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RESEARCH ARTICLE

SCREENING RICE HYBRID GENOTYPES FOR BLAST AND BROWN SPOT DISEASES RESISTANCE AND YIELD PERFORMANCE

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Abstract

Rice occupies a prominent place among the cereals produced in Burkina Faso. However, its production faces constraints that impact the performance of the varieties developed. The aim of the present study was to evaluate new hybrid rice varieties with regard to their resistance to blast and brown spot diseasesand their agronomic performances. The plant material consisted of 9 rice varieties, including 04 local controls. Trials were set up in a Fisher block design with 03 replicates at Bama, Banfora and Sindou sites over a two-year study period. Data were collected on the severity and incidence of blast and brown spot disease, as well as on agronomic parameters. The study showed that hybrids were the most resistant to blast and brown spot disease. In addition, maturity was later at the Sindou site than at the other two sites. The WDR1517, WDR73 and WDR737 hybrids were the latest to reach semi-maturity, with cycles ranging from 120 to 132 days. However, hybrids WDR3015 and WDR306 performed better agronomically, with yields of over 9,000 kg/ha on all sites. Yield stability analysis showed that hybrid WDR73 was the most stable of the varieties, with an average yield of 8310 kg/ha. The three-dimensional analysis also proved that these varieties would adapt to our country's 03 agro-ecological areas.

Introduction:-

Rice (Oryza sativa L.) is one of the world's most widely grown cereals, and one of the most important in feeding the world's population. It is grown on more than 160 million hectares of land, with a production of 730 million tonnes of paddy rice in 2019 (FAOSTAT, 2021). In Africa, rice is produced on around 17,000,000 hectares (FAOSTAT, 2022). In Burkina Faso, rice is ranked 4th in terms of both area and production, after sorghum, maize and millet. It is a strategic crop in terms of its importance to economy and its role in food security. However, it remains the country's leading cereal import, generating a significant outflow of foreign currency that could reach 107 billion CFA by 2025. Although production has risen from 113,724 tons in 2006 to 451,420 tons in 2020, it covers less than 50% of

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population's food requirements. This underperformance is partly due to biotic and abiotic constraints that impact the performance of the varieties developed. Abiotic constraints include drought, low temperatures, salinity and iron toxicity (Konatéet al., 2022). As for biotic constraints we have fungal, bacterial, viral diseases, parasitic nematodes and weeds (Kassankognoet al., 2016; Séréméet al., 2014; Traore et al., 2009; Thioet al., 2017; Wonniet al., 2014).

In view of all these constraints, and aware of the predominant role of rice growing in the economy, stakeholders are constantly looking for ways to increase rice production and meet ever-increasing demand. This necessarily involves providing producers with productive, and diseases resistant varieties. Over eighty (80) rice varieties have been developed by national research. However, almost all of these are pure lines, with yields ranging from 4 to 8 t/ha. The solution could therefore lie in hybrids. Indeed, because of its vigor, hybrid rice can give better yields than non-hybrid varieties. With this in mind, technical assistance from the People's Republic of China to Burkina Faso has introduced new hybrid varieties that could intensify rice production in Burkina Faso. These hybrids are to be evaluated in various agro-ecological areas of the country to observe their adaptability. The aim of the study was to help improve rice productivity in Burkina Faso, by providing producers with productive hybrid rice varieties resistant to the main fungal diseases.

Materials and Methods:-

Study site

The experiments were carried out in two regions of Burkina Faso, namely the Hauts-Bassins region and the Cascades region over two (02) years, 2022 and 2023.

HautsBassinsregion:

A single experiment was carried out in the HautsBassins region, specifically in the Kou Valley irrigated perimeter. The Kou Valley irrigated perimeter is located 30 km from Bobo Dioulasso. Its geographical coordinates are 11°22' north latitude, 04°22' west longitude, with an altitude of 300m. The climate is South Sudanian (Guinko, 1984), with alternating rainy and dry seasons. Average annual rainfall of around 900 mm is unevenly distributed over space and time. Temperatures fluctuate between 17°C and 37°C in the dry season and between 20°C and 32°C in the wet season. The soils in the rice-growing areas of the Kou Valley are hydromorphic with varied textures (Nébié, 1995).

