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A study of the performance of rice varieties from India and the United States (USA) in the rice ecology of Niger

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Abstract

In Niger, rice (Oryza sp.) is the third most produced cereal after millet and sorghum in terms of both area and production. However, efforts to increase production of this cereal are hampered by the lack of productive varieties that are resistant to the main biotic constraint, Rice Yellow Mottle Virus (RYMV). This study contributes to addressing this national concern, through the identification and production of rice varieties with high performance. It consisted of: (i) Screening American (PRESIDIO, WELLS and KATAHOULA), Indian (SWARNA and PAC32) and a local control (IR 1529-680-3-1) rice varieties against RYMV in the greenhouse, (ii) Evaluating the agronomic performance of the rice varieties provided in agronomic trials, set up at the Saga, Toula and Famalé rice-growing sites, according to a Randomized Complete Block (RCB) experimental design, with 6 treatments (varieties) and 5 replications. The parameters measured were agro-morphological characteristics (tillering, plant height) and yield components (number of panicles/planes, grains/ panicle, sterility rate). The results of the tests showed that all the varieties used are moderately susceptible to RYMV and have good productivity, with yields ranging from 6.4 t/ha to 10 t/ha. The variety SWARNA seems to be the most productive and the variety WELLS having recorded the highest 1000 grain weight. All the varieties have a long cycle with an average of 137 days, except WELLS which proved to be early (97 days). These results suggest that the genetic and agronomic performance of the selected varieties should be exploited in the varietal selection programs and that further investigations should be made to confirm the relative tolerance of these varieties.

Keywords: rice, RYMV, agro-morphological parameters, yield components, Niger.

Introduction

With a global production estimated at over 500 million tons, rice is one of the most produced and consumed cereals in the world (FAO, 2022). Sub-Saharan Africa accounts for about 4% of global rice production with a production of 19.4 million tons in 2019/2020. Rice has become the main food in most sub-Saharan African countries. It represents the most important source of food energy in West Africa (Issaka et al, 2021a).

In Niger, rice is the third most important cereal after millet and sorghum in terms of both area and production (Issaka et al., 2021b; SOFRECO, 2022). It is the food whose consumption (2.4 to 52.7 kg per person per year, average 20 kg/person/year) is increasing day by day, particularly due to urbanization and ongoing economic and social changes (Faivre-Dupaigre et al., 2006).

Annual national production, estimated at 256,649 tons of paddy in 2020, represents only 20% of the country's consumption (Issaka et al., 2021b). The production gap is thought to be due to insufficient cultivated area (< 40,000 ha), the absence of highly productive improved varieties, and the effects of numerous abiotic and biotic constraints (Issaka et al., 2012a). Biotic constraints include rice yellow mottle virus (RYMV), which causes significant economic losses. This disease appeared in Niger following the intensification of rice cultivation, with the introduction of highly susceptible exotic and productive varieties (Issaka, 2013).

There are few means of controlling RYMV and, although effective, prophylactic measures remain insufficient. Therefore, the use of genetic resistance appears to be the best strategy to reduce losses associated with the virus (Issaka et al. 2012a). Thus, the four main varieties planted in Niger (IR1529-683-1, Wita8, Guiza and KassoumMo) have all been found to be susceptible to the disease, which is a major handicap to the country's rice production (Issaka et al., 2012a). Other high-yielding irrigated rice varieties adapted to the country's ecological conditions must therefore be developed, offered to producers and popularized, in order to contribute to a significant increase in the productivity of this important grain (Issaka et al., 2012b).

The present study contributes to the improvement of local rice production through the identification and production of high-performing rice variety seeds adapted to the rice ecology of Niger. It consisted of: (i) screening under glass some American and Indian rice varieties and two local controls against RYMV and (ii) evaluating the agronomic performance of the rice varieties provided in agronomic trials.

Materials and Methods

2.1 Experimental sites

The study was conducted on three rice-growing fields(Table 1). These were Famalé, Toula (Tillabéri Department) and Saga(Niamey IV Communal District). The hydrography of all these areas is marked by the presence of the river in the agricultural zone; the presence of the river has favored the multiplication of irrigated rice fields (ONAHA, 2013).

