy planning. Thus, many analyses of agro-morphological diversity have been performed for different crops such as rice (Sanni *et al*., 2010; Akapko, 2011), onion (Boukary, 2012), millet (Akanvou *et al*., 2012), maize (N'da *et al*., 2014), cassava (Kosh-Komba *et al*., 2014), vouandzou (Toure *et al*., 2015) and cowpea (Nadjiam *et al*., 2015). These studies were based on quantitative and qualitative morphological descriptors.

The use of qualitative traits is very important for agro-morphological characterization of crop plants. However, as it has been observed for example for rice (Sanni *et al*., 2010) and maize (N'da *et al*., 2014), many qualitative traits often do not allow fine differentiation of varieties of cultivated plants. The results obtained in the current study are consistent with these earlier observations. Indeed, the analysis of the agro-morphological diversity of 20 rice varieties in agro-ecological conditions of Bouaké using multiple correspondence analyse (MCA) distinguished three (3) groups. The group I contains 9 out of the 10 new improved varieties (AR624H, AR593H, AR034H, AR051H, AR630H, AR601H, AR638H, AR629H and AR043H, plus the local varieties WITA9 and *Soungrouba*). This group is likely specific to sativa improved rice variety knowing that WITA9 was released by AfricaRice in 2000 and *Soungourou* is also an improved variety adopted as local landrace. The group I is characterized by yellow-straw coloured grains, moderately pubescent seeds and easy ginning. The group II, which includes the local varieties *Danané* and GT11 plus the improved variety AR597H, is characterized by non-pubescent seeds, medium apicles, brown-red caryopsis and tawny-red grains. Finally, the group III consisting of the 6 local rice varieties *Djoukeme, Kpaté, Marigbé, Palawan, Demamba, Kouikloné* is characterised by highly pubescent grains, drooping flag leaves and semi-compact branches of the panicles. Different authors used two postulates to explain the relatively weak usefulness of qualitative traits for the agro-morphological discrimination of crop plant varieties. According to N'Da *et al* (2014), the poor contribution of qualitative traits to the structuration of agro-morphological diversity could be explained by the fact that local varieties are selected by peasants whose perception of the different modalities of qualitative characteristics is very subjective. For Sarla and Swamy (2005); Bezançon and Diallo (2006) and Akakpo, (2011), the geographical and / or specific origin of varieties are factors determining the structuration of agro-morphological diversity based on qualitative characteristics. Our results support these assertions. Indeed, all these varieties belong to the species *Oryza sativa* which has an asian origin. In addition, local and improved varieties tend to form two distinct groups.

One of the specific objectives of this study was to identify irrigated rice varieties with the best yielding potential. The highest grain yield was 9.64 t / ha for the improved variety AR043H. This result, although much higher than average yields of local rice varieties and that of the popular WITA9, is far below the 15t / ha which is the potential yield of improved varieties according to AfricaRice. Nevertheless, the yield was increased by 90% comparing to the national average yield of 1 t/ha. Such level of yield increasing underlines the possibility to resorb the gap between need and national rice production. Therefore, our study can recommend the use of hybrid rice seeds for balancing rice production trends in Côte d'Ivoire. Furthermore, there is still an opportunity to improve the observed relative low yield of the improved varieties by assessing genotype x environment interaction effects. Indeed, the mineralogical composition of the soil of the experimental plot has not been preliminary analysed. So the nitrogen fertilizer was not applied according to the characteristics of the soil in a way of rationalization of fertilization in order to reach a targeted yield. Taking these parameters into account in oncoming crop cycles should lead to better yields. On the other hand, the grains have been harvested at an advanced maturity stage which certainly caused losses. In fact, the improved rice varieties provided by AfricaRice are characterised by easy ginning, whereas the later the harvest is performed the greater the losses of grain yield (Lacharme, 2001).

The factorial analysis of quantitative traits revealed significant differences between minimum and maximum values for each rice variety. This shows a strong phenotypic heterogeneity between these 20 varieties. This morphological diversity has identified six groups of rice varieties that differ in plant height, number of tillers per plant, number of panicle per plant, width of plant leaf, grain shape, grain yield and weight of 1000 grains.

Group I contains the 8 improved varieties AR624H, AR593H, AR034H, AR051H, AR630H, AR601H, AR638H and AR629H characterized by medium height, high tillering and very high grain yield with long round grains. Group IV closes the other two improved varieties AR043H and AR597H which are distinguished from those of Group I by the highest numbers of tillers and grain yields. These varieties can thus be of interest in the sense that the high yield is a key feature for rice farmers, but also because the high tillering plays a very important role in the fight against weeds and in general against grassing. (Kenyi *et al*., 2010: Rodendurg and Meike, 2010).

Group II contains rice varieties characterized by high number of spikelets per panicle and high weight of 1000 grains, medium grain length, low grain yield, and narrow leaves. These are semi-round grain varieties. .

Group III closes local varieties with large seedlings, grain shape is semi-round with low tillering and grain yields. However, the large size of their canopy may have advantage in the competitiveness against weeds however (Fontaine et al., 2009).

Group V consists of local rice varieties GT11 and Kpaté characterized by large stems, semi-round and medium-sized seeds and excellent tillering. However they have a very small number of panicles per plant and the yield remains moderate. Thus, their vegetative growth characteristics are similar to those of the improved varieties of Group I and their production characteristics are comparable to those of the local varieties of Group II.