Cascades region:

Two (02) experiments have been set up in the Cascades region, in Banfora and Sindou. The Banfora site is 85 km from Bobo-Dioulasso. Its geographical coordinates are 10°63 west longitude and 04°7 north latitude. The Sindou site is bounded by parallels 10°38' to 10°40' north latitude and meridians 5°09' 0 5°06' west longitude. According to Guinko (1984), the Cascades region has a generally south-Sudanese climate, with a Sudano-Guinean tendency towards the extreme south, with mainly grassy savannah and tree vegetation.

Plant material

The plant material consists of nine (09) hybrid rice varieties, including four (04) control varieties. The characteristics of the varieties are given in Table 1.

Table1:- Characteristics of varieties.

Varieties	Genetic nature	Cycle (day)	Yieldv(t/ha)	Behavior to blast and helminth disease
FKR62N	Interspecific	118	7 à 8	Resistant
FKR84	Pure line	100	6.5	Sensitive
FKR64	Pure line	120	8	Sensitive
FKR19	Pure line	95	7	Sensitive
WDR73	Hybrid	Nd	Nd	Nd
WDR737	Hybrid	Nd	Nd	Nd
WDR3015	Hybrid	Nd	Nd	Nd
WDR1517	Pure line	Nd	Nd	Nd
WDR306	Hybrid	Nd	Nd	Nd

Legend: Nd: Not determined

Methodology:-

Experimental design:

Trials were set up in a completely randomized Fisher block design with three (03) replicates. Each replication included nine (09) varieties. Each elementary plot was 15 m² (5mx3m). Trial dimensions were 31 m long by 17 m wide, giving a total area of 527 m^2 . The distance between replicates was 1m. Plots were also 0.5 m apart. Figure 1 illustrates the experimental set-up for the different trials.

Trial management:Cultivation operations included ploughing and setting up the nursery, plot preparation, transplanting, maintenance, data collection and harvesting. Description of operations:

Ploughing and planting of the nursery: digging was carried out in the vicinity of the study plots. This was followed by crushing, slurrying and levelling. Approximately 40 g of seed of each variety was broadcast on 1 m portions of the surface. These nurseries were covered with straw and netting, then watered and weeded regularly until the transplanting date.

Soil preparation and transplanting: operations were carried out well before transplanting and consisted of ploughing with a tractor or power tiller to a depth of around 15 to 20 cm, followed by planting. After 15 to 21 days, seedlings were carefully removed from the nurseries and transplanted in rows at a rate of 1 plant per stake. Water-retaining bunds about 30 cm high were installed around the plots to maintain the water table.

Maintenance of the trial: compost was applied manually as a bottom dressing, during soil preparation for each trial, at a rate of 5 tons/ha. NPK complex fertilizer (14-23-14) was applied at transplanting at a rate of 200 kg/ha. Then 150 kg of urea (46%) was split into doses of 50 kg/ha at 15 days after transplanting, and the remaining 100 kg was applied at 55 days after transplanting. Weed control was carried out as required at each site.

Harvesting rice: harvesting is carried out when 80% of panicles are straw-yellow in color, depending on the cycle of each variety. The panicle was cut manually using a sickle.

Data collection

Evaluation of agro-morphological traits

Agro-morphological traits were evaluated using the standard IRRI (2002) evaluation scale.