Tableau 1: Characteristics of experimental sites

Rice site	Type of rice cultivation	GPS coordinates
Famalé	Irrigated	N 14° 22.286’; E 1° 12.318’
Toula	Irrigated	N14°11’49’’; E1°27’60’’
Saga	Irrigated	N13°27’13,5 ; E2°08’35,9’’

2.2 Plant material

Six (6) varieties of rice (Oryza sp.) were evaluated (Table 2). These were: (i) two Indian varieties (SWARNA2 and PAC832), (ii) three American varieties (PRESIDIO, WELLS and KATAOULLA) and a RYMV-susceptible control (IR1529-680-3-1).

Table 2: Identity of rice varieties tested

N° Variety	Name of the Variety	Origine	Profil	Resistance gene
V1	PRESIDIO	USA	unknown	unknown
V2	WELLS	USA	unknown	unknown
V3	KATAHOULA	USA	unknown	unknown
V4	PAC 32	India	unknown	unknown
V5	SWARNA	India	unknown	unknown
V6	IR1529- 680-3-1	Africa Rice	Sensitivity indicator	*rymv1-1*

2.3 Methods

Screening tests of the selected varieties

Before the agronomic tests of the introduced varieties were set up, it was necessary to determine their performance with respect to RYMV, the main biotic pathogen responsible for the major biotic constraint of rice in Niger.

Screening tests of the rice varieties were set up in the greenhouse of the National Institute of Agronomics Research of Niger (INRAN) in Kollo. They consisted of (i) sowing three American varieties (KATAOULLA, PRESIDIO, WELLS), two Indian varieties (PAC832 and SAWARNA 2) and a susceptibility control (IR1529-680-3-1) in pots (ii) inoculate three-week-old plants of each variety with crushed RYMV isolates collected from the three agronomic tests sites (Saga, Toula and Famalé) and (iii) observe disease symptoms 21 days after inoculation (DAI).Table 3 gives the references of the isolates used for inoculation during the tests.

Figure 1: Screening of selected varieties in the greenhouse (Left: preparation of the inoculum or grind of the collected isolates and left: a view of the screening tests).

Agronomic performance evaluation of rice varieties in multi-location trials

Experimental design and cultivation techniques

The agronomic evaluation was set up at the Famalé, Toula and Saga sites using a Randomized Complete Block (RCB) design with 6 treatments (varieties) and 5 replications, i.e., 30 plots of 4m² each. Plots were separated by 50 cm aisles and were located 2 m apart on all sides of the border.

After pre-irrigation, the experimental plot was plowed and then planted with a rototiller and a hoe. Then it was the delimitation of the plots and the tracing of the transplanting lines. The 6 varieties evaluated were sown in nursery in pots in a greenhouse. The young plants obtained were transplanted in the field on each of the 3 trial sites, at 21 days after sowing (DAS) and at a rate of 1 or 2 plants per plot. Plots were spaced 20 cm apart. Each replication consisted of 6 blocks each containing 6 elementary plots of 2x2 m^2.

Mineral fertilizer was applied at rates recommended by agricultural research (Issaka et al., 2021b): (i) Basal: 200 kg ha^{-1} of NPK 15-15-15 at transplanting, (ii) first application of urea at a rate of 100 kg ha^{-1}, 15 days after transplanting (DAR) and after weeding, and (iii) 2nd application of urea at a rate of 100kg ha^{-1}, 40 days after transplanting.

Manual weed control was also carried out as needed. Furadan was also used in case Fungal attack.

Figure 2: Experimental field in Saga.

Measured parameters

Evaluation of the resistance profile of varieties against RYMV

The characteristic symptoms of yellow mottle were noted on the plants of the 6 varieties inoculated with the inoculum prepared from the 3 RYMV isolates collected. This evaluation takes place at 21 days of age.

Agronomic characteristics of the varieties

The number of tillers per cluster was counted in each subplot. Similarly, plant height was measured after heading for all varieties. Height was measured from the collar to the top using a tape measure.