Group VI consists of the local varieties *Marigbé* and *Danané*, which have medium height plants and long and semi-round grains. Based on these characteristics, these two local varieties are similar to improved rice varieties. However, this group is distinguished by low grain yields, very low tillering potential and reduced number of panicles per plant.

Some of the traits used in this study, including the number of panicles per plant (Ojo et al., 2009), plant height, leaf length, and leaflet length (Moukoumbi et al., 2011) could also discriminate other rice varieties in different diversity studies. Similar results were observed by Akakpo (2011) on the same variables but also on other variables such as the sowing cycle (SSC) and lodging. Yield parameters such as plant height and the sowing-flowering duration are the distinguishing characteristics most commonly used by farmers (Louette 1994, N'da *et al.* 2014). A strong positive correlation has been established between these two traits in millet. Indeed, Akanvou *et al*. (2012) classified millet varieties into two groups: a medium-sized and early millet group and a large and late millet group. In the current study, the sowing-flowering duration was not considered in the analysis of variance as well as in the Discriminant Factor Analysis. Indeed the data collected for this variable presented outliers that suggest a systematic scoring error. Corrective action for future ratings of this variable is expected to yield more reliable data. The height of the plants, however, discriminates between Group III and V rice varieties with respect to those belonging to groups I, II, IV and VI. Groups III and V, for example, consist of local rice varieties with high plant height collected in Daloa and Danané, two cities located respectively in west-central and north-western Côte d'Ivoire. These two regions are characterized by agro-ecological zones where rainfall is very high. Groups I and IV, on the other hand, consist of improved varieties of AfricaRice, one parent of which has been collected in the Sahel, and groups II and VI, on the other hand, consist of varieties collected in Bouaké and Ouangolodougou, respectively in central and northern Côte d'Ivoire. These agro-ecological zones are characterized by a relatively low rainfall which determines a medium height of the plants. Like the observations made on different cereals such as millet (Akanvou et al., 2012) and maize (N'da et al., 2014), our results show a structuration of the morphological diversity of rice varieties according to agro-ecological zones of origin and therefore according to the availability of water.

IV. Conclusion

The agro-morphological characterization of the 20 varieties of rice made it possible to show the importance of the qualitative and quantitative descriptors in the analysis of the diversity expressed. Qualitative variables showed relatively low variability by distinguishing overall improved varieties from local varieties. On the other hand, quantitative descriptors such as plant height, number of tillers per plant, number of panicles per plant, length of single leaf, grain shape, grain yield and weight of 1000 grains are the most relevant and have distinguished 6 groups of rice varieties.

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Table I: List of qualitative traits scored on the 20 rice varieties

Designations	Abbreviation	Methods of Measurement	Modalities
Flag Leaf Attitude	FLA	Mean of the angle of attachment between leaf blade limb and main panicle axis of 5 plants measured 7 days after flowering or anthesis	Erected, Semi-erected, Horizontal, Descending
Apiculus	API	Observation of the end of the spikelet (extension of the lemma) at grains filling stage	Absent, Short, Long
Grain Colour	GRC	Evaluation of grain colour with RSH color Chart after Harvest	Straw yellow, straw, Brown
Caryopsis Colour	CAC	Assessment of the colour of caryopsis after removing lemmas (husked grain). Stage: after harvest	Red, Brown, White
Grain Pubescence	GRP	Evaluation, using the magnifying glass, of the presence and distribution of mature grains. Stage: after Harvest	Low, Pubescent, Strong
Ginning	GIN	Determined by grasping the panicle with the hand, applying light rolling pressure with the palm and fingers, and evaluating the percentage of grains that are removed. Stage: harvest	Easy, Intermediate, Difficult
Panicle Secondary Branches	PSB	The abundance and distribution of spikelets carried by the secondary branches of the panicle; Stage: after maturity	Dense, Clustered
Panicle Branches Attitude	PBA	The compactness of the panicle, classified according to its mode of branching, the angle of the primary branches and the density of the spikelets. Stage: after anthesis	Compact, Semi-compact, Horizontal, Falling
Panicle Exsertion	PEX	Assessment of how the panicle emerges above the flag leaf. Stage: maturity	Partially Exsert, Just Exsert, Moderately Exsert, well exsert.