1. the number of tillers at 60 days (T60): this consisted of a manual count of the number of tillers per bunch;
2. plant height at maturity (PH): this is a measurement in centimeters taken from the base of the plant to the tip of the highest panicle or leaf at maturity;
3. date of maturity cycle (SMC): this corresponds to the number of days between sowing and plant maturity, when ¾ of the panicles have a straw-yellow color;
4. panicle length (PL): expressed in centimeters, measured at maturity before harvesting;
5. 1000 kernel weight (1000KW): evaluated after counting 1000 grains at a moisture content of 14%, also expressed in grams (g);
6. Yield: obtained by harvesting each plot when 85-90% of panicles are mature. The panicles are then threshed, dried, winnowed and the plot weights determined at 14% moisture. The yield per hectare is obtained by extrapolating the plot yield.

Pathological parameters:

Pathological parameters concerned the evaluation of the importance of the two main fungal diseases: blast and brown spot disease. Incidence and severity of each of these diseases were assessed on plants in five sampling squares laid out in each elementary plot. Severity was assessed by assigning severity scores ranging from 1 to 9 according to the IRRI (2002) standard rating scale (Table 2). Incidence was determined by dividing the number of diseased plants by the total number of plants multiplied by one hundred. These assessments were carried out only at the Bama site in the HautsBassins region.

Table 2:- Rate scale for blast and brown spot diseasesseverity.

Notes	Diseasedleaf area	Assessment
1	No symptoms	Immune (IM)
2	Lessthan 1% of sales	Very resistant (TR)
3	1-3%	Resistant (R)

4	4-10%	Resistant (R)
5	11-15%	Moderatelyresistant (MR)
6	16-25%	Moderately sensitive (MS)
7	26-50%	Sensitive (S)
8	51-75%	Very sensitive (TS)
9	76-100%	Very sensitive (TS)

Source: IRRI (2002)

Data analysis

The data collected was entered into an Excel spreadsheet and the analysis of variance was carried out using R software version 3.1. The same software was used to analyze the stability and adaptability of the varieties. Heritability in the broad sense (H²) was also estimated using the same software in order to understand the influence of the environment on the expression of agro-morphological traits, using the formula below.

$$\mathbf{H}^2 = \frac{\mathbf{Vg}}{\mathbf{Vp}} * 100$$

Results andDiscussion:-

Results:-

Incidence and severity of blast disease

Table 3 shows the results of the analysis of variance of the severity and incidence of blast for the varieties tested. Analysis of variance shows no significant differences between varieties. However, their level of resistance differs according to the IRRI assessment scale. The control variety FKR19 was the most susceptible, with a severity rating of 6.1. Hybrids WDR73, WDR 306, WDR3015, WDR737 and the control FKR62N were highly resistant, with average severity scores ranging from 1.6 to 2.3, followed by hybrid WDR1517 and the control FKR84, which were resistant to blast with severity scores of 3.3 and 3.1 respectively. The lowest incidence rates were recorded by the control variety FKR62N and the hybrids WDR306, WDR737 and WDR73, with incidence rates of 36.59, 37.9, 44.19 and 46.32% respectively.

Table 3:- Severity and incidence of blast disease.

Varieties_	**Severity**	**Incidence (%)**	**NR**
FKR19	6.1	68.88	MS
FKR62N	2.1	36.59	TR
FKR64	4.5	62.44	MR
FKR84	3.1	47.47	R
FRK64	4.8	93.99	MR
WDR1517	3.3	52.28	R
WDR3015	2.3	52.50	TR
WDR306	2	37.90	TR
WDR73	1.6	46.32	TR
WDR737	1.6	44.19	TR
Probability	0.05	0.06	-
Meaning	Ns	Ns	-

Behavior of varieties to brown spot disease

The mean severity scores and mean incidence rates of brown spot disease for the varieties are recorded in Table 4 below. Analysis of variance revealed no significant differences between varieties for either severity or incidence. On the other hand, based on the IRRI rating scale, hybrid WDR3015 was the most susceptible with a score of 4.2. The remain of the control and hybrid varieties were resistant to brown spot disease, with average severity scores ranging from 2 to 3.6. The average incidence of disease was ranged from 40 to 70.78%, obtained with the WDR306 and WDR1517 hybrids.