The vegetative cycle of the varieties was estimated by counting the number of days that the plants of each variety developed; starting from sowing to harvest.

Yield components

The following parameters were considered: (i) the flowering tillers corresponding to the tillers with panicles, counted at the flowering of the plants; (ii) the number of grains per panicle represents the number of healthy and empty grains; the sterility rate corresponding to the ratio between the weight of the empty grains and that of the full grains and (iv) the average yield which is equal to the total weight of the harvest of the yield squares of the varieties reported to the hectare (ha).

The sterility rate of the plants makes it possible to determine the capacity of the tillers to flower in a medium. It is calculated according to the following formula:

$$Ts = \frac{NTt - NTf}{NTt} \times 100$$

With:
Ts = sterility rate;
NTt = total number of tillers;
Tf = flowered tillers

As for the average yield, it was evaluated according to the formula:

$$RDT = NP \times NT \times Npa \times NG \times PG$$

With:
RDT= yield in t/ha;
NP = number of plants per m²,
NT = number of tillers per plant;
NPa/T = number of panicles per tillers;
NG = number of grains per panicle;
PG = weight of a grain (grams) = 1000 grains/1000

After drying, dehulling and winnowing, the weight of 1000 full grains is obtained for each rice variety, by direct weighing of the samples taken using a precision balance.

Results

3.1 Results

Results of variety screening

All varieties recorded a score between 3 and 5, based on the symptom rating scale (Issaka et al., 2012b). These results indicate that all rice varieties tested are more or less susceptible to rice yellow mottle virus.

Agronomic results

These are the results related to developmental cycle, vegetative parameters and yield components.

Development cycle: The results relating to the vegetative cycles of six (6) varieties tested. Table 3 show some heterogeneity among them. IR1529-680-3-1, PAC832, KATAHOULLA, SWARNA and PRESIDIO were all long cycle varieties (average cycle length 137 days) while WELLS was early (average cycle length 97 days).

Table 3: Length of development cycle of tested varieties.

Variety	Vegetative cycle (sowing-maturity)	Yield in T/ha
SWARNA	130-135	7.4
WELLS	94-100	5.8
IR1529-680-3-1	130-136	10
PAC 832	135-140	10
PRESIDIO	135-140	6.4
KATAHOULA	135-140	8.5

Vegetative parameters

The values of plant height recorded are 97 cm and 96 cm, respectively for PAC 832 and SWARNA against 81 to 84 cm for the remaining less tall varieties; the long cycle varieties having the highest heights (Figure 3). Regarding the number of panicles per bunch (Figure 3), PAC832 had the highest value (31 panicles/bunch) and SWARNA, IR1529-680-3-1, PRESIDIO and KATAHOULA had 20, 27, 24 and 23 panicles/bunch, respectively. Wells had the lowest number of panicles (16 panicles/bunch).