Table II: Lists of quantitative traits scored on the 20 rice varieties

Designation	Code	Modality of Measure	Unit
Sowing-Flowering Cycle	CSF	Number of days from sowing to flowering of 50% of the spikelets on the panicles.	Days
Leaf Length	LEL	Average length of the leaves of 5 representative plants; measured from the ligule to the tip of the leaf. Stage: 7 days after anthesis	Centimeter
Leaf Width	LEW	Average width of the leaves of 5 representative plants, measured from the widest part of the leaf. Stage: 7 days after anthesis	Centimeter
Flag Leaf Length	FLL	Average length of the flag leaves of 5 representative plants; measured from the point of insertion to the tip of the leaf. Stage: 7 days after anthesis	Centimeter
Flag Leaf Width	FLW	Average width of the flag leaves of 5 representative plants; measured on the widest part of the Flag leaves. Stage: 7 days after anthesis	Centimeter
Panicle Length	PAL	Average length of the panicles of 5 representative plants; measured from the base to the tip of the panicle. Stage: 7 days after flowering	Centimeter
Grains Number per Panicle	NGP	Average number of grains per panicle; counted on 10 panicles of 5 representative plants. Stage: maturity	No unit
Empty Spread Epilets per Panicle	EEP	Number of empty Grains out of total number of grains per Panicle; Calculated for10 panicles of 5 representative plants. Stage: maturity	%
Stem Diameter	SDI	Average width of the basal part of the main tiller of 5 representative plants; measured with a Vernier calliper at mature stage	Centimeter
Plants Height	PHE	Average height of 5 representative plants; Measure from the soil to the base of the panicle	Centimeter
Number of Tillers per plant	NTP	Number of tillers per plant; Counted on 5 representative plants 40 days after transplantation	No unit
Number of Panicles per plant	NPP	Number of panicle per plant; Counted on 5 representative plants at mature stage	No unit
Grain Length	GLE	Average length of 10 grains of 5 representative plants; measured with a Vernier calliper after harvest	Millimeter
Grain Width	GWI	Average width of 10 grains of 5 representative plants, measured with a Vernier calliper after harvest	Millimeter
Weight of 1000 grains	PMG	Weight of 1000 grains at 14% moisture after steaming at 35°C for 24 hours; Scored for 5 representatives plants after harvest	Gram
Ratio (GLE / GWI)	GLW	Average ratio of length and width of 10 grains of 5 representative plants; Calculated after harvest	No unit
Grain Thickness	GTH	Average thickness of 10 grains, measured with a Vernier calliper	Millimeter
Rates of Fertilized Epilate per Panicle	FEP	Rate of well-developed spikelets out of all the spikelets of 10 panicle of 5 representative panicles	%
Number of Primary Branches	NPB	Average number of primary branches on the main axis of the panicles of 5 representatives plants. Maturity stage	No unit
Grain Yield	GRY	Grain yield for a surface of 1 hectare; estimation based actual harvest on 8 m^2	$t.ha^{-1}$

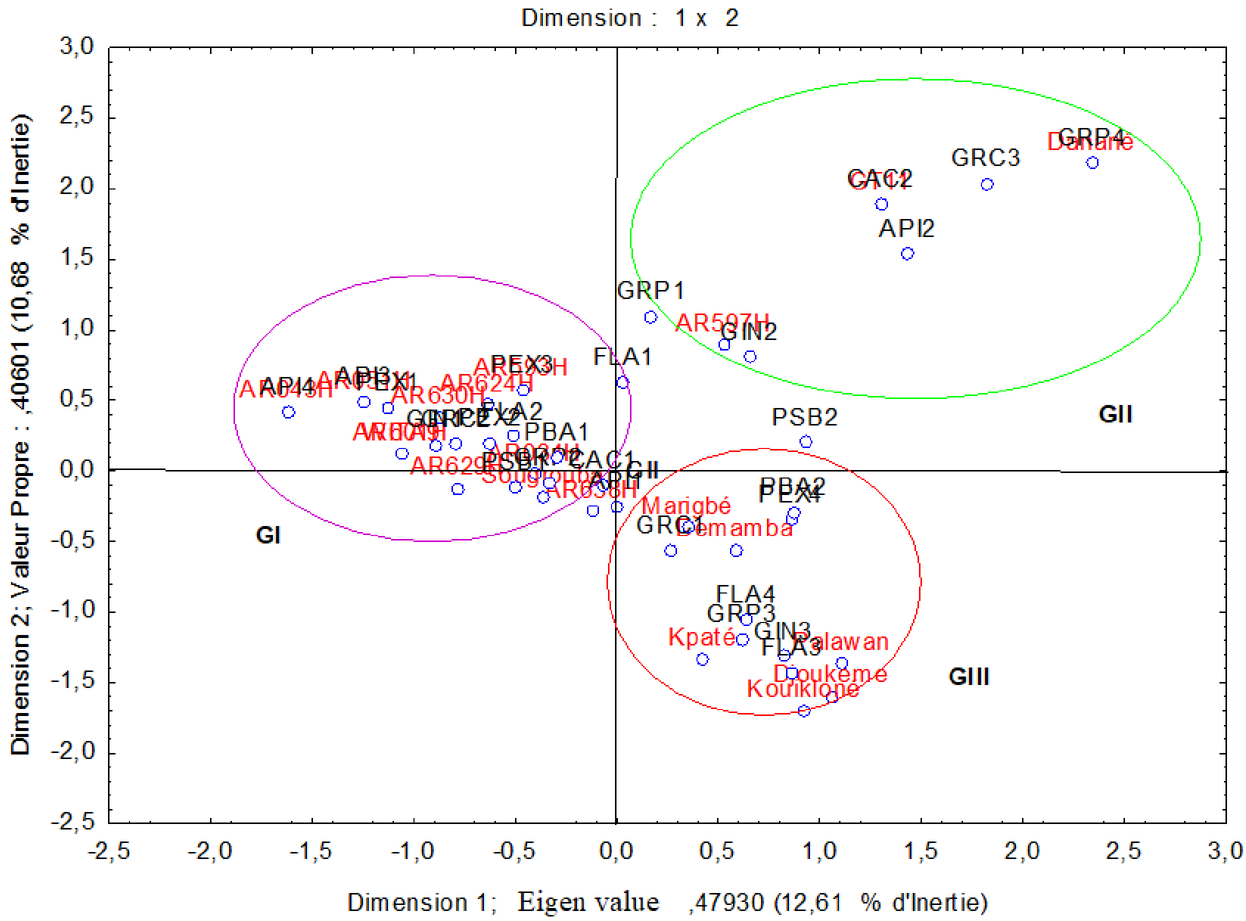

Figure 1: Projection of the Rice Varieties and Qualitative Traits in the Factorial space of the Multiple Correspondence Analysis