Table 4:- Severity and incidence of brown spot disease.

DESIGNATION	**Severity**	**Incidence (%)**	**NR**
FKR62N	3.1	60.00	R

FKR64	2.5	47.50	R
FRK19	3.4	38.34	R
FRK84	3.4	45.33	R
WDR1517	3.6	70.78	R
WDR3015	4.2	49.09	MR
WDR306	2	40.00	R
WDR73	2	50.12	R
WDR737	2	43.70	R
Probability	0.06	0.09	-
Meaning	Ns	Ns	-

Legend: NR: Level of resistance; R: Resistant; MR: Moderately resistant; TR: Very resistant; MS: Moderately sensitive.

Agronomic performance assessment

Average tilleringperformance:

The average number of tillers of different varieties over the two (02) years of evaluation varied very little on the study sites. It ranged from 13 (WDR306) to 17 tillers (FKR62N) for Bama site, from 21 (WDR737) to 29 tillers (FKR84) for Banfora site and from 16 (WDR1517) to 25 tillers (FKR62N) for Sindou site. The results of analysis of variance showed a significant difference (Pr>0.05) only for Sindou site (Table 5). Heritability in the broad sense was very low at all sites except Sindou, where it was moderately high (H^2 =49%). The genotype-environment interaction (GxE) showed no significant difference (Table 5).

Table 5:- Average number of tillers per cluster.

Varieties	Bama	Banfora	Sindou
FKR19	16	24	21
FKR62N	17	25	25
FKR64	15	22	19
FKR84	16	29	23
WDR1517	14	22	16
WDR3015	15	25	21
WDR306	13	22	19
WDR73	14	25	20
WDR737	15	21	19
Probability	0,94	0,57	0,01
Threshold	Ns	Ns	*
G X E	Ns	Ns	Ns
Heritability (%)	16	10	49

Legend: Ns: Not significant, G: genotype, E: environment,

Plant height:

The result of the analysis of variance showed a highly significant difference (Pr<0.05) for all study sites. Hybrid WDR1715 recorded the lowest mean plant height, with values of 79.7, 91.0 and 91.7 cm respectively at Bama, Banfora and Sindou sites. The mean heights of the most removed plants were 96.6 (FKR62N), 111.9 cm (FKR62N) and 102.0 cm (FKR64) respectively in Bama, Banfora and Sindou. Heritability in the broad sense was higher at all sites, with rates of 83, 78 and 75% respectively at Bama, Banfora and Sindou. The genotype-site interaction revealed no significant differences (Table 6).

Table 6:- Plant height at maturity.

Varieties	**Bama**	**Banfora**	**Sindou**
FKR19	90.3	105.3	99.8
FKR62N	96.6	111.9	98.3
FKR64	88.0	103.2	102.0
FKR84	87.1	104.8	96.2
WDR1517	79.7	91.0	91.7
WDR3015	80.9	100.1	88.0

WDR306	91.1	100.4	96.3
WDR73	89.7	102.9	97.7
WDR737	87.1	102.1	91.7
Probability	0.002	0.005	0.008
Threshold	**	**	**
G X E	Ns	Ns	Ns
Heritability (%)	83	78	75

Legend: Ns: Not significant, G: genotype, E: environment

Semi-maturity cycle of varieties:

The result of the analysis of variance for the semi-maturity cycle of varieties is shown in Table 7. The analysis showed a significant difference for this character in all the study sites. At Bama site, the semi-maturity cycle varied from 110 (FKR84) to 130 days (WDR1517), from 112 (FKR84) to 130 days (WDR737) at the Banfora site and from 97 (FKR84) to 132 days (WDR1517 and WDR73) at the Sindou site. The earliest variety was the control FKR84 with maturity ranging from 97 to 110 days. Maturity was later at the Sindou site than at the other two sites. The WDR1517, WDR73 and WDR737 hybrids were the latest to reach semi-maturity, with cycles ranging from 120 to 132 days. Broad heritability was 41% at Bama, 54% at Banfora and 99% at Sindou. Genotype-site interaction was significant at all three sites.