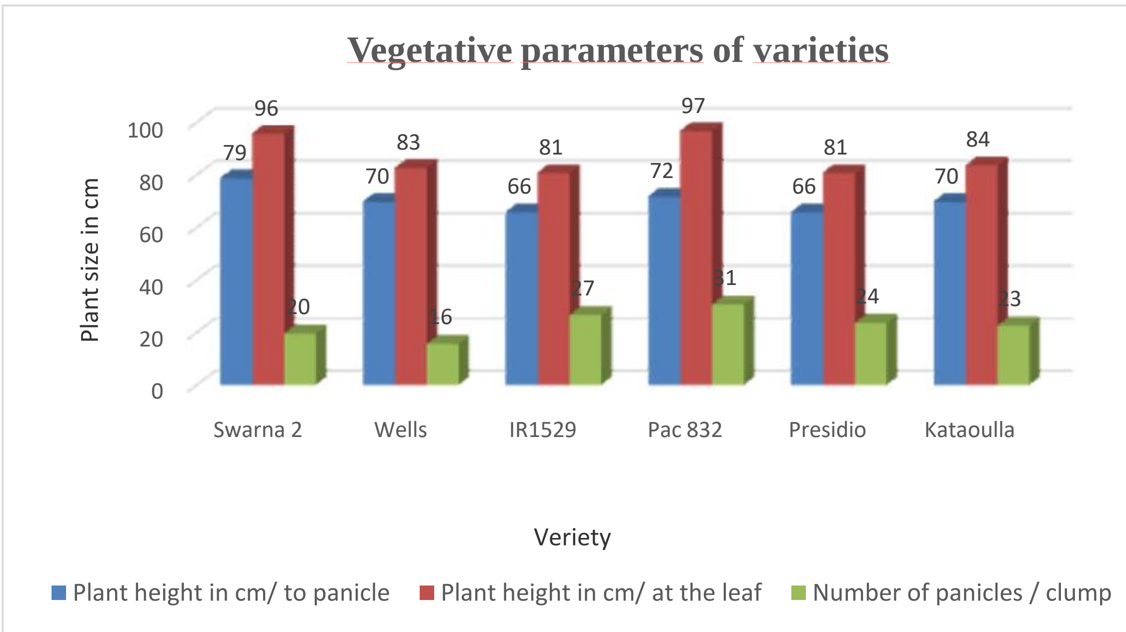

Figure 3: Vegetative parameters of the six (6) varieties tested.

The number of tillers per bunch (Figure 4) indicates that the average number of tillers varies according to the variety. Thus, the varieties PRESIDIO and PAC 832 have the highest number of tillers with an average of 24 tillers/pod compared to varieties IR1529-680-3-1, KATAHOULLA, SAWARNA and WELLS with average numbers of tillers of 21, 19, 17 and 9.8 respectively (Figure 4).

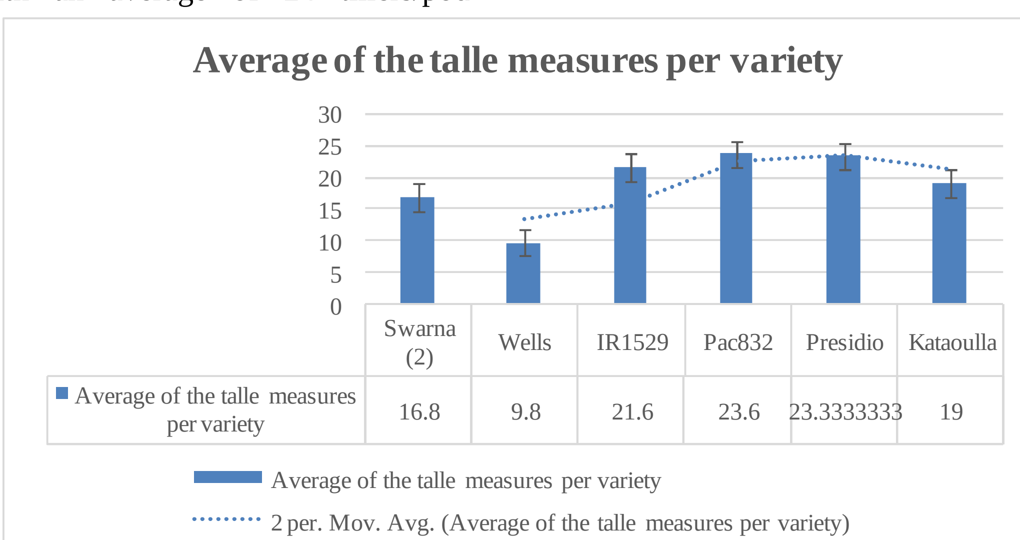

Figure 4: Number of tillers per clump of different rice varieties before flowering

Figure 5 gives the number of flowering tillers. Its analysis shows that the variety KATAHOULLA has the highest number of flowering tillers with 27 flowering tillers/pod. which is clearly higher than the other varieties. As for the varieties SWARNA, IR1529-680-3-1, PAC832 and PRESIDIO, they recorded an average number of 20 flowering tillers/pod against 10 for the variety WELLS.