Legend :

GI = Groupe I

GII = Groupe II

GIII = Groupe III

GRC = Grain Colour: **GRC1** = straw yellow; **GRC2** = straw; **GRC3** = fawn
CAC = Caryopsis Colour: **CAC1** = white; **CAC2** = red brown
GRP = Grains Pubescence: **GRP1** = weak, **GRP2** = pubescent, **GRP3** = high, **GRP4** = absent
GIN = Ginning: **GIN1** = easy; **GIN2** = intermediate; **GIN3** = difficult
FLA = Flag Leaf Attitude: **FLA1** = semi-erected; **FLA2** = erected; **FLA3** = horizontal; **FLA4** = falling
PEX = Panicle Exsertion: **PEX1** = moderate; **PEX2** = just exsert; **PEX3** = partially exsert, **PEX4** = well exsert
PSB = Panicle Secondary Branches: **PSB1** = Clustered; **PSB2** = Dense
PBA = Panicle Branches Attitude: **PBA1** = Compact; **PBA2** = Semi compact
API = Apiculus: **API1** = Absent; **API2** = medium; **API3** = Long; **API4** = short

***Table III:** Mean values of the 20 rice varieties for the scored quantitative traits (a)*

VARIETES	LEL	LEW	FLL	FLW	PAL	PHE	SDI	NPB	NTP
AR624H	$43,29\pm5,36^{abcd}$	$1,16\pm0,04^{abcd}$	$31,62\pm4,43^{ab}$	$1,56\pm0,06^{abcd}$	$27,58\pm0,51^{bcde}$	$74,52\pm0,21^{ab}$	$7,10\pm0,67^{ab}$	$10,86\pm0,65^{bcdef}$	$13,33\pm2,88^{bcde}$
AR597H	$44,63\pm2,62^{abcd}$	$1,13\pm0,04^{abcd}$	$33,56\pm3,43^{ab}$	$1,48\pm0,08^{abcd}$	$28,76\pm1,98^{de}$	$70,34\pm2,74^{ab}$	$7,10\pm0,71^{abc}$	$10,43\pm0,2^{bcde}$	$16,00\pm1,73^{ef}$
AR593H	$38,35\pm2,99^{abc}$	$1,18\pm0,04^{abcd}$	$30,92\pm5,9^{ab}$	$1,49\pm0,14^{abcd}$	$27,48\pm2,03^{bcde}$	$71,66\pm4,92^{ab}$	$7,37\pm0,38^{abc}$	$9,42\pm0,03^{abcd}$	$14,00\pm1^{bcde}$
AR034H	$37,08\pm3,53^{a}$	$1,02\pm0,04^{abc}$	$26,47\pm4,13^{a}$	$1,28\pm0,04^{ab}$	$25,34\pm1,35^{bcd}$	$68,99\pm2,92^{ab}$	$6,85\pm0,18^{ab}$	$10,40\pm1,15^{bcde}$	$16,00\pm1,73^{de}$
AR051H	$41,75\pm2,67^{abcd}$	$1,06\pm0,04^{abc}$	$29,44\pm2,5^{a}$	$1,34\pm0,11^{abc}$	$29,44\pm1,07^{e}$	$72,31\pm2,88^{ab}$	$6,87\pm0,83^{ab}$	$11,07\pm0,76^{cdef}$	$14,33\pm2,08^{cde}$
AR630H	$43,20\pm3,46^{abcd}$	$1,25\pm0,04^{abcd}$	$32,90\pm2,64^{ab}$	$1,68\pm0,14^{bcd}$	$28,48\pm0,8^{cde}$	$72,08\pm3,96^{ab}$	$7,04\pm0,65^{abc}$	$11,12\pm0,22^{cdef}$	$13,33\pm2,08^{bcde}$
AR043H	$40,25\pm0,59^{abc}$	$1,00\pm0,04^{abcd}$	$30,64\pm2,17^{a}$	$1,30\pm0,05^{ab}$	$27,98\pm0,52^{bcde}$	$69,52\pm2,37^{ab}$	$7,12\pm0,27^{ab}$	$11,41\pm0,79^{def}$	$15,66\pm2,08^{def}$
AR601H	$40,22\pm2,02^{abc}$	$1,10\pm0,04^{abcd}$	$31,81\pm3,182^{ab}$	$1,42\pm0,06^{abcd}$	$27,30\pm0,81^{bcde}$	$64,78\pm3,57^{a}$	$6,64\pm0,69^{ab}$	$8,93\pm0,15^{ab}$	$13,66\pm0,57^{bcde}$