Table 7:- Average semi-maturity cycle of varieties.

Varieties	**Bama**	**Banfora**	**Sindou**
FKR19	121	124	125
FKR62N	126	124	123
FKR64	129	126	122
FKR84	110	112	97
WDR1517	130	126	132
WDR3015	124	120	120
WDR306	120	117	120
WDR73	127	129	132
WDR737	120	130	127
Probability	0.03	0.01	<0.0001
Threshold	*	*	***
G x E	*	*	*
Heritability (%)	41	54	99

Legend: G: genotype, E: environment

Panicle length:

The average panicle length of different varieties was discriminating across all sites at the 5% probability threshold, with average panicle lengths ranging from 22.4 cm (WDR 737) to 25.2 cm (FKR64) in Bama; from 26.6 cm (WDR737) to 32.5 cm (FKR62N) in Banfora; and from 22.6 (WDR73) to 25.8 cm in Sindou. Overall, variety performance was better at the Banfora site in terms of panicle length. The interaction between genotypes and sites was highly significant. Heritability in the broad sense was high, at 78.71 and 80% respectively (Table 8).

Table 8:- Paniclelength of varieties.

Varieties	**Bama**	**Banfora**	**Sindou**
FKR19	23.7	31.7	25.7
FKR62N	24.1	32.5	23.7
FKR64	25.2	27.9	25.8
FKR84	22.5	32.4	24.3
WDR1517	23.5	27.1	23.2
WDR3015	22.3	29.3	23.2
WDR306	23.3	29.1	23.4
WDR73	23.5	29.2	22.6
WDR737	22.4	26.6	23.4
Probability	0.007	0.02	0.002

Threshold	**	*	**
GxE	***	***	***
Heritability (%)	78	71	82

Legend: G: genotype, E: environment

1000 kernel weight:

Analysis of variance showed a highly significant difference between varieties at all sites. Average 1000-grain weights ranged from 18.46 to 32.60 g; from 21.39 to 28.23 g and from 24 to 29.08 g respectively at the Bama, Banfora and Sindou sites. The FKR84 control recorded the lowest average 1000-grain weight at all three (03) sites, while the WDR306 hybrid recorded the highest average 1000-grain weight (Table 9). Furthermore, heritability in the broad sense was very high, with at least 70% on all sites.

Table 9:- 1000-grain weight of varieties.

Varieties	**Bama**	**Banfora**	**Sindou**
FKR19	25.26	24.85	24.33
FKR62N	24.24	25.29	25.85
FKR64	22.49	23.39	24.96
FKR84	18.46	20.43	22.50
WDR1517	20.35	21.39	23.43
WDR3015	26.01	28.23	26.21
WDR306	32.60	27.72	29.08
WDR73	30.01	27.26	28.61
WDR737	25.76	26.49	24.00
Probability	<0.0001	0.007	<0.0001
Threshold	***	NS	***
G X E	*	*	*
Heritability (%)	96	76	90

Legend: G: genotype; E: environment

Grain yield (kg/ha):

The results of the analysis of variance for grain yield at the 03 study sites are shown in Table 10 below. The analysis showed a highly significant difference between varieties at all sites. Grain yields ranged from 4713 to 8981 kg/ha, from 6342 to 10843 kg/ha and from 4730 to 8923 kg/ha respectively in Bama, Banfora and Sindou. The best yields were observed at the Banfora site, with yields of over 10,000 kg/ha. Control varieties FKR84 and FKR64 recorded the lowest yields, at 4713 kg/ha and 4942 kg/ha respectively. In contrast, the hybrid varieties WDR306 and WDR3015 achieved the highest paddy yields of 7743 kg/ha and 10803 kg/ha respectively. Heritability in the broad sense was high at over 79% at all three sites. The genotype-site interaction showed a highly significant difference.