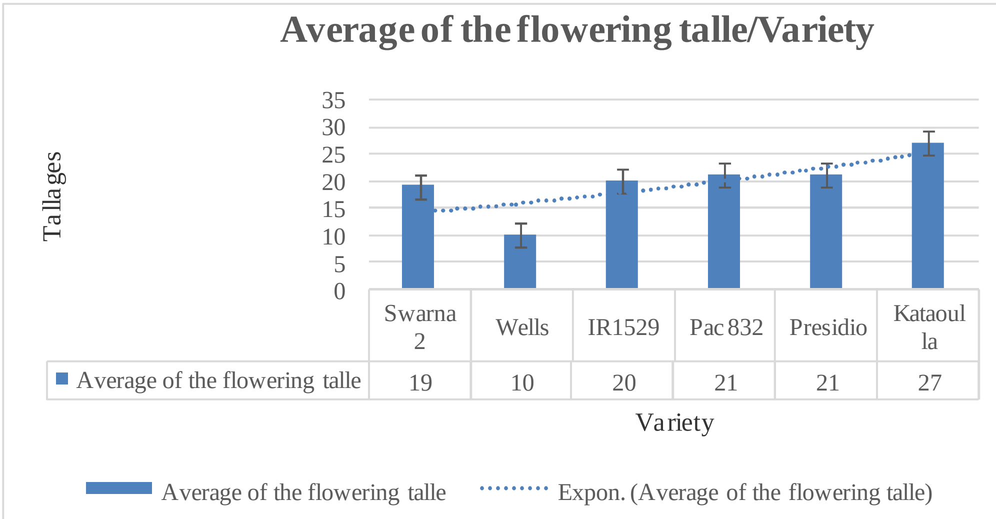

Figure 5: Number of flowering tillers per variety after heading.

Yield components

The average number of tillers / bunch / per m^2, the average weight of 1000 grains per variety, the average number of grains per spikelet, the average production yield and the sterility rate were evaluated at each site and for each variety.

The average number of tillers per unit/m2 was about 2721±3 tillers per unit for SWARNA2, WELLS, IR1529-680-3-1, 21±3 tillers per unit for PAC832 and KATAHOULLA and 13 tillers per unit for PRESIDIO (Figure 6).The varieties SWARNA2 and WELLS had the highest number of grains per spikelet, with 166 and 151 grains respectively (Figure 6).

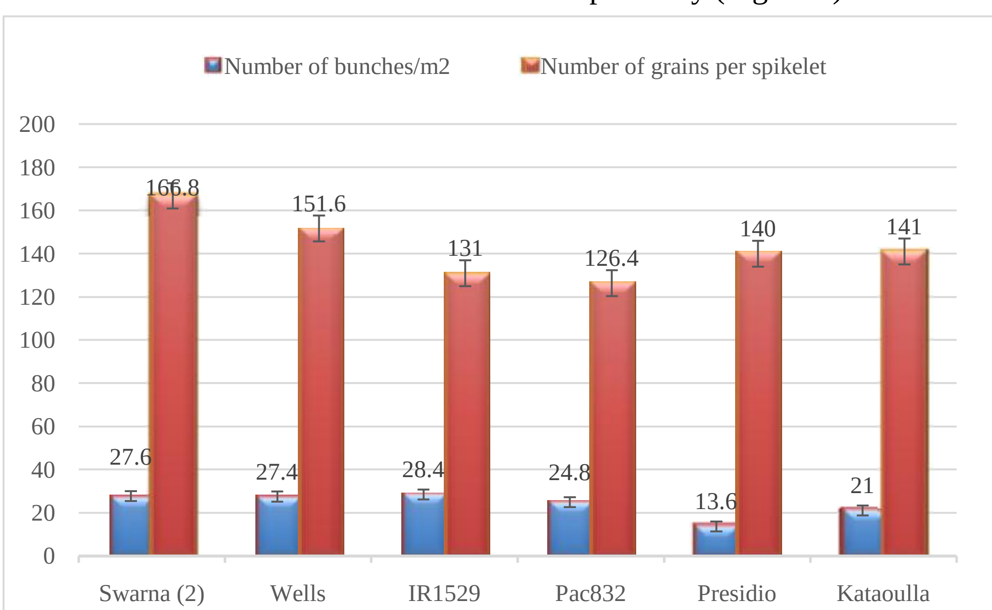

Figure 6: Measurements of production parameters

As for the other four varieties, they recorded an average number of grains per spikelet approximately equal to 135 grains more or less 5.