AR638H	$43,90\pm4,23^{abcd}$	$1,18\pm0,04^{abcd}$	$31,65\pm2,65^{ab}$	$1,59\pm0,05^{abcd}$	$28,09\pm0,17^{bcde}$	$72,68\pm2,72^{ab}$	$7,90\pm0,87^{abcd}$	$11,56\pm0,51^{ef}$	$12,66\pm0,57^{bcde}$
AR629H	$45,94\pm0,82^{abcd}$	$1,18\pm0,04^{abcd}$	$32,84\pm2,52^{ab}$	$1,58\pm0,04^{abcd}$	$27,33\pm1,34^{bcde}$	$74,02\pm1,9^{ab}$	$7,31\pm0,67^{abc}$	$11,77\pm0,4^{ef}$	$13,00\pm2^{bcde}$
Palawan	$48,92\pm5,32^{abcd}$	$1,58\pm0,04^{e}$	$29,92\pm5,55^{a}$	$1,83\pm0,15^{d}$	$28,70\pm2,11^{de}$	$110,88\pm7,62^{e}$	$8,77\pm0,68^{cde}$	$12,67\pm0,46^{f}$	$7,66\pm0,57^{abc}$
Kpaté	$50,99\pm5,31^{bcd}$	$1,24\pm0,04^{bcd}$	$33,38\pm1,5^{ab}$	$1,70\pm0,2^{cd}$	$28,11\pm1,38^{bcde}$	$110,94\pm5,71^{e}$	$9,22\pm0,3^{de}$	$12,07\pm0,5^{ef}$	$20,33\pm7,37^{e}$
Djoukeme	$52,40\pm19,77^{cd}$	$1,43\pm0,04^{de}$	$31,61\pm11,8^{ab}$	$1,67\pm0,21^{bcd}$	$24,34\pm1,64^{b}$	$88,46\pm0,5^{c}$	$9,81\pm0,11^{e}$	$12,71\pm1,01^{f}$	$6,00\pm4,24^{a}$
GT11	$42,93\pm1,84^{abcd}$	$0,98\pm0,04^{ab}$	$34,98\pm2,79^{ab}$	$1,28\pm0,12^{ab}$	$21,74\pm1,78^{a}$	$78,47\pm3,12^{b}$	$8,08\pm0,49^{bcd}$	$9,23\pm0,8^{abc}$	$14,67\pm1,15^{de}$
Danané	$51,13\pm2,65^{bcd}$	$1,34\pm0,04^{cde}$	$35,50\pm1,34^{ab}$	$1,59\pm0,14^{abcd}$	$27,80\pm0,7^{bcde}$	$98,43\pm6,6^{d}$	$8,83\pm0,78^{cde}$	$16,65\pm1,68^{g}$	$7,30\pm1,15^{ab}$
Demamba	$51,55\pm5,16^{bcd}$	$1,44\pm0,04^{de}$	$31,62\pm2,19^{ab}$	$1,78\pm0,12^{d}$	$24,45\pm0,34^{b}$	$105,68\pm3,46^{de}$	$9,43\pm0,1^{de}$	$11,81\pm0,41^{ef}$	$6,33\pm0,57^{a}$
Kouikloné	$54,34\pm0,64^{d}$	$1,43\pm0,04^{de}$	$36,88\pm2,3^{ab}$	$1,72\pm0,08^{cd}$	$26,18\pm0,95^{bcde}$	$103,45\pm4,27^{de}$	$9,25\pm0,9^{de}$	$10,75\pm1,22^{bcdef}$	$9,00\pm1^{abcd}$
Soungrouba	$45,95\pm1,7^{abcd}$	$1,19\pm0,04^{abcd}$	$34,68\pm2,35^{ab}$	$1,52\pm0,35^{abcd}$	$26,29\pm2,06^{bcde}$	$105,74\pm1,78^{de}$	$7,48\pm0,38^{abc}$	$9,04\pm0,12^{abc}$	$10,30\pm0,57^{abcde}$
Marigbé	$46,10\pm3,6^{abcd}$	$0,89\pm0,04^{a}$	$41,92\pm2,7^{b}$	$1,26\pm0,16^{ab}$	$25,45\pm0,56^{bcd}$	$89,04\pm8,85^{c}$	$7,08\pm0,95^{abc}$	$7,97\pm1,19^{a}$	$10,67\pm1,15^{abcde}$
WITA9	$38,37\pm2,39^{ab}$	$0,93\pm0,04^{ab}$	$31,42\pm1,42^{ab}$	$1,19\pm0,07^{a}$	$24,78\pm0,38^{bc}$	$63,63\pm2,58^{a}$	$6,08\pm0,55^{a}$	$9,07\pm0,2^{ab}$	$13,67\pm2,51^{bcde}$
F	3,58	7,29	2,25	5,53	6,59	44,77	8,26	18,52	7
P	<0,0001	<0,0001	0,0159	<0,0001	<0,0001	<0,0001	<0,0001	<0,0001	<0,0001

Table IV: Mean values of the 20 rice varieties for the scored quantitative traits (b)