Table 10:- Average yield performance of varieties.

Varieties	**Banfora**	**Farako-Ba**	**Sindou**
FKR19	5245	8990	4730
FKR62N	6013	8093	5917
FKR64	4942	6342	6833
FKR84	4713	6754	5832
WDR1517	7920	7228	7845
WDR3015	8198	10313	8923
WDR306	8981	10803	7743
WDR73	7801	9533	7359
WDR737	7488	10843	7470
Probability	<0.0001	0.0001	0.004
Threshold	***	***	***
G X E	***	***	***
Heritability (%)	94	91	79

Legend: G: genotype, E: environment

Yield stability of varieties

Table 11 summarizes the ability of varieties to stabilize their yields in the different environments studied. Generally speaking, the best yield performances (over 9000 kg/ha) were observed with hybrids WDR3015 and WDR306. However, hybrid WDR73 was the most stable of the varieties, with an average yield of 8310 kg/ha. It was followed by the control FKR62N and FKR84 with yields of 6104 and 5559 kg/ha respectively.

Table 11:- Yieldstability test results.

Varieties	Stability	Rank(Stability)	Yield(kg/ha)	Rank(Yield)
FKR19	4761369.852	8	6104.0867	7
FKR62N	186834.2744	2	6545.6667	6
FKR64	3347043.324	7	5910.0544	8
FKR84	424163.507	3	5559.8889	9
WDR1517	5357488.2	9	7712.4444	5
WDR3015	547012.6621	4	9393.0922	1
WDR306	1105715.777	5	9354.4511	2
WDR73	154629.4542	1	8310.6056	4
WDR737	1711385.216	6	8726.4067	3

Agroecological adaptability of varieties in relation to study sites

The three-dimensional analysis provided information on the adaptability of the varieties in relation to the three different study sites. Indeed, this analysis showed that hybrid WDR3015, and the controls FKR64 and FKR84 would adapt better to the Sindou site. On the other hand, hybrid WDR737 and the control FKR19 would have adapted better at Banfora. Finally, the Bama site was favourable for hybrids WDR1517, WDR73, WDR306 and the control FKR62N (figure 1).