Concerning the weight of 1000 grains, the varieties WELLS and PAC832 recorded the highest value, with an average of 23.5g against an average weight of 1000 grains approximately equal to 21±2 for the other four varieties. In fact, the average weight of 1000 grains obtained is equal to 22g for SWARNA and KATAOULLA, 23g for WELLS, 21g for IR1529-680-3-1, 24 for PAC832 and 20g for PRESIDIO (Figure 7).

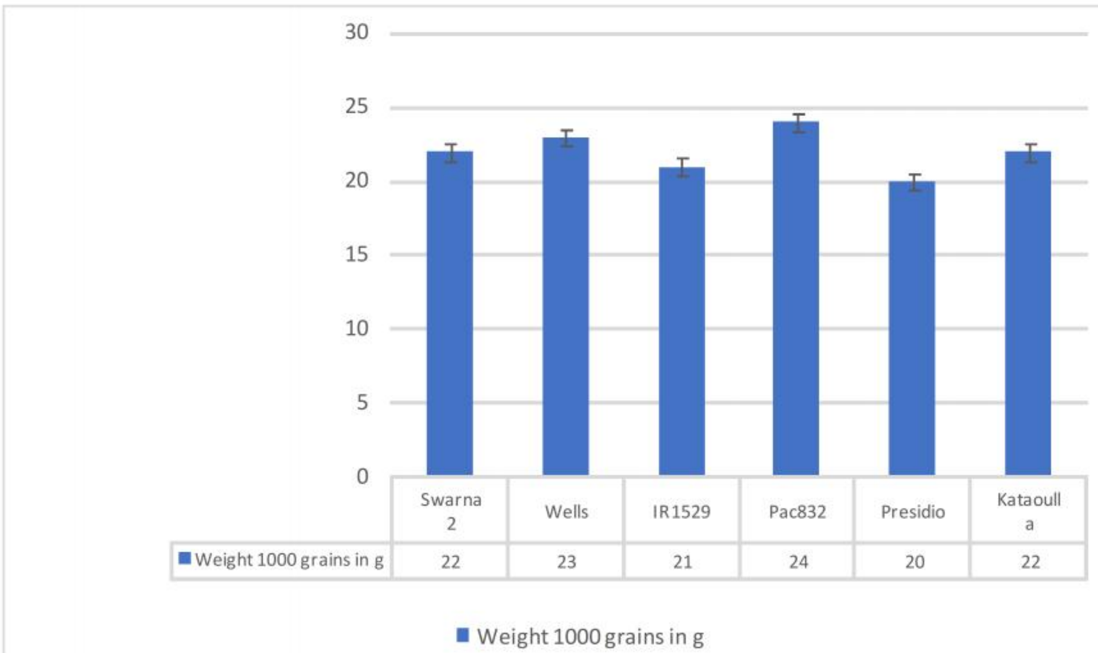

Figure 7: Weight of 1000 grains in grams.

The estimation of the sterility rate (Figure 8) showed that the variety SWARNA2 has 46.92 % of sterile tillers against 51.92 %, 52.91%, 52.62%, 41.30 % of sterile tillers, respectively for the varieties IR1529-680-3-1 (high sterility rate), PAC 832, PRESIDIO and KATAOULLA On the other hand, WELLS did not record any sterile tillers.