VARIETES	NPP	NGP	EEP	FEP	GLE	GWI	GLW	GTH
AR624H	$12,33\pm2,51^{bc}$	$182,43\pm23,93^{abc}$	$21,66\pm3,9^{abcde}$	$78,33\pm3,9^{abcde}$	$11,27\pm0,08^{gh}$	$2,50\pm0,04^{a}$	$4,47\pm0,05^{fg}$	$1,98\pm0,12^{ab}$
AR597H	$14,00\pm1^{c}$	$253,00\pm7,18^{c}$	$28,34\pm3,19^{e}$	$71,65\pm3,19^{a}$	$10,52\pm0,17^{ef}$	$2,52\pm0,02^{a}$	$4,16\pm0,03^{efg}$	$1,95\pm0,03^{ab}$
AR593H	$12,33\pm1,52^{bc}$	$167,75\pm8,62^{ab}$	$9,67\pm1,03^{a}$	$90,32\pm1,03^{e}$	$11,15\pm0,16^{gh}$	$2,40\pm0,07^{a}$	$4,57\pm0,09^{fg}$	$1,96\pm0,03^{ab}$
AR034H	$13,30\pm1,52^{c}$	$207,00\pm17,28^{abc}$	$15,19\pm3,72^{abcde}$	$84,80\pm3,72^{abcde}$	$10,09\pm0,62^{e}$	$2,48\pm0,09^{a}$	$4,07\pm0,4^{ef}$	$1,93\pm0,06^{ab}$
AR051H	$11,66\pm1,52^{bc}$	$200,27\pm6,28^{abc}$	$20,44\pm4,25^{abcde}$	$79,55\pm4,25^{abcde}$	$10,74\pm0,24^{ef}$	$2,31\pm0,17^{a}$	$4,65\pm0,39^{g}$	$1,92\pm0,01^{ab}$
AR630H	$11,66\pm1,57^{bc}$	$208,07\pm21,36^{abc}$	$23,94\pm6,25^{bcde}$	$76,05\pm6,25^{abcd}$	$11,39\pm0,16^{h}$	$2,47\pm0,08^{a}$	$4,59\pm0,12^{fg}$	$1,95\pm0,01^{ab}$
AR043H	$12,30\pm1,52^{bc}$	$252,72\pm36,84^{c}$	$19,30\pm5,19^{abcde}$	$80,69\pm5,19^{abcde}$	$10,49\pm0,13^{ef}$	$2,44\pm0,08^{a}$	$4,29\pm0,11^{fg}$	$1,98\pm0,08^{ab}$
AR601H	$12,00\pm1,73^{bc}$	$179,96\pm12,05^{abc}$	$12,66\pm3,69^{abc}$	$87,33\pm3,69^{cde}$	$11,13\pm0,2^{gh}$	$2,45\pm0,07^{a}$	$4,53\pm0,06^{fg}$	1,95±0,08ab
AR638H	$11,00\pm0^{bc}$	$220,46\pm26^{bc}$	$26,14\pm5,29^{cde}$	$73,85\pm5,29^{abc}$	$11,21\pm0,12^{gh}$	$2,57\pm0,06^{a}$	$4,36\pm0,1^{fg}$	$2,00\pm0,07^{ab}$
AR629H	$12,66\pm1,52^{bc}$	$212,10\pm33,15^{abc}$	$19,98\pm3,75^{abcde}$	$80,01\pm3,75^{abcde}$	$11,30\pm0,1^{gh}$	$2,56\pm0,18^{ab}$	$4,42\pm0,33^{fg}$	$2,04\pm0,09^{ab}$
Palawan	$6,60\pm1,52^{ab}$	$202,43\pm10,62^{abc}$	$7,72\pm0,75^{a}$	$92,27\pm0,75^{e}$	$8,31\pm0,04^{ab}$	$3,62\pm0,19^{d}$	$2,30\pm0,11^{ab}$	$2,13\pm0,08^{b}$
Kpaté	$9,33\pm3,055^{abc}$	$214,05\pm31,92^{abc}$	$27,94\pm2,25^{de}$	$72,05\pm2,25^{ab}$	$8,20\pm0,5^{ab}$	$3,19\pm0,24^{c}$	$2,60\pm0,27^{bc}$	$2,07\pm0,08^{ab}$
Djoukeme	$5,50\pm3,53^{a}$	$217,57\pm51,7^{abc}$	$15,84\pm11,28^{abcde}$	$84,15\pm11,28^{abcde}$	$8,40\pm0,17^{ab}$	$3,11\pm0,04^{c}$	$2,69\pm0,08^{bc}$	$2,01\pm0,02^{ab}$
GT11	$10,33\pm1,52^{abc}$	$151,27\pm2,67^{ab}$	$10,81\pm4,43^{ab}$	$89,18\pm4,43^{de}$	$8,17\pm0,13^{a}$	$2,83\pm0,14^{b}$	$2,88\pm0,12^{c}$	$1,86\pm0,04^{a}$
Danané	$5,66\pm1,52^{a}$	$321,52\pm66,86^{d}$	$15,05\pm3,07^{abcde}$	$84,94\pm3,07^{abcde}$	$9,21\pm0,08^{cd}$	$2,41\pm0,07^{a}$	$3,81\pm0,14^{de}$	$1,87\pm0,01^{a}$
Demamba	$5,33\pm0,57^{a}$	$212,72\pm25,26^{abc}$	$8,55\pm1,92^{a}$	$91,44\pm1,92^{e}$	$7,89\pm0,17^{a}$	$3,73\pm0,09^{d}$	$2,11\pm0,04^{a}$	$2,12\pm0,04^{b}$
Kouikloné	$8,00\pm1^{abc}$	$193,30\pm32,86^{abc}$	$17,67\pm11,66^{abcde}$	$82,32\pm11,66^{abcde}$	$8,79\pm0,13^{bc}$	$3,13\pm0,09^{c}$	$2,80\pm0,12^{c}$	$2,02\pm0,04^{ab}$
Soungrouba	$9,66\pm2,08^{abc}$	$182,31\pm20,48^{abc}$	$7,89\pm2,13^{a}$	$92,10\pm2,13^{e}$	$9,29\pm0,13^{cd}$	$2,65\pm0,09^{ab}$	$3,50\pm0,09^{d}$	$1,93\pm0,11^{ab}$
Marigbé	$12,33\pm4,5^{bc}$	$135,98\pm28,65^{a}$	$14,25\pm4,77^{abcd}$	$85,74\pm4,77^{bcde}$	$10,43\pm0,48^{ef}$	$2,52\pm0,11^{a}$	$4,10\pm0,37^{efg}$	$1,93\pm0,02^{ab}$
WITA9	$12,00\pm2,64^{bc}$	$176,20\pm12,51^{abc}$	$13,66\pm1,71^{abc}$	$86,33\pm1,71^{cde}$	$9,53\pm0,05^{d}$	$2,60\pm0,04^{ab}$	$3,65\pm0,05^{d}$	$2,02\pm0,18^{ab}$
F	5,23	6,31	5,53	5,53	69,69	36,44	53,11	2,7
P	<0,0001	<0,0001	<0,0001	<0,0001	<0,0001	<0,0001	<0,0001	0,0043