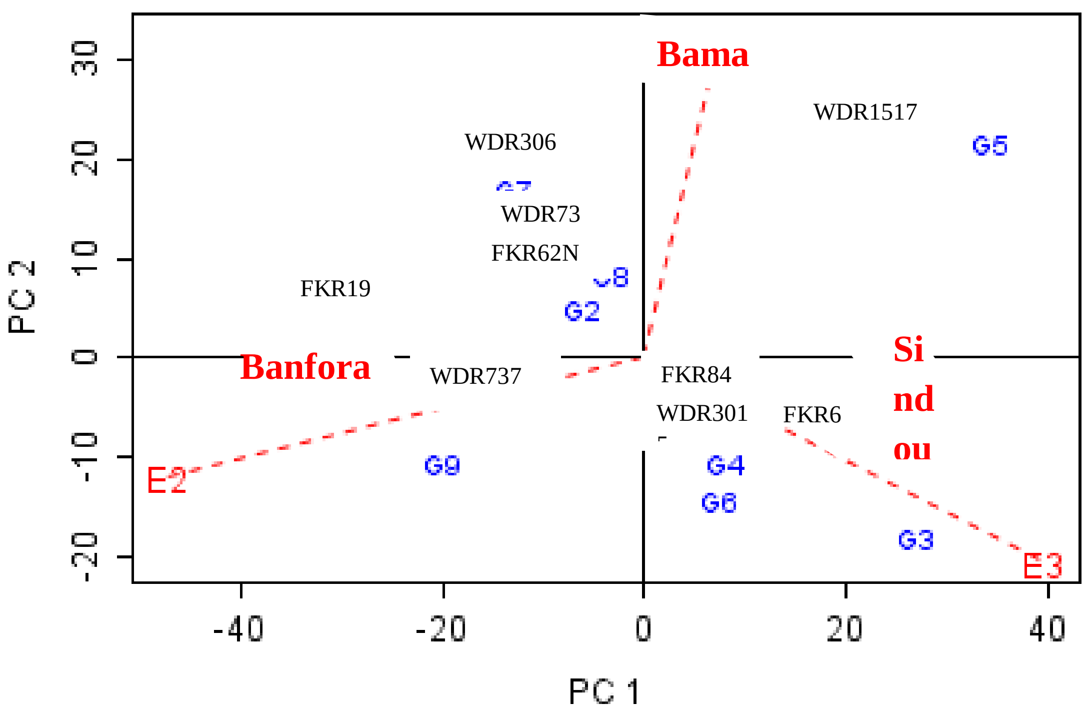

Figure 1:- Agroecological adaptability of varieties on study sites.

Discussion:-

Variations in the severity and incidence of blast and brown spot disease among varieties suggest that they do not behave in the same way with regard to these diseases. Symptoms of these diseases appeared progressively, first on the leaf blades, then generalized to all plots on the susceptible variety FKR19. The 2 to 3 score obtained with the hybrid varieties and the FKR62N control would indicate that these varieties are resistant to these two diseases. These results could be explained by the fact that the hybrid varieties contain resistance genes against these diseases. FKR62N is the result of a cross between O. glaberrimaand O. sativa. These offspring inherit the advantages of productivity from the sativa parent and adaptation to the growing environment and disease tolerance from the glaberrimaparent (Siéet al., 2009).

Some characteristics, such as tillering, showed no significant difference on any of the sites. This trait therefore does not discriminate between the varieties tested. In general, hybrids and local controls had small heights, most often between 80 and 110 cm. Varieties of this size could, under certain conditions, be resistant to lodging caused by high winds. These varieties would therefore be semi-dwarf cultivars. Varieties with such characteristics are renowned for their productivity and good harvest index. Cycle is also an important agronomic feature in the choice of varieties. Generally speaking, none of the varieties had a cycle exceeding 135 days. Varieties with such long cycles could be used for irrigated rice cultivation. The best yield performances and yield components were observed in hybrids. This high productivity potential of hybrids is due to their vigor and ease of adaptation in the agro-ecological areas where the study was carried out. In addition, because of heterosis, hybrid rice would have given a much higher yield than control lines. These hybrids could have a yield advantage of at least 15 to 20% (1.0 to 1.5 t/ha) over the best non-hybrid variety grown under the same conditions.

For this purpose, heritability in the broad sense (H^2%) was estimated to capture the share of genetic factors in the expression of phenotypic traits. This resulted in a variation of between 10% and 99% for the traits studied. According to Robinson et al (1966), heritability in the broad sense (H^2%) is considered high above 60%, low below 30% and moderate between 30% and 60%. As a result, traits with heritability values above 60 are highly genotype-dependent. These results confirm the weak influence of environmental factors on the expression of these traits. Hence, the selection of these hybrids would be more interesting, as the proportion due to the environment is relatively low.

Conclusion:-

The aim of the study was to help improve rice productivity in Burkina Faso, by making available to grower's productive hybrid rice varieties that are resistant to the main fungal diseases. The study showed that hybrids were the most tolerant to blast and brown spot diseases. In addition, hybrids such as WDR3015 and WDR306 had better agronomic performance of over 9,000 kg/ha. Stability analysis showed that hybrid WDR73 was the most stable of the varieties, with an average yield of 8310 kg/ha. The three-dimensional analysis also proved that these varieties would adapt to our country's agroecological zones. This study provided interesting results on the rice hybrids evaluated. It could be of interest to extension services for the release of these varieties. However, it should be supplemented by inoculation tests in a semi-controlled environment to confirm or refute the results of the diseases observed in the field. Finally, it would be advisable to extend the study to other agro-ecological zones of the country.

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Disclosure of conflict of interest

The authors declare no conflicts of interest regarding the publication of this paper.

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