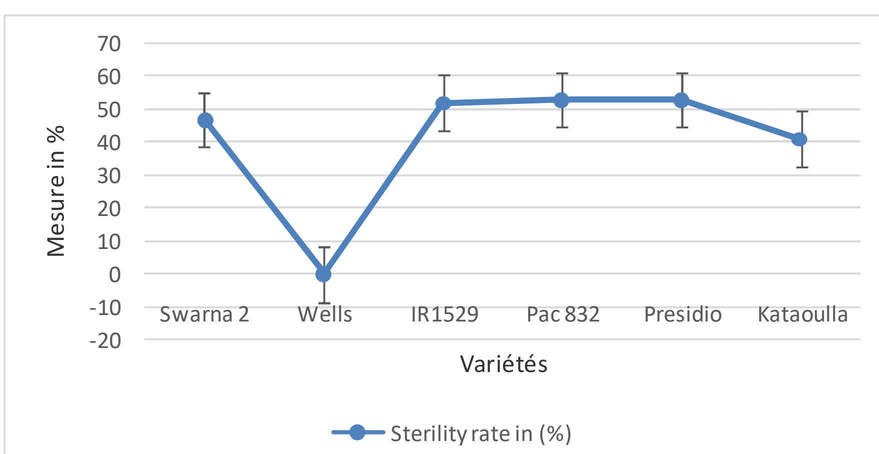

Figure 8: Overview of the sterility rate of the varieties studied

The calculation of the yields of the varieties evaluated gave: 7.4 t/ha for SWARNA2, 5.8 t/ha for Wells, 10 t/ha for IR1529-680-3-1, 10 t/ha for PAC832, 6.4 t/ha for PRESIDIO and 8.5 t/ha for KATAOULLA (Figure 9).

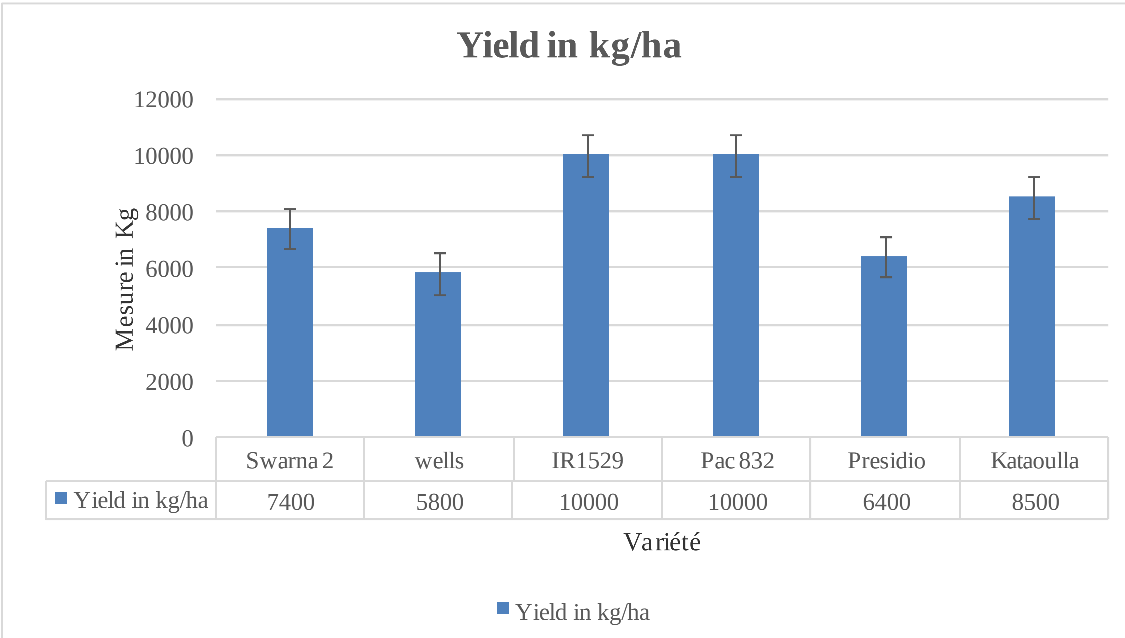

Figure 9: Yield measurements per hectare

Discussion

Local rice production in Niger meets only 20% of rice needs (Issaka et al., 2021b). In order to reduce the 80% production deficit, agricultural research and farmers of the rice sector recommend the development and/or introduction of improved varieties to achieve food security in the long term.

The present study consisted of studying the behavior of six rice varieties introduced from the USA and India, in order to select those that are best adapted to rice cultivation under the agroecological conditions of the study sites. Thus, making available to producers rice seeds with good production potential and adapted to local conditions in Niger.