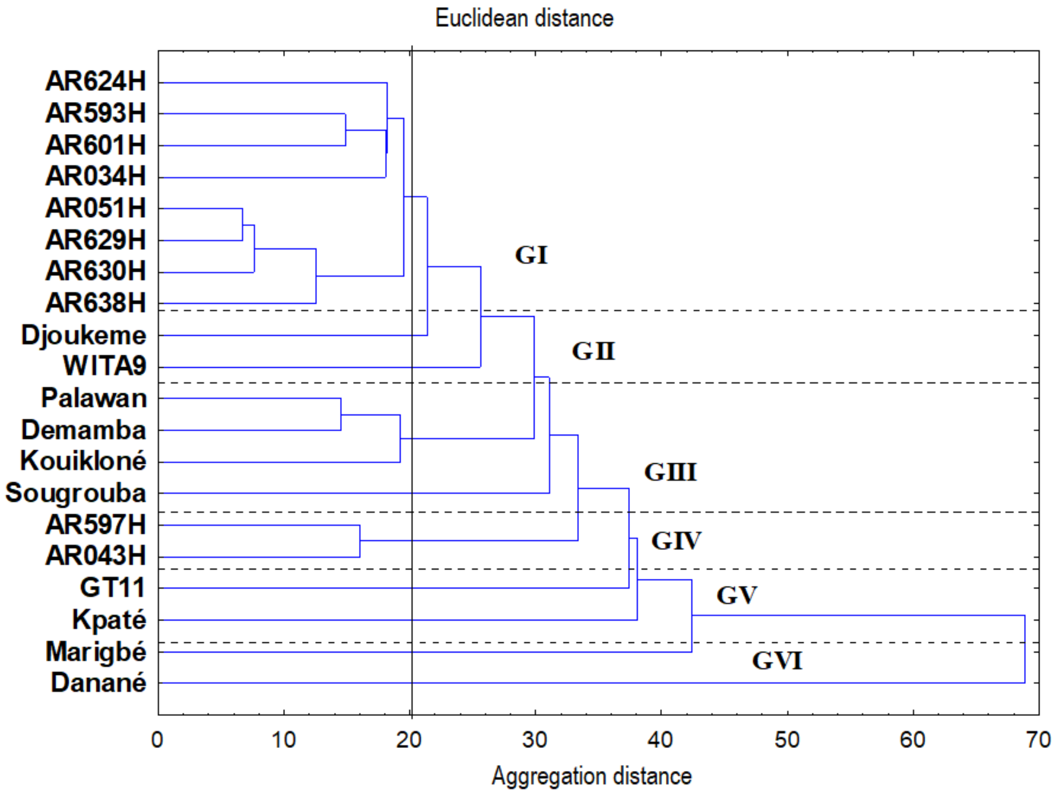

Figure 2: Hierarchical Ascending Classification (HAC) of the 20 rice varieties based on Unweighted Pair Group Method with Arithmetic mean (UPGMA)

Table V: Classification Matrix of Groups of Rice varieties Based on Quantitative Traits

	%	Groupe I	Groupe II	Groupe III	Groupe IV	Groupe V	Groupe VI
Groupe I	100,00	**8**	0	0	0	0	0
Groupe II	100,00	0	**2**	0	0	0	0
Groupe III	100,00	0	0	**4**	0	0	0
Groupe IV	100,00	0	0	0	**2**	0	0
Groupe V	100,00	0	0	0	0	**2**	0
Groupe VI	100,00	0	0	0	0	0	**2**
Total	100,00	**8**	**2**	**4**	**2**	**2**	**2**

Lines: Observed Classifications; Columns: Expected Classifications

Table VI: Summary of Discriminant Factorial Analysis Based on Quantitative Variables

	λ Wilk	λ Partial	F	P-value	Toler.	1-Toler.
PMG	0,000009	0,025936	37,55601	**0,000572**	0,104505	0,895495
LoG/LaG	0,000003	0,092545	9,80555	**0,012776**	0,016275	0,983725
RG	0,000003	0,068253	13,65134	**0,006135**	0,041049	0,958951
LoG	0,000002	0,111587	7,96166	**0,019954**	0,020947	0,979053
LaF	0,000005	0,051351	18,47400	**0,003069**	0,029393	0,970607
NTP	0,000002	0,096729	9,33816	**0,014201**	0,017540	0,982460
NPP	0,000005	0,049405	19,24067	**0,002793**	0,008804	0,991196
NGP	0,000003	0,089654	10,15400	**0,011841**	0,035788	0,964212
HP	0,000002	0,106597	8,38110	**0,017901**	0,115610	0,884390
EFP	0,000001	0,175105	4,71085	0,057082	0,078935	0,921065

Table VII: Centred-reduced Coefficients of the Canonical Discriminant Function

	Comp_1	**Comp_2**	**Comp_3**	**Comp_4**	**Comp_5**
PMG	-2,373	-0,2687	-0,2728	0,3638	-0,02560
LoG/LaG	-18,857	4,3980	0,8209	-0,0395	1,41669
RG	2,980	-1,8522	-0,8866	-0,1716	-0,06503
LoG	11,940	-2,7006	1,3902	0,9289	1,06483
LaF	19,886	-0,5129	-0,4825	6,3334	0,13352
NTP	3,169	-0,1299	-0,0017	0,8729	0,24892
NPP	-4,758	1,4014	0,7124	0,1131	-0,99793
NGP	-0,115	0,0299	0,0468	0,0096	-0,03213
HP	-0,219	0,2137	0,0051	0,1413	0,00822
EFP	-0,449	0,2623	0,1390	0,1139	0,02900
V.Propre	1128,602	44,3190	6,3472	3,5190	1,49508
Prop.Cum	0,953	0,9904	0,9958	0,9987	1,00000

Table VIII: Factorial Coordinates of the Groups of Rice Varieties

	Comp_1	**Comp_2**	**Comp_3**	**Comp_4**	**Comp_5**
Groupe I	-2,8551	**-4,86837**	0,50394	0,51215	0,76697
Groupe II	**-6,0351**	-3,22055	-3,24865	-3,84949	-0,48902
Groupe III	**-15,7754**	6,06764	-2,55333	1,56606	-0,19218
Groupe IV	**-5,4496**	-3,75718	2,26998	0,67276	-2,73815
Groupe V	**81,1772**	4,43444	0,24749	-0,16549	-0,00603
Groupe VI	**-26,7213**	9,88149	3,82206	-1,83851	0,54969

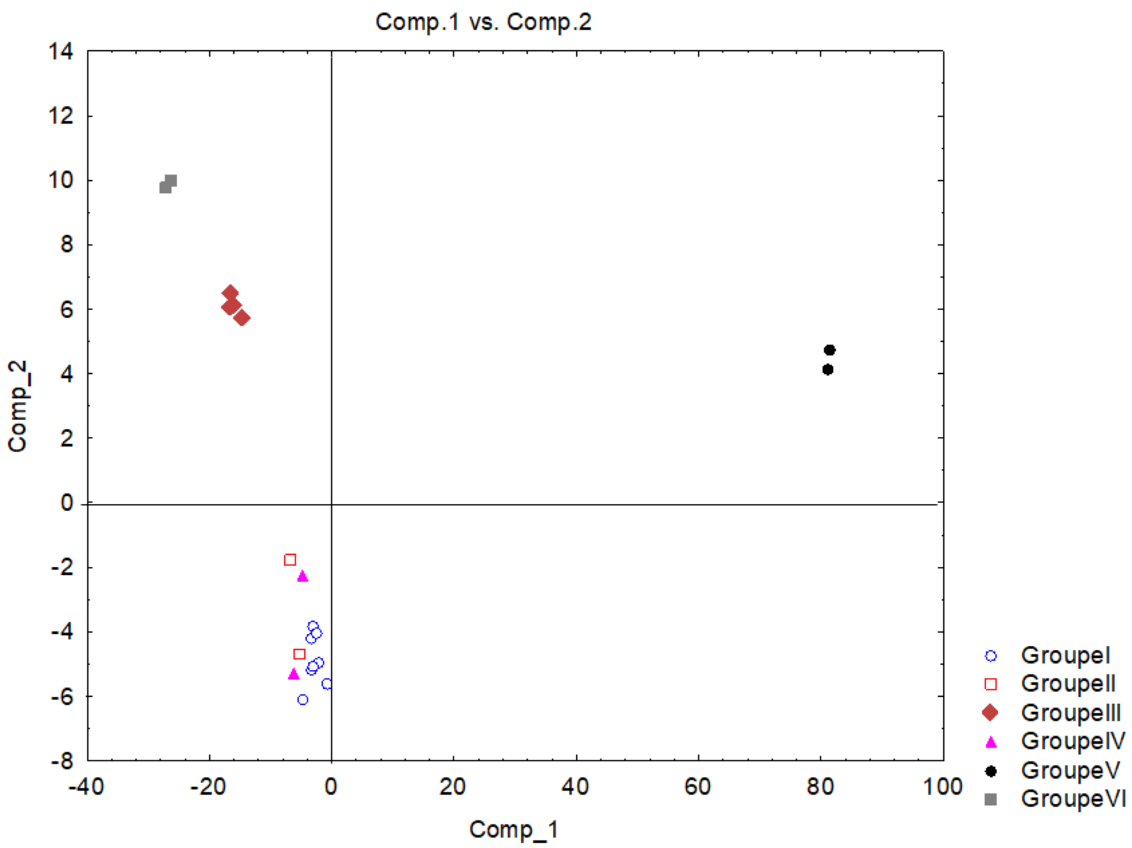

Figure 3: Representation of the different groups of rice varieties in the space determined by the canonical components 1 and 2 of the discriminant factorial analysis