The total number of tillers and the average number of flowering or productive tillers vary according to variety and site. Thus, PRESIDIO and PAC 832 produced the highest total number of tillers (23-24 tillers/pod) and WELLS recorded the lowest number of tillers (9.8 tillers/pod) in all trial sites. Regarding the number of productive tillers, the varieties KATAHOULLA and SWARNA gave the highest number of flowered tillers (27 flowered tillers/packet) and WELLS recorded the lowest number (10 flowered tillers/packet). This suggests that the first two varieties are highly adaptable to the rice ecology of the study sites, while WELLS is not adapted to any of the rice sites, indicating a likely genetic cause. However, the reaction profile of the varieties tested against RYMV shows that they are more or less susceptible to the virus. This might pose a risk to the cultivation of these varieties. These results are in harmony with those of Bouet et al, (2013) regarding the total number of tillers, but disagree with the same authors regarding the number of tillers flowered in agronomic trials in Ivory coast.

These authors reported that a rice planting can produce a total of 9-20 tillers, of which 8-15 tillers are productive. Similar observations were made concerning the height of the stems and the number of panicles per plant of the varieties and per bunch. Indeed, the values for these parameters showed that the variety WELLS was lower with fewer panicles per bunch and PAC 832 was higher with a high number of panicles at all sites.

The different length of the vegetative cycle of the varieties evaluated revealed that the WELLS variety is very early (97 days), whereas all the other varieties have a long cycle (>137 days) in the three experimental sites. These results differ from those of Traoré (2006), who classified rice varieties into early (cycle less than 120 days), semi-early (cycle of about 160 days) and late (cycle between 170 and 180 days). However, they are similar to the results of the National Catalogue of Plant Species and Varieties (CNEV) of Niger (2012). Thus, with an average vegetative cycle of about 100 days, the WELLS variety constitutes a source of earliness genes that could be exploited in varietal selection programs. It offers a clear advantage to the Nigerien rice sector in terms of production time and inputs.

The results of the yield components indicate that SWARNA and WELLS are the best performing varieties in terms of average number of tillers per m2 and number of grains per spikelet; PRESIDIO is the least performing. On the other hand, regarding the weight of 1000 grains, the varieties WELLS and PAC 832 were the best performers with the highest values and PRESIDIO had the lowest weight of 1000 grains. Also, the evaluation of the sterility rate showed that the variety WELLS did not record any sterile tillers against a sterility rate of 41-52.92% for the other 5 varieties (KATAOULLA, SWARNA, IR1529-680-3-1, PAC 832, PRESIDIO). However, despite their high sterility rate, these varieties were the most productive (yields ranging from 6.4 to 10 t/ha); the variety WELLS had the lowest yield.

Overall, the phenological and agronomic performance of the varieties studied on the three trial sites shows a certain adaptation of some of them to the detriment of the others. Thus, the plant material evaluated contains genotypes with very good phenological characteristics and excellent yield components. The variety WELLS stood out for the absence of spikelet abortion and an excellent 1000 grain weight. This could more or less compensate for its yield.

In summary, the five varieties evaluated showed good agronomic (number of total and flowered tillers, vegetative cycle) and phenological (plant size) performances that could be of interest to breeders/improvers, especially in the development of new improved varieties, through the transfer or introgression of the genes conferring these performances. The WELLS variety would serve as a donor of precocity genes and of a better weight of 1000 grains to the genetic funds supporting the varietal improvement. Such material could also be a response to the constraints associated with climate change, which is responsible for the droughts and floods that disrupt the irrigation of rice-growing sites.

Conclusion

The results obtained showed that each ofthe varieties evaluated has proven phenological and/or agronomic performance. However, only the varieties SWARNA, PAC 832 and KATAHOULA appear to be better adapted to the ecological conditions of the study sites. As for the variety WELLS, it has the advantage of being very early, with fewer sterile tillers and a high 1000 grain weight. These genotypes will be used to improve gene banks, with an intent of creating new improved varieties adapted to Niger rice growing ecosystems.

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